Report on the Biological Monitoring of Selected Chemicals of Concern

Results of the New Zealand biological monitoring programme, 2014-2016

lead
mercury
arsenic
cadmium
chromium
antimony
thallium
cotinine
fluoride
phenols
phthalate metabolites

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1. Summary

This report presents the results of the first comprehensive national biological monitoring programme for selected chemicals of concern in New Zealand. The programme aimed to provide New Zealand-specific data for the development of reference values for these chemicals in the general population. Biological samples were collected in 2014-2016 from 319 adults aged 19-64 who provided 304 urine samples and 304 blood samples, and 303 children aged 5-18 who provided 300 urine samples and 193 blood samples. In order to achieve a sample representative for the New Zealand population, participants were selected from all geographic regions, all age groups, both genders, and included both Māori and non-Māori. Blood samples were analysed for lead and mercury and urine samples were analysed for arsenic, cadmium, chromium, thallium, antimony, phenols, phthalate metabolites, cotinine and fluoride. The central tendency of the blood and urine concentrations of the selected chemicals in the study population are represented by the geometric mean. Individual concentrations are not reported. Geometric means and 95% confidence intervals of the blood and urinary concentrations are presented by gender, age group, ethnicity (Māori/non-Māori) and geographic region (Northland/Auckland, Waikato/Bay of Plenty, Lower North Island, South Island), and compared with the results from similar biological monitoring programmes recently conducted in other countries.

For metals and metal compounds, the geometric means (GM) for adults and children respectively were: 13 µg/L and 8 µg/L for blood lead; 1.6 µg/L and 0.9 µg/L for blood mercury; 4.2 µg/L and 3.0 µg/L urine for the inorganic arsenic metabolite dimethylarsinic acid (DMA); 3.5 µg/L and 1.5 µg/L for the organic arsenic compound arsenobetaine (AB); 0.19 µg/L and 0.07 µg/L for cadmium; 0.05 µg/L and 0.03 µg/L for chromium; 0.20 µg/L and 0.05 µg/L for thallium; and 0.06 µg/L and 0.09 µg/L for antimony. With the exception of antimony, the geometric mean levels of all tested chemicals were highest for adults. For lead, mercury and cadmium positive associations with age were observed among adults. Inorganic arsenic and thallium showed geographic variation for both children and adults, with lowest levels observed for the South Island and highest for the North of the North Island.

Urinary cotinine was detected in 11% of adults and 2% of children. Detection frequencies were significantly higher among Māori children (8% detected) compared to non-Māori children (0% detected) and among Māori adults (19% detected) compared to non-Māori adults (6% detected).

The GM for urinary fluorine was 760 µg/L for adults and 630 µg/L for children. For both children and adults, the lowest mean urinary fluoride level was observed for the South Island.

Bisphenol A (BPA), a phenolic chemical used as a monomer in polycarbonate plastics and epoxy resins, was detected in the urine samples of 93% of adults and 89% of children. The geometric mean urinary BPA concentration was 1.8 µg/L for adults and 2.2 µg/L for children. BPA concentrations differed by age group, with the highest GM observed for the 19-24 year age group (2.9 µg/L) and the lowest for the 50-64 age group (1.4 µg/L).

Triclosan, an antibacterial agent used in consumer products such as hand wash, was detected in the urine samples of 85% of adults and 92% of children, at a geometric mean concentration of 4.8 µg/L for adults and 3.9 µg/L for children. The GM of urinary triclosan was more than two times higher for non-Māori children compared to Māori children.

Benzophenone-3 (BP-3), used in personal care products such as sunscreens to absorb and dissipate ultraviolet (UV) radiation, was detected in the urine samples of 100% of adults and children, with a geometric mean of 18.4 µg/L for adults and 20.8 µg/L for children. For adults who had used sunscreen in the 48 hours before urine sampling, the GM for urinary BP-3 was 160 µg/L. BP-3 urinary concentrations were higher among females compared to males. For both adults and children, Māori had lower urinary BP-3 concentrations compared to non-Māori.

Parabens, which are widely used as antimicrobial preservatives in cosmetics, pharmaceuticals, and food and beverage processing, were detected in all urine samples. The geometric mean concentration of the sum of the four parabens (methyl, propyl, ethyl, butyl) was 27.1 µg/L for adults and 17.7 µg/L for children. Methylparaben contributed most to the sum (GM 17.5 µg/L for adults and 11.9 µg/L for children), followed by n-propylparaben (GM 3.4 µg/L for adults and 2.1 µg/L for children), ethylparaben (GM 1.4 µg/L for adults and 0.7 µg/L for children). Paraben urinary concentrations were higher in women compared to men.

Metabolites of phthalates, with their wide range of uses as plasticisers, solvents and additives in many consumer products including plastics, adhesives, pharmaceuticals and personal care products, were detected in all urine samples. The highest urinary concentrations were measured for monobutyl phthalate (mBP, n+iso), a metabolite of dibutyl phthalate (DBP, n+iso), with geometric means of 37 µg/L for adults and 61 µg/L for children. For the DEHP metabolites mEHP, mEOHP and mEHHP, also commonly used as plasticisers, the geometric means for adults and children were 2 and 3, 7 and 14, 9 and 18 µg/L, respectively. Urinary phthalate metabolite concentrations were typically highest for the youngest age groups. For mEP, a metabolite of DEP which is commonly used in personal care products, concentrations were positively associated with age, and higher for women compared to men.

Comparing these New Zealand population based geometric means with the results from biological monitoring programmes recently conducted in other countries, indicated that New Zealand levels are in the same range as those observed for other countries.

Upper reference limits (URLs) were calculated based on the 97.5th percentile of the distribution for adults and children, which can be used as the basis for developing New Zealand-specific notifiable levels and reference values, and help determine whether individuals have been exposed to levels higher than the general population. This biomonitoring programme also provides baseline levels of selected chemicals of concern in the New Zealand population allowing future temporal trends to be assessed.

2. Background

2.1. Introduction

This report presents the results of the first comprehensive national biological monitoring programme for selected chemicals of concern in New Zealand. The programme was commissioned by the New Zealand Ministry of Health (on 10 September 2012) and conducted by Massey University's Centre for Public Health Research (CPHR). Two analytical laboratories were subcontracted to complete the laboratory analyses of blood and urine samples.

Biological monitoring is a proven approach to estimate population exposure for a range of environmental contaminants. In New Zealand, biological monitoring has proven effective in measuring concentrations of persistent organic pollutants (POPs) in serum and breast milk (Bates *et al.*, 1994; Bates *et al.*, 2001; Buckland *et al.*, 2001; Mannetje *et al.*, 2013). The programme described in this report is an expansion of these earlier studies with a specific focus on selected chemicals of concern in blood and urine of adults and children. The chemicals covered include metals and metalloids (lead, mercury, chromium, arsenic, cadmium, thallium, antimony), cotinine, fluoride, environmental phenols (e.g. bisphenol A, parabens), and phthalate metabolites. Biological samples (i.e. blood and urine) were collected in 2014-2016

The programme was designed to provide reference values for levels of chemicals of concern in the general New Zealand population of children aged 5-18 and adults aged 19-65. The programme also provides a benchmark for future biological monitoring to establish temporal trends and aimed to assess the relationship between blood/urine levels and age, geographic region, ethnicity and gender.

This report describes the survey design, field work, analytical methods and results of the programme. Data tables are provided for each chemical, containing descriptive statistics on blood or urine concentrations in the sample population. Differences between age groups, gender, ethnicity (Māori and non-Māori) and geographic regions were assessed and comparisons were made with international biological monitoring programmes.

2.2. Aims

The biological monitoring programme had the following specific aims:

1. To undertake a biological monitoring programme of selected substances of concern (SoCs) in a cross-sectional survey of the New Zealand population including adults and children;
2. To establish baseline levels of SoCs in the New Zealand population to allow for future determination of temporal trends;
3. To compare the New Zealand SoCs levels with international levels;
4. To monitor the influence of gender, age, geographic region and ethnicity in relation to the levels of SoCs in the New Zealand population;
5. To develop a robust methodology for adding or removing SoCs on a national list;
6. To support the Protection Regulation and Assurance Business Unit deliver its environmental and border health protection work programme in relation to hazardous substances.

2.3. Selected chemicals of concern

The list of chemicals of concern included in the programme was primarily based on the chemicals that had been identified by the Ministry of Health in their Request for Proposals (RFP). Other considerations in the choice of chemicals included the available analytical methods, cost of specific tests or test suits, additional cost for specific analytes added to the analytical suite, and being able to directly compare results with other national and international surveys. **Table 1** lists all the chemicals included in the biomonitoring programme.

Table 1. *Chemicals included in the biomonitoring programme*

matrix	chemical group	chemical	specific analyte	acronym
blood	metals	lead	total lead	Pb
		mercury	total mercury	Hg
urine		arsenic	*organic arsenic ('fish arsenic'):*	
			arsenobetaine	AB
			arsenicals of inorganic arsenic origin:	
			dimethylarsinic acid (methylated metabolite of inorganic arsenic)	DMA
			monomethylarsonic acid (methylated metabolite of inorganic arsenic)	MMA
			arsenite	AsIII
			arsenate	AsV
		cadmium	cadmium	Cd
		chromium	chromium	Cr
		thallium	thallium	Tl
		antimony	antimony	Sb
	phenols	phenols	bisphenol A (2,2-bis[4-hydroxyphenyl] propane)	BPA
			triclosan (2,4,4'-trichloro-2'-hydroxyphenyl ether)	TCS
			benzophenone-3	BP-3
			4-tert-octylphenol	tOP
			butyl parabens	
			ethyl parabens	
			methyl parabens	
			propyl parabens	
	phthalates	phthalate ester metabolites	monomethyl phthalate	mMP
			monoethyl phthalate	mEP
			monobutyl phthalate (n+iso)	mBP
			monobenzyl phthalate	mBzP
			mono-2-ethylhexyl phthalate	mEHP
			mono-(2-ethyl-5-oxohexyl) phthalate	mEOHP
			mono-(2-ethyl-5-hydroxyhexyl) phthalate	mEHHP
			mono-cyclohexyl phthalate	mCHP
			mono-(3-carboxypropyl) phthalate	mCPP
			mono-iso-nonyl phthalate	miNP
	tobacco	cotinine	cotinine	
	fluoride	fluoride	fluoride	F^-
	other		creatinine (for urinary volume adjustment)	
			specific gravity (for urinary volume adjustment)	

3. Methods

3.1. Sample frame

The biological monitoring programme included a cross-section of adult and school-age New Zealanders between the ages of 5 and 64 years. We used separate sampling frames for adults (aged 19-64) and children (aged 5-18) as detailed below.

Selection of adults
For the recruitment of adult participants the most recent (2014) New Zealand Electoral Roll was used. The 2014 Electoral Roll included an estimated 93% of the eligible New Zealand voting public (all New Zealand citizens or permanent residents age 18 years or older who lived in New Zealand for one year or more continuously at any stage) (Electoral Commission, 2015). In order to ensure representation from all demographic groups, the sample frame included randomly selected men and women in four age groups (i.e. 19-24, 25-34, 35-49, 50-64 year), from four geographic regions (Northland/Auckland, Waikato/Bay of Plenty, Lower North Island, South Island), and of Māori and non-Māori descent. The study aimed for a total of 300 participants with approximately equal numbers in each of the gender/age/geographical/ethnic sub-groups.

Selection of children
For the recruitment of children we contacted primary, intermediary and high schools located in the four selected geographic regions (Northland/Auckland, Waikato/Bay of Plenty, Lower North Island, South Island). Schools were selected to include children of ethnic diversity (e.g. mixed student body including European and Māori descent). While schools represented the main recruitment avenue, additional recruitment opportunities were also used including: (1) recruitment through already enrolled parents; (2) recruitment through an another study in children of the same age which was already collecting urine samples; (3) public events such as science fairs; and (4) sports clubs.

3.2. Ethical considerations

The study protocol was evaluated by the Central Health and Disability Ethics Committee (14/CEN/44 Biological monitoring of selected chemicals of concern). On 05 May 2014 the application was approved by the Central Health and Disability Ethics Committee, through the HDEC-Expedited Review pathway.

3.3. Fieldwork

3.3.1 Invitation

Contacting adult participants
Individuals selected from the 2014 Electoral Roll were invited by mail to participate in the programme and were sent an invitation letter (Appendix 1 – Adult letter of invitation), information sheet (Appendix 1 – 3.3-Adult information sheet) and a reply form (Appendix 1 – 2.1-Adult Reply form). A short screening interview was conducted by phone before final study enrolment to determine eligibility, using the following exclusion criteria:

- Medical conditions which would prevent providing a blood or urine sample
- Non residency in New Zealand

If the subject was considered eligible they were sent the required instructions and materials for self-collecting a urine sample and attending a nearby pathology laboratory for the collection of a whole blood sample (Appendix 1 – 4.1-Adult Letter with instructions for sample collection; 5.1-Adult Instructions for urine collection; 6.1-Adult consent form; 7.1-Adult consent form for storage future use). Pre-paid postal packages, designed to keep the urine samples cold, were provided to the participants to send the sample to the Centre for Public Health Research (CPHR) in Wellington. Each participant was asked to complete a short questionnaire on potential sources of exposure to the chemicals in the study (Appendix 1 – 8.1-Adult questionnaire).

Contacting the child participants
Children in the 5-18 age range were contacted in different ways (see above), but the majority were contacted through the participating schools, initially by sending a letter to the school principal (Appendix 1 – 1.3-Children School invitation letter). If the school was interested in participating, this was followed by the inclusion of a news item about the study in their regular newsletters, and posted on the school's notice board where possible. Depending on the specific requirements of each school, interested students and their parents were asked to talk to the school administrator to obtain information about the programme and the collection process (Appendix 1 – 1.2-Children invitation letter; 3.1-Children information sheet; 3.2-Children Parent information sheet; 2.2-Children Reply form). A short screening interview was conducted by phone before final study enrolment to determine eligibility, using the following exclusion criteria:

- Medical conditions which would prevent giving a blood or urine sample
- Non residency in New Zealand

If the child was considered eligible the parents were sent the required instructions and materials for self-collection of a urine sample and attending a nearby pathology laboratory for collection of a whole blood sample (Appendix 1 – 4.2-Child Letter with instructions for sample collection; 5.2-Children Instructions for urine collection; 6.2-Children consent form; 7.2-Children consent form for storage future use). Pre-paid postal packages, designed to keep urine samples cold, were provided to send the

sample to CPHR. Parents were also asked to complete a short questionnaire on potential sources of exposure of their children to the chemicals in the study (Appendix 1 – 8.2-Children questionnaire).

Adult participants and parents of children were provided with a freepost envelope to return the completed consent forms and questionnaire to CPHR.

3.3.2 Questionnaire

A questionnaire was used to collect information on a range of factors that have previously been shown to affect blood and urinary concentrations of the selected chemicals. This included information on lifestyle factors, living circumstances, diet and occupation. Participants were asked to complete the questionnaire within two weeks before or after sample collection.

Adult questionnaire
A copy of the adult questionnaire is included in Appendix 1 (8.1-Adult questionnaire). It includes questions on demographics (e.g. ethnicity, education, height and weight), lifestyle factors (e.g. smoking, alcohol, sunscreen use), dwelling (e.g. age, location, type of water supply), diet, some health related issues that may affect exposure (e.g. metallic dental fillings, menopause), and occupation. The questionnaire was designed to take no more than 15 minutes.

Parent questionnaire
A copy of the parent questionnaire (about the child) is included in Appendix 1 (8.2-Children questionnaire). It includes questions on demographics (e.g. ethnicity, place of birth), some lifestyle factors (e.g. smokers in the household, use of sunscreen lotions), primary dwelling (e.g. age, location, type of water supply), diet, and health related issues (e.g. metallic dental fillings). The questionnaire was completed by a parent or primary caregiver and was designed to take no more than 15 minutes.

3.3.3 Blood collection

Blood samples were collected between September 2014 and December 2016. Samples were taken by a trained phlebotomist at a private pathology laboratory, medical clinic, or at the school (in the case of some children). Blood was collected in 10 mL K2EDTA-containing plastic vacutainer blood collection tubes (royal blue tops) using standard venipuncture methods. Collected blood samples were held frozen (-20^{O}C) by the pathology laboratory until they were sent to CPHR in frozen containers. The following sections provide specific blood collection procedures for the adult and child participants.

Sample collection adults

Blood samples from adults (a maximum of 3 x 10 mL vacutainers) were collected at a local pathology laboratory. Adult participants were offered a $20 MTA gift voucher to assist with transport costs. The pathology laboratory personnel and the adult participant completed a form (Appendix 1 – 9.1-Adult clinical form) during the participant's visit which included questions relevant to short-term exposure. The adult participants completed two separate consent forms (Appendix 1 - 6.1-Adult consent form; 7.1-Adult consent form storage future use).

Sample collection children

Blood samples from children (a maximum of 2 x 10 mL vacutainers) were collected at a local pathology laboratory (i.e. a local venue that was convenient for the children and their parents to attend), at a local medical clinic, or in some cases during a collection day at the participating schools. The phlebotomist and the child's parent completed a form (Appendix 1 – 9.2-Children clinical form) during the child's visit which included questions relevant to short-term exposure. The parents completed two separate consent forms (Appendix 1 – 6.2-Children consent form; 7.2-Children consent form storage future use).

3.3.4 Urine collection

For both children and adults first-void morning urine samples were self-collected at the home into 60 mL sterile, pre-labelled polypropylene urine collection containers following the instructions as outlined in the instructions (appendix 1- 5.1 and 5.2). Urine samples were sent to CPHR on the day of collection, or were stored in the participant's home freezer (-20^{O}C) until they were sent to CPHR using a pre-paid postal package, designed to keep samples cold during transit.

3.4. Laboratory analyses

All blood and urine samples from each individual participant were shipped on dry ice to Canterbury Health Laboratories (CHL) in Christchurch (www.chl.co.nz/) which was subcontracted to conduct the analyses for metals and metalloids, cotinine, fluoride, creatinine and specific gravity. These analyses were completed between May 2016 and June 2017.
Sample aliquoting was conducted at CHL after which urine aliquots were shipped on dry ice to Axys Analytical Services in Sidney, Canada (www.axysanalytical.com/), which was subcontracted to conduct the analyses for phenols and phthalates, as this capacity was not available in New Zealand based laboratories. The analyses for phenols and phthalates were completed between March 2017 and September 2017.

3.4.1. Blood lead

Lead concentrations in whole blood were determined using Inductively Coupled Mass spectroscopy (ICP-MS). Blood samples were diluted in an ammonia EDTA solution, aspirated into an argon plasma torch at 2700°C for ion formation. The ions were focused into an octopole reaction system and collided with helium gas. The ions then passed into the quadrupole for detection by the electron multiplier. Equipment: Agilent ICP. LLOD (lower limit of detection): 0.041 µg/L. External QC (quality control): RCPA Quality Assurance Programs. Internal QC: Lyphochek metal control.

3.4.2. Blood mercury

Mercury concentrations in whole blood were determined using ICP-MS. Blood samples were diluted in an ammonia EDTA solution, aspirated into an argon plasma torch at 2700°C for ion formation. The ions were focused into an octopole reaction system and collided with Helium gas. The ions then passed into the quadrupole for detection by the electron multiplier. Equipment: Agilent ICP. LLOD: 1.003 µg/L. Concentrations between 0.2 µg/L and 1.003 µg/L were detectable and used in calculating the geometric means for the study population, but were marked as 'not detected' by the analytical laboratory in the analytical results print-out sent to the participants. In the calculations of the geometric mean, a blood mercury concentration of ½*0.2 µg/L was assumed if not detectable. External QC (quality control): RCPA Quality Assurance Programs. Internal QC: Lyphochek metal control.

3.4.3. Urinary arsenic

Concentrations of arsenic forms in urine were determined using HPLC-ICP-MS. Urine samples were diluted in an ammonia EDTA solution, aspirated into an argon plasma torch at 2700°C for ion formation. The ions were focused into an octopole reaction system and collided with Helium gas. The ions then passed into the quadrupole for detection by the electron multiplier. Equipment: Agilent ICP. LLOD:

0.1 µg/L (for Arsenate, arsenobetaine, arsenocholine, DMA, MMA). A urinary concentration of ½*0.1 µg/L was assumed if not detectable. External QC (quality control): RCPA Quality Assurance Programs. Internal QC: Lyphochek metal control.

3.4.4. Urinary cadmium

Cadmium concentrations in urine were determined using ICP-MS. Urine samples were diluted in an ammonia EDTA solution, aspirated into an argon plasma torch at 2700°C for ion formation. The ions were focused into an octopole reaction system and collided with Helium gas. The ions then passed into the quadrupole for detection by the electron multiplier. Equipment: Agilent ICP. LLOD: 0.079 µg/L. A blood urinary concentration of ½*0.079 µg/L was assumed if not detectable. External QC (quality control): RCPA Quality Assurance Programs. Internal QC: Lyphochek metal control.

3.4.5. Urinary chromium

Chromium concentrations in urine were determined using ICP-MS. Urine samples were diluted in an ammonia EDTA solution, aspirated into an argon plasma torch at 2700°C for ion formation. The ions were focused into an octopole reaction system and collided with Helium gas. The ions then passed into the quadrupole for detection by the electron multiplier. Equipment: Agilent ICP. LLOD: 0.104 µg/L. Concentrations between 0.02 µg/L and 0.104 µg/L were detectable and used in calculating the geometric means for the study population, but were marked as 'not detected' by the analytical laboratory in the analytical results print-out sent to the participants. In the calculations of the geometric mean, a urinary chromium concentration of ½*0.02 µg/L was assumed if not detectable. External QC (quality control): RCPA Quality Assurance Programs. Internal QC: Lyphochek metal control.

3.4.6. Urinary thallium

Thallium concentrations in urine were determined using ICP-MS. Urine samples were diluted in an ammonia EDTA solution, aspirated into an argon plasma torch at 2700°C for ion formation. The ions were focused into an octopole reaction system and collided with Helium gas. The ions then passed into the quadrupole for detection by the electron multiplier. Equipment: Agilent ICP. LLOD: 0.1 µg/L. Concentrations between 0.02 µg/L and 0.1 µg/L were detectable and used in calculating the geometric means for the study population, but were marked as 'not detected' by the analytical laboratory in the analytical results print-out sent to the participants. In the calculations of the geometric mean, a urinary thallium concentration of ½*0.02 µg/L was assumed if not detectable. External QC (quality control): RCPA Quality Assurance Programs. Internal QC: Lyphochek metal control

3.4.7. Urinary antimony

Antimony concentrations in urine were determined using ICP-MS. Urine samples were diluted in an ammonia EDTA solution, aspirated into an argon plasma torch at 2700°C for ion formation. The ions were focused into an octopole reaction system and collided with Helium gas. The ions then passed into the quadrupole for detection by the electron multiplier. Equipment: Agilent ICP. LLOD: 0.1 µg/L. Concentrations between 0.02 µg/L and 0.1 µg/L were detectable and used in calculating the geometric means for the study population, but were marked as 'not detected' by the analytical laboratory in the analytical results print-out sent to the participants. In the calculations of the geometric mean, a urine antimony concentration of ½*0.02 µg/L was assumed if not detectable. External QC (quality control): RCPA Quality Assurance Programs. Internal QC: Lyphochek metal control.

3.4.8. Urinary cotinine

Cotinine concentrations in urine were determined using LC-MS: Liquid chromatography–mass spectrometry. Urine samples were diluted with a deuterated cotinine internal standard. Equipment: SCIX 3200. LLOD: 0.5 µg/L. External QC (quality control): not applicable. Internal QC: in-house.

3.4.9. Urinary fluoride

Fluoride concentrations in urine were determined using ISE: Ion Selective electrode. The urine samples were mixed with a buffer and the free fluoride concentration was measured by a single crystal lanthanum-fluoride membrane electrode. LLOD: 19 µg/L. External QC (quality control): water Chek. Internal QC: Lyphochek metal control.

3.4.10. Urinary phenols

Phenolics concentrations in urine were determined using LC-MS/MS: Liquid chromatography tandem-mass spectrometry.
Limit of detection (LOD):

BPA	0.4 µg/L
triclosan	0.4 µg/L
benzophenone-3	0.2 µg/L
4-tert-octylphenol	0.2 µg/L
methylparabens	0.08 µg/L
ethylparabens	0.08 µg/L
propylparabens	0.08 µg/L
butylparabens	0.08 µg/L

3.4.11. Urinary phthalate metabolites

Phthalate metabolite concentrations in urine were determined using LC-MS/MS: Liquid chromatography tandem-mass spectrometry. Axys method: MLA-059. MDL (Method Detection Limit) protocol: Federal Register 40 CFR Part 136, Appendix B, no iteration.
Limit of detection (LOD):

monomethyl phthalate (mMP)	1 µg/L
monoethyl phthalate (mEP)	2 µg/L
monobutyl phthalate (mBP)	1 µg/L
monobenzyl phthalate (mBzP)	1 µg/L
mono-2-ethylhexyl phthalate (mEHP)	1 µg/L
mono-(2-ethyl-5-oxohexyl) phthalate (mEOHP)	1 µg/L
mono-(2-ethyl-5-hydroxyhexyl) phthalate (mEHHP)	1 µg/L
mono-cyclohexyl phthalate (mCHP)	1 µg/L
mono-(3-carboxypropyl) phthalate (mCPP)	2 µg/L
mono-iso-nonyl phthalate (miNP)	1 µg/L

3.4.12. Urinary creatinine

Creatinine in urine was determined using ABBOTT 8200. Creatinine was measured using the colorimetric end-point Jaffe method. LLOD: not applicable. External QC (quality control): RCPA Quality Assurance Programs. Internal QC: Biorad.

3.4.13. Urinary specific gravity

The specific gravity of the urine samples was determined with a refractometer. LLOD (lower limit of detection): not applicable. External QC (quality control): not applicable. Internal QC: not applicable.

3.5. Statistical analyses

Data were imported from MS Access and MS Excel into SAS analytical software. Blood concentrations were expressed as µg/L blood. Urine concentrations were expressed as µg/L urine, as well as µg/g creatinine and µg/L urine adjusted for specific gravity. Appendix 2 includes the molar weight to allow levels to be converted to µmol/L. Geometric means (GM) of the blood and urine concentrations, the GM's 95% confidence interval, and the 95th percentile, were calculated for adults and children. GMs were also calculated separately by age group, gender, ethnicity (Māori/non-Māori) and geographic region. Levels below the limit of detection were set to half the limit of detected as specified in paragraph 3.4., and used in the calculation of the GM. If the detection frequency was less than 33%, summary statistics including the samples below the limit of detection are not presented.

Adjustment of urinary concentrations

The survey used spot urine samples rather that 24-hour urine voids for practical reasons. Spot urine samples are subject to the variability in the volume of urine and the differential dilution of endogenous and exogenous chemicals from void to void. The best method to adjust the urinary concentrations of environmental chemicals for urinary dilution remains a subject of debate (Barr *et al.*, 2005; Hoet *et al.*, 2016). Urinary creatinine is a chemical by-product generated from muscle metabolism. Its production and excretion are considered to be relatively constant over 24 hours, and many biomonitoring studies have therefore used systematic creatinine adjustment of urinary concentrations of biomarkers. However, more recently is has been proposed that creatinine adjustment carries the risk of over-adjustment (Hoet *et al.*, 2016) and an alternative method of specific gravity adjustment has been proposed (Hoet *et al.*, 2016). A urine specific gravity test compares the specific gravity of urine to the density of water. Urinary concentrations were adjusted to the specific gravity of 1.018 (study mean) using the below formula (Sorahan *et al.*, 2008): Urine concentration (individual's urine concentrations adjusted for specific gravity)= (individual's measured concentration) * (1.018-1) / (individual's measured specific gravity-1).

In this report urinary concentrations are presented unadjusted (µg/L) in first instance. In addition, two ways to adjust for the effect of urinary dilution are used and presented in the results: (1) urinary concentrations adjusted for urinary creatinine and expressed as µg/g creatinine; (2) urinary concentrations adjusted for specific gravity expressed as µg/L. Urine samples were not excluded based on the creatinine or specific gravity measurements. The results for the study population's urinary creatinine concentrations and specific gravity are provided in appendix 3.

Comparison of concentrations between demographic groups

Geometric means of the blood and urine concentrations are presented by age, ethnicity, gender and geographic region. To evaluate whether differences in geometric means between groups are statistically significant, general linear regression was used involving the 4 categorical variables for demographic factors (age-group, sex, ethnicity, geographic region) as independent variables with the log-transformed blood or urine concentration as the dependent variable. The R^2 was used as an indication of the variance in the log-transformed blood or urine concentrations explained by the 4 independent variables. A low p-value (<0.05) was used as an indicator of the variable's association with the dependent variable.

4. Results

4.1. Study population

Adults

A total of 5908 invitations were posted to addresses on the Electoral Roll. For 4058 we had no response after additional attempts to contact people by phone. Contact by phone was only possible for 1428 individuals, for whom phone numbers could be identified. Of the 1859 invited individuals for whom a response was received, 228 were returned to sender, 672 refused participation, 441 were not eligible (did not have a phone, no longer living in New Zealand, illness or impairment or deceased). A total of 518 adults were interested in the study, of which 319 participated in the study. Of the 319 adult participants, 304 provided a blood sample and 304 provided a urine sample (**Table 2** and **3**).

Table 2. *Number of adult blood samples available in the biomonitoring programme 2014-2016*

Age Group	Gender	Ethnicity Group	Northland/ Auckland	Waikato/Bay of Plenty	Lower North Island	South Island	total
19-24	male	Māori	1	2	2	1	**6**
		Non-Māori	4	6	5	1	**16**
	female	Māori	3	4	1	2	**10**
		Non-Māori	7	6	2	5	**20**
25-34	male	Māori	3	2	4	3	**12**
		Non-Māori	5	7	4	3	**19**
	female	Māori	0	2	5	4	**11**
		Non-Māori	7	8	3	4	**22**
35-49	male	Māori	4	4	3	4	**15**
		Non-Māori	4	6	7	9	**26**
	female	Māori	3	7	4	6	**20**
		Non-Māori	4	6	7	7	**24**
50-64	male	Māori	6	2	4	5	**17**
		Non-Māori	5	6	8	10	**29**
	female	Māori	5	5	6	5	**21**
		Non-Māori	4	12	14	6	**36**
total			**65**	**85**	**79**	**75**	**304**

Table 3. *Number of adult urine samples available in the biomonitoring programme 2014-2016*

Age Group	Gender	Ethnicity group	Northland/ Auckland	Waikato/Bay of Plenty	Lower North Island	South Island	total
19-24	male	Māori	1	2	1	1	**5**
		Non-Māori	4	6	6	2	**18**
	female	Māori	3	4	1	2	**10**
		Non-Māori	7	6	3	4	**20**
25-34	male	Māori	3	2	5	4	**14**
		Non-Māori	5	7	3	3	**18**
	female	Māori	1	2	5	4	**12**
		Non-Māori	7	7	3	4	**21**
35-49	male	Māori	4	3	3	4	**14**
		Non-Māori	3	6	5	9	**23**
	female	Māori	4	7	5	6	**22**
		Non-Māori	4	6	8	6	**24**
50-64	male	Māori	6	3	4	5	**18**
		Non-Māori	6	6	8	10	**30**
	female	Māori	5	5	5	5	**20**
		Non-Māori	4	12	13	6	**35**
total			**67**	**84**	**78**	**75**	**304**

Children

A total of 150 schools were invited to participate in the study of which 40 replied positively and placed information of the study in their newsletter. A total of 113 children were recruited through schools. In addition, 47 children were recruited through enrolled parents and 145 through other ways, mainly through another study in school children for which urine samples were also being collected (for the purpose of measuring pesticide metabolites). In total, 303 children participated in the study, of which 193 provided a blood sample and 300 provided a urine sample (**Table 4** and **5**).

Table 4. *Number of child blood samples available in the biomonitoring programme 2014-2016*

Age Group	Gender	Ethnicity group	Northland/ Auckland	Waikato/Bay of Plenty	Lower North Island	South Island	total
5-7	male	Māori	3	1	1	0	**5**
		Non-Māori	2	5	3	5	**15**
	female	Māori	1	1	7	0	**9**
		Non-Māori	1	2	5	1	**9**
8-10	male	Māori	3	3	0	0	**6**
		Non-Māori	4	4	15	7	**30**
	female	Māori	1	1	7	0	**9**
		Non-Māori	1	1	17	6	**25**
11-17	male	Māori	3	3	4	0	**10**
		Non-Māori	8	5	13	3	**29**
	female	Māori	5	2	3	0	**10**
		Non-Māori	10	8	15	3	**36**
total			**42**	**36**	**90**	**25**	**193**

Table 5. *Number of child urine samples available in the biomonitoring programme 2014-2016*

Age Group	Gender	Ethnicity group	Northland/ Auckland	Waikato/Bay of Plenty	Lower North Island	South Island	total
5-7	male	Māori	3	3	3	0	**9**
		Non-Māori	4	5	8	5	**22**
	female	Māori	2	1	12	0	**15**
		Non-Māori	1	2	13	2	**18**
8-10	male	Māori	3	5	7	0	**15**
		Non-Māori	4	5	33	8	**50**
	female	Māori	1	3	13	0	**17**
		Non-Māori	2	1	27	8	**38**
11-17	male	Māori	3	4	5	0	**12**
		Non-Māori	8	7	17	4	**36**
	female	Māori	7	3	9	0	**19**
		Non-Māori	12	9	25	3	**49**
total			**50**	**48**	**172**	**30**	**300**

4.2. Results by chemical

The sections below provide a short background section for each chemical. This is followed by tables with geometric means (GM) and 95% confidence interval (95%CI) of the levels measured in blood and urine of the adult and child study populations, stratified by age, sex, ethnicity and study region. The R^2 indicates how much of the variance in the log transformed blood or urine concentration is explained by age-group, gender, ethnicity and geographic region. A p-value below 0.05 indicates that the variable is a statistically significant determinant of the blood/urine concentration in the study population.

4.2.1. Blood lead

Elemental lead occurs naturally in rocks and soils and is mined from ores or recycled from scrap metal and batteries. Lead is used in a number of applications ranging from solders, glass, ammunition, and radiation shielding. Lead was previously used in plumbing materials and there may be remaining lead in existing household plumbing. Humans are exposed to lead via inhalation or ingestion of lead from historical contamination (e.g. roadside dust, deteriorated lead-based paint). Before the phasing out leaded petrol, motor vehicle exhaust also contributed to lead exposure for the general public. Effects of lead exposure in adults include neurocognitive effects, decreased renal function, increased blood pressure, and reduced fertility. Lead exposure is a particular concern for children because of reported adverse neurodevelopmental effects at low exposure levels. Lead is generally measured in whole blood to enable assessment of recent lead intake and equilibration with stored lead in other body compartments, including bone. Blood levels of lead have reduced considerably over the past 30 years (Hinton *et al.*, 1986; Jones *et al.*, 2009). The notification of 'lead poisoning' under the Health Act 1956 was amended in 2007 to a blood lead of 100 µg/L (10 µg/dL; 0.48 µmol/L) or greater for all ages.

The results for blood lead are included in **Table 6a** for adults and **Table 6b** for children. Lead was detected in all blood samples. The geometric mean blood lead level was 13 µg/L (1.3 µg/dL) for adults and 8 µg/L (0.8 µg/dL) for children. The arithmetic mean was 15 µg/L (1.5 µg/dL) for adults and 9 µg/L (0.9 µg/dL) for children. The 95th percentile was 29 µg/L (2.9 µg/dL) for adults and 16 µg/L (1.6 µg/dL) for children. None of the study participants had blood lead levels above the notifiable blood lead level of 100 µg/L (10 µg/dL). Children had lower blood lead levels compared to adults and for the adults, a higher age was associated with higher blood lead levels. For both children and adults, males had higher blood lead levels compared to females. Some differences between regions were observed for children (highest mean levels for Northland/Auckland), but these were not observed for adults.

For adults who indicated they were currently a smoker (n=26), the GM was 15.41 µg/L (95%CI 12.95-18.33). For adults who indicated they were currently not a smoker (n=278), the GM was 12.92 µg/L (95%CI 12.12-13.77).

Table 6a. *Geometric means for blood lead, adults.*

	n	n< LOD	GM µg/dL	GM µg/L	95%CI	(R2) p-value
all	304	0	1.31	13.11	12.35-13.93	(0.250)
age 19-24	52	0	0.97	9.73	8.60-11.01	
25-34	64	0	1.09	10.92	9.83-12.13	
35-49	85	0	1.25	12.53	11.23-13.98	
50-64	103	0	1.77	17.74	16.10-19.55	**<0.0001**
male	140	0	1.49	14.85	13.72-16.07	
female	164	0	1.18	11.80	10.83-12.85	**<0.0001**
Māori	112	0	1.31	13.10	11.89-14.44	
non-Māori	192	0	1.31	13.12	12.15-14.17	0.848
Northland/Auckland	65	0	1.19	11.90	10.63-13.32	
Waikato/BoP	85	0	1.23	12.31	11.04-13.73	
lower North Island	79	0	1.36	13.58	11.98-15.39	
South Island	75	0	1.48	14.78	13.01-16.78	0.158

LOD: limit of detection (0.041 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable.

Table 6b. *Geometric means for blood lead, children.*

	n	n< LOD	GM µg/dL	GM µg/L	95%CI	(R2) p-value
all	193	0	0.85	8.48	7.92-9.08	(0.121)
age 5-7	38	0	0.85	8.50	7.24-9.99	
8-10	70	0	0.85	8.54	7.63-9.56	
11-18	85	0	0.84	8.43	7.61-9.33	0.954
male	95	0	0.91	9.14	8.34-10.01	
female	98	0	0.79	7.90	7.15-8.72	**0.008**
Māori	49	0	0.95	9.53	8.52-10.66	
non-Māori	144	0	0.82	8.15	7.51-8.85	0.093
Northland/Auckland	42	0	1.00	10.00	8.80-11.37	
Waikato/BoP	36	0	0.70	7.04	5.96-8.30	
lower North Island	90	0	0.89	8.88	8.17-9.66	
South Island	25	0	0.71	7.14	5.54-9.20	**0.002**

LOD: limit of detection (0.041 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable.

4.2.2. Blood mercury

Mercury occurs naturally in elemental, organic and inorganic forms. Elemental mercury is used in a number of applications including production of electrical equipment, and in dental amalgams. Methyl mercury, an organic form of mercury, is generated by metabolism of mercury by microorganisms in aquatic sediments and can bio-accumulate in fish species and in humans via diet. Inorganic mercury is used in the production of batteries, cosmetics and alternative medicines. International and New Zealand studies (Crump 1998) have shown adverse neurodevelopmental effects from mercury exposure, particularly in young children. Currently, there is no notifiable blood mercury level in New Zealand. Assessment of blood levels of mercury is an appropriate method to estimate dietary intake of organic forms of mercury (e.g. methyl mercury). Elevated mercury in blood usually indicates exposure to organic mercury such as from eating fish containing methylmercury, or recent occupational exposure to a high level of elemental mercury vapour.

The results for blood mercury are included in **Table 7a** for adults and **Table 7b** for children. Mercury was detected in 99% of the adult blood samples and 93% of the child blood samples. The geometric mean blood mercury level was 1.6 µg/L for adults and 0.9 µg/L for children. The arithmetic mean blood mercury level was 2.4 µg/L for adults and 1.4 µg/L for children. The 95th percentile was 6 µg/L for adults and 4 µg/L for children. Children had lower blood mercury levels compared to adults, and for adults, a higher age was associated with higher blood mercury levels. Boys had higher blood mercury levels compared to girls, but the same pattern was not observed for adults. For adults there appeared to be a South to North gradient in the region-specific blood mercury levels although this did not reach statistical significance, and this pattern was not observed for children.

Of the 304 adults who provided a blood sample, 83 indicated they had eaten fish in the 48 hours prior to sampling, with a GM of 2.24 µg/L (95%CI 1.87-2.69). The GM of the 221 adults who did not have fish 48 hours before sampling was 1.47 µg/L (95%CI 1.30-1.65). For the 35 children that had eaten fish 48 hours before sampling the GM was 1.92 µg/L (95%CI 1.40-2.63), compared to 0.71 µg/L (95%CI 0.61-0.83) for children who did not have fish.

Table 7a. *Geometric means for blood mercury, adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value
all	304	2	1.646	1.488-1.820	(0.139)
age 19-24	52	2	0.918	0.696-1.210	
25-34	64	0	1.585	1.271-1.977	
35-49	85	0	1.674	1.417-1.977	
50-64	103	0	2.231	1.931-2.577	**<0.0001**
male	140	0	1.738	1.498-2.016	
female	164	2	1.571	1.371-1.800	0.320
Māori	112	1	1.772	1.491-2.106	
non-Māori	192	1	1.576	1.394-1.782	0.339
Northland/Auckland	65	2	1.890	1.499-2.384	
Waikato/BoP	85	0	1.689	1.379-2.067	
lower North Island	79	0	1.583	1.344-1.865	
South Island	75	0	1.477	1.203-1.812	0.079

LOD: limit of detection (0.2 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable.

Table 7b. *Geometric means for blood mercury, children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value
all	193	13	0.854	0.735-0.992	(0.058)
age 5-7	38	2	0.911	0.657-1.262	
8-10	70	6	0.779	0.594-1.021	
11-18	85	5	0.895	0.725-1.105	0.449
male	95	4	1.069	0.859-1.331	
female	98	9	0.686	0.564-0.835	**0.002**
Māori	49	2	0.784	0.604-1.018	
non-Māori	144	11	0.879	0.734-1.052	0.743
Northland/Auckland	42	2	0.795	0.584-1.083	
Waikato/BoP	36	4	0.827	0.570-1.200	
lower North Island	90	4	0.882	0.719-1.082	
South Island	25	3	0.897	0.550-1.464	0.705

LOD: limit of detection (0.2 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable.

4.2.3. Urinary arsenic

Arsenic is a non-essential metalloid and a widely distributed element found in several forms resulting from geothermal activity, mining operations, coal burning, and smelting operations. In several countries arsenic is naturally present at high levels in groundwater. Arsenic compounds have been used for medical purposes, pigments, pesticides, and timber treatment (i.e. CCA). Arsenic is highly toxic in its inorganic form. Inorganic arsenic has also been associated with long-term health effects including developmental effects, neurotoxicity, diabetes, pulmonary disease, cardiovascular disease and cancer (WHO, 2016). General population exposure to inorganic arsenic can occur through consumption of contaminated drinking water and to a lesser extent rice, grains, seaweed and fish. Fish and seafood consumption is the main route of exposure for organic arsenic, which is rapidly excreted and has not been associated with toxic effects in humans. After recent seafood ingestion, organic arsenic in the form of arsenobetaine (AB) and arsenocholine will greatly increase the level of total urinary arsenic. When seafood intake is avoided, inorganic arsenic related compounds in the form of dimethylarsenic acid (DMA), the major metabolite of inorganic arsenic, and monomethylarsonic acid (MMA) compose most of the total of arsenic species measured in the urine.

Inorganic arsenic

The inorganic arsenic related compounds determined in urine included dimethylersinic acid (DMA), the major metabolite of inorganic arsenic, monomethylarsonic acid (MMA), arsenite (AsIII) and arsenate (AsV). The detection frequency of these compounds for adults and children were 79% and 72% for DMA, and 3% and 14% for MMA. AsIII and AsV were not detected in any of the samples from adults and in one and two of the samples from children, respectively.

The results for total inorganic arsenic (DMA+MMA+AsIII+AsV) are presented in **Table 8a** for adults and **Table 8b** for children. Inorganic arsenic was detected in 79% of adults and 74% of children. The geometric mean urinary inorganic arsenic level was 4.2 µg/L for adults and 3.2 µg/L for children. The arithmetic mean urinary inorganic arsenic level was 17.9 µg/L for adults and 19.2 µg/L for children. The 95th percentile was 63 µg/L for adults and 70 µg/L for children. For both adults and children there was a strong South to North gradient in urinary inorganic arsenic levels, with the lowest GMs for the South Island.

Of the 304 adults who provided a urine sample, 79 indicated they had eaten fish in the 48 hours prior to sampling, for which the GM was 8.97 µg/L (95%CI 5.59-14.41). The GM of the 225 adults who did not have fish 48 hours before sampling was 3.20 µg/L (95%CI 2.29-4.49). For the 37 children that had eaten fish 48 hours before sampling the GM was 14.38 µg/L (95%CI 7.28-28.41), compared to 2.40 µg/L (95%CI 1.59-3.63) for children who did not have fish.

Table 8a. *Geometric means for total inorganic arsenic (DMA+MMA+AsIII+AsV), adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM ug/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	304	63	4.19	3.16-5.55	(0.071)	3.35	2.57-4.37	(0.045)	4.59	3.50-6.02	(0.056)
age 19-24	53	9	5.88	3.12-11.09		3.76	2.05-6.91		6.08	3.31-11.20	
25-34	65	13	4.44	2.42-8.14		2.83	1.57-5.08		4.33	2.39-7.87	
35-49	83	17	3.98	2.31-6.87		3.17	1.90-5.29		4.43	2.63-7.47	
50-64	103	24	3.52	2.16-5.75	0.842	3.68	2.33-5.80	0.863	4.25	2.66-6.77	0.936
male	140	21	6.24	4.28-9.11		4.00	2.77-5.80		5.97	4.12-8.65	
female	164	42	2.98	1.99-4.45	**0.005**	2.88	1.98-4.19	0.173	3.67	2.50-5.40	0.053
Māori	115	27	3.68	2.31-5.87		2.90	1.86-4.52		3.91	2.48-6.15	
non-Māori	189	36	4.52	3.18-6.43	0.655	3.66	2.63-5.09	0.500	5.07	3.62-7.09	0.473
Northland/Auckland	67	10	6.74	3.85-11.82		5.43	3.14-9.38		7.71	4.51-13.18	
Waikato/BoP	84	12	6.68	4.19-10.65		4.68	3.03-7.22		6.81	4.33-10.71	
lower North Island	78	16	3.51	2.04-6.03		2.91	1.72-4.91		3.79	2.23-6.42	
South Island	75	25	1.94	1.03-3.67	**0.0040**	1.74	0.97-3.13	**0.012**	2.28	1.24-4.16	**0.006**

LOD: limit of detection (0.1 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 8b. *Geometric means for total inorganic arsenic (DMA+MMA+AsIII+AsV), children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM ug/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	299	77	3.16	2.32-4.31	(0.055)	3.15	2.32-4.28	(0.063)	2.94	2.16-3.98	(0.058)
age 5-7	64	14	5.41	2.82-10.40		6.35	3.34-12.09		4.87	2.56-9.28	
8-10	120	34	2.38	1.45-3.91		2.56	1.56-4.20		2.20	1.35-3.61	
11-18	115	29	3.15	1.94-5.12	0.156	2.65	1.65-4.27	0.034	2.98	1.85-4.82	0.178
male	144	40	3.15	1.99-4.99		3.02	1.92-4.75		2.83	1.80-4.44	
female	155	37	3.17	2.09-4.80	0.786	3.28	2.16-4.96	0.541	3.04	2.01-4.59	0.619
Māori	87	21	3.17	1.84-5.45		3.10	1.79-5.36		2.90	1.68-5.01	
non-Māori	212	56	3.16	2.17-4.59	0.301	3.17	2.20-4.59	0.225	2.95	2.04-4.26	0.249
Northland/Auckland	49	9	5.72	2.82-11.61		4.56	2.28-9.13		5.16	2.62-10.16	
Waikato/BoP	48	8	6.43	3.15-13.10		6.85	3.15-14.89		6.16	2.96-12.80	
lower North Island	172	48	2.70	1.80-4.04		2.81	1.90-4.17		2.53	1.70-3.77	
South Island	30	12	0.96	0.34-2.69	**0.006**	0.95	0.34-2.69	**0.004**	0.83	0.30-2.33	**0.003**

LOD: limit of detection (0.1 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.
For one of the 300 available urine samples arsenic results were not available due to insufficient sample to perform the analysis.

The results for the major inorganic arsenic metabolite DMA are presented in **Table 9a** for adults and **Table 9b** for children. These results are almost identical to the results for total inorganic arsenic in **Tables 8a** and **8b**, as DMA was the major contributor to total inorganic arsenic. DMA was detected in 79% of adults and 74% of children and was the predominant inorganic arsenic compound measured. The geometric mean urinary DMA level was 4.2 µg/L for adults and 3.2 µg/L for children. The arithmetic mean urinary DMA level was 17.9 µg/L for adults and 19.2 µg/L for children. The 95th percentile was 63 µg/L for adults and 70 µg/L for children. Among adults, men had higher urinary DMA levels compared to women, but this gender pattern was not observed among children. For both adults and children there was a South to North gradient in urinary DMA levels, with the lowest GMs for the South Island.

The results for the inorganic arsenic metabolite MMA are presented in **Table 10a** for adults and **Table 10b** for children. MMA was detected in 3% of adults and 14% of children. Because of these low detection frequencies the p-values in **Tables 10a** and **10b** refer to differences in detection frequency between groups and not differences in GM between groups. Detection frequencies were significantly higher in the younger age groups. There were no statistically significant differences in detection frequency of MMA between the different gender and ethnic groups. Among children the lowest MMA detection frequency was observed for the lower North Island.

Table 9a. *Geometric means for urinary dimethylarsinic acid (DMA), adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM ug/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	304	63	4.18	3.16-5.54	(0.071)	3.35	2.57-4.37	(0.045)	4.59	3.50-6.02	(0.056)
age 19-24	53	9	5.88	3.12-11.09		3.76	2.05-6.90		6.08	3.31-11.19	
25-34	65	13	4.42	2.41-8.11		2.82	1.57-5.06		4.32	2.38-7.85	
35-49	83	17	3.98	2.31-6.87		3.17	1.90-5.29		4.43	2.62-7.46	
50-64	103	24	3.52	2.16-5.75	0.843	3.68	2.33-5.80	0.860	4.25	2.66-6.77	0.935
male	140	21	6.23	4.27-9.09		4.00	2.76-5.79		5.96	4.12-8.64	
female	164	42	2.98	1.99-4.45	**0.005**	2.88	1.98-4.19	0.173	3.67	2.50-5.40	0.053
Māori	115	27	3.68	2.31-5.87		2.90	1.86-4.52		3.91	2.48-6.15	
non-Māori	189	36	4.52	3.18-6.43	0.656	3.66	2.63-5.09	0.501	5.06	3.62-7.08	0.474
Northland/Auckland	67	10	6.74	3.85-11.81		5.43	3.14-9.37		7.70	4.50-13.17	
Waikato/BoP	84	12	6.68	4.19-10.64		4.67	3.03-7.21		6.80	4.32-10.70	
lower North Island	78	16	3.51	2.04-6.02		2.90	1.72-4.91		3.78	2.23-6.42	
South Island	75	25	1.94	1.03-3.67	**0.004**	1.74	0.97-3.13	**0.012**	2.27	1.24-4.16	**0.006**

LOD: limit of detection (0.1 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 9b. *Geometric means for urinary dimethylarsinic acid (DMA), children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM ug/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	299	85	3.01	2.20-4.12	(0.061)	3.00	2.19-4.11	(0.068)	2.80	2.05-3.82	(0.064)
age 5-7	64	14	5.40	2.81-10.36		6.33	3.33-12.04		4.85	2.55-9.24	
8-10	120	40	2.18	1.31-3.65		2.35	1.41-3.93		2.02	1.22-3.37	
11-18	115	31	3.04	1.86-4.98	0.121	2.56	1.58-4.15	**0.028**	2.88	1.77-4.68	0.138
male	144	42	3.08	1.94-4.89		2.95	1.86-4.65		2.76	1.75-4.35	
female	155	43	2.95	1.92-4.53	0.941	3.05	1.99-4.69	0.686	2.83	1.85-4.34	0.770
Māori	87	23	3.05	1.75-5.29		2.98	1.70-5.22		2.79	1.59-4.86	
non-Māori	212	62	3.00	2.04-4.39	0.295	3.01	2.07-4.39	0.222	2.80	1.92-4.07	0.245
Northland/Auckland	49	10	5.53	2.70-11.36		4.41	2.17-8.95		4.99	2.50-9.96	
Waikato/BoP	48	9	6.09	2.93-12.64		6.48	2.92-14.39		5.83	2.76-12.33	
lower North Island	172	50	2.64	1.76-3.98		2.76	1.85-4.10		2.48	1.66-3.71	
South Island	30	16	0.76	0.26-2.25	**0.003**	0.76	0.25-2.28	**0.003**	0.66	0.22-1.96	**0.002**

LOD: limit of detection (0.1 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.
For one of the 300 available urine samples arsenic results were not available due to insufficient sample to perform the analysis.

Table 10a. *Geometric means for urinary monomethylarsonic acid (MMA), adults. GMs based on detected values only.*

	n	n> LOD	%>LOD*	(R2) p-value	GM µg/L	95%CI	GM µg/g crea	95%CI	GM µg/L spgr	95%CI
all	304	8	3%	(0.038)	0.44	0.20-0.96	0.22	0.11-0.42	0.33	0.16-0.69
age 19-24	53	2	4%		0.20		0.14		0.19	
25-34	65	5	8%		0.52	0.20-1.31	0.24	0.12-0.51	0.37	0.14-0.96
35-49	83	1	1%		0.98		0.34		0.53	
50-64	103	0	0%	**0.019**						
male	140	4	3%		0.54	0.17-1.72	0.27	0.11-0.65	0.39	0.12-1.27
female	164	4	2%	0.920	0.36	0.15-0.82	0.18	0.08-0.39	0.28	0.14-0.55
Māori	115	3	3%							
non-Māori	189	5	3%	0.949	0.56	0.21-1.54	0.26	0.11-0.61	0.42	0.17-1.07
Northland/Auckland	67	3	4%		0.25		0.14		0.22	
Waikato/BoP	84	1	1%		2.10		0.74		1.64	
lower North Island	78	2	3%		0.64		0.32		0.40	
South Island	75	2	3%	0.692	0.31		0.16		0.21	

LOD: limit of detection (0.1 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; the p-value of the multivariate regression model for that variable with detected as the dependent variable; crea: creatinine adjusted; spgr: specific gravity adjusted.
*: percentage of samples with a detectable level of MMA

Table 10b. *Geometric means for urinary monomethylarsonic acid (MMA), children. GMs based on detected values only.*

	n	n> LOD	%>LOD*	(R2) p-value	GM µg/L	95%CI	GM µg/g crea	95%CI	GM µg/L spgr	95%CI
all	299	41	14%	(0.096)	0.39	0.30-0.51	0.32	0.22-0.46	0.34	0.25-0.47
age 5-7	64	11	17%		0.42	0.25-0.70	0.43	0.23-0.80	0.37	0.21-0.66
8-10	120	13	11%		0.31	0.21-0.46	0.29	0.18-0.47	0.26	0.16-0.42
11-18	115	17	15%	0.590	0.46	0.30-0.69	0.29	0.15-0.54	0.40	0.24-0.66
male	144	22	15%		0.41	0.28-0.59	0.32	0.18-0.54	0.33	0.21-0.50
female	155	19	12%	0.999	0.38	0.27-0.54	0.32	0.21-0.50	0.36	0.23-0.57
Māori	87	11	13%		0.35	0.22-0.54	0.24	0.14-0.39	0.27	0.17-0.42
non-Māori	212	30	14%	0.343	0.41	0.30-0.57	0.36	0.23-0.55	0.38	0.26-0.55
Northland/Auckland	49	14	29%		0.37	0.23-0.59	0.26	0.15-0.44	0.29	0.17-0.47
Waikato/BoP	48	13	27%		0.41	0.26-0.66	0.36	0.17-0.77	0.37	0.21-0.65
lower North Island	172	9	5%		0.49	0.29-0.81	0.48	0.30-0.77	0.52	0.29-0.92
South Island	30	5	17%	**<0.0001**	0.29	0.15-0.53	0.21	0.09-0.51	0.22	0.10-0.48

LOD: limit of detection (0.1 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; the p-value of the multivariate regression model for that variable with detected as the dependent variable; crea: creatinine adjusted; spgr: specific gravity adjusted.
For one of the 300 available urine samples arsenic results were not available due to insufficient sample to perform the analysis.
*: percentage of samples with a detectable level of MMA

Organic arsenic

The results for arsenobetaine are presented in **Table 11a** for adults and **Table 11b** for children. Organic arsenic in the form of arsenobetaine (AB), the predominant arsenic species in most marine fish, was detected in 68% of adults and 53% of children. The geometric mean urinary AB level was 3.5 µg/L for adults and 1.5 µg/L for children. The arithmetic mean urinary AB level was 69.6 µg/L for adults and 117.1 µg/L for children. The 95th percentile was 231 µg/L for adults and 247 µg/L for children. Among adults, men had higher urinary AB levels compared to women, but this gender pattern was no longer statistically significant after creatinine and specific gravity adjustment, and a gender pattern was not observed among children. Among children, AB levels were higher for non-Māori compared to Māori, but this ethnicity pattern was not observed among adults.

Of the 304 adults who provided a urine sample, 79 indicated they had eaten fish in the 48 hours prior to sampling, and this group had a GM of 24.60 µg/L (95%CI 13.98-43.27). The GM of the 225 adults who did not have fish 48 hours before sampling was 1.77 µg/L (95%CI 1.17-2.68). For the 37 children that had eaten fish 48 hours before sampling the GM was 41.21 µg/L (95%CI 15.32-110.85), compared to 0.91 µg/L (95%CI 0.56-1.48) for children who did not have fish.

Table 11a. *Geometric means for urinary organic arsenic arsenobetaine (AB), adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	304	98	3.51	2.44-5.04	(0.042)	2.81	1.98-3.99	(0.025)	3.85	2.71-5.48	(0.030)
age 19-24	53	21	2.40	0.96-6.01		1.54	0.62-3.79		2.49	1.01-6.15	
25-34	65	16	4.65	2.26-9.58		2.96	1.44-6.11		4.54	2.21-9.34	
35-49	83	22	5.67	2.88-11.17		4.52	2.37-8.60		6.30	3.29-12.09	
50-64	103	39	2.43	1.29-4.57	0.253	2.53	1.38-4.63	0.300	2.92	1.59-5.39	0.292
male	140	35	5.65	3.42-9.34		3.62	2.19-6.01		5.40	3.28-8.91	
female	164	63	2.34	1.41-3.89	**0.014**	2.26	1.39-3.67	0.178	2.88	1.76-4.72	0.074
Māori	115	34	4.54	2.56-8.07		3.58	2.05-6.26		4.82	2.74-8.48	
non-Māori	189	64	3.00	1.88-4.78	0.294	2.43	1.55-3.80	0.357	3.36	2.14-5.28	0.380
Northland/Auckland	67	24	3.22	1.46-7.11		2.60	1.20-5.63		3.68	1.71-7.96	
Waikato/BoP	84	21	4.83	2.51-9.28		3.38	1.78-6.40		4.92	2.57-9.41	
lower North Island	78	28	2.68	1.33-5.42		2.22	1.13-4.35		2.89	1.46-5.74	
South Island	75	25	3.51	1.64-7.51	0.615	3.14	1.51-6.52	0.800	4.10	1.98-8.53	0.708

LOD: limit of detection (0.1 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 11b. *Geometric means for urinary organic arsenic arsenobetaine (AB), children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95% CI	(R2) p-value	GM µg/L spgr	95% CI	(R2) p-value
all	299	142	1.50	1.01-2.24	(0.078)	1.50	1.01-2.23	(0.074)	1.39	0.94-2.07	(0.080)
age 5-7	64	32	1.25	0.54-2.89		1.46	0.64-3.36		1.12	0.49-2.58	
8-10	120	67	0.88	0.47-1.64		0.95	0.51-1.77		0.81	0.44-1.51	
11-18	115	43	2.91	1.54-5.49	**0.011**	2.45	1.29-4.66	0.044	2.76	1.46-5.21	**0.010**
male	144	67	1.85	1.02-3.37		1.77	0.98-3.22		1.66	0.92-3.00	
female	155	75	1.24	0.73-2.10	0.310	1.28	0.75-2.17	0.451	1.19	0.70-2.01	0.396
Māori	87	54	0.49	0.25-0.95		0.47	0.24-0.92		0.44	0.23-0.87	
non-Māori	212	88	2.39	1.48-3.84	**0.002**	2.40	1.49-3.86	**0.001**	2.23	1.39-3.57	**0.001**
Northland/Auckland	49	25	0.89	0.37-2.12		0.71	0.30-1.67		0.80	0.34-1.90	
Waikato/BoP	48	24	1.94	0.61-6.16		2.07	0.64-6.67		1.86	0.60-5.81	
lower North Island	172	81	1.42	0.86-2.35		1.48	0.90-2.44		1.33	0.81-2.21	
South Island	30	12	3.24	0.86-12.21	0.436	3.23	0.82-12.66	0.272	2.82	0.75-11	0.415

LOD: limit of detection (0.1 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.
For one of the 300 available urine samples arsenic results were not available due to insufficient sample to perform the analysis.

4.2.4. Urinary cadmium

Cadmium is a non-essential heavy metal. Cadmium is primarily sourced as a by-product of processing zinc-containing ores and sulphide ores and is used in battery manufacture. Emissions of air-borne cadmium come from burning fossil fuels and incineration of solid waste. Cadmium is a natural impurity in phosphate rock used to produce phosphate fertilisers. With continuous fertiliser application cadmium may accumulate in soil and there is evidence that cadmium is accumulating in New Zealand agricultural soils (Kim, 2005). Soil cadmium may be absorbed by common food plants including cereals and potatoes. Cadmium is toxic at very low exposure levels and has been associated with acute and chronic health effects, including kidney damage and resulting renal dysfunction. Exposure to cadmium is primarily from contaminated water and food, including potatoes, cereals and oysters. Cigarette smoke is a significant cadmium source and the body burden of cadmium in smokers is typically twice that of non-smokers. Urinary levels of cadmium are an accepted indicator of cumulative exposure and the concentration of cadmium in the kidney. Cadmium has a long retention time in the human body, with a half-life of approximately 15 years in the kidney (WHO, 2011) and urinary cadmium reflects long-term body burden of cadmium.

The results for cadmium are presented in **Table 12a** for adults and **Table 12b** for children. Cadmium was detected in 89% of the adult urine samples and 53% of the child urine samples. The geometric mean urinary cadmium was 0.19 µg/L for adults and 0.07 µg/L for children. The arithmetic mean urinary cadmium was 0.28 µg/L for adults and 0.09 µg/L for children. The 95th percentile was 0.64 µg/L for adults and 0.17 µg/L for children. Age was strongly and positively associated with cadmium levels. There were no consistently observed differences in urinary cadmium levels between men and women or boys and girls. Among adults, Māori had higher cadmium levels, although this was no longer statistically significant after specific gravity adjustment. Among children a difference between Māori and non-Māori for cadmium was not observed. For adults, cadmium levels differed among geographic regions, but this was not observed for children.

For adults who indicated they were currently a smoker (n=26), the GM was 0.30 µg/L (95%CI 0.22-0.41). For adults who indicated they were currently not a smoker (n=278), the GM was 0.19 µg/L (95%CI 0.17-0.21).

Table 12a. *Geometric means for urinary cadmium, adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	304	33	0.19	0.18-0.21	(0.129)	0.15	0.14-0.17	(0.368)	0.21	0.19-0.23	(0.220)
age 19-24	53	10	0.13	0.10-0.15		0.08	0.07-0.10		0.13	0.11-0.16	
25-34	65	10	0.16	0.13-0.20		0.10	0.08-0.12		0.16	0.13-0.19	
35-49	83	6	0.21	0.18-0.25		0.17	0.15-0.20		0.24	0.20-0.28	
50-64	103	7	0.25	0.21-0.29	**<0.0001**	0.26	0.23-0.30	**<0.0001**	0.30	0.26-0.35	**<0.0001**
male	140	12	0.21	0.18-0.24		0.13	0.12-0.15		0.20	0.18-0.23	
female	164	21	0.18	0.16-0.21	0.140	0.18	0.15-0.20	**0.0003**	0.22	0.20-0.25	0.125
Māori	115	10	0.23	0.19-0.27		0.18	0.15-0.21		0.24	0.21-0.28	
non-Māori	189	23	0.17	0.16-0.20	**0.014**	0.14	0.13-0.16	**0.026**	0.20	0.18-0.22	0.052
Northland/Auckland	67	8	0.21	0.17-0.27		0.17	0.14-0.21		0.24	0.19-0.30	
Waikato/BoP	84	13	0.18	0.15-0.22		0.13	0.11-0.16		0.19	0.16-0.22	
lower North Island	78	10	0.17	0.14-0.20		0.14	0.12-0.16		0.18	0.16-0.21	
South Island	75	2	0.21	0.18-0.25	0.190	0.19	0.16-0.23	**0.001**	0.25	0.22-0.29	**0.005**

LOD: limit of detection (0.079 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 12b. *Geometric means for urinary cadmium, children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	300	140	0.07	0.07-0.08	(0.023)	0.07	0.07-0.08	(0.097)	0.07	0.06-0.07	(0.031)
age 5-7	64	33	0.07	0.06-0.08		0.08	0.07-0.09		0.06	0.05-0.07	
8-10	120	47	0.08	0.07-0.09		0.09	0.08-0.10		0.08	0.07-0.08	
11-18	116	60	0.07	0.06-0.08	0.146	0.06	0.05-0.07	**0.0003**	0.07	0.06-0.08	0.083
male	144	68	0.07	0.07-0.08		0.07	0.06-0.08		0.07	0.06-0.07	
female	156	72	0.07	0.07-0.08	0.789	0.08	0.07-0.09	0.112	0.07	0.07-0.08	0.223
Māori	87	42	0.07	0.06-0.08		0.07	0.06-0.08		0.07	0.06-0.08	
non-Māori	213	98	0.07	0.07-0.08	0.794	0.07	0.07-0.08	0.688	0.07	0.06-0.08	0.860
Northland/Auckland	50	26	0.07	0.06-0.08		0.05	0.05-0.07		0.06	0.05-0.07	
Waikato/BoP	48	27	0.07	0.06-0.08		0.07	0.06-0.09		0.06	0.05-0.08	
lower North Island	172	75	0.08	0.07-0.08		0.08	0.07-0.09		0.07	0.07-0.08	
South Island	30	12	0.08	0.06-0.10	0.619	0.08	0.06-0.10	0.093	0.07	0.06-0.09	0.691

LOD: limit of detection (0.079 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

4.2.5. Urinary chromium

Chromium is an essential nutrient required for sugar and fat metabolism. Chromium occurs as either trivalent (III) or hexavalent (VI) states, with chromium (III) being the most common and stable in the environment. Chromium (III) is an essential nutrient while chromium (VI) is toxic and associated with carcinogenicity, respiratory effects, and renal effects in humans (NHMRC, 2006). Diet is the main exposure route for chromium however there is no information on dietary intake in New Zealand (Ministry for the Environment, 2011). The majority of absorbed chromium is excreted in faeces and urine so urinary chromium will provide useful information on absorbed chromium from dietary sources, reflecting recent exposure.

The results for chromium are presented in **Table 13a** for adults and **Table 13b** for children. Chromium was detected in 59% of the adult urine samples and 44% of the child urine samples. The geometric mean urinary chromium was 0.05 µg/L for adults and 0.03 µg/L for children. The arithmetic mean urinary chromium was 0.18 µg/L for adults and 0.14 µg/L for children. The 95th percentile was 0.75 µg/L for adults and 0.48 µg/L for children. There were no consistent differences in urinary chromium levels between age groups, men and women, ethnicity groups, or geographic regions. However, children in the lower North Island had higher urinary chromium levels compared to children from the other regions, albeit based on small numbers above the limit of detection for some regions. Overall, the relatively low detection frequency for chromium limits the statistical interpretation of these data.

Table 13a. *Geometric means for urinary chromium, adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	304	126	0.05	0.04-0.06	(0.053)	0.04	0.03-0.05	(0.053)	0.06	0.05-0.07	(0.043)
age 19-24	53	26	0.04	0.02-0.06		0.03	0.02-0.04		0.04	0.03-0.06	
25-34	65	30	0.05	0.03-0.07		0.03	0.02-0.05		0.05	0.03-0.07	
35-49	83	29	0.07	0.05-0.10		0.05	0.04-0.08		0.08	0.05-0.11	
50-64	103	41	0.05	0.04-0.07	0.227	0.05	0.04-0.07	**0.006**	0.06	0.05-0.08	0.089
male	140	47	0.07	0.05-0.10		0.05	0.04-0.06		0.07	0.05-0.09	
female	164	79	0.04	0.03-0.05	**0.001**	0.04	0.03-0.05	0.320	0.05	0.04-0.06	0.059
Māori	115	52	0.05	0.04-0.07		0.04	0.03-0.05		0.05	0.04-0.07	
non-Māori	189	74	0.05	0.04-0.07	0.764	0.04	0.03-0.05	0.529	0.06	0.05-0.07	0.482
Northland/Auckland	67	27	0.06	0.04-0.09		0.05	0.03-0.07		0.07	0.05-0.10	
Waikato/BoP	84	36	0.05	0.04-0.07		0.04	0.03-0.05		0.05	0.04-0.07	
lower North Island	78	34	0.04	0.03-0.06		0.04	0.03-0.05		0.05	0.03-0.07	
South Island	75	29	0.05	0.04-0.08	0.630	0.05	0.03-0.07	0.420	0.06	0.04-0.09	0.403

LOD: limit of detection (0.02 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 13b. *Geometric means for urinary chromium, children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	300	167	0.03	0.03-0.04	(0.148)	0.03	0.03-0.04	(0.168)	0.03	0.03-0.04	(0.166)
age 5-7	64	38	0.03	0.02-0.05		0.04	0.03-0.05		0.03	0.02-0.04	
8-10	120	67	0.03	0.02-0.04		0.03	0.03-0.05		0.03	0.02-0.04	
11-18	116	62	0.04	0.03-0.05	0.254	0.03	0.02-0.04	0.598	0.04	0.03-0.05	0.204
male	144	89	0.03	0.02-0.04		0.03	0.02-0.04		0.03	0.02-0.03	
female	156	78	0.04	0.03-0.05	0.472	0.04	0.03-0.05	0.190	0.04	0.03-0.05	0.253
Māori	87	51	0.03	0.02-0.04		0.03	0.02-0.04		0.03	0.02-0.03	
non-Māori	213	116	0.04	0.03-0.05	0.116	0.04	0.03-0.05	0.062	0.03	0.03-0.04	0.071
Northland/Auckland	50	36	0.02	0.01-0.03		0.02	0.01-0.02		0.02	0.01-0.03	
Waikato/BoP	48	37	0.02	0.01-0.02		0.02	0.01-0.03		0.02	0.01-0.02	
lower North Island	172	68	0.05	0.04-0.07		0.06	0.04-0.07		0.05	0.04-0.07	
South Island	30	26	0.01	0.01-0.02	**<0.0001**	0.01	0.01-0.02	**<0.0001**	0.01	0.01-0.02	**<0.0001**

LOD: limit of detection (0.02 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

4.2.6. Urinary thallium

Thallium is a non-essential heavy metal that is found in trace amounts in the earth's crust. Major releases of thallium to the environment are from processes such as coal-burning, metal smelting and metal mining in which thallium is a trace contaminant of the raw materials, rather than from facilities producing or using thallium compounds. Thallium and thallium compounds are soluble and highly toxic. Thallium toxicity can occur at the workplace after respiratory or dermal exposure. Population exposure occurs mainly through eating fruits and green vegetables grown in thallium rich soils, or grown in the vicinity of sources releasing thallium into the air, including coal-burning power plants, cement factories, and smelting operations. Urinary thallium levels reflect recent exposure.

The results for thallium are presented in **Table 14a** for adults and **Table 14b** for children. Thallium was detected in urine of 97% of the adults and 79% of the children. The geometric mean urinary thallium concentration was 0.20 µg/L for adults and 0.05 µg/L for children. The arithmetic mean urinary thallium concentration was µg/L for 0.28 adults and 0.10 µg/L for children. The 95th percentile was 0.64 µg/L for adults and 0.34 µg/L for children. There were no consistent differences in urinary thallium levels between age groups, men and women, or ethnicity groups. Differences in urinary thallium levels between geographic regions were observed for both adults and children, with the lowest GM observed for the South Island.

Table 14a. *Geometric means for urinary thallium, adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	304	8	0.20	0.18-0.22	(0.163)	0.16	0.14-0.18	(0.112)	0.22	0.20-0.24	(0.116)
age 19-24	53	0	0.20	0.16-0.25		0.13	0.10-0.16		0.21	0.17-0.26	
25-34	65	2	0.21	0.17-0.27		0.14	0.11-0.17		0.21	0.17-0.26	
35-49	83	3	0.22	0.18-0.27		0.18	0.15-0.22		0.25	0.21-0.30	
50-64	103	3	0.17	0.14-0.20	0.116	0.18	0.15-0.21	**0.007**	0.21	0.18-0.24	0.174
male	140	2	0.23	0.20-0.26		0.14	0.13-0.16		0.22	0.19-0.24	
female	164	6	0.18	0.15-0.21	**0.004**	0.17	0.15-0.20	0.141	0.22	0.19-0.25	0.831
Māori	115	2	0.20	0.17-0.24		0.16	0.14-0.19		0.21	0.18-0.25	
non-Māori	189	6	0.20	0.17-0.22	0.561	0.16	0.14-0.18	0.994	0.22	0.19-0.25	0.884
Northland/Auckland	67	0	0.21	0.17-0.25		0.17	0.14-0.20		0.24	0.20-0.28	
Waikato/BoP	84	0	0.29	0.25-0.35		0.21	0.18-0.24		0.30	0.26-0.34	
lower North Island	78	1	0.20	0.17-0.24		0.17	0.14-0.20		0.22	0.18-0.26	
South Island	75	7	0.12	0.10-0.16	**<0.0001**	0.11	0.09-0.14	**<0.0001**	0.14	0.12-0.18	**<0.0001**

LOD: limit of detection (0.02 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 14b. *Geometric means for urinary thallium, children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	300	64	0.05	0.05-0.06	(0.037)	0.05	0.05-0.06	(0.037)	0.05	0.04-0.06	(0.046)
age 5-7	64	18	0.05	0.04-0.07		0.06	0.04-0.08		0.05	0.03-0.06	
8-10	120	22	0.05	0.04-0.06		0.06	0.05-0.07		0.05	0.04-0.06	
11-18	116	24	0.06	0.05-0.07	0.843	0.05	0.04-0.06	0.402	0.06	0.05-0.07	0.720
male	144	33	0.05	0.04-0.07		0.05	0.04-0.06		0.05	0.04-0.06	
female	156	31	0.06	0.05-0.07	0.849	0.06	0.05-0.07	0.500	0.05	0.04-0.06	0.659
Māori	87	26	0.05	0.04-0.07		0.05	0.04-0.07		0.05	0.04-0.06	
non-Māori	213	38	0.05	0.05-0.06	0.531	0.05	0.05-0.06	0.326	0.05	0.04-0.06	0.379
Northland/Auckland	50	6	0.07	0.05-0.09		0.06	0.04-0.07		0.06	0.05-0.08	
Waikato/BoP	48	14	0.05	0.03-0.06		0.05	0.03-0.07		0.04	0.03-0.06	
lower North Island	172	32	0.06	0.05-0.07		0.06	0.05-0.07		0.05	0.05-0.07	
South Island	30	12	0.03	0.02-0.05	**0.018**	0.03	0.02-0.05	**0.030**	0.03	0.02-0.04	**0.009**

LOD: limit of detection (0.02 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

4.2.7. Urinary antimony

Antimony (Sb) is a silvery-white metal that is found in the earth's crust. Certain mineral deposits, hot springs and mining can result in locally elevated soil levels. Antimony is used in lead storage batteries, solder, sheet and pipe metal, bearings, castings, and pewter. Antimony oxide is added to textiles and plastics as a flame retardant. It is also used in paints, ceramics, and fireworks, and as enamels for plastics, metal, and glass. Antimony toxicity can occur due to occupational exposure. The general population is exposed to antimony primarily through food, tobacco smoking and, to a lesser extent, from air and drinking water. Levels of urinary antimony reflect recent exposure.

The results for antimony are presented in **Table 15a** for adults and **Table 15b** for children. Antimony was detected in 90% of the adult urine samples and 99% of the child urine samples. The geometric mean urinary antimony was 0.06 µg/L for adults and 0.09 µg/L for children. The arithmetic mean urinary antimony was 0.10 µg/L for adults and 0.11 µg/L for children. The 95th percentile was 0.22 µg/L for adults and 0.25 µg/L for children. Among adults, there were no consistent differences in urinary antimony levels between age groups, men and women, ethnicity groups, or geographic regions. Among children, the GM for urinary antimony was higher for girls compared to boys and lowest in the Northland/Auckland region.

For adults who indicated they were currently a smoker (n=26), the GM was 0.12 µg/L (95%CI 0.09-0.16). For adults who indicated they were currently not a smoker (n=278), the GM was 0.06 µg/L (95%CI 0.05-0.07).

Table 15a. *Geometric means for urinary antimony, adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	304	29	0.062	0.055-0.069	(0.060)	0.049	0.044-0.055	(0.024)	0.068	0.061-0.075	(0.019)
age 19-24	53	3	0.071	0.058-0.089		0.046	0.036-0.058		0.074	0.060-0.092	
25-34	65	2	0.072	0.060-0.087		0.046	0.038-0.055		0.070	0.060-0.083	
35-49	83	8	0.064	0.052-0.080		0.051	0.041-0.064		0.071	0.058-0.088	
50-64	103	16	0.050	0.041-0.061	**0.037**	0.052	0.043-0.063	0.840	0.060	0.050-0.073	0.438
male	140	13	0.071	0.060-0.083		0.045	0.039-0.053		0.068	0.058-0.079	
female	164	16	0.055	0.048-0.063	**0.014**	0.053	0.046-0.061	0.139	0.068	0.059-0.077	0.980
Māori	115	9	0.066	0.056-0.077		0.052	0.044-0.061		0.070	0.060-0.081	
non-Māori	189	20	0.059	0.051-0.068	0.256	0.048	0.042-0.055	0.535	0.066	0.058-0.076	0.611
Northland/Auckland	67	7	0.054	0.043-0.067		0.043	0.034-0.054		0.061	0.050-0.076	
Waikato/BoP	84	10	0.069	0.056-0.085		0.048	0.040-0.058		0.070	0.058-0.085	
lower North Island	78	6	0.058	0.048-0.071		0.048	0.040-0.059		0.063	0.053-0.075	
South Island	75	6	0.065	0.051-0.082	0.310	0.058	0.046-0.072	0.324	0.076	0.061-0.094	0.443

LOD: limit of detection (0.02 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 15b. *Geometric means for urinary antimony, children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	300	3	0.091	0.085-0.098	(0.054)	0.091	0.084-0.098	(0.195)	0.085	0.079-0.091	(0.086)
5-7	64	0	0.095	0.081-0.111		0.111	0.095-0.131		0.085	0.075-0.097	
8-10	120	0	0.097	0.088-0.107		0.105	0.095-0.116		0.090	0.083-0.099	
11-18	116	3	0.084	0.073-0.096	0.308	0.070	0.061-0.080	**<0.0001**	0.079	0.070-0.089	0.276
male	144	0	0.087	0.079-0.096		0.084	0.075-0.093		0.078	0.072-0.085	
female	156	3	0.095	0.085-0.107	0.169	0.098	0.088-0.109	**0.004**	0.091	0.083-0.101	**0.008**
Māori	87	1	0.100	0.086-0.117		0.098	0.084-0.114		0.092	0.081-0.104	
non-Māori	213	2	0.088	0.081-0.096	0.105	0.088	0.081-0.096	0.308	0.082	0.076-0.089	0.159
Northland/Auckland	50	3	0.073	0.056-0.094		0.058	0.046-0.072		0.065	0.053-0.081	
Waikato/BoP	48	0	0.106	0.088-0.126		0.112	0.094-0.135		0.101	0.087-0.117	
lower North Island	172	0	0.092	0.084-0.100		0.096	0.088-0.105		0.087	0.080-0.093	
South Island	30	0	0.102	0.084-0.123	**0.029**	0.101	0.083-0.123	**<0.0001**	0.088	0.075-0.104	**0.002**

LOD: limit of detection (0.02 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

4.2.8. Urinary cotinine

Cotinine is the main metabolite of nicotine and is used as a biomarker for exposure to tobacco smoke. Nicotine, the active ingredient in smoking products, is readily absorbed and is biologically metabolised to cotinine within several hours. Non-smokers typically have serum cotinine levels less than 1 µg/L, with those exposed to ETS having levels in the 1-10 µg/L range. Smokers have been reported to have serum cotinine levels in excess of 500 µg/L. Urinary cotinine concentrations are generally substantially higher than blood concentrations and a study from the US reported a median urinary cotinine of 17 µg/L for male non-smokers, 2500 µg/L for smokers smoking 1-19 cigarettes per day and 7200 µg/L for smokers smoking 20+ cigarettes per day (Vine *et al.*, 1993). Urinary cotinine provides a good indication of recent nicotine exposure, and is preferred in many studies because of the ease of collecting urine samples from a wide range of people, including children. Assessment of urinary cotinine levels will enable determination of recent exposure to environmental tobacco smoke and inform assessments of the effectiveness of current and future policy programmes to minimise the health effects of smoking and environmental tobacco smoke.

The results for cotinine are presented in **Table 16a** for adults and **Table 16b** for children. Urinary cotinine was detected in 11% of adults and 2% of children. Detection frequencies were significantly higher among Māori compared to non-Māori, for both children and adults. The GM for adults with detectible levels of cotinine was 563 µg/L, and 12 µg/L for children.

Of the 33 adults with detectable levels of cotinine, 25 were current smokers, who had a GM of 868 µg/L (95%CI 523-1439). Of the 33 adults with detectable levels of cotinine, 8 indicated they were currently not a smoker, who had a GM of 145 µg/L (95%CI 29-737).

Table 16a. *Geometric means for urinary cotinine, adults. The GMs are based on >LOD values only.*

	n	n> LOD	%> LOD	(R2) p-value	GM µg/L	95%CI	GM µg/g crea	95%CI	GM µg/L spgr	95%CI
all	304	33	11%	(0.067)	563	319-992	437	233-820	600	333-1080
age 19-24	53	5	9%		532	139-2034	276	86-885	434	138-1369
25-34	65	10	15%		274	70-1076	152	41-557	244	67-885
35-49	83	11	13%		684	336-1393	641	261-1576	853	366-1986
50-64	103	7	7%	0.356	1207	834-1746	1513	881-2599	1570	942-2616
male	140	10	7%		371	115-1190	209	58-755	353	104-1204
female	164	23	14%	0.060	675	368-1238	603	316-1152	755	408-1397
Māori	115	22	19%		555	295-1043	500	248-1007	629	321-1234
non-Māori	189	11	6%	**0.0004**	578	191-1751	335	100-1121	545	181-1642
Northland/Auckland	67	6	9%		285	74-1099	192	41-899	308	73-1299
Waikato/BoP	84	10	12%		758	296-1944	519	177-1525	702	261-1891
lower North Island	78	7	9%		681	252-1842	541	201-1454	726	276-1906
South Island	75	10	13%	0.761	550	182-1655	521	155-1756	669	210-2134

LOD: limit of detection (0.5 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate regression model for that variable with detected as the dependent variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 16b. *Geometric means for urinary cotinine, children. The GMs are based on >LOD values only.*

	n	n> LOD	%> LOD	(R2) p-value	GM µg/L	95%CI	GM µg/g crea	95%CI	GM µg/L spgr	95%CI
all	300	7	2%	(0.065)	12	3-50	10	3-36	10	2-42
age 5-7	64	3	5%		15	2-106	13	2-68	12	2-83
8-10	120	2	2%		4	2-8	4	2-10	4	2-7
11-18	116	2	2%	0.576	24	2-364	19	2-207	23	2-315
male	144	3	2%		11	1-116	8	1-76	9	1-104
female	156	4	3%	0.825	13	3-56	12	4-38	11	3-44
Māori	87	7	8%		12	3-45	10	3-33	10	3-38
non-Māori	213	0	0%	**<0.0001**						
Northland/Auckland	50	1	2%		5		5		5	
Waikato/BoP	48	1	2%		3		2		3	
lower North Island	172	5	3%		19	4-92	16	4-61	15	3-77
South Island	30	0	0%	0.821						

LOD: limit of detection (0.5 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model p-value: the p-value of the multivariate regression model for that variable with detected as the dependent variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

4.2.9. Urinary fluoride

Fluoride is an ion of fluorine and is ubiquitous in the environment in air, soil, water, plants, animals and food. Fluoride is known to have a protective effect against tooth decay by preventing demineralization of tooth enamel during attack by acid-producing plaque bacteria. In infants and young children ingested fluoride is incorporated into the developing enamel, making the teeth more resistant to decay. Fluoride is added to most tooth pastes and fluoride is also added to approximately half of New Zealand's public water supplies as an equitable way to prevent dental caries. Fluoridation of the public drinking water supplies involves the deliberate adjustment of fluoride concentrations in drinking water from their natural low levels (0.1-0.2 mg/L in most parts of New Zealand) upward up to between 0.7 and 1.0 mg/L (Royal Society of New Zealand, 2014). There is some controversy regarding fluoridation of water supplies in New Zealand because of perceived health concerns related to exposure to excess fluoride (e.g. dental fluorosis in children, unsubstantiated links with cancer, allergic conditions, and other diseases). However, the only observed side effect of fluoridation at levels used in New Zealand is minimal fluorosis, which is not considered of major cosmetic significance (Royal Society of New Zealand, 2014). There is compelling evidence that fluoridation of water at the established and recommended levels produces broad benefits for the dental health of New Zealanders (Royal Society of New Zealand, 2014). Urinary fluoride reflects recent exposure.

The results for fluoride are presented in **Table 17a** for adults and **Table 17b** for children. Fluoride was detected in all urine samples. The geometric mean urinary fluorine was 760 µg/L for adults and 630 µg/L for children. The arithmetic mean urinary fluorine concentration was 893 µg/L for adults and 752 µg/L for children. The 95th percentile was 1760 µg/L for adults and 1600 µg/L for children. Among children, older age was associated with lower urinary fluoride levels. Among adults, a higher urinary fluoride level was observed for females compared to males after creatinine or specific gravity adjustment. This gender pattern was not observed among children. For both children and adults, the lowest geometric mean urinary fluoride level was observed for the South Island.

Table 17a. *Geometric means for urinary fluoride, adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	304	0	759	710-812	(0.132)	608	563-657	(0.237)	833	778-892	(0.156)
age 19-24	53	0	804	700-924		515	442-599		832	729-950	
25-34	65	0	740	645-850		472	414-538		723	631-829	
35-49	83	0	749	651-863		597	511-697		833	721-962	
50-64	103	0	757	675-849	0.932	789	690-904	**<0.0001**	912	809-1029	0.055
male	140	0	778	708-854		499	455-548		744	681-814	
female	164	0	744	677-818	0.332	720	644-805	**<0.0001**	918	831-1013	**0.002**
Māori	115	0	758	681-845		598	525-681		805	717-903	
non-Māori	189	0	760	698-827	0.859	615	559-676	0.525	851	782-926	0.370
Northland/Auckland	67	0	964	842-1103		776	669-900		1101	968-1253	
Waikato/BoP	84	0	797	706-901		558	490-636		812	730-904	
lower North Island	78	0	821	727-928		680	573-808		886	762-1031	
South Island	75	0	535	474-604	**<0.0001**	479	417-551	**<0.0001**	627	551-713	**<0.0001**

LOD: limit of detection (19 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 17b. *Geometric means for urinary fluoride, children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	299	0	628	586-674	(0.190)	626	577-678	(0.307)	584	546-624	(0.210)
age 5-7	64	0	743	642-859		871	754-1006		668	584-764	
8-10	120	0	679	616-750		731	653-817		629	567-698	
11-18	115	0	528	469-593	**0.001**	443	389-503	**<0.0001**	500	448-559	**0.003**
male	144	0	651	588-720		624	555-701		584	529-644	
female	155	0	608	553-669	0.138	627	562-701	0.933	584	532-640	0.654
Māori	87	0	597	528-675		583	509-669		546	489-609	
non-Māori	212	0	642	590-698	0.152	644	584-710	0.040	600	552-652	0.044
Northland/Auckland	50	0	492	410-590		390	317-480		444	379-520	
Waikato/BoP	48	0	502	422-597		535	426-671		481	408-566	
lower North Island	171	0	762	704-826		796	735-862		716	664-773	
South Island	30	0	450	370-546	**<0.0001**	448	344-583	**<0.0001**	391	314-487	**<0.0001**

LOD: limit of detection (19 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.
For one of the 300 available urine samples fluoride results were not available due to insufficient sample to perform the analysis.

4.2.10. Urinary phenols

Urinary bisphenol A

Bisphenol A (BPA) is a phenolic chemical used primarily as a monomer in polycarbonate plastics and epoxy resins. Polycarbonate plastics are rigid plastics used to make products such as compact discs, automobile parts, eyeglass lenses, toys, as well as products that can get into direct contact with food such as baby bottles and plastic dinnerware. Epoxy resins are used for lining canned food containers, wine vat linings, epoxy resin-based paints, floorings and some dental composites. Population exposure to BPA may occur through ingestion of food, which has been in contact with BPA containing materials. BPA is more likely to migrate into oily or fatty foods such as meat, fish and coconut cream. BPA is classified by the New Zealand Environmental Protection Authority as a "suspected human reproductive or developmental toxicant" (6.8B) and as "acutely toxic (oral and dermal)" (6.1E). BPA has weak estrogenic properties i.e. it has the capacity to mimic the female sex hormone, but the human health effects from BPA from low environmental exposures are unknown. The average dietary exposure to BPA by New Zealanders from consumption of canned foods has been estimated as 0.0008 µg/kg body weight/day, based on measurements of BPA in canned foods and New Zealand dietary recall data (Thompson and Grounds, 2005). The European Food Safety Authority (EFSA) published a re-evaluation of BPA exposure and toxicity in 2015 when it reduced the tolerable daily intake (TDI) for BPA from 50 to 4 µg/kg body weight/day (EFSA, 2016). There is no evidence that BPA accumulates in the body. Urinary levels of BPA include both conjugated and unconjugated forms and reflect recent exposure.

The results for urinary BPA are presented in **Table 18a** for adults and **18b** for children. The detection frequency was 93% for adults and 89% for children. The geometric mean urinary BPA was 1.8 µg/L for adults and 2.2 µg/L for children. The arithmetic mean urinary triclosan concentration was 3.1 µg/L for adults and 3.2 µg/L for children, and the 95th percentile was 11.7 µg/L for adults and 9.6 µg/L for children. Of all age groups, the geometric mean of the 19-24 year age group was the highest (2.9 µg/L). The oldest age group (50-64) had the lowest GM for BPA (1.4 µg/L). There were no consistent differences in urinary BPA concentrations between males and females or between Māori and non-Māori. For children, differences among geographic regions were observed, with the highest GM for the Northland/Auckland region (3.2 µg/L).

Table 18a. *Geometric means for urinary bisphenol A, adults.*

	n	n< LOD	GM µg/L	95% CI	(R2) p-value	GM µg/g crea	95% CI	(R2) p-value	GM µg/L spgr	95% CI	(R2) p-value
all	302	20	1.80	1.60-2.03	(0.095)	1.45	1.30-1.61	(0.026)	1.98	1.78-2.21	(0.057)
age 19-24	53	1	2.88	2.22-3.74		1.84	1.46-2.33		2.98	2.36-3.78	
25-34	65	5	2.03	1.54-2.66		1.29	0.99-1.69		1.98	1.53-2.56	
35-49	82	10	1.73	1.36-2.20		1.39	1.14-1.71		1.93	1.57-2.38	
50-64	102	4	1.36	1.15-1.61	**0.0003**	1.41	1.19-1.67	0.241	1.63	1.38-1.93	**0.005**
male	140	8	2.12	1.77-2.55		1.36	1.15-1.61		2.03	1.71-2.41	
female	162	12	1.57	1.34-1.82	**0.006**	1.52	1.33-1.75	0.328	1.93	1.69-2.22	0.596
Maori	114	9	1.82	1.49-2.22		1.45	1.21-1.74		1.94	1.61-2.34	
non-Maori	188	11	1.79	1.55-2.07	0.604	1.44	1.26-1.65	0.897	2.00	1.75-2.28	0.977
Northland/Auckland	67	2	2.10	1.63-2.69		1.69	1.35-2.11		2.40	1.92-2.99	
Waikato/BoP	83	6	1.95	1.57-2.42		1.38	1.13-1.69		2.00	1.64-2.45	
lower North Island	77	8	1.65	1.30-2.08		1.36	1.08-1.70		1.77	1.42-2.20	
South Island	75	4	1.58	1.24-2.01	0.486	1.42	1.15-1.74	0.540	1.85	1.48-2.31	0.397

LOD: limit of detection (0.4 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 18b. *Geometric means for urinary bisphenol A, children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	299	34	2.18	1.96-2.41	(0.080)	2.17	1.96-2.39	(0.086)	2.02	1.83-2.23	(0.081)
age 5-7	64	9	2.17	1.71-2.74		2.54	2.06-3.14		1.95	1.57-2.43	
8-10	120	13	2.21	1.88-2.60		2.38	2.04-2.78		2.05	1.74-2.41	
11-18	115	12	2.14	1.82-2.53	0.568	1.80	1.53-2.11	**0.002**	2.03	1.74-2.38	0.557
male	144	13	2.38	2.05-2.76		2.28	1.97-2.64		2.13	1.85-2.46	
female	155	21	2.00	1.73-2.31	0.099	2.07	1.80-2.36	0.489	1.92	1.67-2.21	0.304
Maori	87	9	2.60	2.21-3.06		2.54	2.20-2.94		2.38	2.06-2.75	
non-Maori	212	25	2.02	1.78-2.30	0.136	2.03	1.79-2.30	0.292	1.89	1.67-2.15	0.219
Northland/Auckland	50	4	3.24	2.57-4.09		2.57	2.04-3.24		2.92	2.31-3.70	
Waikato/BoP	48	4	2.35	1.85-2.98		2.50	1.91-3.27		2.25	1.84-2.75	
lower North Island	171	21	2.05	1.79-2.35		2.14	1.88-2.44		1.93	1.69-2.20	
South Island	30	5	1.39	1.01-1.91	**0.001**	1.38	1.05-1.82	**0.004**	1.21	0.89-1.63	**0.0003**

LOD: limit of detection (0.4 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Urinary triclosan

Triclosan has been used internationally as a preservative and antiseptic agent in consumer products (e.g. soaps, deodorants) for over 30 years. General population exposure results from the use and ingestion of triclosan-containing products via oral ingestion and dermal absorption. Triclosan is not currently known to be hazardous to humans and classified by the New Zealand Environmental Protection Authority as "acutely toxic (oral)" (6.1E) based on animal data. The human health effects of low-level exposure to triclosan are unknown, but some animal studies suggest it may be an endocrine disrupting chemical, and there is some evidence that triclosan exposure is associated with increased allergies in young people (Bertelsen et al., 2012). In humans, triclosan is excreted in urine and faeces, and urine is the preferred biological matrix for exposure assessment, reflecting recent exposure.

The results for urinary triclosan are presented in **Table 19a** for adults and **19b** for children. The detection frequency was 85% for adults and 92% for children. The geometric mean urinary triclosan was 5.8 µg/L for adults and 3.9 µg/L for children. The arithmetic mean urinary triclosan concentration was 133 µg/L for adults and 88 µg/L for children, and the 95th percentile was 963 µg/L for adults and 607 µg/L for children. Of all age groups, the geometric mean of the 19-24 year age group was the highest (14.2 µg/L). There were no consistent differences in urinary triclosan concentrations between males and females or among the different geographic regions. There were marked differences in urinary triclosan concentrations between Māori and non-Māori children, with the GM for non-Māori children more than double the GM for Māori children. For adults this difference between ethnic groups was much less pronounced and did not reach statistical significance.

Of the 303 adults who provided a urine sample, 157 indicated they had used anti-bacterial soaps or hand sanitizers in the 48 hours before urine sampling, with a GM of 8.59 µg/L (95%CI 5.42-13.61). The GM of the 146 adults who did not recall using these products 48 hours before sampling was 3.76 µg/L (95%CI 2.57-5.52). Children indicating having used anti-bacterial soaps or hand sanitizers in the 48 hours before urine sampling (n=73), had a GM urinary triclosan concentration of 4.69 µg/L, marginally higher compared to the GM of 125 children that did not recall using these products (3.36 µg/L).

Table 19a. *Geometric means for urinary triclosan, adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	303	44	5.77	4.26-7.82	(0.038)	4.63	3.43-6.25	(0.037)	6.34	4.69-8.56	(0.039)
age 19-24	53	2	14.15	6.97-28.75		9.06	4.34-18.92		14.65	7.10-30.20	
25-34	65	8	5.74	3.14-10.50		3.66	2.01-6.68		5.61	3.07-10.25	
35-49	82	11	5.01	2.79-9.00		4.04	2.28-7.16		5.61	3.17-9.91	
50-64	103	23	4.08	2.40-6.94	**0.040**	4.24	2.50-7.17	0.215	4.90	2.90-8.30	0.077
male	141	20	5.88	3.84-9.00		3.78	2.48-5.77		5.64	3.68-8.62	
female	162	24	5.68	3.69-8.73	0.939	5.52	3.62-8.43	0.184	7.02	4.60-10.71	0.433
Māori	114	16	4.70	2.90-7.63		3.74	2.29-6.10		5.01	3.09-8.11	
non-Māori	189	28	6.53	4.43-9.63	0.389	5.27	3.60-7.70	0.309	7.30	4.98-10.71	0.281
Northland/Auckland	67	15	4.71	2.50-8.88		3.79	2.01-7.14		5.38	2.89-10.01	
Waikato/BoP	83	9	5.30	3.05-9.20		3.75	2.19-6.43		5.43	3.16-9.34	
lower North Island	77	14	5.24	2.82-9.72		4.31	2.34-7.94		5.62	3.02-10.47	
South Island	76	6	8.35	4.48-15.57	0.396	7.47	4.04-13.84	0.197	9.79	5.29-18.10	0.271

LOD: limit of detection (0.4 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 19b. *Geometric means for urinary triclosan, children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	299	24	3.85	2.96-5.03	(0.074)	3.84	2.95-4.99	(0.076)	3.58	2.75-4.66	(0.084)
age 5-7	64	5	2.29	1.38-3.81		2.69	1.65-4.38		2.06	1.27-3.33	
8-10	120	13	3.60	2.33-5.57		3.87	2.52-5.95		3.34	2.17-5.14	
11-18	115	6	5.52	3.61-8.47	0.119	4.63	2.99-7.17	0.521	5.24	3.42-8.03	0.086
male	144	11	3.30	2.28-4.77		3.16	2.17-4.62		2.96	2.05-4.27	
female	155	13	4.45	3.05-6.51	0.141	4.59	3.19-6.61	0.061	4.27	2.94-6.21	0.079
Māori	87	9	1.78	1.25-2.55		1.74	1.22-2.50		1.63	1.14-2.33	
non-Māori	212	15	5.29	3.78-7.40	**0.0003**	5.30	3.81-7.38	**0.0001**	4.94	3.55-6.88	**0.0002**
Northland/Auckland	50	2	3.16	1.80-5.54		2.50	1.41-4.44		2.85	1.62-5.01	
Waikato/BoP	48	4	5.38	2.76-10.48		5.73	3.01-10.90		5.15	2.69-9.86	
lower North Island	171	16	3.54	2.46-5.08		3.69	2.57-5.30		3.32	2.31-4.77	
South Island	30	2	5.16	2.25-11.85	0.459	5.14	2.38-11.09	0.222	4.49	2.08-9.70	0.379

LOD: limit of detection (0.4 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Urinary benzophenone-3 (BP-3)

Benzophenone-3 (2-hydroxy-4-methoxybenzophenone) is used as a sunscreen or sun-block in lotions, conditioners, and cosmetics and as a UV stabilizer in plastic surface coatings and polymers. Human exposure to BP-3 may occur through dermal application of sunscreens and cosmetic products. Small amounts of BP-3 can be absorbed through human skin and excreted in the urine (Gonzalez *et al.*, 2006). A study in the US population, based on NHANES data, indicated an increasing trend of urinary BP-3 concentration since 2005-2006, with consistently higher levels in females than in males (Han *et al.*, 2016). Human health effects of BP-3 are unclear but recent in vivo and in vitro studies have indicated potential endocrine-disrupting effects of BP-3 such as disturbance of estrogenic signalling, androgenic activity, and the hypothalamic pituitary axis (Krause *et al.*, 2012). Urinary BP-3 levels include both conjugated and unconjugated forms and reflect recent exposure.

The results for urinary BP-3 are presented in **Table 20a** for adults and **20b** for children. BP-3 was detected in all but one of the urinary samples from children and adults. The geometric mean urinary BP-3 was 18.4 µg/L for adults and 20.8 µg/L for children. The specific gravity adjusted urinary concentrations were very similar for adults and children (GMs of 20.2 and 19.4 µg/L respectively). The arithmetic mean urinary BP-3 was 125 µg/L for adults and 101 µg/L for children. The 95th percentile was 585 µg/L for adults and 279 µg/L for children. Age was an important determinant of urinary BP-3 concentrations for adults, with the highest concentrations observed for the younger age groups. Among children, urinary concentrations of BP-3 were comparable across the three age groups. BP-3 urinary concentrations were higher among females compared to males, particularly for adults. For both adults and children, Māori had lower urinary BP-3 concentrations compared to non-Māori. Among children, the GM for urinary BP-3 was 3 to 5 times lower in the South Island compared to the three North Island regions.

Of the 303 adults, 29 reported to have used sunscreen in the 48 hours prior to urine sampling, with a geometric mean urinary BP-3 concentration of 159.8 µg/L. The 274 adults who had not used sunscreen in the past 48 hours had a geometric mean urinary BP-3 concentration of 14.6 µg/L.

Children who reported to have used sunscreen in the 48 hours prior to urine sampling (n=8), had a geometric mean urinary BP-3 concentration of 22.9 µg/L. Children who reported to not have used sunscreen in the past 48 hours (n=189), had a geometric mean urinary BP-3 concentration of 17.9 µg/L.

Table 20a. *Geometric means for urinary benzophenone-3, adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	303	1	18.4	14.9-22.7	(0.141)	14.8	12.0-18.2	(0.144)	20.2	16.4-25.0	(0.149)
age 19-24	53	0	33.9	21.2-54.4		21.7	13.4-35.1		35.1	21.6-57.1	
25-34	65	0	34.9	22.2-54.9		22.3	13.9-35.7		34.1	21.4-54.4	
35-49	82	0	17.9	12.2-26.3		14.5	10.0-21.1		20.1	13.7-29.4	
50-64	103	1	9.1	6.5-12.9	**<0.0001**	9.5	6.7-13.4	**0.007**	11.0	7.8-15.5	**<0.0001**
male	141	1	12.7	9.6-16.7		8.1	6.3-10.6		12.2	9.3-15.9	
female	162	0	25.5	18.7-34.6	**0.0008**	24.8	18.5-33.2	**0.0001**	31.5	23.2-42.7	**<0.0001**
Māori	114	0	14.1	9.9-20.2		11.2	7.9-15.9		15.1	10.6-21.4	
non-Māori	189	1	21.6	16.7-27.9	**0.050**	17.4	13.5-22.5	**0.026**	24.1	18.6-31.3	**0.022**
Northland/Auckland	67	0	18.6	12.6-27.6		15.0	9.8-22.9		21.3	14.0-32.3	
Waikato/BoP	83	0	24.1	16.0-36.3		17.1	11.8-24.7		24.7	16.7-36.5	
lower North Island	77	1	16.6	10.5-26.3		13.7	8.6-21.7		17.8	11.3-28.2	
South Island	76	0	15.0	10.0-22.6	0.752	13.5	9.0-20.1	0.984	17.6	11.6-26.7	0.912

LOD: limit of detection (0.2 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 20b. *Geometric means for urinary benzophenone-3, children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	298	1	20.8	17.6-24.7	(0.111)	20.8	17.5-24.8	(0.124)	19.4	16.3-23.0	(0.122)
age 5-7	64	0	21.0	14.9-29.5		24.6	17.5-34.5		18.8	13.5-26.3	
8-10	119	1	21.6	16.2-28.9		23.5	17.6-31.2		20.1	15.2-26.7	
11-18	115	0	20.0	15.3-26.1	0.507	16.7	12.7-22.2	**0.027**	18.9	14.4-24.9	0.557
male	143	1	18.7	14.8-23.6		18.0	14.2-22.9		16.8	13.3-21.2	
female	155	0	23.1	18.0-29.5	0.311	23.8	18.5-30.5	0.116	22.1	17.3-28.3	0.157
Māori	87	0	18.3	13.7-24.5		17.9	13.4-24.0		16.7	12.6-22.3	
non-Māori	211	1	22.0	17.8-27.1	**0.039**	22.1	17.9-27.4	**0.018**	20.6	16.7-25.4	**0.022**
Northland/Auckland	50	0	30.3	20.0-46.0		24.0	15.3-37.7		27.4	17.9-41.9	
Waikato/BoP	48	0	13.9	9.5-20.5		14.8	10.0-22.0		13.3	9.3-19.0	
lower North Island	170	1	25.7	20.4-32.3		27.0	21.5-33.9		24.2	19.3-30.4	
South Island	30	0	6.5	4.7-8.9	**<0.0001**	6.5	4.8-8.7	**<0.0001**	5.6	4.1-7.7	**<0.0001**

LOD: limit of detection (0.2 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Urinary 4-tert-octylphenol (tOP)

4-tertiary-octylphenol [tOP; 4-(1,1,3,3-tetramethylbutyl)propane], is both a degradation product of and an intermediate in the manufacture of octylphenol ethoxylates, which are nonionic surfactants used in detergents, pesticide formulations, and other applications. Exposure to tOP may occur from contact with personal care products, detergents, water, and food containing tOP.(Calafat *et al.*, 2008). Human health effects of tOP are unknown, but tOP has been associated with developmental and reproductive alterations in aquatic species and in laboratory animals (Calafat *et al.*, 2008). Urinary levels of 4-tert-octyphenol reflect recent exposure.

TOP was detected in 3% of urine samples from adults and children and results are therefore not presented.

Urinary parabens

Parabens are esters of *p*-hydroxybenzoic acid and widely used as antimicrobial preservatives in cosmetics, pharmaceuticals, and food and beverage processing. The group includes methylparaben, ethylparaben, propylparaben, isopropylparaben, butylparaben, isobutylparaben, and benzylparaben, with methylparaben (MP) and propylparaben (PP) being two of the most used parabens (Andersen, 2008). General population exposure occurs with use of paraben-containing personal care products or consumption of foods or pharmaceuticals containing parabens. Concentrations can be considerably higher in females compared to males, likely reflecting the use of personal care products containing these compounds (Calafat *et al.*, 2010). Parabens are popular preservatives because of their low toxicity and cost, their broad inertness, and their worldwide regulatory acceptance, but their potential estrogenic activity has raised some concerns (Andersen, 2008). Ethylparaben is classified by the New Zealand Environmental Protection Authority as “acutely toxic (oral)” (6.1E, based on studies in mice). In 2006, the Cosmetic Ingredient Review (CIR) expert panel concluded that methyl, ethyl, propyl, isopropyl, butyl, isobutyl, and benzyl parabens are safe as cosmetic ingredients in the practices of use and use concentrations (up to 0.4% if used alone, up to 0.8% in mixtures) (Andersen, 2008). Levels of urinary paraben metabolites reflect recent exposure.

Methylparaben

The geometric urinary concentrations for methylparaben are reported in **Table 21a** for adults and **Table 21b** for children. Methylparaben was detected in all urine samples. Of the four parabens measured (methyl paraben, propylparaben, ethylparaben, butylparaben), the highest GMs were observed for methylparaben, with a geometric mean of 17.5 µg/L for adults (arithmetic mean 91 µg/L; 95th percentile 324 µg/L) and 11.9 µg/L for children (arithmetic mean 296 µg/L; 95th percentile 376 µg/L). Female gender was associated with higher urinary ethylparaben concentrations for both adults and children, but the difference was particularly striking for adults for which the GM was 3 times higher for females compared to males. The GMs for methylparaben were similar for Māori and non-Māori and there were no marked differences in GM among the geographic regions.

Table 21a. *Geometric means for urinary methylparaben, adults.*

	n	n<LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	303	0	17.5	14.5-21.1	(0.100)	14.0	11.6-17.0	(0.191)	19.2	15.9-23.2	(0.151)
age 19-24	53	0	18.9	11.8-30.2		12.1	7.4-19.8		19.5	12.0-31.7	
25-34	65	0	17.1	11.8-24.7		10.9	7.5-15.8		16.7	11.5-24.2	
35-49	82	0	16.9	11.9-23.9		13.6	9.4-19.7		18.9	13.1-27.1	
50-64	103	0	17.6	12.6-24.5	0.997	18.3	13.0-25.6	0.131	21.1	15.3-29.3	0.808
male	141	0	10.2	8.0-13.0		6.6	5.2-8.3		9.8	7.7-12.4	
female	162	0	28.0	21.7-36.2	**<0.0001**	27.2	21.1-35.2	**<0.0001**	34.6	26.9-44.6	**<0.0001**
Māori	114	0	16.9	12.8-22.2		13.4	10.1-17.9		18.0	13.6-23.7	
non-Māori	189	0	17.9	13.9-22.9	0.695	14.4	11.1-18.7	0.516	20.0	15.5-25.7	0.451
Northland/Auckland	67	0	19.3	13.1-28.5		15.5	10.5-23.1		22.1	15.0-32.4	
Waikato/BoP	83	0	20.6	14.6-29.1		14.6	10.1-21.0		21.1	14.8-30.0	
lower North Island	77	0	16.9	11.9-24.0		13.9	9.5-20.3		18.1	12.6-26.0	
South Island	76	0	13.9	9.3-20.8	0.626	12.5	8.3-18.7	0.856	16.3	10.9-24.5	0.722

LOD: limit of detection (0.08 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 21b. *Geometric means for urinary methylparaben, children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	299	0	11.9	9.6-14.7	(0.035)	11.8	9.6-14.6	(0.059)	11.0	9.0-13.5	(0.043)
age 5-7	64	0	16.6	9.9-27.8		19.5	11.8-32.1		14.9	9.1-24.5	
8-10	120	0	10.9	7.8-15.2		11.7	8.5-16.1		10.1	7.3-14.0	
11-18	115	0	10.8	7.9-14.7	0.187	9.1	6.6-12.4	**0.010**	10.3	7.6-13.9	0.218
male	144	0	9.6	7.2-12.9		9.2	6.9-12.4		8.6	6.5-11.5	
female	155	0	14.4	10.7-19.5	0.051	14.9	11.1-19.9	**0.013**	13.8	10.4-18.5	**0.019**
Māori	87	0	12.1	8.6-16.9		11.8	8.4-16.5		11.0	8.0-15.2	
non-Māori	212	0	11.8	9.1-15.4	0.471	11.8	9.1-15.4	0.329	11.0	8.5-14.3	0.368
Northland/Auckland	50	0	14.3	8.5-23.8		11.3	6.5-19.7		12.9	7.7-21.6	
Waikato/BoP	48	0	12.8	7.3-22.5		13.7	7.9-23.8		12.3	7.3-20.8	
lower North Island	171	0	12.2	9.2-16.1		12.7	9.7-16.6		11.4	8.7-15.0	
South Island	30	0	6.7	3.9-11.6	0.246	6.7	3.8-11.8	0.186	5.8	3.4-10.0	0.155

LOD: limit of detection (0.08 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

n-Propylparaben

The geometric urinary concentrations for propylparaben are reported in **Table 22a** for adults and **Table 22b** for children. Propylparaben was detected in most samples (detection frequency 100% for adults and 99% for children). The urinary propylparaben geometric mean was 3.38 µg/L for adults (arithmetic mean 22 µg/L; 95th percentile 76 µg/L) and 2.11 µg/L for children (arithmetic mean 16 µg/L; 95th percentile 41 µg/L). Female gender was associated with higher urinary propylparaben concentrations for adults, with the GM being 3 times higher for females compared to males. The GMs for propylparaben were similar for Māori and non-Māori and there were no marked differences in GM among the geographic regions.

Table 22a. *Geometric means for urinary n-propylparaben, adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	303	1	3.38	2.73-4.18	(0.063)	2.71	2.18-3.37	(0.130)	3.71	3.00-4.60	(0.099)
age 19-24	53	0	3.86	2.29-6.50		2.47	1.45-4.21		3.99	2.34-6.80	
25-34	65	0	2.65	1.80-3.91		1.69	1.15-2.48		2.59	1.76-3.82	
35-49	82	0	3.76	2.48-5.70		3.03	1.96-4.70		4.21	2.74-6.45	
50-64	103	1	3.38	2.31-4.95	0.712	3.51	2.40-5.13	0.076	4.06	2.79-5.90	0.393
male	141	1	2.16	1.63-2.85		1.39	1.05-1.84		2.07	1.57-2.73	
female	162	0	4.99	3.69-6.75	**0.0002**	4.86	3.61-6.53	**<0.0001**	6.17	4.59-8.30	**<0.0001**
Māori	114	0	3.52	2.52-4.90		2.80	1.98-3.95		3.75	2.68-5.25	
non-Māori	189	1	3.30	2.50-4.34	0.777	2.66	2.01-3.52	0.944	3.69	2.80-4.86	0.985
Northland/Auckland	67	0	3.59	2.27-5.68		2.89	1.82-4.57		4.10	2.62-6.41	
Waikato/BoP	83	0	4.43	2.98-6.59		3.13	2.07-4.76		4.54	3.03-6.81	
lower North Island	77	1	2.83	1.84-4.35		2.32	1.51-3.58		3.03	1.97-4.65	
South Island	76	0	2.86	1.90-4.30	0.446	2.56	1.66-3.93	0.720	3.35	2.19-5.12	0.536

LOD: limit of detection (0.08 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 22b. *Geometric means for urinary n-propylparaben, children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	299	2	2.11	1.75-2.56	(0.021)	2.10	1.75-2.54	(0.039)	1.96	1.63-2.36	(0.022)
age 5-7	64	1	2.93	1.89-4.56		3.44	2.24-5.28		2.64	1.73-4.03	
8-10	120	0	1.95	1.46-2.61		2.10	1.59-2.77		1.81	1.37-2.40	
11-18	115	1	1.91	1.42-2.58	0.177	1.60	1.19-2.16	**0.007**	1.81	1.36-2.42	0.212
male	144	2	2.00	1.50-2.68		1.92	1.44-2.56		1.80	1.36-2.37	
female	155	0	2.22	1.73-2.85	0.565	2.29	1.80-2.92	0.259	2.13	1.68-2.71	0.336
Māori	87	0	2.29	1.66-3.15		2.23	1.62-3.08		2.09	1.54-2.84	
non-Māori	212	2	2.05	1.62-2.58	0.981	2.05	1.63-2.58	0.811	1.91	1.53-2.40	0.883
Northland/Auckland	50	0	2.90	1.78-4.70		2.30	1.41-3.74		2.62	1.64-4.17	
Waikato/BoP	48	2	2.01	1.20-3.37		2.14	1.26-3.62		1.92	1.16-3.19	
lower North Island	171	0	2.04	1.60-2.59		2.13	1.69-2.69		1.92	1.52-2.41	
South Island	30	0	1.67	0.93-3.00	0.432	1.67	0.95-2.92	0.672	1.45	0.84-2.51	0.399

LOD: limit of detection (0.08 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Ethylparaben

The geometric urinary concentrations for ethylparaben are reported in **Table 23a** for adults and **Table 23b** for children. Ethylparaben was detected in most samples (detection frequency 100% for adults and 98% for children). The geometric mean was 1.39 µg/L for adults (arithmetic mean 15 µg/L; 95th percentile 36 µg/L) and 0.67 µg/L for children (arithmetic mean 9 µg/L; 95th percentile 15 µg/L). Female gender was associated with higher urinary ethylparaben concentrations for adults, but not for children. The GM was also significantly higher for non-Māori adults compared to Māori adults, while this ethnic difference was not observed for children. There were no marked differences in GM among the geographic regions.

Table 23a. *Geometric means for urinary ethylparaben, adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	303	1	1.39	1.14-1.69	(0.042)	1.11	0.91-1.36	(0.121)	1.52	1.25-1.85	(0.144)
age 19-24	53	0	1.19	0.75-1.87		0.76	0.49-1.19		1.23	0.79-1.91	
25-34	65	0	1.27	0.86-1.88		0.81	0.54-1.21		1.24	0.83-1.85	
35-49	82	1	1.46	1.00-2.13		1.17	0.80-1.72		1.63	1.11-2.39	
50-64	103	0	1.53	1.08-2.16	0.740	1.59	1.12-2.25	**0.020**	1.84	1.30-2.59	0.327
male	141	1	1.08	0.85-1.38		0.69	0.54-0.89		1.04	0.81-1.32	
female	162	0	1.72	1.29-2.31	**0.014**	1.68	1.25-2.24	**<0.0001**	2.13	1.59-2.85	**0.0001**
Māori	114	1	1.03	0.76-1.40		0.82	0.60-1.12		1.10	0.81-1.49	
non-Māori	189	0	1.66	1.29-2.13	**0.014**	1.34	1.04-1.72	**0.006**	1.85	1.44-2.38	**0.005**
Northland/Auckland	67	0	1.30	0.85-1.98		1.05	0.68-1.60		1.48	0.98-2.25	
Waikato/BoP	83	0	1.34	0.96-1.88		0.95	0.68-1.32		1.38	1.00-1.91	
lower North Island	77	0	1.51	0.98-2.33		1.24	0.79-1.95		1.62	1.04-2.52	
South Island	76	1	1.39	0.96-2.03	0.963	1.25	0.85-1.83	0.622	1.63	1.12-2.39	0.823

LOD: limit of detection (0.08 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 23b. *Geometric means for urinary ethylparaben, children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	299	5	0.68	0.58-0.81	(0.012)	0.68	0.58-0.80	(0.032)	0.63	0.54-0.75	(0.018)
age 5-7	64	1	0.72	0.52-1.01		0.85	0.62-1.16		0.65	0.48-0.89	
8-10	120	0	0.68	0.52-0.89		0.73	0.56-0.95		0.63	0.48-0.81	
11-18	115	4	0.67	0.50-0.90	0.762	0.56	0.42-0.74	0.064	0.63	0.48-0.84	0.824
male	144	1	0.64	0.50-0.81		0.61	0.48-0.78		0.57	0.45-0.72	
female	155	4	0.73	0.57-0.93	0.346	0.75	0.60-0.94	0.111	0.70	0.55-0.88	0.166
Māori	87	2	0.65	0.46-0.92		0.64	0.46-0.89		0.59	0.43-0.83	
non-Māori	212	3	0.70	0.57-0.85	0.424	0.70	0.58-0.84	0.256	0.65	0.54-0.79	0.306
Northland/Auckland	50	0	0.82	0.58-1.16		0.65	0.45-0.94		0.74	0.53-1.04	
Waikato/BoP	48	2	0.78	0.44-1.40		0.83	0.49-1.42		0.75	0.43-1.29	
lower North Island	171	3	0.65	0.52-0.80		0.67	0.55-0.82		0.61	0.49-0.74	
South Island	30	0	0.56	0.34-0.93	0.440	0.56	0.33-0.93	0.367	0.49	0.30-0.80	0.327

LOD: limit of detection (0.08 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Butylparaben

The results for butyl parabens are reported in **Table 24a** for adults and **Table 24b** for children. Butylparaben was detected in 32% of urine samples from adults and in 33% of samples from children. Because the detection frequency was relatively low, and the ½ limit of detection (LOD) was used for those samples below LOD, the GMs are close to the limit of detection for both adults and children.

Table 24a. *Geometric means for urinary butylparaben, adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	303	206	0.08	0.07-0.10	(0.093)	0.07	0.06-0.08	(0.183)	0.09	0.08-0.11	(0.144)
age 19-24	53	29	0.10	0.07-0.14		0.06	0.04-0.09		0.11	0.07-0.15	
25-34	65	44	0.09	0.06-0.14		0.06	0.04-0.09		0.09	0.06-0.14	
35-49	82	60	0.07	0.05-0.08		0.05	0.04-0.07		0.07	0.06-0.09	
50-64	103	73	0.08	0.06-0.11	0.274	0.09	0.06-0.12	0.098	0.10	0.07-0.14	0.425
male	141	113	0.06	0.05-0.07		0.04	0.03-0.04		0.06	0.05-0.06	
female	162	93	0.11	0.09-0.15	**<0.0001**	0.11	0.09-0.14	**<0.0001**	0.14	0.11-0.18	**<0.0001**
Māori	114	82	0.07	0.05-0.08		0.05	0.04-0.07		0.07	0.06-0.09	
non-Māori	189	124	0.09	0.08-0.12	**0.030**	0.08	0.06-0.10	**0.015**	0.11	0.08-0.13	**0.011**
Northland/Auckland	67	42	0.09	0.06-0.13		0.07	0.05-0.11		0.10	0.07-0.15	
Waikato/BoP	83	57	0.08	0.06-0.10		0.06	0.04-0.07		0.08	0.06-0.11	
lower North Island	77	59	0.08	0.05-0.11		0.06	0.04-0.09		0.08	0.06-0.12	
South Island	76	48	0.09	0.07-0.12	0.564	0.08	0.06-0.11	0.121	0.10	0.08-0.14	0.191

LOD: limit of detection (0.08 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 24b. *Geometric means for urinary butylparaben, children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	299	201	0.08	0.07-0.09	(0.015)	0.08	0.07-0.09	(0.024)	0.07	0.06-0.09	(0.022)
age 5-7	64	45	0.07	0.05-0.10		0.09	0.06-0.12		0.07	0.05-0.09	
8-10	120	76	0.08	0.06-0.10		0.09	0.07-0.11		0.07	0.06-0.09	
11-18	115	80	0.08	0.06-0.11	0.873	0.07	0.05-0.10	0.321	0.08	0.06-0.11	0.790
male	144	103	0.07	0.06-0.10		0.07	0.06-0.09		0.07	0.05-0.08	
female	155	98	0.09	0.07-0.11	0.382	0.09	0.07-0.11	0.141	0.08	0.07-0.10	0.192
Māori	87	58	0.08	0.06-0.11		0.08	0.06-0.11		0.07	0.06-0.10	
non-Māori	212	143	0.08	0.07-0.10	0.723	0.08	0.07-0.10	0.516	0.08	0.06-0.09	0.577
Northland/Auckland	50	32	0.10	0.06-0.15		0.08	0.05-0.12		0.09	0.06-0.13	
Waikato/BoP	48	35	0.08	0.05-0.13		0.09	0.06-0.14		0.08	0.05-0.13	
lower North Island	171	110	0.08	0.07-0.10		0.09	0.07-0.10		0.08	0.06-0.09	
South Island	30	24	0.05	0.04-0.07	0.364	0.05	0.04-0.07	0.315	0.05	0.03-0.06	0.254

LOD: limit of detection (0.08 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Total paraben (methylparaben+propylparaben+ethylparaben+butylparaben)

The results for the sum of the four measured parabens are included in **Table 25a** for adults and **Table 25b** for children. The geometric mean was 27.1 µg/L for adults (arithmetic mean 129 µg/L; 95th percentile 467 µg/L) and 17.7 µg/L for children (arithmetic mean 322 µg/L; 95th percentile 402 µg/L). Females had higher urinary total paraben concentrations in adults, with the GM for women being more than double the GM for men. The same pattern was observed for children, but the gender difference was not as pronounced and did not reach statistical significance.

Table 25a. *Geometric means for urinary total paraben (methyl+propyl+ethyl+butyl), adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	303	0	27.1	22.7-32.5	(0.087)	21.8	18.1-26.2	(0.185)	29.8	24.8-35.7	(0.141)
age 19-24	53	0	27.5	17.4-43.7		17.6	10.9-28.6		28.5	17.7-45.9	
25-34	65	0	24.8	17.4-35.4		15.8	11.1-22.6		24.2	16.9-34.7	
35-49	82	0	28.1	20.1-39.2		22.7	15.9-32.4		31.4	22.2-44.5	
50-64	103	0	27.7	20.2-38.1	0.962	28.8	20.9-39.6	**0.050**	33.3	24.4-45.4	0.569
male	141	0	16.7	13.3-21.0		10.7	8.5-13.5		16.0	12.7-20.1	
female	162	0	41.4	32.2-53.3	**<0.0001**	40.3	31.4-51.7	**<0.0001**	51.2	40.0-65.5	**<0.0001**
Māori	114	0	25.8	19.7-33.6		20.5	15.5-27.1		27.5	21.0-36.0	
non-Māori	189	0	28.0	22.0-35.5	0.566	22.6	17.6-28.9	0.398	31.3	24.6-39.9	0.342
Northland/Auckland	67	0	29.5	20.2-43.1		23.8	16.2-34.8		33.7	23.3-48.8	
Waikato/BoP	83	0	30.9	22.2-42.9		21.8	15.4-31.0		31.6	22.6-44.3	
lower North Island	77	0	25.7	18.0-36.7		21.1	14.5-30.8		27.5	19.2-39.6	
South Island	76	0	23.1	16.0-33.5	0.761	20.7	14.1-30.5	0.859	27.1	18.5-39.8	0.768

LOD: limit of detection (0.08 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 25b. *Geometric means for total paraben (methyl+propyl+ethyl+butyl), children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	299	0	17.7	14.5-21.7	(0.030)	17.7	14.5-21.5	(0.161)	16.5	13.6-20.0	(0.077)
age 5-7	64	0	24.7	15.2-40.0		28.9	18.1-46.3		22.2	14.0-35.3	
8-10	120	0	16.2	11.8-22.3		17.4	12.8-23.6		15.0	11.0-20.4	
11-18	115	0	16.3	12.0-22.0	0.071	13.6	10.1-18.4	**<0.0001**	15.4	11.5-20.6	**0.0008**
male	144	0	14.6	11.0-19.3		14.0	10.6-18.5		13.1	10.0-17.1	
female	155	0	21.3	15.9-28.4	0.341	22.0	16.7-28.9	0.384	20.4	15.5-26.9	0.161
Māori	87	0	18.2	13.2-25.2		17.8	13.0-24.4		16.7	12.3-22.6	
non-Māori	212	0	17.5	13.6-22.6	0.693	17.6	13.7-22.6	0.601	16.4	12.8-21.0	0.413
Northland/Auckland	50	0	22.4	13.8-36.4		17.8	10.6-29.9		20.2	12.5-32.9	
Waikato/BoP	48	0	19.8	11.5-34.1		21.1	12.3-36.1		18.9	11.3-31.7	
lower North Island	171	0	17.7	13.5-23.1		18.4	14.3-23.8		16.6	12.8-21.4	
South Island	30	0	10.3	6.1-17.4	0.247	10.3	6.0-17.6	0.671	9.0	5.4-15.0	0.063

LOD: limit of detection (0.08 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

4.2.11. Urinary phthalate metabolites

Phthalates are synthetic compounds first introduced and used in commercial products in the 1920s. Since the early 1930s they have been widely used as plasticisers, solvents and additives in many consumer products including plastics, adhesives, pharmaceuticals and personal care products. Phthalates are added to plastics to enhance flexibility and durability, but are not chemically bound to it and can therefore be released during use or disposal of plastic products. Exposure can occur through diet, inhalation, dermal absorption, and ingestion of house dust. Animal studies suggest the potential for developmental and reproductive effects following exposure, but the health effects in humans are currently unclear. Phthalates do not accumulate in the body and are rapidly metabolised and excreted through urine. Urinary levels of phthalate metabolites therefore reflect recent exposure. The urinary phthalate metabolites determined in this study and their parent chemical are listed below.

Phthalate (parent chemical)	Metabolite determined in urine
dimethyl phthalate (DMP)	monomethyl phthalate (mMP)
diethyl phthalate (DEP)	monoethyl phthalate (mEP)
dibutyl phthalate (DBP) (di-n&di-iso)	monobutyl phthalate (mBP) (n+iso)
butylbenzyl phthalate (BBzP)	monobenzyl phthalate (mBzP)
di(2-ethylhexyl) phthalate (DEHP)	mono-2-ethylhexyl phthalate (mEHP)
di(2-ethylhexyl) phthalate (DEHP)	mono-(2-ethyl-5-oxohexyl) phthalate (mEOHP)
di(2-ethylhexyl) phthalate (DEHP)	mono-(2-ethyl-5-hydroxyhexyl) phthalate (mEHHP)
dicyclohexyl phthalate (DCHP)	mono-cyclohexyl phthalate (mCHP)
di-n-octyl phthalate (DOP)	mono-(3-carboxypropyl) phthalate (mCPP)
di-iso-nonyl phthalate (DiNP)	mono-iso-nonyl Phthalate (miNP)

Dimethyl phthalate (DMP)

DMP is a low molecular weight phthalate used in personal care products, as a solvent and plasticiser, and in insect repellents, lacquers, paints, plastics, and rubbers (Koniecki *et al.*, 2011; Serrano *et al.*, 2014). DMP is classified by the New Zealand Environmental Protection Authority as "acutely toxic" (6.1C inhalation based on a study in cats and 6.1D oral based on a study in rabbits). The urinary biomarker and metabolite of DMP determined in this study is monomethyl phthalate (mMP).

MMP was detected in 4% of the samples of adults and 10% of the samples of children. Due to the low detection frequency of mMP only the detection frequencies for mMP for children are presented in **Table 26**. The detection frequency was highest (16%) for the youngest age group (age 5-7).

Table 26. *Detection frequency for urinary monomethyl phthalate (mMP), children.*

	n	n< LOD	Detection frequency
all	298	268	10%
age 5-7	64	54	16%
8-10	119	104	13%
11-18	115	110	4%
male	144	131	9%
female	154	137	11%
Māori	86	76	12%
non-Māori	212	192	9%
Northland/Auckland	50	48	4%
Waikato/BoP	48	45	6%
lower North Island	170	148	13%
South Island	30	27	10%

Diethyl phthalate (DEP)

DEP is a low molecular weight phthalate, used in personal care products and in packaging materials for foodstuffs and pharmaceuticals (Rocha *et al.*, 2017). DEP is classified by the New Zealand Environmental Protection Authority as "acutely toxic" (6.1D, oral, based on a study in rabbits). The urinary biomarker and metabolite of DEP determined in the study is monoethyl phthalate (mEP).

The results for mEP are presented in **Table 27a** for adults and **Table 27b** for children. MEP was detected in 96% of the samples of adults and in 64% of the samples of children. The geometric mean urinary mEP level was 19.1 µg/L for adults and 12.9 µg/L for children. The arithmetic mean urinary mEP level was 42 µg/L for adults and 36 µg/L for children. The 95th percentile was 147 µg/L for adults and 109 µg/L for children. Urinary mEP levels were higher in women compared to men, but this pattern was not observed in children.

Table 27a. *Geometric means for urinary monoethyl phthalate (mEP), adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	304	11	19.1	16.7-22.0	(0.033)	15.3	13.3-17.6	(0.121)	21.0	18.3-24.1	(0.072)
age 19-24	53	1	24.8	17.9-34.4		15.9	11.4-22.2		25.7	18.7-35.3	
25-34	65	4	14.1	10.3-19.2		9.0	6.7-12.0		13.7	10.2-18.6	
35-49	83	3	18.4	14.6-23.2		14.6	11.5-18.6		20.4	16.2-25.6	
50-64	103	3	21.0	16.4-26.8	0.068	21.9	17.1-27.9	**<0.0001**	25.3	19.8-32.3	**0.008**
male	140	3	18.7	15.5-22.5		12.0	10.0-14.3		17.9	15.0-21.3	
female	164	8	19.5	16.0-23.9	0.761	18.9	15.4-23.2	**0.001**	24.1	19.7-29.5	**0.026**
Māori	115	3	18.7	15.3-22.8		14.7	12.0-18.1		19.8	16.3-24.1	
non-Māori	189	8	19.4	16.1-23.4	0.901	15.7	13.0-18.9	0.591	21.7	18.1-26.1	0.521
Northland/Auckland	67	3	19.1	13.7-26.7		15.4	11.0-21.6		21.9	15.7-30.4	
Waikato/BoP	84	3	19.4	15.1-24.9		13.6	10.6-17.4		19.8	15.5-25.1	
lower North Island	78	4	16.2	12.4-21.1		13.4	10.1-17.9		17.5	13.3-23.0	
South Island	75	1	22.4	17.2-29.0	0.411	20.0	15.7-25.6	0.076	26.2	20.4-33.6	0.128

LOD: limit of detection (2 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 27b. *Geometric means for urinary monoethyl phthalate (mEP), children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	298	19	12.9	11.3-14.7	(0.018)	12.8	11.4-14.5	(0.036)	12.0	10.6-13.5	(0.015)
age 5-7	64	4	13.2	9.6-18.0		15.5	11.9-20.1		11.9	9.0-15.6	
8-10	119	5	13.0	10.8-15.6		13.9	11.8-16.4		12.0	10.2-14.2	
11-18	115	10	12.6	10.1-15.9	0.962	10.7	8.7-13.1	0.056	12.0	9.7-14.8	0.952
male	144	7	13.4	11.3-16.0		12.9	10.9-15.2		12.1	10.3-14.1	
female	154	12	12.4	10.2-15.1	0.622	12.8	10.8-15.2	0.753	11.9	9.9-14.2	0.983
Māori	86	6	14.7	11.2-19.4		14.4	11.3-18.3		13.5	10.6-17.2	
non-Māori	212	13	12.2	10.5-14.2	0.169	12.3	10.7-14.1	0.266	11.4	9.9-13.1	0.212
Northland/Auckland	50	1	14.6	10.9-19.6		11.6	8.7-15.4		13.2	10.1-17.2	
Waikato/BoP	48	4	14.2	9.6-21.1		15.1	10.6-21.7		13.6	9.6-19.3	
lower North Island	170	14	11.7	9.8-13.8		12.2	10.5-14.2		11.0	9.4-12.9	
South Island	30	0	15.6	10.7-22.8	0.391	15.5	11.1-21.8	0.360	13.6	9.6-19.1	0.441

LOD: limit of detection (2 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Dibutyl phthalate (DBP)

DBP is a plasticiser which includes di-n-butyl phthalate (DnBP) and diisobutyl phthalate (DiBP) and is commonly used in consumer products. DnBP is classified by the New Zealand Environmental Protection Authority as a "known or presumed human reproductive or developmental toxicant" (6.8A based on a study in rats) and as "acutely toxic (oral)" (6.1E, based on a study in mice) and DiBP as a "suspected human reproductive or developmental toxicant" (6.8B based on a study in rats). The urinary biomarker and metabolite of DBP determined in the study is monobutyl phthalate (mBP), including both the "n" and "iso" forms.

The results for mBP are presented in **Table 28a** for adults and **Table 28b** for children. mBP was detected in all samples of adults and children. The geometric mean (GM) urinary mBP levels was 37.0 µg/L for adults and 60.6 µg/L for children. The 95th percentile was 146 µg/L for adults and 198 µg/L for children. The highest GM was observed for the youngest age group (71.6 µg/L for the 5-7 year olds) with gradually lower urinary mBP levels in the older age groups.

Table 28a. *Geometric means for urinary monobutyl phthalate (mBP, n+iso), adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	304	0	37.0	33.4-40.9	(0.071)	29.6	27.2-32.2	(0.058)	40.6	37.2-44.3	(0.058)
19-24	53	0	48.0	38.0-60.6		30.7	25.2-37.4		49.7	40.8-60.4	
25-34	65	0	46.5	38.3-56.6		29.7	25.0-35.2		45.4	37.8-54.7	
35-49	83	0	36.6	30.6-43.9		29.2	25.3-33.7		40.7	35.1-47.2	
50-64	103	0	28.2	23.5-33.8	**0.001**	29.4	25.0-34.7	0.992	34.0	28.9-40.0	**0.023**
male	140	0	38.5	33.5-44.2		24.7	22.1-27.6		36.8	32.7-41.4	
female	164	0	35.8	30.9-41.4	0.425	34.6	30.7-39.0	**<0.0001**	44.1	38.9-50.0	**0.039**
Māori	115	0	35.3	30.2-41.3		27.8	24.4-31.7		37.4	32.8-42.8	
non-Māori	189	0	38.1	33.4-43.4	0.606	30.8	27.6-34.4	0.205	42.6	38.0-47.8	0.166
Northland/Auckland	67	0	36.5	29.9-44.5		29.4	24.9-34.6		41.7	35.1-49.5	
Waikato/BoP	84	0	43.1	35.7-51.9		30.1	25.8-35.2		43.9	37.2-51.8	
lower North Island	78	0	34.5	28.5-41.6		28.6	24.8-32.9		37.2	31.9-43.3	
South Island	75	0	34.0	27.0-42.7	0.427	30.4	24.7-37.5	0.903	39.8	32.4-48.8	0.758

LOD: limit of detection (1 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 28b. *Geometric means for urinary monobutyl phthalate (mBP, n+iso), children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	299	0	60.6	55.8-65.7	(0.069)	60.3	55.8-65.1	(0.174)	56.3	52.4-60.4	(0.056)
5-7	64	0	71.6	59.5-86.2		84.0	72.3-97.6		64.4	55.2-75.3	
8-10	119	0	64.9	57.0-73.9		69.8	61.8-78.7		60.1	53.1-68.0	
11-18	116	0	51.4	45.6-58.0	**0.008**	43.2	38.8-48.1	**<0.0001**	48.8	44.2-53.7	**0.007**
male	144	0	68.5	61.1-76.8		65.6	58.5-73.6		61.4	55.3-68.2	
female	155	0	54.0	48.2-60.6	**0.014**	55.7	50.2-61.8	0.171	51.9	47.1-57.1	0.064
Māori	86	0	62.7	54.4-72.2		61.2	53.8-69.5		57.3	51.1-64.3	
non-Māori	213	0	59.7	54.1-66.0	0.554	59.9	54.4-65.9	0.984	55.8	51.1-61.0	0.811
Northland/Auckland	50	0	65.8	57.1-75.9		52.2	45.5-59.9		59.4	52.6-67.1	
Waikato/BoP	48	0	60.6	49.7-74.0		64.5	51.1-81.5		58.0	48.9-68.9	
lower North Island	171	0	57.6	51.5-64.4		60.1	54.1-66.7		54.1	48.9-59.8	
South Island	30	0	70.3	52.0-95.1	0.368	70.0	56.4-86.8	0.588	61.1	47.7-78.3	0.527

LOD: limit of detection (1 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Butylbenzyl phthalate (BBzP)

Butylbenzyl phthalate (BBzP), also called benzyl butyl phthalate (BBP), is mainly used as a plasticiser in polymers and its most common use is in vinyl tiles. BBzP is also present in food conveyor belts, artificial leather, toy and food packaging (Zhang *et al.*, 2016). BBzP is classified by the New Zealand Environmental Protection Authority as "acutely toxic (oral)" (6.1E, based on a study in rats). The urinary biomarker and metabolite of BBzP determined in this study is monobenzyl phthalate (mBzP).

The results for mBzP are presented in **Table 29a** for adults and **Table 29b** for children. MBzP was detected in 82% of the samples of adults and in 93% of the samples of children. The GM urinary mBzP levels was 4.2 µg/L for adults and 7.7 µg/L for children. The arithmetic mean urinary mBzP levels was 9.0 µg/L for adults and 15.2 µg/L for children. The 95th percentile was 33 µg/L for adults and 51 µg/L for children. The highest GM was observed for the youngest age group (9.2 µg/L for the 5-7 year olds) with gradually lower urinary mBzP levels in the older age groups. For children there was some geographic variation in mBzP concentration, with the highest concentrations observed for the Northland/Auckland area (10.7 µg/L). This geographic variation was not observed for adults.

Table 29a. *Geometric means for urinary monobenzyl phthalate (mBzP), adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	304	54	4.17	3.62-4.81	(0.127)	3.34	2.95-3.79	(0.028)	4.58	4.03-5.21	(0.077)
age 19-24	53	5	5.39	4.23-6.86		3.45	2.69-4.42		5.57	4.42-7.02	
25-34	65	8	6.23	4.51-8.59		3.97	2.92-5.39		6.08	4.45-8.31	
35-49	83	12	4.76	3.62-6.27		3.79	3.00-4.80		5.29	4.17-6.71	
50-64	103	29	2.56	2.02-3.23	**<0.0001**	2.67	2.16-3.30	0.069	3.08	2.50-3.80	**0.0002**
male	140	16	5.39	4.40-6.60		3.46	2.87-4.17		5.15	4.26-6.23	
female	164	38	3.36	2.77-4.06	**0.0004**	3.25	2.74-3.85	0.629	4.14	3.49-4.92	0.080
Māori	115	21	4.26	3.38-5.37		3.36	2.75-4.11		4.52	3.68-5.55	
non-Māori	189	33	4.12	3.44-4.93	0.695	3.33	2.84-3.92	0.988	4.62	3.92-5.44	0.899
Northland/Auckland	67	9	3.86	2.98-4.98		3.10	2.46-3.91		4.41	3.49-5.56	
Waikato/BoP	84	15	4.57	3.43-6.09		3.20	2.48-4.13		4.66	3.56-6.09	
lower North Island	78	13	4.50	3.44-5.89		3.73	2.93-4.75		4.86	3.83-6.16	
South Island	75	17	3.74	2.75-5.08	0.450	3.35	2.56-4.38	0.690	4.37	3.33-5.75	0.836

LOD: limit of detection (1 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 29b. *Geometric means for urinary monobenzyl phthalate (mBzP), children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	299	21	7.68	6.73-8.76	(0.070)	7.64	6.76-8.64	(0.091)	7.13	6.31-8.06	(0.062)
age 5-7	64	4	9.20	6.95-12.19		10.79	8.39-13.88		8.28	6.39-10.73	
8-10	119	7	7.97	6.45-9.85		8.57	7.02-10.46		7.38	6.04-9.03	
11-18	116	10	6.69	5.44-8.24	0.144	5.62	4.69-6.73	**<0.0001**	6.35	5.26-7.65	0.163
male	144	7	8.90	7.42-10.69		8.53	7.18-10.14		7.98	6.74-9.46	
female	155	14	6.70	5.55-8.07	0.061	6.90	5.81-8.19	0.229	6.43	5.41-7.64	0.144
Māori	86	8	9.16	6.98-12.03		8.94	7.08-11.29		8.38	6.59-10.66	
non-Māori	213	13	7.15	6.17-8.29	0.111	7.17	6.22-8.27	0.184	6.69	5.81-7.69	0.143
Northland/Auckland	50	0	11.80	9.14-15.24		9.36	7.37-11.89		10.65	8.30-13.67	
Waikato/BoP	48	5	7.63	5.15-11.31		8.12	5.54-11.91		7.30	5.15-10.35	
lower North Island	171	16	6.62	5.57-7.87		6.91	5.89-8.10		6.22	5.30-7.30	
South Island	30	0	8.85	6.24-12.55	**0.012**	8.81	6.33-12.26	0.104	7.69	5.44-10.88	**0.014**

LOD: limit of detection (1 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Di(2-ethylhexyl) phthalate (DEHP)

DEHP, also called di-s-octyl phthalate, is a high molecular weight phthalate, primarily used as a plasticiser in the manufacture of flexible vinyl plastic which is commonly used in consumer products, flooring and wall coverings, food contact applications, and medical devices. More recently DEHP has been replaced by higher molecular weight phthalates such as DiNP in many applications due to concerns regarding possible adverse effects of DEHP-exposures in humans (Dekant & Bridges, 2016).
DEHP is classified by the New Zealand Environmental Protection Authority as a "known or presumed human reproductive or developmental toxicant" (6.8A, based on a study in mice) and as "harmful to human target organs or systems" (6.9B, oral, based on a study in rats).

In this study urinary concentrations of three DEHP metabolites were measured: mono(2-ethylhexyl) phthalate (mEHP) and two oxidative metabolites, mono-(2-ethyl-5-oxohexyl) phthalate (mEOHP) and mono-(2-ethyl-5-hydroxylhexyl) phthalate (MEHHP). mEHP is considered the most toxic and active one among these phthalate metabolites (Gobas *et al.*, 2017). Geometric means of urinary concentrations are presented for each of these metabolites individually, as well as for their sum.

The results for mEHP are presented in **Table 30a** for adults and **Table 30b** for children. mEHP was detected in 82% of the samples of adults and in 90% of the samples of children. The GM urinary mEHP concentration was 2.0 µg/L for adults and 2.7 µg/L for children. The arithmetic mean urinary mEHP concentration was 3.4 µg/L for adults and 3.8 µg/L for children. The 95th percentile was 10 µg/L for adults and 11 µg/L for children. The highest GM was observed for the youngest age group (3.2 µg/L for the 5-7 year age group) and the lowest for the oldest age group (1.2 µg/L for the 50-64 year age group). For adults the GM urinary mEHP levels were higher for Māori compared to non-Māori, but this pattern was not observed for children.

Table 30a. *Geometric means for urinary mono-2-ethylhexyl phthalate (mEHP), adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95% CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	304	76	1.99	1.77-2.23	(0.164)	1.59	1.44-1.76	(0.051)	2.18	1.97-2.41	(0.114)
age 19-24	53	7	2.66	2.08-3.39		1.70	1.37-2.11		2.75	2.22-3.41	
25-34	65	6	2.80	2.27-3.46		1.79	1.43-2.24		2.74	2.21-3.40	
35-49	83	21	2.25	1.78-2.85		1.79	1.49-2.16		2.50	2.06-3.03	
50-64	103	42	1.24	1.04-1.49	**<0.0001**	1.30	1.09-1.54	**0.050**	1.50	1.28-1.76	**<0.0001**
male	140	28	2.33	1.97-2.76		1.50	1.29-1.73		2.23	1.93-2.59	
female	164	48	1.73	1.49-2.02	**0.004**	1.68	1.46-1.92	0.283	2.14	1.86-2.46	0.588
Māori	115	22	2.34	1.93-2.82		1.84	1.58-2.15		2.48	2.11-2.91	
non-Māori	189	54	1.80	1.56-2.08	**0.013**	1.46	1.28-1.66	**0.034**	2.02	1.77-2.30	**0.043**
Northland/Auckland	67	15	2.18	1.70-2.81		1.76	1.40-2.21		2.49	2.01-3.10	
Waikato/BoP	84	21	2.28	1.80-2.89		1.60	1.29-1.98		2.32	1.86-2.91	
lower North Island	78	22	1.75	1.41-2.17		1.45	1.22-1.72		1.89	1.57-2.26	
South Island	75	18	1.79	1.46-2.19	0.294	1.60	1.35-1.91	0.713	2.10	1.77-2.48	0.393

LOD: limit of detection (1 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 30b. *Geometric means for urinary mono-2-ethylhexyl phthalate (mEHP), children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	299	29	2.72	2.47-3.00	(0.032)	2.71	2.46-2.98	(0.071)	2.53	2.33-2.75	(0.021)
age 5-7	64	4	3.24	2.63-3.99		3.80	3.11-4.65		2.92	2.42-3.51	
8-10	119	12	2.65	2.26-3.10		2.85	2.47-3.28		2.45	2.14-2.81	
11-18	116	13	2.54	2.20-2.94	0.208	2.13	1.82-2.50	**0.0001**	2.41	2.12-2.74	0.258
male	144	12	2.95	2.56-3.40		2.82	2.43-3.29		2.64	2.32-3.01	
female	155	17	2.53	2.23-2.87	0.136	2.61	2.31-2.94	0.652	2.43	2.18-2.70	0.368
Māori	86	8	2.95	2.45-3.55		2.88	2.42-3.43		2.70	2.31-3.16	
non-Māori	213	21	2.63	2.36-2.95	0.274	2.64	2.35-2.97	0.556	2.46	2.23-2.72	0.380
Northland/Auckland	50	5	3.06	2.35-3.99		2.43	1.86-3.17		2.76	2.20-3.48	
Waikato/BoP	48	6	2.71	2.10-3.50		2.89	2.14-3.91		2.60	2.07-3.27	
lower North Island	171	16	2.57	2.29-2.90		2.68	2.39-3.02		2.42	2.18-2.69	
South Island	30	2	3.10	2.32-4.14	0.490	3.09	2.48-3.85	0.781	2.69	2.15-3.38	0.685

LOD: limit of detection (1 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

The results for mEOHP are presented in **Table 31a** for adults and **Table 31b** for children. mEOHP was detected in 99% of the samples of adults and in 100% of the samples of children. The GM urinary mEOHP concentration was 7.0 µg/L for adults and 14.2 µg/L for children. The arithmetic mean urinary mEOHP concentration was 9.9 µg/L for adults and 18.5 µg/L for children. The 95th percentile was 26 µg/L for adults and 47 µg/L for children. The highest GM was observed for the youngest age group (18.7 µg/L for the 5-7 year age group) with gradually lower levels in the older age groups (5.2 µg/L for the 50-64 year age group).

Table 31a. *Geometric means for urinary mono-(2-ethyl-5-oxohexyl) phthalate (mEOHP), adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	304	2	7.0	6.4-7.7	(0.120)	5.6	5.2-6.1	(0.058)	7.7	7.1-8.3	(0.085)
age 19-24	53	0	9.1	7.4-11.1		5.8	4.9-6.8		9.4	7.9-11.1	
25-34	65	1	8.3	6.8-10.1		5.3	4.4-6.4		8.1	6.7-9.8	
35-49	83	0	7.5	6.3-9.1		6.0	5.2-6.9		8.4	7.2-9.7	
50-64	103	1	5.2	4.5-6.0	**<0.0001**	5.4	4.7-6.2	0.665	6.3	5.5-7.1	**0.004**
male	140	0	7.6	6.7-8.6		4.9	4.4-5.4		7.3	6.5-8.1	
female	164	2	6.5	5.7-7.5	0.055	6.3	5.7-7.0	**0.001**	8.0	7.2-9.0	0.247
Māori	115	1	7.4	6.3-8.6		5.8	5.1-6.6		7.8	6.9-8.9	
non-Māori	189	1	6.8	6.1-7.6	0.247	5.5	5.0-6.0	0.533	7.6	6.9-8.4	0.662
Northland/Auckland	67	0	7.8	6.5-9.5		6.3	5.3-7.4		8.9	7.7-10.4	
Waikato/BoP	84	0	8.5	7.1-10.2		6.0	5.1-6.9		8.7	7.4-10.2	
lower North Island	78	1	6.2	5.2-7.3		5.1	4.5-5.8		6.6	5.8-7.6	
South Island	75	1	5.8	4.8-7.0	**0.011**	5.2	4.4-6.1	0.173	6.8	5.8-8.0	**0.021**

LOD: limit of detection (1 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 31b. *Geometric means for urinary mono-(2-ethyl-5-oxohexyl) phthalate (mEOHP), children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	299	0	14.2	13.1-15.4	(0.107)	14.1	13.0-15.3	(0.205)	13.2	12.3-14.2	(0.106)
age 5-7	64	0	18.7	15.5-22.5		21.9	18.5-25.9		16.8	14.2-19.9	
8-10	119	0	15.1	13.2-17.2		16.2	14.6-18.0		14.0	12.6-15.6	
11-18	116	0	11.5	10.2-12.9	**<0.0001**	9.6	8.5-10.9	**<0.0001**	10.9	9.8-12.1	**<0.0001**
male	144	0	15.7	13.9-17.7		15.1	13.2-17.1		14.1	12.6-15.7	
female	155	0	12.9	11.5-14.5	0.054	13.3	12.0-14.8	0.466	12.4	11.3-13.6	0.200
Māori	86	0	15.2	12.8-17.9		14.8	12.6-17.3		13.9	12.0-16.0	
non-Māori	213	0	13.8	12.6-15.2	0.448	13.9	12.6-15.3	0.873	12.9	11.9-14.0	0.659
Northland/Auckland	50	0	17.3	14.2-21.1		13.7	11.3-16.6		15.6	13.2-18.4	
Waikato/BoP	48	0	13.3	10.4-16.9		14.1	10.6-18.9		12.7	10.3-15.8	
lower North Island	171	0	13.4	12.1-14.9		14.0	12.6-15.5		12.6	11.5-13.8	
South Island	30	0	15.8	12.1-20.6	**0.040**	15.7	12.9-19.1	0.685	13.7	11.1-16.9	**0.042**

LOD: limit of detection (1 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

The results for mEHHP are presented in **Table 32a** for adults and **Table 32b** for children. mEHHP was detected in 96% of the samples of adults and in 98% of the samples of children. The GM urinary mEHHP concentration was 9.0 µg/L for adults and 17.6 µg/L for children. The arithmetic mean urinary mEHHP concentration was 14.1 µg/L for adults and 24.7 µg/L for children. The 95th percentile was 39 µg/L for adults and 68 µg/L for children. The highest GM was observed for the youngest age group (20.3 µg/L for the 5-7 year age group) and the lowest for the oldest age group (7.5 µg/L for the 50-64 year age group).

Table 32a. *Geometric means for urinary mono-(2-ethyl-5-hydroxyhexyl) phthalate (mEHHP), adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	304	12	9.0	8.0-10.1	(0.050)	7.2	6.5-8.0	(0.025)	9.9	8.9-10.9	(0.017)
age 19-24	53	4	9.4	7.0-12.8		6.0	4.6-7.9		9.8	7.4-12.9	
25-34	65	1	11.3	9.0-14.2		7.2	5.8-8.9		11.0	8.9-13.7	
35-49	83	4	9.1	7.2-11.6		7.2	5.9-8.9		10.1	8.2-12.5	
50-64	103	3	7.5	6.3-8.9	0.108	7.8	6.7-9.2	0.392	9.0	7.8-10.5	0.629
male	140	6	10.2	8.7-12.0		6.6	5.7-7.6		9.8	8.5-11.3	
female	164	6	8.0	6.8-9.4	**0.030**	7.8	6.8-8.9	0.102	9.9	8.6-11.4	0.921
Māori	115	7	9.7	7.9-11.9		7.6	6.5-9.0		10.3	8.6-12.3	
non-Māori	189	5	8.6	7.5-9.8	0.265	6.9	6.1-7.9	0.483	9.6	8.5-10.9	0.575
Northland/Auckland	67	5	9.5	7.2-12.4		7.6	6.0-9.6		10.8	8.6-13.6	
Waikato/BoP	84	3	10.3	8.2-12.9		7.2	5.8-8.9		10.5	8.4-13.0	
lower North Island	78	2	7.9	6.5-9.7		6.6	5.5-7.9		8.6	7.2-10.2	
South Island	75	2	8.4	6.7-10.4	0.370	7.5	6.2-9.0	0.693	9.8	8.1-11.9	0.448

LOD: limit of detection (1 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 32b. *Geometric means for urinary mono-(2-ethyl-5-hydroxyhexyl) phthalate (mEHHP), children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	299	6	17.6	15.9-19.4	(0.069)	17.5	15.9-19.3	(0.122)	16.3	15.0-17.9	(0.063)
age 5-7	64	4	20.3	15.9-25.9		23.8	18.8-30.1		18.3	14.5-23.1	
8-10	119	0	19.3	16.6-22.4		20.7	18.3-23.5		17.8	15.7-20.3	
11-18	116	2	14.8	12.8-17.1	**0.014**	12.4	10.7-14.4	**<0.0001**	14.0	12.3-16.0	**0.012**
male	144	1	20.0	17.4-22.9		19.1	16.6-22.0		17.9	15.8-20.2	
female	155	5	15.7	13.6-18.0	**0.032**	16.1	14.1-18.4	0.243	15.0	13.2-17.0	0.107
Māori	86	2	19.9	16.4-24.0		19.4	16.2-23.2		18.2	15.4-21.5	
non-Māori	213	4	16.8	14.9-18.8	0.205	16.8	15.0-18.8	0.423	15.7	14.1-17.4	0.291
Northland/Auckland	50	1	22.1	17.4-28.0		17.5	14.1-21.7		19.9	16.3-24.3	
Waikato/BoP	48	0	17.5	13.6-22.6		18.6	13.8-25.1		16.8	13.3-21.1	
lower North Island	171	4	16.7	14.8-18.8		17.4	15.4-19.6		15.7	14.0-17.5	
South Island	30	1	16.5	11.2-24.3	0.115	16.4	11.7-23.1	0.530	14.3	10.1-20.4	0.087

LOD: limit of detection (1 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

The results for the summed DEHP metabolites (mEHP+ mEOHP+ mEHHP) expressed as sum-DEHP, are presented in **Table 33a** for adults and **Table 33b** for children. The GM urinary sum-DEHP concentration was 18.9 µg/L for adults and 35.5 µg/L for children. As for each of the 3 metabolites included in sum-DEHP, the highest GM was observed for the youngest age group (44.0 µg/L for the 5-7 year age group) and the lowest for the oldest age group (14.5 µg/L for the 50-64 year age group).

Table 33a. *Geometric means for the sum of urinary mEHP, mEOHP and mEHHP, adults (sum-DEHP).*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	304	0	18.9	17.2-20.9	(0.107)	15.2	14.0-16.4	(0.031)	20.8	19.2-22.5	(0.056)
age 19-24	53	0	22.7	18.3-28.1		14.5	12.3-17.2		23.5	19.7-28.1	
25-34	65	0	23.1	18.8-28.2		14.7	12.1-17.8		22.5	18.5-27.4	
35-49	83	0	20.2	16.6-24.6		16.1	13.9-18.6		22.4	19.2-26.2	
50-64	103	0	14.5	12.4-16.8	**0.001**	15.1	13.1-17.3	0.815	17.4	15.3-19.8	**0.039**
male	140	0	21.7	19.1-24.5		13.9	12.5-15.5		20.7	18.7-23.0	
female	164	0	16.9	14.7-19.4	**0.005**	16.3	14.6-18.4	0.053	20.8	18.4-23.5	0.961
Māori	115	0	20.6	17.4-24.4		16.3	14.3-18.5		21.9	19.1-25.1	
non-Māori	189	0	18.0	16.0-20.2	0.106	14.5	13.1-16.1	0.234	20.1	18.2-22.3	0.313
Northland/Auckland	67	0	20.8	16.8-25.7		16.7	14.0-20.0		23.7	20.1-28.0	
Waikato/BoP	84	0	22.4	18.6-27.1		15.7	13.4-18.4		22.8	19.2-27.2	
lower North Island	78	0	16.6	14.0-19.7		13.8	12.0-15.8		17.9	15.7-20.5	
South Island	75	0	16.5	13.6-20.1	0.053	14.8	12.6-17.4	0.353	19.4	16.4-22.8	0.081

LOD: limit of detection; 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 33b. *Geometric means for the sum of urinary mEHP, mEOHP and mEHHP, children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	299	0	35.5	32.5-38.7	(0.083)	35.3	32.4-38.4	(0.161)	32.9	30.6-35.5	(0.077)
age 5-7	64	0	44.0	36.0-53.7		51.6	42.9-62.0		39.5	32.9-47.5	
8-10	119	0	37.6	32.7-43.2		40.4	36.0-45.3		34.8	31.0-39.0	
11-18	116	0	29.7	26.2-33.6	**0.002**	24.9	21.9-28.4	**<0.0001**	28.2	25.3-31.3	**0.001**
male	144	0	39.4	34.8-44.7		37.8	33.1-43.1		35.3	31.6-39.5	
female	155	0	32.1	28.6-36.1	**0.045**	33.1	29.7-36.9	0.384	30.9	27.9-34.1	0.161
Māori	86	0	38.8	32.6-46.2		37.9	32.2-44.5		35.5	30.6-41.1	
non-Māori	213	0	34.2	31.0-37.7	0.284	34.3	31.0-37.9	0.601	32.0	29.3-34.8	0.413
Northland/Auckland	50	0	43.8	35.5-54.0		34.7	28.5-42.3		39.5	33.2-47.0	
Waikato/BoP	48	0	34.3	26.9-43.6		36.5	27.4-48.6		32.8	26.5-40.6	
lower North Island	171	0	33.4	30.0-37.2		34.9	31.4-38.7		31.4	28.6-34.5	
South Island	30	0	37.1	27.8-49.4	0.069	36.9	29.6-46.1	0.671	32.2	25.4-40.9	0.063

LOD: limit of detection; 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Dicyclohexyl phthalate (DCHP)

DCHP is a common plasticiser ingredient for production of nitrocellulose, ethyl cellulose, vinyl acetate, polyvinyl chloride, and resins. The urinary biomarker and metabolite of DCHP determined in the study is mono-cyclohexyl phthalate (mCHP).

mCHP was detected in 1% of the samples of adults (n=3) and 0% of the samples of children. Because of the low detection frequency the results for mCHP are not reported.

di-n-octyl phthalate (DOP)

DOP is a high molecular weight phthalate and a commonly used plasticiser found in a variety of consumer products. The urinary biomarker and metabolite of DOP determined in the study is mono-(3-carboxypropyl) phthalate (mCPP).

The results for mCPP are presented in **Table 34a** for adults and **Table 34b** for children. mCPP was detected in 63% of the samples of adults and in 76% of the samples of children. The GM urinary mCPP levels was 2.4 µg/L for adults and 3.3 µg/L for children. The arithmetic mean urinary mCPP levels was 5.5 µg/L for adults and 5.2 µg/L for children. The 95th percentile was 18 µg/L for adults and 12 µg/L for children. The highest GM was observed for the youngest age group (4.4 µg/L for the 5-7 year age group) and the lowest for the oldest age group (2.0 µg/L for the 50-64 year age group).

Table 34a. *Geometric means for urinary mono-(3-carboxypropyl) phthalate (mCPP), adults.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	304	112	2.36	2.10-2.66	(0.044)	1.89	1.68-2.13	(0.029)	2.59	2.32-2.90	(0.020)
age 19-24	53	17	2.69	2.09-3.46		1.72	1.34-2.21		2.78	2.20-3.52	
25-34	65	31	2.44	1.88-3.16		1.56	1.23-1.97		2.38	1.88-3.02	
35-49	83	27	2.68	2.06-3.48		2.13	1.64-2.77		2.98	2.31-3.84	
50-64	103	37	1.96	1.64-2.34	0.123	2.04	1.69-2.47	0.242	2.36	1.98-2.82	0.333
male	140	43	2.73	2.31-3.23		1.75	1.48-2.08		2.61	2.22-3.07	
female	164	69	2.09	1.77-2.46	**0.020**	2.02	1.72-2.38	0.230	2.58	2.20-3.02	0.883
Māori	115	45	2.20	1.82-2.67		1.74	1.44-2.09		2.34	1.95-2.80	
non-Māori	189	67	2.46	2.12-2.86	0.426	1.99	1.71-2.32	0.211	2.76	2.39-3.19	0.155
Northland/Auckland	67	26	2.26	1.76-2.91		1.82	1.40-2.38		2.58	2.02-3.31	
Waikato/BoP	84	30	2.49	2.02-3.09		1.75	1.42-2.14		2.54	2.07-3.12	
lower North Island	78	26	2.58	2.03-3.28		2.14	1.71-2.68		2.79	2.24-3.47	
South Island	75	30	2.11	1.66-2.68	0.524	1.89	1.47-2.43	0.687	2.47	1.94-3.13	0.864

LOD: limit of detection (2 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

Table 34b. *Geometric means for urinary mono-(3-carboxypropyl) phthalate (mCPP), children.*

	n	n< LOD	GM µg/L	95%CI	(R2) p-value	GM µg/g crea	95%CI	(R2) p-value	GM µg/L spgr	95%CI	(R2) p-value
all	299	71	3.33	3.04-3.66	(0.114)	3.32	3.01-3.65	(0.210)	3.10	2.84-3.37	(0.111)
age 5-7	64	8	4.36	3.63-5.24		5.12	4.31-6.07		3.92	3.31-4.65	
8-10	119	18	3.85	3.30-4.50		4.14	3.58-4.80		3.57	3.10-4.12	
11-18	116	45	2.48	2.18-2.82	**<0.0001**	2.08	1.83-2.37	**<0.0001**	2.35	2.09-2.64	**<0.0001**
male	144	26	3.67	3.23-4.17		3.52	3.05-4.06		3.29	2.92-3.71	
female	155	45	3.05	2.67-3.48	0.099	3.14	2.76-3.57	0.593	2.93	2.60-3.30	0.330
Māori	86	19	3.51	3.02-4.09		3.43	2.90-4.05		3.21	2.81-3.67	
non-Māori	213	52	3.26	2.91-3.66	0.696	3.27	2.92-3.67	0.869	3.05	2.74-3.39	0.961
Northland/Auckland	50	11	3.77	3.02-4.72		2.99	2.39-3.74		3.41	2.77-4.18	
Waikato/BoP	48	17	2.84	2.32-3.47		3.02	2.28-4.01		2.72	2.22-3.33	
lower North Island	171	37	3.38	2.97-3.84		3.52	3.11-3.99		3.17	2.83-3.56	
South Island	30	6	3.25	2.52-4.21	0.121	3.24	2.51-4.17	0.687	2.83	2.24-3.57	0.120

LOD: limit of detection (2 µg/L); 95%CI: 95% confidence interval of the geometric mean (GM); R^2: R-squared of the multivariate linear regression model; p-value: the p-value of the multivariate linear regression model for that variable; crea: creatinine adjusted; spgr: specific gravity adjusted.

di-iso-nonyl phthalate (DiNP)

DiNP is a high molecular weight phthalate used as a plasticiser. DiNP is a "general purpose" phthalate which is an alternative for most of the uses of DEHP. The urinary biomarker and metabolite of DiNP determined in the study is mono-iso-nonyl Phthalate (miNP).

MiNP was detected in 1% of the samples of adults (n=3) and in 0% of the samples of children. Because of the low detection frequency the results for miNP are not reported.

Age and urinary concentrations of phthalate metabolites

As shown above, for all phthalate metabolites studied, age is an important determinant of exposure. **Table 35** lists the GMs for each age group for those phthalate metabolites detected in most samples. These numbers are also graphically represented in **Figure 1**. For all the phthalates, except DEP, highest GM levels were observed in the younger age groups, with gradually reducing levels with increasing age groups. The ratio in GM levels between the youngest and the oldest age groups range from 2.2 to 3.5-times. The age pattern is markedly different for mEP, a metabolite of DEP, which is mainly used in personal care products. For mEP the urinary levels tend to be higher for the older age groups, with a distinct peak for the 19-24 year age group.

Table 35. *Geometric means (µg/L) of phthalate metabolites by age group.*

	Geometric mean (µg/L) for each age group						
	5-7	8-10	11-18	19-24	25-34	35-49	50-64
mEP (metabolite of DEP)	13.2	13.0	12.6	24.8	14.1	18.4	21.0
mBP (metabolite of DBP)	71.6	64.9	51.4	48.0	46.5	36.6	28.2
mBzP (metabolite of BBzP)	9.2	8.0	6.7	5.4	6.2	4.8	2.6
mEHP (metabolite of DEHP)	3.2	2.6	2.5	2.7	2.8	2.3	1.2
mEOHP (metabolite of DEHP)	18.7	15.1	11.5	9.1	8.3	7.5	5.2
mEHHP (metabolite of DEHP)	20.3	19.3	14.8	9.4	11.3	9.1	7.5
sum of 3 DEHP metabolites	44.0	37.6	29.7	22.7	23.1	20.2	14.5
mCPP (metabolite of DOP)	4.4	3.9	2.5	2.7	2.4	2.7	2.0

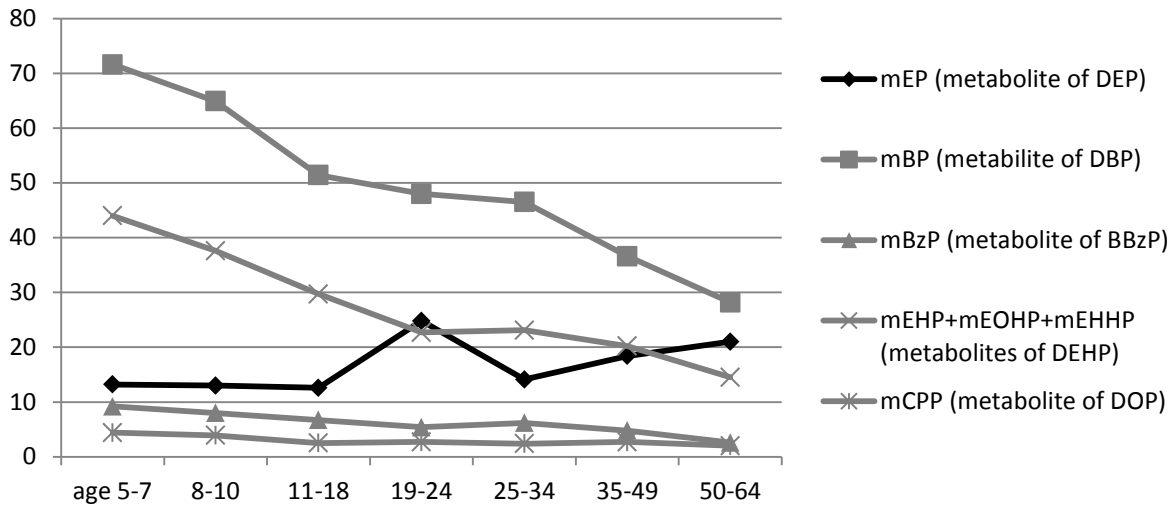


Figure 1. *Geometric means (µg/L) of phthalate metabolites by age group.*

5. Comparison with other countries

Several countries have conducted similar general population biomonitoring studies or programmes in recent years, including Austria (Hohenblum *et al.*, 2012), Belgium (Schoeters *et al.*, 2012; Hoet *et al.*, 2013), Canada (Haines *et al.*, 2011; Haines & Murray, 2012; Haines *et al.*, 2016; Saravanabhavan *et al.*, 2016), the Czech Republic (Cerna *et al.*, 2007; Cerna *et al.*, 2012), European countries (DEMOCOPHES) (Casteleyn & Aerts, 2015; Casteleyn *et al.*, 2015; Den Hond *et al.*, 2015), France (Frery *et al.*, 2012; Nisse *et al.*, 2016; Tagne-Fotso *et al.*, 2016), Germany (Schulz *et al.*, 2007a; Schulz *et al.*, 2007b; Kolossa-Gehring *et al.*, 2012), Korea (Lee *et al.*, 2012; Sul *et al.*, 2012; Lee *et al.*, 2014; Choi *et al.*, 2016; Kim *et al.*, 2016), Spain (Perez-Gomez *et al.*, 2013; Canas *et al.*, 2014; Lopez-Herranz *et al.*, 2016), UK (Morton *et al.*, 2014; Saravanabhavan *et al.*, 2016) and the US (CDC, 2017).

These biomonitoring studies or programmes vary widely in the list of tested substances and the number of participants. Both the programmes conducted in the US and Canada included an extensive list of tested substances, large numbers of participants, and repeated surveys at regular intervals, thus providing insight in trends over time. Both also report results for children. The paragraphs below include more information on the monitoring programmes from the US and Canada.

US (NHANES)

The National Health and Nutrition Examination Survey (NHANES) is a program of studies designed to assess the health and nutritional status of adults and children in the United States. NHANES is a major program of the National Center for Health Statistics (NCHS), which is part of the Centers for Disease Control and Prevention (CDC) and has the responsibility for producing vital and health statistics for the US. The sample for the survey is selected to represent the US population of all ages. To produce reliable statistics, NHANES over-samples persons 60 and older, African Americans, Asians, and Hispanics. Blood and urine samples have been collected since 1999, and the survey was repeated every 2 years (1999-2000, 2001-2002, 2003-2004, 2005-2006, 2007-2008, 2009-2010, 2011-2012, 2013-2014). The Fourth National Report on Human Exposure to Environmental Chemicals published in 2017 includes the most recent biomonitoring results (2013-2014), as well as the results for all the previous survey cycles since 1999 (CDC, 2017).

Canada (The Canadian Health Measures Survey)

The Canadian Health Measures Survey (CHMS) was launched in 2007 to collect key information relevant to the health of Canadians. The target population for CHMS consists of persons 3 to 79 years of age living in Canada. The survey includes the collection of blood and urine and has thus far reported on 4 survey cycles: 2007-2009, 2009-2011, 2012-2013 and 2014-2015. The fourth report on human biomonitoring of environmental chemicals in Canada published in 2017, reports the most recent results of Survey Cycle 4 (2014-2015) (Health Canada, 2017). Comparisons with earlier cycles has also been reported in 2016 (Saravanabhavan *et al.*, 2016).

The tables in the following sections include the geometric means reported for the most recent US (NHANES) and Canadian (The Canadian Health Measures Survey) survey cycles (if available), as well as geometric means from population based surveys from other countries if identified through a medline search. Geometric means reported from studies using a sample that was not representative for the general population (e.g. only pregnant women; only occupationally exposed) are not included.

Studies that used pooled biological samples rather than individual samples are not included in the following tables, because concentrations based on pooled samples are not directly comparable to geometric means of collections of individual samples. Results from pooled samples can however be compared with the arithmetic mean of collections of individual samples, as the impact of outliers on the summary statistic is similar in these situations. Therefore, to enable comparison with recent Australian studies that were based on pooled samples, the Australian summary statistics are included in the text and compared to the arithmetic mean of the levels in the individual New Zealand samples.

5.1 International comparison blood lead

The GMs for blood lead concentrations for New Zealand adults and children, and those reported for other countries, are listed in **Table 36**. The blood lead concentrations for adults and children in New Zealand were comparable to the geometric means reported for US and Canada. However, for these countries a downward trend over time has been observed with the most recent results indicating concentrations below those observed for New Zealand, which could reflect the earlier phase out by over a decade of lead in petrol in North America compared to New Zealand.

The New Zealand blood lead concentrations in adults are lower than those reported for Korea, France, Spain, and Germany, although it should be noted that these surveys were conducted several years before the New Zealand survey.

Table 36. *Comparison of population geometric means of blood lead concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	304	13.1	12.4-13.9	This study
US	2007-2008	20+	5364	13.8	13.1-14.6	(CDC, 2017)
US	2009-2010	20+	5765	12.3	11.9-12.8	(CDC, 2017)
US	2011-2012	20+	5030	10.9	10.3-11.6	(CDC, 2017)
US	2013-2014	20+	2695	9.67	9.21-10.2	(CDC, 2017)
Canada	2007-2009	6-79	5319	13	12-14	(Haines *et al.*, 2016)
Canada	2009-2011	3-79	6070	12	11-12	(Haines *et al.*, 2016)
Canada	2012-2013	3-79	5538	11	10-11	(Haines *et al.*, 2016)
Canada	2014-2015	3-79	5498	9.5	9.0-10.0	(Health Canada, 2017)
Korea	2012-2014	19-70+	6455	19.4	18.9-19.9	(Choi *et al.*, 2016)
France (North)	2008-2010	20-59	1992	18.8	18.3-19.3	(Nisse *et al.*, 2016)
Spain	2009-2010	18-65	1880	24.03	22.98-25.12	(Canas *et al.*, 2014)
Germany	1998	25-69	3974	31.6	nr	(Schulz *et al.*, 2007b)
New Zealand	2014-2016	5-18	193	8.5	7.9-9.1	This study
US	2007-2008	6-11	1011	9.88	9.14-10.7	(CDC, 2017)
US	2009-2010	6-11	1009	8.38	7.92-8.87	(CDC, 2017)
US	2011-2012	6-11	1048	6.81	6.23-7.44	(CDC, 2017)
US	2013-2014	6-11	1075	5.67	5.29-6.07	(CDC, 2017)
Canada	2007-2009	6-11	910	9.0	8.1-9.9	(Health Canada, 2015)
Canada	2009-2011	6-11	961	7.9	7.4-8.4	(Health Canada, 2017)
Canada	2012-2013	6-11	944	7.1	6.7-7.6	(Health Canada, 2017)
Canada	2014-2015	6-11	925	5.9	5.5-6.2	(Health Canada, 2017)
Germany	2003-2006	6-14	1245	15.7	nr	(Schulz *et al.*, 2007b)
Italy	2008-2010	13-15	252	9.5	nr	(Pino *et al.*, 2012)

5.2 International comparison blood mercury

The GMs for blood mercury concentrations for New Zealand adults and children, and those reported for other countries, are listed in **Table 37**. The GM for blood mercury concentration in adult New Zealanders was higher than the GM reported for US, Canada and Germany, comparable to France, and lower than that reported for Korea. For New Zealand children, the GM for blood mercury was higher than the GM reported for the US, Canada and Germany, while comparable to the GM reported for Italy.

Table 37. *Comparison of population geometric means of blood mercury concentrations (µg/L), reported for different countries*

Country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	304	1.65	1.49-1.82	This study
no fish consumption 48 hours prior			221	1.47	1.30-1.65	This study
fish consumption 48 hours prior			83	2.24	1.87-2.68	This study
US	2007-2008	20+	5364	0.944	0.833-1.07	(CDC, 2017)
US	2009-2010	20+	5765	1.04	0.956-1.14	(CDC, 2017)
US	2011-2012	20+	5030	0.863	0.753-0.990	(CDC, 2017)
US	2013-2014	20+	2695	0.814	0.736-0.900	(CDC, 2017)
Canada	2007-2009	6-79	5319	0.69	0.55-0.86	(Haines *et al.*, 2016)
Canada	2009-2011	3-79	6070	0.69	0.56-0.87	(Haines *et al.*, 2016)
Canada	2012-2013	3-79	5538	0.79	0.64-0.97	(Haines *et al.*, 2016)
Canada	2014-2015	3-79	5498	*		(Health Canada, 2017)
Korea	2012-2014	19-70+	6457	3.11	3.02-3.21	(Choi *et al.*, 2016)
France (North)	2008-2010	20-59	1992	1.38	1.32-1.45	(Nisse *et al.*, 2016)
Germany	1998	25-69	3973	0.61	nr	(Schulz *et al.*, 2007b)
New Zealand	2014-2016	5-18	193	0.85	0.74-0.99	This study
no fish consumption 48 hours prior			157	0.71	0.61-0.83	This study
fish consumption 48 hours prior			35	1.92	1.40-2.63	This study
US	2007-2008	6-11	1011	*		(CDC, 2017)
US	2009-2010	6-11	1009	*		(CDC, 2017)
US	2011-2012	6-11	1048	0.330	0.287-0.379	(CDC, 2017)
US	2013-2014	6-11	1075	*		(CDC, 2017)
Canada	2007-2009	6-11	910	0.26	0.22-0.32	(Health Canada, 2017)
Canada	2009-2011	6-11	961	0.28	0.22-0.34	(Health Canada, 2017)
Canada	2012-2013	6-11	944	*		(Health Canada, 2017)
Canada	2014-2015	6-11	925	*		(Health Canada, 2017)
Germany	2003-2006	6-14	1240	0.24	nr	(Schulz *et al.*, 2007b)
Italy	2008-2010	13-15	252	0.84	nr	(Pino *et al.*, 2012)

* Not calculated: proportion of results below limit of detection was too high to provide a valid result.

5.3 International comparison urinary arsenic

Arsenobetaine (AB) is the main organic form of arsenic detectable in urine, indicative of recent fish consumption. The GMs for urinary AB concentrations for New Zealand adults and children, and those reported for other countries, are listed in **Table 38**. Urinary levels of AB in adult New Zealanders are approximately two times higher compared to data reported for the US, but lower than those reported for high fish consuming nations such as Spain(Navarro Serrano *et al.*, 2016) (see table) and Japan (Hata *et al.*, 2007) (not included in the table as the GM was not reported). For children a direct comparison with other countries could not be made, as results for the US were not presented due to a high proportion of samples being below the limit of detection.

Table 38. *Comparison of population geometric means of urinary arsenobetaine (AB) concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	304	3.51	2.44-5.04	This study
no fish consumption 48 hours prior			225	1.77	1.17-2.68	This study
fish consumption 48 hours prior			79	24.59	13.98-43.27	This study
US	2007-2008	20+	1820	1.46	1.28-1.67	(CDC, 2017)
US	2009-2010	20+	2035	1.92	1.63-2.26	(CDC, 2017)
US	2011-2012	20+	1724	*		(CDC, 2017)
US	2013-2014	20+	1807	*		(CDC, 2017)
Spain	nr	20-67	124	29.1	nr	(Navarro Serrano *et al.*, 2016)
New Zealand	2014-2016	5-18	299	1.50	1.01-2.23	This study
no fish consumption 48 hours prior			116	0.91	0.56-1.48	This study
fish consumption 48 hours prior			37	41.21	15.32-110.9	This study
US	2007-2008	6-11	390	*		(CDC, 2017)
US	2009-2010	6-11	380	*		(CDC, 2017)
US	2011-2012	6-11	401	*		(CDC, 2017)
US	2013-2014	6-11	397	*		(CDC, 2017)

* Not calculated: proportion of results below limit of detection was too high to provide a valid result.

Dimethylarsinic acid (DMA) is a main inorganic arsenic related compound found in urine. The GMs for urinary DMA concentrations for New Zealand adults and children, and those reported for other countries, are listed in **Table 39**. Urinary levels of DMA in adult New Zealanders are comparable to data reported for the US and Canada while below that reported for Spain. For urinary DMA concentrations in children few comparison studies were available, but studies from the US indicate that New Zealand levels of urinary DMA in children are below those reported for the US

Table 39. *Comparison of population geometric means of urinary dimethylarsinic acid (DMA) concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	304	4.18	3.16-5.54	This study
no fish consumption 48 hours prior			225	3.20	2.29-4.48	This study
fish consumption 48 hours prior			79	8.95	5.57-14.37	This study
US	2007-2008	20+	1820	3.66	3.43-3.91	(CDC, 2017)
US	2009-2010	20+	2035	3.79	3.51-4.09	(CDC, 2017)
US	2011-2012	20+	1724	3.51	3.22-3.82	(CDC, 2017)
US	2013-2014	20+	1807	3.17	2.93-3.43	(CDC, 2017)
Canada	2009-2011	3-79	2538	3.5	3.0-4.0	(Haines *et al.*, 2016)
Canada	2012-2013	3-79	2536	3.6	3.2-4.0	(Haines *et al.*, 2016)
Spain	nr	20-67	124	7.5	nr	(Navarro Serrano *et al.*, 2016)
New Zealand	2014-2016	5-18	299	3.01	2.20-4.12	This study
no fish consumption 48 hours prior			116	2.28	1.50-3.47	This study
fish consumption 48 hours prior			37	13.61	6.63-27.96	This study
US	2007-2008	6-11	390	3.86	3.45-4.32	(CDC, 2017)
US	2009-2010	6-11	380	3.53	3.17-3.92	(CDC, 2017)
US	2011-2012	6-11	401	3.43	3.06-3.85	(CDC, 2017)
US	2013-2014	6-11	397	3.33	2.95-3.75	(CDC, 2017)

Monomethyl arsonic acid (MMA) was only detected in 3% of adults and 14% of children, and the proportion of results below limit of detection was too high to provide a valid result, which was also the case for the US studies (except for the 2013-2014 NHANES survey).

Table 40. *Comparison of population geometric means of urinary monomethyl arsonic acid (MMA) concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	298	*		This study
US	2007-2008	20+	1820	*		(CDC, 2017)
US	2009-2010	20+	2035	*		(CDC, 2017)
US	2011-2012	20+	1724	*		(CDC, 2017)
US	2013-2014	20+	1807	0.406	0.365-0.450	(CDC, 2017)
New Zealand	2014-2016	5-18	222	*		This study
US	2007-2008	6-11	390	*		(CDC, 2017)
US	2009-2010	6-11	380	*		(CDC, 2017)
US	2011-2012	6-11	401	*		(CDC, 2017)
US	2013-2014	6-11	397	*		(CDC, 2017)

* Not calculated: proportion of results below limit of detection was too high to provide a valid result.

5.4 International comparison urinary cadmium

The GMs for urinary cadmium concentrations for New Zealand adults and children, and those reported for other countries, are listed in **Table 41**.The geometric mean of urinary cadmium concentrations of adult New Zealanders is comparable to that reported for US and the Europe DEMOCOPHES study, and lower than that reported for Canada, Korea and Spain. For children, the New Zealand GM is also comparable to the GM reported for Europe DEMOCOPHES, while below that reported for Canada.

Table 41. *Comparison of population geometric means of urinary cadmium concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	304	0.19	0.18-0.21	This study
US	2007-2008	20+	1857	0.232	0.215-0.251	(CDC, 2017)
US	2009-2010	20+	2019	0.229	0.213-0.245	(CDC, 2017)
US	2011-2012	20+	1715	0.194	0.178-0.211	(CDC, 2017)
US	2013-2014	20+	1811	0.156	0.146-0.167	(CDC, 2017)
Canada	2007-2009	6-79	5491	0.34	0.31-0.38	(Haines *et al.*, 2016)
Canada	2009-2011	3-79	6311	0.38	0.34-0.43	(Haines *et al.*, 2016)
Korea	2012-2014	19-70$_+$	6469	0.38	0.36-0.39	(Choi *et al.*, 2016)
France (North)	2008-2010	20-59	1910	0.37	0.35-0.39	(Nisse *et al.*, 2016)
Spain	2009-2010	18-65	1770	0.28	0.27-0.32	(Lopez-Herranz *et al.*, 2016)
Belgium	2010-2011	18-80	1001	0.228	0.211-0.245	(Hoet *et al.*, 2013)
Germany (non smokers)	1998	25-69	2758	0.209	nr	(Schulz *et al.*, 2007b)
Germany (smokers)	1998	25-69	1293	0.334	nr	(Schulz *et al.*, 2007b)
Europe (DEMOCOPHES) urban	2011	31-52	844	0.216	0.203-0.229	(Morck *et al.*, 2015)
Europe (DEMOCOPHES) rural	2011	31-50	841	0.220	0.207-0.233	(Morck *et al.*, 2015)
New Zealand	2014-2016	5-18	300	0.074	0.069-0.079	This study
US	2007-2008	6-11	394	0.064	0.058-0.071	(CDC, 2017)
US	2009-2010	6-11	378	0.057	0.053-0.061	(CDC, 2017)
US	2011-2012	6-11	399	*		(CDC, 2017)
US	2013-2014	6-11	402	*		(CDC, 2017)
Canada	2007-2009	6-11	1033	0.22	0.19-0.26	(Health Canada, 2015)
Germany	2003-2006	6-14	1354	0.071	nr	(Schulz *et al.*, 2007b)
Europe (DEMOCOPHES)	2011	6-11	848	0.066	0.062-0.070	(Morck *et al.*, 2015)
Europe (DEMOCOPHES)	2011	6-11	850	0.069	0.065-0.074	(Morck *et al.*, 2015)

* Not calculated: proportion of results below limit of detection was too high to provide a valid result.

5.5 International comparison urinary chromium

The GMs for urinary chromium concentrations for New Zealand adults and children, and those reported for other countries, are listed in **Table 42**. Very few studies have reported geometric means of urinary concentrations for chromium in adults and comparisons with the US and Canada cannot be made. The New Zealand mean urinary chromium concentration is considerably lower than the most recent results reported for France and Belgium.

Table 42. *Comparison of population geometric means of urinary chromium concentrations (µg/L), reported for different countries*

country	Year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	304	0.052	0.043-0.063	This study
France (North)	2008-2010	20-59	1910	0.38	0.36-0.40	(Nisse *et al.*, 2016)
Belgium	2010-2011	18-80	1001	0.103	0.10-0.11	(Hoet *et al.*, 2013)
New Zealand	2014-2016	5-18	300	0.034	0.028-0.040	This study

5.6 International comparison urinary thallium

The GMs for urinary thallium concentrations for New Zealand adults and children, and those reported for other countries, are listed in **Table 43**. New Zealand urinary thallium concentrations in adults are similar to those reported by Canada, France and Belgium, and higher than those reported for the US. For children, the New Zealand levels of urinary thallium are lower than those reported for the US.

Table 43. *Comparison of population geometric means of urinary thallium concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	304	0.199	0.179-0.220	This study
US	2007-2008	20+	1857	0.140	0.133-0.148	(CDC, 2017)
US	2009-2010	20+	2019	0.142	0.133-0.150	(CDC, 2017)
US	2011-2012	20+	1715	0.147	0.136-0.159	(CDC, 2017)
US	2013-2014	20+	1811	0.137	0.129-0.146	(CDC, 2017)
Canada	2009-2011	3-79	6311	0.23	0.21-0.24	(Haines *et al.*, 2016)
France (North)	2008-2010	20-59	1910	0.21	0.20-0.22	(Nisse *et al.*, 2016)
Belgium	2010-2011	18-80	1001	0.168	0.16-0.18	(Hoet *et al.*, 2013)
New Zealand	2014-2016	5-18	300	0.054	0.048-0.062	This study
US	2007-2008	6-11	394	0.166	0.150-0.185	(CDC, 2017)
US	2009-2010	6-11	378	0.161	0.147-0.176	(CDC, 2017)
US	2011-2012	6-11	399	0.157	0.143-0.172	(CDC, 2017)
US	2013-2014	6-11	402	0.149	0.131-0.170	(CDC, 2017)

5.7 International comparison urinary antimony

The GMs for urinary antimony concentrations for New Zealand adults and children, and those reported for other countries, are listed in **Table 44**. New Zealand urinary antimony concentrations in adults are similar to those reported for France and marginally higher than levels most recently reported for Belgium, US and Canada. New Zealand urinary antimony concentrations in children are also above those most recently reported for the US and Canada. The pattern of somewhat higher levels among children compared to adults observed in this study, was also observed in studies from the US and Canada.

Table 44. *Comparison of population geometric means of urinary antimony concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	304	0.062	0.055-0.069	This study
US	2007-2008	20+	1857	0.058	0.054-0.062	(CDC, 2017)
US	2009-2010	20+	2018	0.045	0.051-0.057	(CDC, 2017)
US	2011-2012	20+	1715	*		(CDC, 2017)
US	2013-2014	20+	1811	0.042	0.038-0.045	(CDC, 2017)
Canada	2007-2009	6-79	5492	0.042	0.040-0.045	(Haines *et al.*, 2016)
Canada	2009-2011	3-79	6311	0.046	0.044-0.048	(Haines *et al.*, 2016)
France (North)	2008-2010	20-59	1910	0.06	0.05-0.07	(Nisse *et al.*, 2016)
Belgium	2010-2011	18-80	1001	0.029	0.03-0.03	(Hoet *et al.*, 2013)
New Zealand	2014-2016	5-18	300	0.091	0.085-0.098	This study
US	2007-2008	6-11	394	0.068	0.061-0.077	(CDC, 2017)
US	2009-2010	6-11	378	0.069	0.061-0.079	(CDC, 2017)
US	2011-2012	6-11	399	0.064	0.059-0.069	(CDC, 2017)
US	2013-2014	6-11	402	0.052	0.045-0.060	(CDC, 2017)
Canada	2007-2009	6-11	1034	0.05	0.05-0.05	(Health Canada, 2015)

* Not calculated: proportion of results below limit of detection was too high to provide a valid result.

5.8 International comparison urinary cotinine

Due to the low detection frequency of cotinine in the New Zealand samples, valid comparisons with Geometric Means reported for other countries could not be made.

5.9 International comparison urinary fluoride

The GMs for urinary fluoride concentrations for New Zealand adults and children, and those reported for other countries, are listed in **Table 45**. Only very few studies have reported population levels of urinary fluoride. Concentrations of fluoride in New Zealand adults are higher than those reported for Canada, but comparable to those reported for Brazil (Bauru) and Japan.

Data from the US or Canada were not available for urinary fluoride concentrations in children. Some studies conducted in areas with high concentrations of naturally occurring fluoride reported very high urinary fluoride concentrations for children (i.e. 12000 µg/L for children living in Ethiopia (Rango *et al.*, 2014) and 2000 µg/L for children living in India (Singh *et al.*, 2007)).

Table 45. *Comparison of population geometric means of urinary fluoride concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	304	759	710-812	This study
Canada	2009-2011	3-79	2530	500	460-550	(Haines *et al.*, 2016)
Canada	2012-2013	3-79	2671	430	390-480	(Haines *et al.*, 2016)
Canada	2014-2015	3-79	2574	470	380-590	(Health Canada, 2017)
Brazil (Bauru, water fluoridated)	1995-1996	5-50	167	750*	Nr	(Heintze *et al.*, 1998)
Brazil (Garca, water fluoridated)	1995-1996	5-50	206	1190*	Nr	(Heintze *et al.*, 1998)
Brazil (Itapolis, water not fluoridated)	1995-1996	5-50	172	360*	Nr	(Heintze *et al.*, 1998)
Japan	nr	19-59	167	614	241-1633	(Usuda *et al.*, 2007)
New Zealand	2014-2016	5-18	299	628	586-674	This study
Canada	2009-2011	6-11	514	500	440-570	(Health Canada, 2017)
Canada	2012-2013	6-11	549	400	360-450	(Health Canada, 2017)
Canada	2014-2015	6-11	533	470	370-600	(Health Canada, 2017)

*median (not GM)

5.10 International comparison urinary phenols

The GMs for the urinary phenols determined for New Zealand are compared with those reported for other countries in the paragraphs below.

Bisphenol A (BPA)

The GMs for urinary BPA concentrations for New Zealand adults and children, and those reported for other countries, are listed in Table 46. This table indicates that New Zealand levels are comparable to those that have been reported for the US and Canada, but that the most recent GMs reported for US and Canada are below those of New Zealand.

Table 46. *Comparison of population geometric means of urinary bisphenol A concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	302	1.80	1.60-2.03	This study
US	2007-2008	20+	1814	1.99	1.82-2.18	(CDC, 2017)
US	2009-2010	20+	1914	1.79	1.67-1.93	(CDC, 2017)
US	2011-2012	20+	1705	1.48	1.35-1.61	(CDC, 2017)
US	2013-2014	20+	1815	1.26	1.18-1.35	(CDC, 2017)
Canada	2007-2009	6-79	5476	1.2	1.1-1.2	(Haines *et al.*, 2016)
Canada	2009-2011	3-79	2560	1.2	1.1-1.3	(Haines *et al.*, 2016)
Canada	2012-2013	3-79	5670	1.1	1.0-1.2	(Haines *et al.*, 2016)
Canada	2014-2015	3-79	2560	1.0	0.95-1.1	(Health Canada, 2017)
Korea	2012-2014	19-70+	6263	1.09	1.02-1.16	(Choi *et al.*, 2016)
Israel	2011	20-74	245	2.39	nr	(Berman *et al.*, 2014)
New Zealand	2014-2016	5-18	299	2.18	1.96-2.41	This study
US	2007-2008	6-11	389	2.48	2.21-2.77	(CDC, 2017)
US	2009-2010	6-11	415	1.81	1.55-2.10	(CDC, 2017)
US	2011-2012	6-11	396	1.58	1.41-1.78	(CDC, 2017)
US	2013-2014	6-11	409	1.43	1.30-1.59	(CDC, 2017)
Canada	2007-2009	6-11	1031	1.3	1.2-1.4	(Health Canada, 2017)
Canada	2009-2011	6-11	516	1.4	1.1-1.7	(Health Canada, 2017)
Canada	2012-2013	6-11	1004	1.2	1.1-1.4	(Health Canada, 2017)
Canada	2014-2015	6-11	511	1.1	0.9-1.4	(Health Canada, 2017)
India	2012-2013	2-14	76	5.08	nr	(Xue *et al.*, 2015)
Sweden	2015	3-4	113	1.4	nr	(Larsson *et al.*, 2017)

Urinary BPA concentrations based on pooled urine samples collected in 2010-2011 from Queensland (Australia) residents have also been reported (Heffernan *et al.*, 2013). Concentrations in pooled samples are compared below with the arithmetic mean concentration of the New Zealand individual samples, because both pooled samples and arithmetic means are similarly affected by outliers.

For 15 pools of samples from adults (age 15-75) each consisting of 28 individual samples, the geometric mean was 2.61 µg/L for the Australian study. For the New Zealand samples, the arithmetic mean BPA concentration was 3.1 µg/L for adults. For 64 pooled samples each including individuals samples of 7 Australian children age 0-5 the GM BPA concentration was 2.98 µg/L. For the New Zealand samples, the arithmetic mean BPA concentration was 3.2 µg/L for children. The New Zealand urinary concentrations for BPA therefore are similar to the concentrations reported for the pooled samples from Australia.

Triclosan

The GMs for urinary concentrations of the preservative and antiseptic agent triclosan in New Zealand adults and children, and those reported for other countries, are listed in **Table 47**. Only a few countries have reported on urinary triclosan concentrations in the general population. For these countries, the GMs were two to three times higher than those observed for New Zealand, for both adults and children.

Table 47. *Comparison of population geometric means of urinary triclosan concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	303	5.8	4.3-7.8	This study
US	2007-2008	20+	1814	15.4	13.7-17.3	(CDC, 2017)
US	2009-2010	20+	1914	15.5	12.9-18.5	(CDC, 2017)
US	2011-2012	20+	1705	12.7	11.2-14.4	(CDC, 2017)
US	2013-2014	20+	1815	10.3	9.32-11.3	(CDC, 2017)
Canada	2009-2011	3-79	2550	16	13-20	(Haines *et al.*, 2016)
Canada	2012-2013	3-79	5645	17	15-19	(Haines *et al.*, 2016)
Canada	2014-2015	3-79	2558	*		(Health Canada, 2017)
New Zealand	2014-2016	5-18	299	3.9	3.0-5.0	This study
US	2007-2008	6-11	389	11.8	7.57-18.2	(CDC, 2017)
US	2009-2010	6-11	415	10.9	9.35-12.8	(CDC, 2017)
US	2011-2012	6-11	396	7.18	5.73-9.01	(CDC, 2017)
US	2013-2014	6-11	409	8.24	6.70-10.1	(CDC, 2017)
Canada	2009-2011	6-11	515	8.5	6.7-11	(Health Canada, 2017)
Canada	2012-2013	6-11	1001	11	8.4-16	(Health Canada, 2017)
Canada	2014-2015	6-11	510	*		(Health Canada, 2017)

* Not calculated: proportion of results below limit of detection was too high to provide a valid result.

Urinary triclosan concentrations based on pooled urine samples collected in 2012-2013 from Queensland (Australia) residents have also been reported (Heffernan *et al.*, 2015). Concentrations in pooled samples are compared below with the arithmetic mean concentration of the New Zealand individual samples, because both pooled samples and arithmetic means are similarly affected by outliers.

For 24 pools of all age groups (0->60 year) each consisting of 100 individual samples, the geometric mean was 88 µg/L for the Australian study. For the New Zealand samples, the arithmetic mean triclosan concentration was 133 µg/L for adults. For a pooled sample of 100 Australian children age 5-14 the triclosan concentration was 106 µg/L. For the New Zealand samples, the arithmetic mean triclosan concentration was 88 µg/L for children. The New Zealand urinary concentrations for triclosan therefore appear comparable to the concentrations reported for the pooled samples from Australia.

Benzophenone-3

The GMs for urinary concentrations of the sunscreen component benzophenone-3 (BP3), in New Zealand adults and children, and those reported for other countries, are listed in **Table 48**. Only a few countries have reported on urinary BP3 concentrations in the general population. The GMs reported for the US were comparable to those reported here for New Zealand. The GM based on adults from Belgium was considerably lower, as was the GM based on children from India.

Table 48. *Comparison of population geometric means of urinary benzophenone-3 concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	303	18.4	14.9-22.7	This study
US	2007-2008	20+	1814	17.3	13.0-23.0	(CDC, 2017)
US	2009-2010	20+	1914	22.3	17.9-27.7	(CDC, 2017)
US	2011-2012	20+	1705	23.1	17.8-30.0	(CDC, 2017)
US	2013-2014	20+	1815	24.6	19.7-30.6	(CDC, 2017)
Belgium	2013	1-85	261	1.3	nr	(Dewalque *et al.*, 2014)
NZ	2014-2016	5-18	298	20.8	17.6-24.7	This study
US	2007-2008	6-11	389	24.1	15.0-38.7	(CDC, 2017)
US	2009-2010	6-11	415	21.7	15.6-30.2	(CDC, 2017)
US	2011-2012	6-11	396	18.7	12.3-28.2	(CDC, 2017)
US	2013-2014	6-11	409	26.0	16.5-40.9	(CDC, 2017)
India	2012-2013	2-14	76	0.91	nr	(Xue *et al.*, 2015)

Urinary BP3 concentrations based on pooled urine samples collected in 2012-2013 from Queensland (Australia) residents have also been reported (Heffernan *et al.*, 2015). Concentrations in pooled samples are compared below with the arithmetic mean concentration of the New Zealand individual samples, because both pooled samples and arithmetic means are similarly affected by outliers.

For 24 pools of all age groups (0->60 year) each consisting of 100 individual samples, the geometric mean was 62 µg/L for the Australian study. For the New Zealand samples, the arithmetic mean BP3 concentration was 125 µg/L for adults. For a pooled sample of 100 Australian children age 5-14 the BP3 concentration was 26 µg/L. For the New Zealand samples, the arithmetic mean BP3 concentration was 100 µg/L for children. The New Zealand urinary concentrations for BP3 therefore appear higher compared to the concentrations reported for the pooled samples from Australia.

4-tert-octylphenol

Urinary concentrations of 4-tert-octylphenol reported for different countries are listed in **Table 49**. Only the US has reported on 4-tert-octylephenol but levels were below the limit of detection for the majority of samples, as was the case for the New Zealand samples.

Table 49. *Comparison of population geometric means of urinary 4-tert-octylphenol concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	303	*		This study
US	2007-2008	20+	1814	*		(CDC, 2017)
US	2009-2010	20+	1914	*		(CDC, 2017)
New Zealand	2014-2016	5-18	299	*		This study
US	2007-2008	6-11	389	*		(CDC, 2017)
US	2009-2010	6-11	415	*		(CDC, 2017)

*Not calculated: proportion of results below limit of detection was too high to provide a valid result.

Parabens

The GMs for urinary parabens (methylparaben, propylparaben, ethylparaben, butylparaben), in New Zealand adults and children, and those reported for other countries, are listed in **Table 52-55**.

Methylparaben

For methylparaben, the GMs reported for the US are generally two times higher than the GMs reported here for New Zealand, for both adults and children (**Table 52**). The GM for New Zealand adults is comparable to the GM reported for Canada, Belgium and Greece, while the GM for New Zealand children is higher than those reported for China and India.

Table 52. *Comparison of population geometric means of urinary methylparaben concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	303	17.5	14.5-21.1	This study
US	2007-2008	20+	1814	63.0	51.8-76.7	(CDC, 2017)
US	2009-2010	20+	1914	61.0	53.5-69.6	(CDC, 2017)
US	2011-2012	20+	1705	46.8	41.3-53.1	(CDC, 2017)
US	2013-2014	20+	1815	52.2	46.0-59.3	(CDC, 2017)
Canada	2014-2015	3-79	2564	17	13-22	(Health Canada, 2017)
China, Shanghai	2010	22-58	26	30.5	nr	(Wang *et al.*, 2013)
Belgium	2013	1-85	261	19.0	nr	(Dewalque *et al.*, 2014)
Greece	2012	2-87	100	15.2	nr	(Asimakopoulos *et al.*, 2014)
New Zealand	2014-2016	5-18	299	11.9	9.6-14.7	This study
US	2007-2008	6-11	389	35.2	25.0-49.6	(CDC, 2017)
US	2009-2010	6-11	415	33.9	27.4-41.9	(CDC, 2017)
US	2011-2012	6-11	396	18.5	15.7-21.9	(CDC, 2017)
US	2013-2014	6-11	409	28.6	21.4-38.1	(CDC, 2017)
Canada	2014-2015	6-11	514	7.6	6.4-9.1	(Health Canada, 2017)
China, Tianjin	2012	9-10	70	5.28	nr	(Wang *et al.*, 2013)
India	2012-2013	2-14	76	6.77	nr	(Xue *et al.*, 2015)

Urinary methylparaben concentrations based on pooled urine samples collected in 2012-2013 from Queensland (Australia) residents have also been reported (Heffernan *et al.*, 2015). Concentrations in pooled samples are compared below with the arithmetic mean concentration of the New Zealand individual samples, because both pooled samples and arithmetic means are similarly affected by outliers.

For 24 pools of all age groups (0->60 year) each consisting of 100 individual samples, the geometric mean was 232 µg/L for the Australian study. For the New Zealand samples, the arithmetic mean methylparaben concentration was 91 µg/L for adults. For four pooled samples of 100 Australian children age 5-14 each, the methylparaben concentrations were 306, 378, 882 and 496 µg/L. For the New Zealand samples, the arithmetic mean methylparaben concentration was 296 µg/L for children. The New Zealand urinary concentrations for methylparaben therefore appear comparable to the concentrations reported for the pooled samples from Australia for children. For adults the Australian levels appear to be higher compared to the New Zealand methylparaben levels.

Propylparaben

For propylparaben, the GMs reported for New Zealand adults and children are generally comparable to the GMs reported for other countries (**Table 53**).

Table 53. *Comparison of population geometric means of urinary n-propylparaben concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	303	3.38	2.73-4.18	This study
US	2007-2008	20+	1814	8.04	6.56-9.84	(CDC, 2017)
US	2009-2010	20+	1914	7.58	6.28-9.15	(CDC, 2017)
US	2011-2012	20+	1705	6.29	5.45-7.25	(CDC, 2017)
US	2013-2014	20+	1815	6.27	5.51-7.12	(CDC, 2017)
Canada	2014-2015	3-79	2564	2.5	1.8-3.5	(Health Canada, 2017)
China, Shanghai	2010	22-58	26	5.07	nr	(Wang *et al.*, 2013)
Belgium	2013	1-85	261	1.5	nr	(Dewalque *et al.*, 2014)
Greece	2012	2-87	100	6.2	nr	(Asimakopoulos *et al.*, 2014)
New Zealand	2014-2016	5-18	299	2.11	1.75-2.56	This study
US	2007-2008	6-11	389	3.61	2.39-5.44	(CDC, 2017)
US	2009-2010	6-11	415	3.28	2.58-4.17	(CDC, 2017)
US	2011-2012	6-11	396	2.20	1.81-2.68	(CDC, 2017)
US	2013-2014	6-11	409	2.96	2.20-3.99	(CDC, 2017)
Canada	2014-2015	6-11	514	1.2	0.99-1.6	(Health Canada, 2017)
China, Tianjin	2012	9-10	70	1.89	nr	(Wang *et al.*, 2013)
India	2012-2013	2-14	76	0.86	nr	(Xue *et al.*, 2015)

Urinary propylparaben concentrations based on pooled urine samples collected in 2012-2013 from Queensland (Australia) residents have also been reported (Heffernan *et al.*, 2015). Concentrations in pooled samples are compared below with the arithmetic mean concentration of the New Zealand individual samples, because both pooled samples and arithmetic means are similarly affected by outliers.

For 24 pools of all age groups (0->60 year) each consisting of 100 individual samples, the geometric mean was 61 µg/L for the Australian study. For the New Zealand samples, the arithmetic mean propylparaben concentration was 22 µg/L for adults. For four pooled samples of 100 Australian children age 5-14 each, the propylparaben concentrations were 92.5, 107, 125 and 86.1 µg/L. For the New Zealand samples, the arithmetic mean propylparaben concentration was 16 µg/L for children. The New Zealand urinary concentrations for propylparaben therefore appear to be lower compared to the concentrations reported for the pooled samples from Australia.

Ethylparaben

For ethylparaben, the GMs reported for New Zealand adults and children are generally comparable to the GMs reported for other countries that reported detectable levels in a majority of samples (**Table 54**). For the US study more than half of the samples were below the detection limit of 1 µg/L and a GM was not reported. However, a 95th percentile was reported (85 µg/L adults and 11 µg/L for the year 20013-14). For New Zealand the respective 95th percentiles were 36 µg/L for adults and 15 µg/L for children, comparable to the 95th percentiles reported for the US.

Table 54. *Comparison of population geometric means of urinary ethylparaben concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	303	1.39	1.14-1.69	This study
US	2007-2008	20+	1814	*		(CDC, 2017)
US	2009-2010	20+	1914	*		(CDC, 2017)
US	2011-2012	20+	1705	*		(CDC, 2017)
US	2013-2014	20+	1815	*		(CDC, 2017)
Canada	2014-2015	3-79	2564	*		(Health Canada, 2017)
China, Shanghai	2010	22-58	26	0.34	nr	(Wang *et al.*, 2013)
Belgium	2013	1-85	261	2.1	nr	(Dewalque *et al.*, 2014)
Greece	2012	2-87	100	2.0	nr	(Asimakopoulos *et al.*, 2014)
New Zealand	2014-2016	5-18	299	0.68	0.58-0.81	This study
US	2007-2008	6-11	389	*		(CDC, 2017)
US	2009-2010	6-11	415	*		(CDC, 2017)
US	2011-2012	6-11	396	*		(CDC, 2017)
US	2013-2014	6-11	409	*		(CDC, 2017)
Canada	2014-2015	6-11	514	*		(Health Canada, 2017)
China, Tianjin	2012	9-10	70	0.97	nr	(Wang *et al.*, 2013)
India	2012-2013	2-14	76	0.22	nr	(Xue *et al.*, 2015)

* Not calculated: proportion of results below limit of detection was too high to provide a valid result.

Urinary ethylparaben concentrations based on pooled urine samples collected in 2012-2013 from Queensland (Australia) residents have also been reported (Heffernan *et al.*, 2015). Concentrations in pooled samples are compared below with the arithmetic mean concentration of the New Zealand individual samples, because both pooled samples and arithmetic means are similarly affected by outliers.

For 24 pools of all age groups (0->60 year) each consisting of 100 individual samples, the geometric mean was 33.5 µg/L for the Australian study. For the New Zealand samples, the arithmetic mean ethylparaben concentration was 11 µg/L for adults. For four pooled samples of 100 Australian children age 5-14 each, the ethylparaben concentrations were 24.1, 54.8, 18.9 and 42.3 µg/L. For the New Zealand samples, the arithmetic mean ethylparaben concentration was 9 µg/L for children. The New Zealand urinary concentrations for ethylparaben therefore appear lower compared to the concentrations reported for the pooled samples from Australia.

Butylparaben

Butylparaben was detected in a third of the New Zealand samples, and geometric means assuming levels of half of the limit of detection in the samples with levels below the limit of detection are therefore not reliable and placed in parentheses in **Table 55**. For the US samples the proportion of results below the limit of detection was also too high to provide a valid result. The GM reported for Greece however appears to be considerably higher than the GM for adult New Zealanders.

Table 55. *Comparison of population geometric means of urinary butylparaben concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	303	*(0.08)	(0.07-0.10)	This study
US	2007-2008	20+	1814	*		(CDC, 2017)
US	2009-2010	20+	1914	*		(CDC, 2017)
US	2011-2012	20+	1705	*		(CDC, 2017)
US	2013-2014	20+	1815	*		(CDC, 2017)
Canada	2014-2015	3-79	2564	*		(Health Canada, 2017)
China, Shanghai	2010	22-58	26	*		(Wang *et al.*, 2013)
Belgium	2013	1-85	261	*		(Dewalque *et al.*, 2014)
Greece	2012	2-87	100	1.2	nr	(Asimakopoulos *et al.*, 2014)
New Zealand	2014-2016	5-18	299	* (0.08)	(0.07-0.09)	This study
US	2007-2008	6-11	389	*		(CDC, 2017)
US	2009-2010	6-11	415	*		(CDC, 2017)
US	2011-2012	6-11	396	*		(CDC, 2017)
US	2013-2014	6-11	409	*		(CDC, 2017)
Canada	2014-2015	6-11	514	*		(Health Canada, 2017)
China, Tianjin	2012	9-10	70	0.04	nr	(Wang *et al.*, 2013)

* Not calculated: proportion of results below limit of detection was too high to provide a valid result.

Urinary butylparaben concentrations based on pooled urine samples collected in 2012-2013 from Queensland (Australia) residents have also been reported (Heffernan *et al.*, 2015). Concentrations in pooled samples are compared below with the arithmetic mean concentration of the New Zealand individual samples, because both pooled samples and arithmetic means are similarly affected by outliers.

For 24 pools of all age groups (0->60 year) each consisting of 100 individual samples, the geometric mean was 4.3 µg/L for the Australian study. For the New Zealand samples, the arithmetic mean butylparaben concentration was 0.9 µg/L for adults. For four pooled samples of 100 Australian children age 5-14 each, the butylparaben concentrations were 1.9, 3.4, 8.7 and 3 µg/L. For the New Zealand samples, the arithmetic mean butylparaben concentration was 0.8 µg/L for children. The New Zealand urinary concentrations for butylparaben therefore appear to be lower compared to the concentrations reported for the pooled samples from Australia.

5.11 International comparison urinary phthalate metabolites

The GMs for urinary phthalate metabolite concentrations for New Zealand adults and children, and those reported for other countries, are listed in **Tables 54-63**.

Monomethyl phthalate (mMP)

Monomethyl phthalate (mMP) (**Table 54**) was not detected in the vast majority of the New Zealand samples, similar to what has been reported for the US and Canada. Relatively high urinary mMP concentrations have been reported for Taiwan.

Table 54. *Comparison of population geometric means of urinary monomethyl phthalate (mMP) concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	304	*		This study
US	2007-2008	20+	1814	*		(CDC, 2017)
US	2009-2010	20+	1914	*		(CDC, 2017)
US	2011-2012	20+	1705	*		(CDC, 2017)
Canada	2007-2009	6-49	3237	*		(Haines *et al.*, 2016)
Canada	2009-2011	3-79	2559	*		(Haines *et al.*, 2016)
Taiwan	2013	18-65	290	31.3	nr	(Huang *et al.*, 2015)
New Zealand	2014-2016	5-18	299	*		This study
US	2007-2008	6-11	389	*		(CDC, 2017)
US	2009-2010	6-11	415	2.13	1.83-2.47	(CDC, 2017)
US	2011-2012	6-11	396	2.33	1.78-3.04	(CDC, 2017)
Brazil	2012-2013	6-14	300	7.61	nr	(Rocha *et al.*, 2017)
Taiwan	2013	7-18	97	37.5	nr	(Huang *et al.*, 2015)
Germany	2007-2009	6-8	104	4.9	3.8-6.3	(Kasper-Sonnenberg *et al.*, 2012)

* Not calculated: proportion of results below limit of detection was too high to provide a valid result.

In pooled urine samples from Queensland Australia, collected in 2012-2013 (Gomez Ramos *et al.*, 2016), the concentrations of mMP (GM for 24 pooled urine samples) of 0->60 year old Australians was 1.7 µg/L and for infants aged 0-5 years the GM urinary concentrations for 4 pools was 2.2 µg/L.

Monoethyl phthalate (mEP)

Urinary concentrations of monoethyl phthalate (mEP) have shown considerable reductions over time based on studies from the US and Canada (**Table 55**). Levels in New Zealand are comparable to those most recently reported for Canada and Taiwan, while the most recent data from the US are higher compared to the urinary concentrations reported for New Zealand.

Table 55. *Comparison of population geometric means of urinary monoethyl phthalate (mEP) concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	304	19.1	16.7-22.0	This study
US	2007-2008	20+	1814	95.3	85.4-106	(CDC, 2017)
US	2009-2010	20+	1914	69.0	61.8-76.9	(CDC, 2017)
US	2011-2012	20+	1705	40.2	34.9-46.5	(CDC, 2017)
Canada	2007-2009	6-49	3237	56	47-66	(Haines *et al.*, 2016)
Canada	2009-2011	3-79	2561	44	36-54	(Haines *et al.*, 2016)
Canada	2012-2013	3-79	2547	14	12-16	(Haines *et al.*, 2016)
Taiwan	2013	18-65	290	14.0	nr	(Huang *et al.*, 2015)
Belgium	2013	1-85	261	37.6	nr	(Dewalque *et al.*, 2014)
New Zealand	2014-2016	5-18	299	12.9	11.3-14.7	This study
US	2007-2008	6-11	389	49.0	42.4-56.6	(CDC, 2017)
US	2009-2010	6-11	415	35.2	31.2-39.8	(CDC, 2017)
US	2011-2012	6-11	396	23.4	18.7-29.2	(CDC, 2017)
Brazil	2012-2013	6-14	300	70.0	nr	(Rocha *et al.*, 2017)
Taiwan	2013	7-18	97	11.5	nr	(Huang *et al.*, 2015)
Germany	2007-2009	6-8	104	39.1	31.3-48.7	(Kasper-Sonnenberg *et al.*, 2012)
Sweden	2015	3-4	113	32	nr	(Larsson *et al.*, 2017)

Urinary mEP concentrations based on pooled urine samples collected in 2012-2013 from Queensland (Australia) residents have also been reported (Gomez Ramos *et al.*, 2016). Concentrations in pooled samples are compared below with the arithmetic mean concentration of the New Zealand individual samples, because both pooled samples and arithmetic means are similarly affected by outliers.

For 24 pools of all age groups (0->60 year) each consisting of 100 individual samples, the geometric mean was 130 µg/L for the Australian study. For the New Zealand samples, the arithmetic mean mEP concentration was 42 µg/L for adults. For 4 pools of children age 0-5 each consisting of 100 individual samples, the GM mEP concentration was 63.9 µg/L. For the New Zealand samples, the arithmetic mean mEP concentration was 36 µg/L for children. The New Zealand urinary concentrations for mEP therefore appear to be lower compared to the concentrations reported for the pooled samples from Australia.

Monobutyl phthalate (mBP)

In this study, concentrations of mono-n-butyl phthalate (mnBP) and mono-iso-butyl phthalate (miBP) were measured together and expressed as the combined value for monobutyl phthalate (mBP). Other countries have reported GMs for mnBP and miBP separately (**Table 56**), and values reported for these metabolites therefore need to be added to be comparable with mBP. Urinary concentrations of mnBP+miBP have shown considerable reductions over time based on studies from the US. The urinary mBP concentration of the New Zealand samples are higher than those reported for the US, Canada, Brazil and Taiwan.

Table 56. *Comparison of population geometric means of urinary monobutyl phthalate (mBP) (mono-n-butyl phthalate (mnBP)+ mono-iso-butyl phthalate (miBP)) concentrations (µg/L), reported for different countries*

Country	year	age	Sample size	GM	95%CI	reference
New Zealand (mBP)	2014-2016	19-64	304	37.0	33.4-40.9	This study
US (mnBP) (miBP)	2007-2008	20+	1814	17.2 6.47	15.6-19.1 5.91-7.09	(CDC, 2017)
US (mnBP) (miBP)	2009-2010	20+	1914	13.5 7.03	12.0-15.1 6.26-7.90	(CDC, 2017)
US (mnBP) (miBP)	2011-2012	20+	1705	7.04 5.57	6.04-8.21 4.92-6.31	(CDC, 2017)
Canada (mnBP)	2007-2009	6-79	3237	23	21-25	(Haines *et al.*, 2016)
Canada (mnBP)	2009-2011	3-79	2555	20	18-22	(Haines *et al.*, 2016)
Taiwan (mnBP) (miBP)	2013	18-65	290	12.8 4.4	nr	(Huang *et al.*, 2015)
Belgium (mnBP) (miBP)	2013	1-85	261	31.3 26.2	nr	(Dewalque *et al.*, 2014)
New Zealand (mBP)	2014-2016	5-18	299	60.6	55.8-65.7	This study
US (mnBP) (miBP)	2007-2008	6-11	389	26.9 10.7	22.5-32.1 8.94-12.8	(CDC, 2017)
US (mnBP) (miBP)	2009-2010	6-11	415	21.7 10.2	19.0-24.8 9.10-11.4	(CDC, 2017)
US (mnBP) (miBP)	2011-2012	6-11	396	11.1 8.28	8.73-14.2 6.93-9.91	(CDC, 2017)
Brazil (mBP)	2012-2013	6-14	300	31.4	nr	(Rocha *et al.*, 2017)
Taiwan (mnBP) (miBP)	2013	7-18	97	17.6 7.2	nr	(Huang *et al.*, 2015)
Korea (mBP)	2012	6-19	342	31.19	29.37-33.45	(Ha *et al.*, 2014)
Germany (mnBP) (miBP)	2007-2009	6-8	104	48.1 66.2	40.5-57.1 55.0-80.0	(Kasper-Sonnenberg *et al.*, 2012)
Sweden (mnBP)	2015	3-4	113	55	nr	(Larsson *et al.*, 2017)

Urinary mnBP and miBP concentrations based on pooled urine samples collected in 2012-2013 from Queensland (Australia) residents have also been reported (Gomez Ramos *et al.*, 2016). Concentrations in pooled samples are compared below with the arithmetic mean concentration of the New Zealand individual samples, because both pooled samples and arithmetic means are similarly affected by outliers. For 24 pools of all age groups (0->60 year) each consisting of 100 individual samples, the geometric mean was 24.7 µg/L for MnBP and 21.0 µg/L for MiBP for the Australian study. For the New Zealand samples, the arithmetic mean mBP concentration was 60.5 µg/L for adults. For 4 pools of children age 0-5 each consisting of 100 individual samples, the GM was 29.7 µg/L for MnBP and 26.4 µg/L for MiBP. For the New Zealand samples, the arithmetic mean mBP concentration was 78.3 µg/L for children. The New Zealand urinary concentrations for mBP therefore appear to be comparable to the concentrations reported for the pooled samples from Australia.

Monobenzyl phthalate (mBzP)

Urinary concentrations of monobenzyl phthalate (mBzP) have shown reductions over time based on studies from the US (**Table 57**). The New Zealand concentrations are comparable to the most recent concentrations reported for the US.

Table 57. *Comparison of population geometric means of urinary monobenzyl phthalate (mBzP) concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	304	4.17	3.62-4.81	This study
US	2007-2008	20+	1814	6.18	5.40-7.08	(CDC, 2017)
US	2009-2010	20+	1914	5.61	4.97-6.34	(CDC, 2017)
US	2011-2012	20+	1705	3.98	3.60-4.39	(CDC, 2017)
Canada	2007-2009	6-79	3237	12	9.7-14	(Haines *et al.*, 2016)
Canada	2009-2011	3-79	2559	7.5	6.6-8.6	(Haines *et al.*, 2016)
Korea	2012-2014	19-70+	6252	2.82	2.63-3.02	(Choi *et al.*, 2016)
Taiwan	2013	18-65	290	0.4	nr	(Huang *et al.*, 2015)
Belgium	2013	1-85	261	5.5	nr	(Dewalque *et al.*, 2014)
New Zealand	2014-2016	5-18	299	7.68	6.73-8.76	This study
US	2007-2008	6-11	389	15.4	12.3-19.3	(CDC, 2017)
US	2009-2010	6-11	415	11.6	9.51-14.1	(CDC, 2017)
US	2011-2012	6-11	396	8.62	7.22-10.3	(CDC, 2017)
Brazil	2012-2013	6-14	300	2.21	nr	(Rocha *et al.*, 2017)
Taiwan	2013	7-18	97	0.4	nr	(Huang *et al.*, 2015)
Germany	2007-2009	6-8	104	12.5	10.2-15.3	(Kasper-Sonnenberg *et al.*, 2012)
Sweden	2015	3-4	113	9.0	nr	(Larsson *et al.*, 2017)

Urinary mBzP concentrations based on pooled urine samples collected in 2012-2013 from Queensland (Australia) residents have also been reported (Gomez Ramos *et al.*, 2016). Concentrations in pooled samples are compared below with the arithmetic mean concentration of the New Zealand individual samples, because both pooled samples and arithmetic means are similarly affected by outliers.

For 24 pools of all age groups (0->60 year) each consisting of 100 individual samples, the geometric mean was 5.3 µg/L for the Australian study. For the New Zealand samples, the arithmetic mean mBzP concentration was 9 µg/L for adults. For 4 pools of children age 0-5 each consisting of 100 individual samples, the GM mBzP concentration was 5.5 µg/L. For the New Zealand samples, the arithmetic mean mBzP concentration was 15 µg/L for children.

Mono-2-ethylhexyl phthalate (mEHP)

Urinary concentrations of mono-2-ethylhexyl phthalate (mEHP) have shown reductions over time based on studies from the US and Canada (**Table 58**). The New Zealand concentrations in adults are comparable to the most recent concentrations reported for the US and Canada, while for New Zealand children the concentrations are higher than those reported for the US since 2007.

Table 58. *Comparison of population geometric means of urinary mono-2-ethylhexyl phthalate (mEHP) concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	304	1.99	1.77-2.23	This study
US	2007-2008	20+	401	2.99	2.39-3.75	(CDC, 2017)
US	2009-2010	20+	420	1.82	1.52-2.16	(CDC, 2017)
US	2011-2012	20+	1705	1.33	1.19-1.48	(CDC, 2017)
Canada	2007-2009	6-49	3237	3.6	3.2-4.0	(Haines *et al.*, 2016)
Canada	2009-2011	3-79	2498	1.9	1.7-2.1	(Haines *et al.*, 2016)
Taiwan	2013	18-65	290	4.4	nr	(Huang *et al.*, 2015)
Belgium	2013	1-85	261	2.7	nr	(Dewalque *et al.*, 2014)
New Zealand	2014-2016	5-18	299	2.72	2.47-3.00	This study
US	2007-2008	6-11	389	2.39	2.05-2.80	(CDC, 2017)
US	2009-2010	6-11	415	1.64	1.45-1.85	(CDC, 2017)
US	2011-2012	6-11	396	1.41	1.23-1.61	(CDC, 2017)
Brazil	2012-2013	6-14	300	17.2	nr	(Rocha *et al.*, 2017)
Taiwan	2013	7-18	97	4.0	nr	(Huang *et al.*, 2015)
Germany	2007-2009	6-8	104	3.9	3.3-4.7	(Kasper-Sonnenberg *et al.*, 2012)
Sweden	2015	3-4	113	1.5	nr	(Larsson *et al.*, 2017)

Urinary mEHP concentrations based on pooled urine samples collected in 2012-2013 from Queensland (Australia) residents have also been reported (Gomez Ramos *et al.*, 2016). Concentrations in pooled samples are compared below with the arithmetic mean concentration of the New Zealand individual samples, because both pooled samples and arithmetic means are similarly affected by outliers.

For 24 pools of all age groups (0->60 year) each consisting of 100 individual samples, the geometric mean was 6.0 µg/L for the Australian study. For the New Zealand samples, the arithmetic mean mEHP concentration was 3.4 µg/L for adults. For 4 pools of children age 0-5 each consisting of 100 individual samples, the GM mEHP concentration was 4.2 µg/L. For the New Zealand samples, the arithmetic mean mEHP concentration was 3.8 µg/L for children. The New Zealand urinary concentrations for mEHP therefore appear to be comparable to the concentrations reported for the pooled samples from Australia.

Mono-(2-ethyl-5-oxohexyl) phthalate (mEOHP)

Urinary concentrations of mono-(2-ethyl-5-oxohexyl) phthalate (mEOHP) have shown reductions over time based on studies from the US and Canada (**Table 59**). The New Zealand concentrations in adults are comparable to the most recent concentrations reported for the US and Canada, while for New Zealand children the concentrations are higher than those reported for the US since 2009.

Table 59. *Comparison of population geometric means of urinary mono-(2-ethyl-5-oxohexyl) phthalate (mEOHP) concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	304	7.0	6.4-7.7	This study
US	2007-2008	20+	1814	11.1	9.48-13.1	(CDC, 2017)
US	2009-2010	20+	1914	7.59	6.64-8.68	(CDC, 2017)
US	2011-2012	20+	1705	4.83	4.45-5.23	(CDC, 2017)
Canada	2007-2009	6-49	3237	14	13-16	(Haines *et al.*, 2016)
Canada	2009-2011	3-79	2561	7.4	6.9-8.0	(Haines *et al.*, 2016)
Korea	2012-2014	19-70+	6392	12.1	11.6-12.6	(Choi *et al.*, 2016)
Taiwan	2013	18-65	290	10.7	nr	(Huang *et al.*, 2015)
Belgium	2013	1-85	261	8.6	nr	(Dewalque *et al.*, 2014)
New Zealand	2014-2016	5-18	299	14.2	13.1-15.4	This study
US	2007-2008	6-11	389	16.9	13.9-20.6	(CDC, 2017)
US	2009-2010	6-11	415	9.78	8.72-11.0	(CDC, 2017)
US	2011-2012	6-11	396	6.96	5.86-8.28	(CDC, 2017)
Brazil	2012-2013	6-14	300	12.7	nr	(Rocha *et al.*, 2017)
Taiwan	2013	7-18	97	16.9	nr	(Huang *et al.*, 2015)
Korea	2012	6-19	342	13.46	12.55-14.44	(Ha *et al.*, 2014)
Germany	2007-2009	6-8	104	26.2	22.7-30.3	(Kasper-Sonnenberg *et al.*, 2012)
Sweden	2015	3-4	113	11	nr	(Larsson *et al.*, 2017)

Urinary mEOHP concentrations based on pooled urine samples collected in 2012-2013 from Queensland (Australia) residents have also been reported (Gomez Ramos *et al.*, 2016). Concentrations in pooled samples are compared below with the arithmetic mean concentration of the New Zealand individual samples, because both pooled samples and arithmetic means are similarly affected by outliers.

For 24 pools of all age groups (0->60 year) each consisting of 100 individual samples, the geometric mean was 16.1 µg/L for the Australian study. For the New Zealand samples, the arithmetic mean mEOHP concentration was 9.9 µg/L for adults. For 4 pools of children age 0-5 each consisting of 100 individual samples, the GM mEOHP concentration was 17.2 µg/L. For the New Zealand samples, the arithmetic mean mEOHP concentration was 18.5 µg/L for children. The New Zealand urinary concentrations for mEOHP therefore appear to be comparable to the concentrations reported for the pooled samples from Australia.

Mono-(2-ethyl-5-hydroxyhexyl) phthalate (mEHHP)

Urinary concentrations of mono-(2-ethyl-5-hydroxyhexyl) phthalate (mEHHP) have shown reductions over time based on studies from the US and Canada (**Table 60**). The New Zealand concentrations in adults are comparable to the concentrations reported for the US and Canada.

Table 60. *Comparison of population geometric means of urinary mono-(2-ethyl-5-hydroxyhexyl) phthalate (mEHHP) concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	304	9.0	8.0-10.1	This study
US	2007-2008	20+	1814	20.5	17.4-24.1	(CDC, 2017)
US	2009-2010	20+	1914	12.4	10.7-14.3	(CDC, 2017)
US	2011-2012	20+	1705	7.58	7.03-8.16	(CDC, 2017)
Canada	2007-2009	6-49	3237	23	21-26	(Haines *et al.*, 2016)
Canada	2009-2011	3-79	2561	13	12-14	(Haines *et al.*, 2016)
Korea	2012-2014	19-70+	6406	17.5	16.7-18.2	(Choi *et al.*, 2016)
Taiwan	2013	18-65	290	20.2	nr	(Huang *et al.*, 2015)
New Zealand	2014-2016	5-18	299	17.6	15.9-19.4	This study
US	2007-2008	6-11	389	28.6	23.4-34.8	(CDC, 2017)
US	2009-2010	6-11	415	15.0	13.2-17.1	(CDC, 2017)
US	2011-2012	6-11	396	10.5	8.82-12.4	(CDC, 2017)
Brazil	2012-2013	6-14	300	18.5	nr	(Rocha *et al.*, 2017)
Taiwan	2013	7-18	97	21.9	nr	(Huang *et al.*, 2015)
Korea	2012	6-19	342	17.12	15.96-18.17	(Ha *et al.*, 2014)
Germany	2007-2009	6-8	104	29.3	25.2-34.0	(Kasper-Sonnenberg *et al.*, 2012)
Sweden	2015	3-4	113	17	nr	(Larsson *et al.*, 2017)

Urinary mEHHP concentrations based on pooled urine samples collected in 2012-2013 from Queensland (Australia) residents have also been reported (Gomez Ramos *et al.*, 2016). Concentrations in pooled samples are compared below with the arithmetic mean concentration of the New Zealand individual samples, because both pooled samples and arithmetic means are similarly affected by outliers.

For 24 pools of all age groups (0->60 year) each consisting of 100 individual samples, the geometric mean was 26.4 µg/L for the Australian study. For the New Zealand samples, the arithmetic mean mEHHP concentration was 14.1 µg/L for adults. For 4 pools of children age 0-5 each consisting of 100 individual samples, the GM mEHHP concentration was 24.3 µg/L. For the New Zealand samples, the arithmetic mean mEHHP concentration was 24.7 µg/L for children. The New Zealand urinary concentrations for mEHHP therefore appear to be comparable to the concentrations reported for the pooled samples from Australia.

Mono-cyclohexyl phthalate (mCHP)

Mono-cyclohexyl phthalate (mCHP) (**Table 61**) was not detected in the vast majority of the New Zealand samples which is similar to what has been reported for the US, Canada and Germany.

Table 61. *Comparison of population geometric means of urinary mono-cyclohexyl phthalate (mCHP) concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	304	*		This study
US	2007-2008	20+	1814	*		(CDC, 2017)
US	2009-2010	20+	1914	*		(CDC, 2017)
Canada	2007-2009	6-49	3237	*		(Haines *et al.*, 2016)
Canada	2009-2011	3-79	2551	*		(Haines *et al.*, 2016)
New Zealand	2014-2016	5-18	299	*		This study
US	2007-2008	6-11	389	*		(CDC, 2017)
US	2009-2010	6-11	415	*		(CDC, 2017)
Brazil	2012-2013	6-14	300	0.98	nr	(Rocha *et al.*, 2017)
Germany	2007-2009	6-8	104	*		(Kasper-Sonnenberg *et al.*, 2012)

* Not calculated: proportion of results below limit of detection was too high to provide a valid result.

Mono-(3-carboxypropyl) phthalate (mCPP)

Urinary concentrations of mono-(3-carboxypropyl) phthalate (mCPP) have remained fairly stable for adults and reduced over time for children, as indicated by studies from the US and Canada (**Table 62**). The New Zealand concentrations in adults and children are comparable to the most recent concentrations reported for the US.

For pooled urine samples from Queensland Australia collected in 2012-2013 (Gomez Ramos *et al.*, 2016), the GM urinary concentrations of mCPP for 24 pooled urine samples of 0->60 year old Australians was 6.7 µg/L and for infants aged 0-5 years the GM urinary concentrations for 4 pools was 6.2 µg/L which is higher than the urinary levels reported for New Zealand. These are comparable to the arithmetic mean urinary mCPP levels for New Zealand adults (5.5 µg/L) and New Zealand children (5.2 µg/L).

Table 62. *Comparison of population geometric means of urinary mono-(3-carboxypropyl) phthalate (mCPP) concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	304	2.36	2.10-2.66	This study
US	2007-2008	20+	1814	2.41	2.18-2.67	(CDC, 2017)
US	2009-2010	20+	1914	2.80	2.40-3.28	(CDC, 2017)
US	2011-2012	20+	1705	2.94	2.46-3.50	(CDC, 2017)
Canada	2007-2009	6-49	3237	1.5	1.3-1.6	(Haines *et al.*, 2016)
Canada	2009-2011	3-79	2543	1.9	1.8-2.1	(Haines *et al.*, 2016)
New Zealand	2014-2016	5-18	299	3.33	3.04-3.66	This study
US	2007-2008	6-11	389	6.01	4.80-7.53	(CDC, 2017)
US	2009-2010	6-11	415	4.54	3.74-5.52	(CDC, 2017)
US	2011-2012	6-11	396	3.38	2.87-3.97	(CDC, 2017)
Brazil	2012-2013	6-14	300	1.37	nr	(Rocha *et al.*, 2017)
Germany	2007-2009	6-8	104	2.6	2.2-3.0	(Kasper-Sonnenberg *et al.*, 2012)

Mono-iso-nonyl Phthalate (miNP)

Mono-iso-nonyl Phthalate (miNP) **(Table 63)** was not detected in the majority of the New Zealand samples, which is similar to what has been reported for other countries.

Table 63. *Comparison of population geometric means of urinary mono-iso-nonyl Phthalate (miNP) concentrations (µg/L), reported for different countries*

country	year	age	Sample size	GM	95%CI	reference
New Zealand	2014-2016	19-64	304	*		This study
US	2007-2008	20+	1814	*		(CDC, 2017)
US	2009-2010	20+	1914	*		(CDC, 2017)
US	2011-2012	20+	1705	*		(CDC, 2017)
Canada	2007-2009	6-49	3236	*		(Haines *et al.*, 2016)
Canada	2009-2011	3-79	2556	*		(Haines *et al.*, 2016)
Taiwan	2013	18-65	290	*		(Huang *et al.*, 2015)
New Zealand	2014-2016	5-18	299	*		This study
US	2007-2008	6-11	389	*		(CDC, 2017)
US	2009-2010	6-11	415	*		(CDC, 2017)
US	2011-2012	6-11	396	*		(CDC, 2017)
Brazil	2012-2013	6-14	300	*		(Rocha *et al.*, 2017)
Taiwan	2013	7-18	97	*		(Huang *et al.*, 2015)

* Not calculated: proportion of results below limit of detection was too high to provide a valid result.

6. Reference values and upper reference limits

The available data on levels of chemicals of concern in blood and urine samples from adults (n=304 and 304, respectively) and children (n=193 and 300, respectively), were used to calculate reference values for New Zealand adults and children. Reference values are typically derived from measurements obtained from a representative sample of a well-characterised population, in this case adults and children living in New Zealand, and tested between 2014 and 2016.

Reference values and their upper reference limits can facilitate the interpretation of biomonitoring data. In particular, they can help assess whether levels measured in individuals or sub groups are higher than would normally be expected in the New Zealand population. Reference values are not based on what is currently known about the possible health effects associated with exposure to these compounds, and observed values above the URL do therefore not necessarily indicate a health risk, nor do they imply that no adverse health effects will occur below this level.

Following the guidelines of the International Federation of Clinical Chemistry, URLs were defined based on the rounded value of the upper 95% confidence limit around the 97.5th percentile (Solberg, 1987). The same definition is also frequently used in other countries (Hoet *et al.*, 2013), although 95th percentiles have also been used for the purpose of defining URLs (Schulz *et al.*, 2011; Saravanabhavan *et al.*, 2016). **Tables 63** to **65** list the 2.5th percentile (P2.5), the 50th percentile (P50), the 95th percentile (P95) and the 97.5th percentile (P97.5) of the distribution of the biomonitoring data separately for adults and children, as well as the 95% confidence interval around the 97.5th percentile and the URL derived from this.

Table 63a. *Reference values and upper reference limits (URL) for metals, metalloids and fluoride for adult New Zealanders (age 19-65)*

	unit	LOD	%< LOD	GM	95%CI GM	P2.5	P50	P95	P97.5	95%CI P97.5	URL
lead	µg/L blood	0.041	0%	13.1	12.3-13.9	4.1	12.1	28.9	36.9	28.1-48.4	48
mercury	µg/L blood	0.2	1%	1.6	1.5-1.8	0.15	1.7	6.0	9.1	6.7-12.2	12
inorganic arsenic	µg/L urine	0.1	21%	4.2	3.2-5.5	<LOD	11.7	63	76	53-109	110
total (mainly DMA)	µg/g creat			3.4	2.6-4.4	<LOD	7.8	43	70	43-111	110
	µg/L spgr			4.6	3.5-6.0	<LOD	11.7	70	97	67-140	140
organic arsenic	µg/L urine	0.1	32%	3.5	2.4-5.0	<LOD	9.6	231	404	248-658	700
AB	µg/g creat			2.8	2.0-4.0	<LOD	7.1	185	314	166-574	600
	µg/L spgr			3.9	2.7-5.5	<LOD	10.7	247	484	267-876	900
cadmium	µg/L urine	0.079	11%	0.19	0.18-0.21	<LOD	0.15	0.64	1.03	0.76-1.39	1.4
	µg/g creat			0.15	0.14-0.17	<LOD	0.15	0.63	0.89	0.64-1.25	1.3
	µg/L spgr			0.21	0.19-0.23	<LOD	0.20	0.75	0.99	0.70-1.40	1.4
chromium	µg/L urine	0.02	41%	0.052	0.043-0.063	<LOD	0.06	0.75	1.22	0.82-1.82	1.8
	µg/g creat			0.042	0.035-0.050	<LOD	0.04	0.50	0.72	0.53-0.98	1.0
	µg/L spgr			0.057	0.048-0.068	<LOD	0.06	0.70	0.98	0.65-1.47	1.5
thallium	µg/L urine	0.02	3%	0.20	0.18-0.22	<LOD	0.21	0.64	0.74	0.56-0.99	1.0
	µg/g creat			0.16	0.14-0.18	<LOD	0.16	0.66	0.85	0.60-1.20	1.2
	µg/L spgr			0.22	0.20-0.24	<LOD	0.22	0.74	0.86	0.76-0.97	1.0
antimony	µg/L urine	0.02	10%	0.062	0.055-0.069	<LOD	0.07	0.22	0.30	0.18-0.50	0.5
	µg/g creat			0.049	0.044-0.055	<LOD	0.05	0.20	0.31	0.21-0.45	0.5
	µg/L spgr			0.068	0.061-0.075	<LOD	0.08	0.21	0.30	0.18-0.50	0.5
fluoride	µg/L urine	19	0%	759	710-812	216	788	1763	2208	1828-2664	2700
	µg/g creat			608	563-657	163	574	1895	2387	1856-3071	3100
	µg/L spgr			833	778-892	253	845	2087	2567	2028-3248	3200

LOD:Limit of Detection; GM: geometric mean; 95%CI: 95% confidence interval; P97.5: 97.5th percentile; URL: upper reference limit; creat: creatinine; spgr: specific gravity adjusted.

Table 63b. *Reference values and upper reference limits (URL) for metals, metalloids and fluoride for New Zealand children (age 5-18)*

	unit	LOD	%< LOD	GM	95%CI GM	P2.5	P50	P95	P97.5	95%CI P97.5	URL
lead	µg/L blood	0.04	0%	8.5	7.9-9.1	2.1	7.6	16.1	19.9	15.9-24.8	25
mercury	µg/L blood	0.2	7%	0.9	0.7-1.0	<LOD	0.8	4.1	5.1	3.7-7.1	7
inorganic arsenic	µg/L urine	0.1	26%	3.2	2.3-4.3	<LOD	10.1	70	88	53-147	150
total (mainly DMA)	µg/g creat			3.2	2.3-4.3	<LOD	9.4	74	98	74-131	130
	µg/L spgr			2.9	2.2-4.0	<LOD	9.4	65	98	67-142	140
organic arsenic - AB	µg/L urine	0.1	47%	1.5	1.0-2.2	<LOD	1.6	247	619	239-1582	1600
	µg/g creat			1.5	1.0-2.2	<LOD	1.4	419	687	310-1515	1500
	µg/L spgr			1.4	0.9-2.1	<LOD	1.5	245	547	217-1381	1400
cadmium	µg/L urine	0.079	47%	0.074	0.069-0.079	<LOD	0.04	0.17	0.21	0.17-0.24	0.2
	µg/g creat			0.074	0.068-0.079	<LOD	0.08	0.21	0.23	0.20-0.28	0.3
	µg/L spgr			0.069	0.064-0.074	<LOD	0.08	0.18	0.20	0.16-0.24	0.2
chromium	µg/L urine	0.02	56%	0.034	0.028-0.040	<LOD	<LOD	0.48	0.90	0.46-1.77	1.8
	µg/g creat			0.034	0.028-0.040	<LOD	<LOD	0.50	0.78	0.48-1.26	1.3
	µg/L spgr			0.031	0.026-0.037	<LOD	<LOD	0.44	0.68	0.40-1.14	1.1
thallium	µg/L urine	0.02	21%	0.054	0.048-0.062	<LOD	0.05	0.34	0.40	0.34-0.47	0.5
	µg/g creat			0.054	0.047-0.062	<LOD	0.06	0.37	0.58	0.39-0.87	0.9
	µg/L spgr			0.051	0.044-0.058	<LOD	0.06	0.32	0.44	0.35-0.56	0.6
antimony	µg/L urine	0.02	1%	0.091	0.085-0.098	0.01	0.09	0.25	0.31	0.26-0.37	0.4
	µg/g creat			0.091	0.084-0.098	0.02	0.09	0.23	0.32	0.22-0.46	0.5
	µg/L spgr			0.085	0.079-0.091	0.02	0.08	0.22	0.23	0.18-0.29	0.3
fluoride	µg/L urine	19	0%	628	586-674	176	644	1595	1855	1507-2282	2300
	µg/g creat			626	577-678	135	634	1932	2096	1875-2344	2300
	µg/L spgr			584	546-624	189	593	1512	1781	1514-2094	2100

LOD:Limit of Detection; GM: geometric mean; 95%CI: 95% confidence interval; P97.5: 97.5th percentile; URL: upper reference limit; creat: creatinine; spgr: specific gravity adjusted.

Tables 63a and **63b** provide the suggested upper reference limits for metals, metalloids and fluoride for New Zealand adults and children, respectively.

For blood lead the URL is 48 µg/L for adults and 25 µg/L for children, both below New Zealand's current blood lead notification level of 100 µg/L (10 µg/dL; 0.48 µmol/L). Health Agencies for Europe and the USA have set blood lead levels of concern since the 1960s (Taylor *et al.*, 2014). The United States' Centers for Disease Control and Prevention (CDC) have used a "blood lead level of concern" of 100 µg/L (10 µg/dL) since 1991 until 2012. In 2012 this term of "blood lead level of concern" was removed as CDC declared there is no safe level of lead in children's blood (Taylor *et al.*, 2014). Instead, an intervention (reference) level of 50 µg/L (5 µg/dL) for individual children was established (CDC, 2012). In Australia the current recommended public health goal for blood lead is 100 µg/L (10 µg/dL) (Taylor *et al.*, 2014) (since 1993), but recently changes have been recommended including a new blood lead intervention level of no more than 50 µg/L (5 ug/dL), with a national goal for all children under 5 year of age to have a blood lead level of below 10 µg/L (1 ug/dL) by 2020(Taylor *et al.*, 2014). In 2009, The German Human Biomonitoring Commission (HBC) concluded that establishing an effect threshold for blood lead levels would be arbitrary and therefore not justified, as several findings consistently had shown no threshold levels (Schulz *et al.*, 2011). In 2011, the HBC reported a reference value (based on the 95th population percentile) for blood lead of 35 µg/L (3.5 ug/dL) for children (aged 3-14 years), 70 µg/L for adult women and 90 µg/L for adult men (Schulz *et al.*, 2011).

For blood mercury the suggested upper reference limit was 12 µg/L for adults and 7 µg/L for children. While currently there is no blood mercury notification level in New Zealand, levels above 10 µg/L are considered by the analytical laboratory used to analyse the samples in this study as requiring repeat testing after exclusion of fish from the diet. For levels >20 µg/L it is recommend that possible environmental exposure should be reviewed. The U.S. EPA reference blood mercury level is 5.8 µg/L (Schober *et al.*, 2003). In some states of the US 'reportable levels' and 'investigation levels' are used. For example, for blood mercury New York State uses a 'reportable level' of 5 µg/L and an 'investigation level' of ≥15 µg/L (McKelvey *et al.*, 2007). The current Health Canada blood mercury guidance value is 20 µg/L for the general adult population and a provisional guidance value of 8 µg/L for children (Lye *et al.*, 2013). In 2011, The German Human Biomonitoring Commission (HBC) reported a reference value (based on the 95th population percentile) for blood mercury of 0.8 µg/L for children (aged 3-14 years) who ate fish 3 times per month or less, and 2.0 µg/L for adults who ate fish 3 times per month or less (Schulz *et al.*, 2011). The German Human Biomonitoring Commission's health-related human biomonitoring (HBM) values are 5 µg/L (HBM I) and 15 µg/L (HBM II) (Schulz *et al.*, 2011). The HBM I value represents the concentration of a substance in human biological material below which – according to the knowledge and judgement of the commission and with regard to the substance under consideration – there is no risk for adverse health effects and, consequently, no need for action. The HBM II value represents the concentration of a substance in human biological material above which – according to the knowledge and judgement of the commission and with regard to the substance under consideration – there is an increased risk for adverse health effects and, consequently, an urgent need to reduce exposure and to provide individual biomedical care (advice).

While for urinary organic and inorganic arsenic the GMs were lower for children compared to adults, the suggested upper reference limit was higher for children due to outliers as expressed by the higher 97.5th percentile and wider confidence interval for children, particularly for organic arsenic. For inorganic arsenic (predominantly DMA), the URL for adults was 110 µg/L and 150 µg/L for children. There is no urinary arsenic notification level for inorganic arsenic in New Zealand, but the analytical laboratory uses an unexposed reference range of 0-20 µg/g creatinine for DMA. For organic arsenic (AB), the URL for adults was 700 µg/L and 1600 µg/L for children.

For urinary cadmium the suggested upper reference limit was higher for adults (1.4 µg/L) compared to children (0.2 µg/L). There is no urinary cadmium notification level for New Zealand, but the analytical laboratory considers urinary cadmium concentrations below 2 µg/L as normal.

For urinary chromium the suggested upper reference limit was similar for adults (1.8 µg/L) and children (1.8 µg/L). There is no urinary chromium notification level for New Zealand, but the analytical laboratory considers urinary chromium concentrations below 1 µg/L as normal.

For urinary thallium the suggested upper reference limit was higher for adults (1.0 µg/L) compared to children (0.5 µg/L). There is no urinary thallium notification level

for New Zealand, but the analytical laboratory considers urinary thallium concentrations below 1 µg/L as normal.

For antimony, the suggested upper reference limits were very similar for adults (0.5 µg/L) and children (0.4 µg/L). There is no urinary antimony notification level for New Zealand, but the analytical laboratory considers urinary antimony concentrations below 1.2 µg/L as normal.

For urinary fluoride the suggested upper reference limit was similar for adults (2700 µg/L) and children (2300 µg/L), while creatinine adjusted and specific gravity adjusted URLs differed more substantially between adults and children. The analytical laboratory considers levels below 589 µg /L as normal.

Tables 64a and **64b** provide the suggested upper reference limits for environmental phenols including BPA, triclosan, BP-3 and parabens, for New Zealand adults and children, respectively. The URL for BPA is relatively low compared to the other phenols. The URLs for triclosan, BP-3 and the parabens are considerably higher, due to the high outliers for these compounds. For the phenols, the URLs based on the samples from children are very similar to those of adults.

Table 64a. *Reference values and upper reference limits (URL) for phenols for adult New Zealanders (age 19-65)*

		LOD	%< LOD	GM	95%CI GM	P2.5	P50	P95	P97.5	95%CI P97.5	URL
Bisphenol A	µg/L urine	0.4	93%	1.80	1.60-2.03	<LOD	1.87	12	17	13-22	25
	µg/g creat			1.45	1.30-1.61	<LOD	1.51	7	8	3-12	15
	µg/L spgr			1.98	1.78-2.21	<LOD	1.94	9	13	6-21	25
triclosan	µg/L urine	0.4	15%	5.77	4.26-7.82	<LOD	2.6	963	1161	998-1351	1360
	µg/g creat			4.63	3.43-6.25	<LOD	1.8	654	901	675-1202	1210
	µg/L spgr			6.34	4.69-8.56	<LOD	2.6	951	1270	975-1653	1660
BP-3	µg/L urine	0.2	0%	18.40	14.90-22.74	0.85	14.31	585	899	503-1600	1600
	µg/g creat			14.77	12.00-18.18	0.82	10.59	429	974	509-1859	1860
	µg/L spgr			20.21	16.36-24.97	1.01	14.32	690	1752	1027-2988	3000
methylparaben	µg/L urine	0.08	0%	17.49	14.52-21.08	1.73	14.33	324	737	369-1381	1400
	µg/g creat			14.04	11.56-17.04	1.15	11.14	258	632	244-1537	1540
	µg/L spgr			19.21	15.91-23.21	1.92	15.41	348	894	403-1981	2000
n-propylparaben	µg/L urine	0.08	0%	3.38	2.73-4.18	0.15	2.83	76	145	63-327	330
	µg/g creat			2.71	2.18-3.37	0.10	2.19	89	124	76-200	200
	µg/L spgr			3.71	3.00-4.60	0.16	2.85	108	162	87-301	310
ethylparaben	µg/L urine	0.08	0%	1.39	1.14-1.69	0.14	0.92	36	108	38-309	310
	µg/g creat			1.11	0.91-1.36	0.12	0.74	31	103	37-266	270
	µg/L spgr			1.52	1.25-1.85	0.18	0.98	42	140	53-369	370

LOD:Limit of Detection; GM: geometric mean; 95%CI: 95% confidence interval; P97.5: 97.5th percentile; URL: upper reference limit; creat: creatinine; spgr: specific gravity adjusted.

Table 64b. *Reference values and upper reference limits (URL) for phenols for New Zealand children (age 5-18)*

		LOD	%< LOD	GM	95%CI GM	P2.5	P50	P95	P97.5	95%CI P97.5	URL
Bisphenol A	µg/L urine	0.4	89%	2.18	1.96-2.41	<LOD	2.17	10	12	9-15	15
	µg/g creat			2.17	1.96-2.39	<LOD	2.12	9	12	8-17	20
	µg/L spgr			2.02	1.83-2.23	<LOD	1.92	8	15	10-21	25
triclosan	µg/L urine	0.4	8%	3.85	2.96-5.03	<LOD	1.8	607	918	674-1248	1250
	µg/g creat			3.84	2.95-4.99	<LOD	1.9	497	835	572-1218	1220
	µg/L spgr			3.58	2.75-4.66	<LOD	1.6	479	781	503-1214	1220
BP-3	µg/L urine	0.2	0%	20.8	17.6-24.7	1.8	17.3	279	640	283-1448	1450
	µg/g creat			20.8	17.5-24.8	1.8	18.4	357	573	321-1017	1020
	µg/L spgr			19.4	16.3-23.0	1.8	15.7	300	555	300-1027	1030
methylparaben	µg/L urine	0.08	0%	11.87	9.60-14.68	1.26	7.18	376	3810	972-14265	14300
	µg/g creat			11.82	9.59-14.57	1.07	6.88	343	3777	968-14330	14400
	µg/L spgr			11.03	8.98-13.54	1.31	6.12	333	3463	875-13594	13600
n-propylparaben	µg/L urine	0.08	1%	2.11	1.75-2.56	0.13	1.82	41	84	31-227	230
	µg/g creat			2.10	1.75-2.54	0.12	1.91	34	69	22-213	220
	µg/L spgr			1.96	1.63-2.36	0.12	1.65	37	90	32-258	260
ethylparaben	µg/L urine	0.08	2%	0.68	0.58-0.81	0.10	0.49	15	44	11-180	180
	µg/g creat			0.68	0.58-0.80	0.11	0.50	13	46	13-150	150
	µg/L spgr			0.63	0.54-0.75	0.11	0.44	13	53	15-194	200

LOD:Limit of Detection; GM: geometric mean; 95%CI: 95% confidence interval; P97.5: 97.5th percentile; URL: upper reference limit; creat: creatinine; spgr: specific gravity adjusted.

Tables 65a and **65b** provide the suggested upper reference limits for phthalate metabolites, for New Zealand adults and children, respectively. Overall, also for the phthalates the URLs based on the samples from children are similar to those of adults.

Table 65a. *Reference values and upper reference limits (URL) for phthalate metabolites for adult New Zealanders (age 19-65)*

	unit	LOD	%< LOD	GM	95%CI GM	P2.5	P50	P95	P97.5	95%CI P97.5	URL
mEP	µg/L urine	1	4%	19.1	16.7-22.0	<LOD	19.1	147.4	228	155-334	340
	µg/g creat			15.3	13.3-17.6	<LOD	13.7	155.0	230	143-368	370
	µg/L spgr			21.0	18.3-24.1	<LOD	19.0	161.9	255	154-422	430
mBP	µg/L urine	1	0%	37.0	33.4-40.9	7.7	36.1	146.4	221	114-423	430
	µg/g creat			29.6	27.2-32.2	7.9	26.2	95.8	121	64-229	230
	µg/L spgr			40.6	37.2-44.3	9.9	37.0	146.3	196	94-408	410
mBzP	µg/L urine	1	18%	4.2	3.6-4.8	<LOD	4.6	32.7	48	28-82	90
	µg/g creat			3.3	2.9-3.8	<LOD	3.2	20.5	31	20-46	50
	µg/L spgr			4.6	4.0-5.2	<LOD	5.0	27.9	40	26-62	70
mEHP	µg/L urine	1	18%	2.0	1.8-2.2	<LOD	2.1	10.1	12	8-18	20
	µg/g creat			1.6	1.4-1.8	<LOD	1.6	6.5	8	5-11	20
	µg/L spgr			2.2	2.0-2.4	<LOD	2.2	9.2	11	8-15	20
mEOHP	µg/L urine	1	1%	7.0	6.4-7.7	1.4	7.0	25.8	32	24-43	50
	µg/g creat			5.6	5.2-6.1	1.3	5.6	16.9	21	16-27	30
	µg/L spgr			7.7	7.1-8.3	2.0	7.7	22.5	31	21-45	50
mEHHP	µg/L urine	1	4%	9.0	8.0-10.1	<LOD	9.6	38.8	45	33-61	70
	µg/g creat			7.2	6.5-8.0	<LOD	8.0	25.7	35	24-51	60
	µg/L spgr			9.9	8.9-10.9	<LOD	10.3	36.4	43	29-64	70
mCPP	µg/L urine	1	37%	2.4	2.1-2.7	<LOD	1.9	18.2	35	16-76	80
	µg/g creat			1.9	1.7-2.1	<LOD	1.5	11.7	29	13-65	70
	µg/L spgr			2.6	2.3-2.9	<LOD	2.2	17.6	45	21-98	100

LOD:Limit of Detection; GM: geometric mean; 95%CI: 95% confidence interval; P97.5: 97.5th percentile; URL: upper reference limit; creat: creatinine; spgr: specific gravity adjusted.

Table 65b. *Reference values and upper reference limits (URL) for phthalate metabolites for New Zealand children (age 5-18)*

	unit	LOD	%< LOD	GM	95%CI GM	P2.5	P50	P95	P97.5	95%CI P97.5	URL
mEP	µg/L urine	1	36%	12.9	11.3-14.7	<LOD	**12.0**	**109.3**	**167**	**72-385**	390
	µg/g creat			12.8	11.4-14.5	<LOD	**11.8**	**66.5**	**211**	**93-481**	490
	µg/L spgr			12.0	10.6-13.5	<LOD	**10.7**	**78.4**	**189**	**84-411**	420
mBP	µg/L urine	1	0%	60.6	55.8-65.7	**12.7**	**60.6**	**198.2**	**257**	**205-322**	330
	µg/g creat			60.3	55.8-65.1	**16.9**	**60.2**	**213.9**	**264**	**187-373**	380
	µg/L spgr			56.3	52.4-60.4	**17.4**	**53.5**	**159.4**	**215**	**167-276**	280
mBzP	µg/L urine	1	7%	7.7	6.7-8.8	<LOD	**7.4**	**50.5**	**87**	**60-126**	130
	µg/g creat			7.6	6.8-8.6	<LOD	**7.1**	**44.9**	**69**	**38-124**	130
	µg/L spgr			7.1	6.3-8.1	<LOD	**6.8**	**42.8**	**59**	**32-110**	110
mEHP	µg/L urine	1	10%	2.7	2.5-3.0	<LOD	**2.8**	**11.2**	**14**	**12-17**	20
	µg/g creat			2.7	2.5-3.0	<LOD	**2.6**	**11.1**	**13**	**10-16**	20
	µg/L spgr			2.5	2.3-2.8	<LOD	**2.6**	**8.5**	**11**	**9-14**	20
mEOHP	µg/L urine	1	0%	14.2	13.1-15.4	**3.1**	**14.3**	**47.0**	**62**	**48-81**	90
	µg/g creat			14.1	13.0-15.3	**3.1**	**13.7**	**46.8**	**68**	**55-84**	90
	µg/L spgr			13.2	12.3-14.2	**3.7**	**12.9**	**36.6**	**48**	**37-62**	70
mEHHP	µg/L urine	1	2%	17.6	15.9-19.4	**2.7**	**18.7**	**68.1**	**78**	**60-101**	110
	µg/g creat			17.5	15.9-19.3	**3.2**	**18.1**	**67.2**	**90**	**71-114**	120
	µg/L spgr			16.3	15.0-17.9	**2.9**	**17.1**	**54.0**	**60**	**47-78**	80
mCPP	µg/L urine	1	24%	3.3	3.0-3.7	<LOD	**3.0**	**11.8**	**20**	**11-34**	40
	µg/g creat			3.3	3.0-3.6	<LOD	**3.2**	**12.0**	**17**	**10-28**	30
	µg/L spgr			3.1	2.8-3.4	<LOD	**2.9**	**10.1**	**14**	**8-23**	30

LOD:Limit of Detection; GM: geometric mean; 95%CI: 95% confidence interval; P97.5: 97.5th percentile; URL: upper reference limit; creat: creatinine; spgr: specific gravity adjusted.

7. Recommendations for future biological monitoring of selected chemicals of concern

This is the first national biomonitoring study representative for adults and children living in New Zealand on human environmental exposure of selected chemicals of concern measured in whole blood and urine, including metals and metalloids, cotinine, fluoride, phenols and phthalates. It did not include persistent organic pollutants, as these compounds were evaluated for adult New Zealanders in two previous surveys (Bates *et al.*, 2004; 't Mannetje *et al.*, 2013) and are typically measured in pooled serum samples. Repetition of a similar biomonitoring programme in the future will enable the monitoring of trends over time. The US and Canada both have biomonitoring programmes that have been repeated every 2 to 3 years. These studies have shown that changes in population levels of certain chemicals of concern can occur fast (i.e. phthalate urinary concentrations have more than halved in a 5 year time period). This suggests that the reference values and upper reference limits as reported here (Table 63-65) may need updating in 5 years. Because urinary concentrations for most of the chemicals of concern represent recent exposure, repetition of the biological monitoring programme will also provide a timely evaluation of the effectiveness of regulatory changes in relation to these chemicals.

For future biological monitoring of selected chemicals of concern, we recommend the following:

- To conduct it as part of a larger nationwide survey (e.g. the New Zealand nutrition survey), if possible. This would reduce the cost for recruitment and has the advantage that details on diet are already collected. In addition, it would optimise the use of biological samples collected as part of the larger nationwide survey, which, in the case of urine, is generally available in sufficient volume to allow for testing of both nutritional indicators and selected chemicals of concern.
- To include questions that enable the evaluation of the determinants of exposure, as was done for this survey.
- To use similar inclusion criteria, age range and geographic representation, to optimise comparability over time.
- To recruit a similar number of study participants (i.e. 300 children and 300 adults). This number of participants will provide sufficient study power to detect age, gender, ethnicity and geographic patterns, as demonstrated in this study.
- To ensure sufficiently low detection limits are achieved by the analytical laboratories, for the survey to provide useful results, taking into account possible reductions in population levels since the last survey.
- To consider inclusion of additional chemicals of concern. Biological monitoring has developed rapidly over the past two decades and advancements in analytical techniques have provided additional options for the number of chemicals and compounds that can be monitored in the general population. Recommendations to aid decision making are included below.

Listed below are issues to be taken into consideration when including or excluding compounds in future New Zealand biomonitoring programmes.

- Is the compound a biomarker of an environmental exposure (as opposed to biomarkers of effect, disease or susceptibility)? A valid biomarker of exposure is one that links the biomarker in the subject to a specific environmental exposure. Ideally, a biomarker will be unique to the substance under investigation, although this is often not the case (Zelenka *et al.*, 2011).
- Is the environmental exposure or its metabolites biologically relevant and relevant for public health? Answering this question requires up to date reviews of the scientific literature.
- Does the concentration of the biomarker increase with exposure?
- Are reference values available for the compound? The availability of reference values increases the value of repeating biomonitoring of this compound over time. Blood lead is an excellent example of this, for which repeated biomonitoring programmes have indicated substantial decreases in population levels of blood lead over time, reflecting environmental exposure.
- Can the compound be determined in human body fluids and have standard operating procedures (SOPs) been evaluated and published?
- What volume of human body fluids is required to conduct the analyses? Particularly when including children in the biomonitoring programme, sample volume is an important criterion.
- Are the detection limits sufficiently low and the expected detection frequency of the compound sufficiently high in the population? For example, for compounds detected in less than half of the samples, geometric means are generally not calculated. A review article from 2007 indicates which substances are found in blood or urine samples of less or more than 50% of the population (Angerer *et al.*, 2007).
- Does a New Zealand based laboratory provide routine analyses for the compound? This will facilitate the analyses of single samples that can be compared with the reference values resulting from the biomonitoring programme. For example, New Zealand laboratories currently do not provide analyses of phthalates and phenols, and if individual urine sample results (e.g. from individuals in a highly exposed job) are to be compared with the reference values, the urine sample will have to be sent overseas.
- Can pre-analytic and analytic contamination be sufficiently controlled? This is particularly relevant for compounds that can be found in medical and analytical equipment or omnipresent in an indoor environment.
- Is the biomarker stable in the sample matrix? If the biomarker is not stable, this may complicate the sample collection and storage procedures.
- Does the compound provide the possibility of comparing with other countries? Countries that have conducted repeated surveys at regular intervals include the US (NHANES survey repeated every 2 years since 1999) and Canada (The Canadian Health Measures Survey repeated every 3 years since 2007).
- Are there sources of exposure of the compound present in New Zealand? Are these sources particularly relevant for New Zealand? For example, with New Zealand's strong agricultural sector, population exposure to pesticides is particularly relevant.
- What are the analytical costs of adding the compound to the list? In some cases adding compounds to a suite of analytes may not substantially alter the total analytical cost.

A weight of evidence approach for selecting exposure biomarkers for biomarkers has been developed (Zelenka *et al.*, 2011) in the US, which recommends a framework following six steps:

1. Specify the intended use of the biomarker.
2. Rigorously define the exposure question against which the biomarkers will be evaluated.
3. Develop the list of competing biomarkers and matrices.
4. Rate each criterion as to its relevance in answering the exposure question.
5. Rate the suitability of each biomarker for each criterion.
6. Complete the required calculations and interpretation.

8. Discussion

This national biological monitoring programme provides descriptive statistics on blood and urine concentrations of metals, metalloids, cotinine, fluoride, phenols and phthalates, for a sample of the New Zealand population. The programme aimed to include 300 children and 300 adults with an age range from 5 to 64 years, men and women, Māori and non-Māori and all geographic regions in New Zealand. The limitations of the biological monitoring programme are discussed below.

For practical reasons different recruitment methods were used for children and adults, which may have impacted on the representativeness of the sample. For example, children were mainly recruited through schools, while adults were selected from the electoral roll and invited by mail to participate in the study. As considerable effort and commitment was required from individuals and their families to participate in the study (i.e. go to a local pathology lab to have a blood sample taken and self-collect a urine sample), participation rates were low, particularly for children. To partially mitigate this, we had an opportunity to use urine samples which were being collected as part of another study in children conducted at the same time. However, this resulted in a relative over-representation of children from the lower North Island. As a consequence, population geometric means in the presence of substantial geographic variation in urinary concentrations need to be interpreted with caution. This is relevant for the urinary fluoride levels for children, which were highest for the lower North Island. The over-representation of children from the lower North Island will therefore have inflated the overall geometric mean of urinary fluoride concentrations for New Zealand children and region-specific GMs need to be considered. The results based on blood samples (lead and mercury) are not affected by an over-representation of children from the lower North Island, but for children the number of blood samples included in the study was smaller than the number of urine samples. For adults the representativeness of the study population for the general population in terms of age, sex, ethnicity and geographic region was evaluated by comparing the unweighted geometric means (as reported here) with GMs weighted by the age, sex, ethnicity and geographic distribution of the New Zealand population (not reported). This showed very similar GMs for the unweighted and weighted sample, providing support that the sample was sufficiently representative for the New Zealand population in terms of age, ethnicity, geographic region and gender.

Although our ability to measure environmental chemicals at very low concentrations has advanced, the proportion of samples in which the compound could not be detected remained high for some analytes, and assumptions on the actual level had to be made. As a rule, we used half the detection limit for those samples below the limit of detection. Geometric means including those below the limit of detection were, however, not presented, if the detection frequency was below 33%. In these cases the detection frequency was presented.

All urine concentrations are presented unadjusted, as well as creatinine adjusted, and specific gravity adjusted. Each method to adjust for urinary volume has their own limitations, and creatinine adjustment has been shown to potentially result in over adjustment (Hoet *et al.*, 2016). Particularly when comparing urinary concentrations

between age groups and genders, the type of urinary volume adjustment needs to be taken into account, as creatinine concentrations and specific gravity of the urine both depend strongly but differentially on age and gender (see appendix 3). Consistency in age and sex differences independently of the adjustment method used was therefore interpreted as the strongest evidence of such age and sex differences in urinary concentrations. If gender or age differences were only apparent for creatinine adjusted urine concentrations, these differences were generally disregarded.

Another limitation of using urinary samples in biomonitoring studies is that for most included compounds the urinary concentrations generally reflect recent exposure, as opposed to chronic exposure which would be most relevant for any health effects. Elevated levels can therefore not be interpreted as indicative of health risk. Additionally, for some compounds the metabolites are measured, rather than the parent compound, which makes an individual's result dependent on that person's individual metabolic rate which can vary widely within populations. However, on a population level these individual variations will be balanced out and do not impact on the population geometric mean as reported here.

This is the first biomonitoring study in New Zealand reporting on blood and urinary concentrations of selected chemicals of concern. The results provide baseline levels representative for New Zealanders during the period 2014 to 2016. Health risk assessments were outside the scope of this study. From this data it is therefore not possible to draw conclusions about potential health risks, and the reported levels can only be interpreted as an indicator of exposure.

9. Conclusions

The conclusions of the biomonitoring programme are presented by chemical, followed by more general conclusions regarding these chemicals and associations with age, sex, ethnicity and geographic region.

Population levels of the selected chemicals are represented by the geometric mean, reflecting the central tendency of the blood and urine concentrations in the study population. The geometric means, representative for the New Zealand general population, are also compared with those reported for other countries.

Blood lead

- Total lead was determined in whole blood samples collected during 2014-2016 from 304 adults and 193 children living in New Zealand.
- Lead was detected in all samples.
- The geometric mean (GM) blood lead level was 13 µg/L (1.3 µg/dL) for adults and 8 µg/L (0.8 µg/dL) for children.
- None of the study participants had blood lead levels above the notifiable blood lead level of 100 µg/L (10 µg/dL).
- Lead levels were positively associated with age and male gender.
- Among children lead levels were highest for the Northland/Auckland region, but this pattern was not observed for adults.
- The blood lead concentrations for adults and children in New Zealand were comparable to the geometric means reported for the US and Canada, although for these countries a downward trend over time has been observed with the most recent results indicating concentrations below those observed for New Zealand.

Blood mercury

- Total mercury was determined in whole blood samples collected during 2014-2016 from 304 adults and 193 children living in New Zealand.
- Mercury was detected in 99% of the adult blood samples and 93% of the child blood samples.
- The geometric mean (GM) blood mercury level was 1.6 µg/L for adults and 0.9 µg/L for children.
- There currently is no New Zealand blood mercury notification level. None of the participants had blood mercury concentrations above Health Canada's blood mercury guidance value of 20 µg/L.
- Mercury levels were higher for those who reported fish consumption in the 48 hours before blood taking.
- Mercury levels were positively associated with age and male gender although this gender pattern was only observed for children, not for adults.
- The GM for blood mercury in New Zealanders was approximately double the GM reported for US, Canada and Germany. The New Zealand GMs were comparable to those reported for France, and lower than that reported for Korea.

Urinary inorganic arsenic

- Inorganic arsenic related compounds, including dimethylersinic acid (DMA), monomethylarsonic acid (MMA), arsenite (AsIII) and arsenate (AsV), were determined in morning void urine samples collected during 2014-2016 from 304 adults and 299 children living in New Zealand.
- DMA was the dominant inorganic arsenic related compound, accounting for practically all inorganic arsenic measured.
- DMA was detected in 79% of adults and 72% of children. MMA was detected in 3% of adults and 14% of children. AsIII and AsV were not detected in any of the adult samples and in one and two samples respectively of the children samples.
- The geometric mean (GM) urinary DMA level was 4.2 µg/L for adults and 3.0 µg/L for children.
- For both adults and children there was a strong South to North gradient in urinary DMA levels, with the lowest GMs observed for the South Island.
- Fish consumption in the 48 hours prior to sampling was associated with higher urinary levels of DMA, for both adults and children.
- Urinary levels of DMA in adult New Zealanders were comparable to those reported for the US and Canada while below those reported for Spain. New Zealand levels of urinary DMA in children were below those reported for the US.

Urinary organic arsenic

- The organic arsenic compound arsenobetaine (AB) was determined in morning void urine samples collected during 2014-2016 from 304 adults and 299 children living in New Zealand.
- AB was detected in samples from 68% of the adults and 53% of the children.
- The geometric mean urinary AB level was 3.5 µg/L for adults and 1.5 µg/L for children.
- Among children, AB levels were higher for non-Māori compared to Māori, but this ethnicity pattern was not observed among adults.
- Fish consumption in the 48 hours prior to sampling was associated with substantially higher urinary levels of AB, for both adults (24.6 µg/L) and children (41.2 µg/L).
- Urinary levels of AB in adult New Zealanders were higher than data reported for the US, but lower than those reported for high fish consuming nations such as Spain and Japan.

Urinary cadmium

- Cadmium was determined in morning void urine samples collected during 2014-2016 from 304 adults and 300 children living in New Zealand.
- Cadmium was detected in 89% of the adult urine samples and 53% of the child urine samples.
- The geometric mean (GM) urinary cadmium was 0.19 µg/L for adults and 0.07 µg/L for children.
- Age was strongly and positively associated with cadmium levels. For adults cadmium levels differed among geographic regions but this was not observed for children.
- The GM of urinary cadmium concentrations of New Zealanders was comparable to those reported for US and Europe, and lower than that reported for Canada, for both adults and children.

Urinary chromium

- Chromium was determined in morning void urine samples collected during 2014-2016 from 304 adults and 300 children living in New Zealand.
- Chromium was detected in 59% of the adult urine samples and 44% of the child urine samples. The relatively low detection frequency for chromium limits the statistical interpretation of these data.
- The geometric mean urinary chromium was 0.05 µg/L for adults and 0.03 µg/L for children.
- Apart from the higher GMs observed for adults compared to children, there were no consistent differences in urinary chromium levels between age groups, men and women, ethnicity groups, or geographic regions. Among children the geometric mean for the lower North Island was more than double that of the other three regions, but this pattern was not observed for adults.
- The New Zealand GMs for urinary chromium were below those reported for France and Belgium. Comparisons with the US and Canada could not be made.

Urinary thallium

- Thallium was determined in morning void urine samples collected during 2014-2016 from 304 adults and 300 children living in New Zealand.
- Thallium was detected in 97% of the adult urine samples and 79% of the child urine samples.
- The geometric mean (GM) urinary thallium was 0.20 µg/L for adults and 0.05 µg/L for children.
- Apart from the higher GM observed for adults compared to children, there were no consistent differences in urinary chromium levels between age groups, men and women, or ethnicity groups.
- Differences in urinary thallium levels between geographic regions were observed for both adults and children, with the lowest GM observed for the South Island.
- New Zealand urinary thallium concentrations in adults were similar to those reported for Canada, France and Belgium, and higher than those reported for the US. For children the New Zealand levels were lower than those reported for the US.

Urinary antimony

- Antimony was determined in morning void urine samples collected during 2014-2016 from 304 adults and 300 children living in New Zealand.
- Antimony was detected in 90% of the adult urine samples and 99% of the child urine samples.
- The geometric mean urinary antimony was 0.06 µg/L for adults and 0.09 µg/L for children.
- Among children, the GM for antimony was higher for girls compared to boys and lowest in the Northland/Auckland region. These gender and regional patterns were not observed for adults.
- New Zealand urinary antimony concentrations in adults were similar to those reported for France and marginally higher than levels most recently reported for Belgium, US and Canada. New Zealand urinary antimony concentrations in children were also above those most recently reported for the US and Canada. The pattern of higher levels among children compared to adults observed in this study, was also observed in the studies from the US and Canada.

Urinary cotinine

- Cotinine was determined in morning void urine samples collected during 2014-2016 from 304 adults and 300 children living in New Zealand.
- Urinary cotinine was detected in 11% of adults and 2% of children.
- Detection frequencies were significantly higher among Māori children (8% detected) compared to non-Māori children (0% detected). Also among adults detection frequencies were significantly higher among Māori (19% detected) compared to non-Māori (6% detected).

Urinary fluoride

- Fluoride was determined in morning void urine samples collected during 2014-2016 from 304 adults and 299 children living in New Zealand.
- Fluoride was detected in all urine samples.
- The geometric mean urinary fluorine was 760 µg/L for adults and 630 µg/L for children.
- Among children, older age was associated with lower urinary fluoride levels. Among adults, a higher urinary fluoride level was observed for females compared to males, while this pattern was not observed among children.
- For both children and adults, the lowest urinary fluoride GM was observed for the South Island.
- Concentrations of fluoride in New Zealand adults are marginally higher than those reported for Canada, but comparable to those reported for Brazil and Japan.

Urinary phenols: BPA

- BPA was determined in morning void urine samples collected during 2014-2016 from 303 adults and 299 children living in New Zealand.
- BPA was detected in the urine samples of 93% of adults and 89% of children.
- The geometric mean urinary BPA concentration was 1.8 µg/L for adults and 2.2 µg/L for children.
- BPA concentrations differed by age group, with the highest GM observed for the 19-24 year age group (2.9 µg/L) and the lowest for the 50-64 age group (1.4 µg/L).
- There were no consistent differences in urinary BPA concentrations between men and women or between Māori and non-Māori.
- For children geographic variation in urinary BPA concentrations were observed, with the highest GM for the Northland/Auckland region.
- The urinary BPA concentrations for New Zealand were comparable to those reported for Australia, US and Canada, although the most recent GMs reported for the US and Canada were below those of New Zealand, for both adults and children.

Urinary phenols: triclosan

- Triclosan was determined in morning void urine samples collected during 2014-2016 from 303 adults and 299 children living in New Zealand.
- Triclosan was detected in the urine samples of 85% of adults and 92% of children.
- The geometric mean urinary triclosan concentration was 4.8 µg/L for adults and 3.9 µg/L for children.
- Among children, triclosan levels were positively associated with age, while in adults they were negatively associated with age, with the highest GM for triclosan observed for the 19-24 year age group.
- There were no consistent differences in urinary triclosan concentrations between males and females or among the different geographic regions.
- Adults who recalled using anti-bacterial soaps or hand sanitizers in the 48 hours before urine sampling, had a GM for urinary triclosan two times (8.6 µg/L) the GM of those who had not recently used these products (3.8 µg/L).
- There were marked differences in urinary triclosan concentrations between Māori and non-Māori children, with the GM for non-Māori children more than double the GM for Māori children. For adults this difference between ethnic groups was much less pronounced and did not reach statistical significance.
- The urinary triclosan concentrations for New Zealand were generally below those reported for the US and Canada, and comparable to those reported for Australia.

Urinary phenols: Benzophenone-3 (BP-3)

- BP-3 was determined in morning void urine samples collected during 2014-2016 from 303 adults and 298 children living in New Zealand.
- BP-3 was detected in the urine samples of 100% of adults and children.
- The geometric mean urinary BP-3 concentration was 18.4 µg/L for adults and 20.8 µg/L for children.
- Age was negatively associated with urinary BP-3 concentrations for adults, while among children urinary concentrations of BP-3 were comparable across the three age groups.
- BP-3 urinary concentrations were higher among females compared to males, particularly for adults.
- Adults who had used sunscreen in the 48 hours before urine sampling, had a GM for urinary BP-3 10 times (160 µg/L) the GM of those who had not recently used sunscreen (15 µg/L).
- For both adults and children, Māori had lower urinary BP-3 concentrations compared to non-Māori.
- New Zealand BP-3 levels were comparable to those reported for the US, and higher than those reported for Belgium, India and Australia.

Urinary phenols: 4-tert-octylphenol

- 4-tert-octylphenol was determined in morning void urine samples collected during 2014-2016 from 303 adults and 299 children living in New Zealand.
- 4-tert-octylphenol was detected in the urine samples of 3% of adults and 3% of children.
- This low detection frequency is comparable to what has been reported for the US.

Urinary phenols: parabens

- Four urinary parabens were determined in morning void urine samples collected during 2014-2016 from 303 adults and 299 children living in New Zealand: methylparaben, n-propylparaben, ethylparaben, butylparaben.
- The detection frequency of methylparaben, propylparaben, and ethylparaben was high (>98%), while the detection frequency of butylparaben was 32% for adults and 33% for children.
- The geometric mean concentration of the sum of the four parabens was 27.1 µg/L for adults and 17.7 µg/L for children.
- Methylparaben contributed most to the sum (methylparaben GM 17.5 µg/L for adults and 11.9 µg/L for children), followed by propylparaben (GM 3.4 µg/L for adults and 2.1 µg/L for children) and ethylparaben (GM 1.4 µg/L for adults and 0.7 µg/L for children).
- While GMs were generally higher for adults than for children, age was not associated with paraben concentrations for either adults or children.
- For all four parabens the GM urinary concentrations were higher in women compared to men. This gender difference was not observed for children.
- GMs for Māori and non-Māori were similar for methylparaben and propylparaben, while for ethylparaben and butylparaben GMs were higher for non-Māori compared to Māori (only for adults, not for children).
- Geographic differences in urinary paraben levels were not observed.
- New Zealand methylparaben levels were lower than those reported for the US, and comparable to the levels reported for China, Belgium, Greece and Australia.

Urinary phthalates

- Ten phthalate metabolites were determined in morning void urine samples collected during 2014-2016 from 304 adults and 299 children living in New Zealand.
- The following phthalate metabolites were detected in the majority of samples: mEP, mBP, mBzP, mEHP, mEOHP, mEHHP, mCPP.
- The following phthalate metabolites had very low detection frequencies: mMP, mCHP, miNP.
- The highest urinary concentrations were measured for monobutyl phthalate (mBP, n+iso), a metabolite of dibutyl phthalate (DBP, n+iso), commonly used as a plasticiser and other applications. The geometric mean was 37 µg/L for adults and 61 µg/L for children.
- For the DEHP metabolites mEHP, mEOHP and mEHHP, also commonly used as plasticisers, the geometric means for adults and children were 2 and 3, 7 and 14, 9 and 18 µg/L, respectively.
- For mBzP and mCPP, metabolites of the plasticisers BBzP and DOP, the geometric means of urinary concentrations for adults and children were 4 and 8, 2 and 3 µg/L, respectively.
- For mEP, a metabolite of DEP which is commonly used in personal care products, food packaging and pharmaceuticals, the geometric mean was 19 µg/L for adults and 13 µg/L for children.
- For the metabolites of phthalates commonly used as plasticisers, the highest concentrations were observed for the youngest age groups. Associations with sex, ethnicity or region were not observed.
- For mEP, a metabolite of DEP which is commonly used in personal care products, concentrations were positively associated with age, and higher for women compared to men.
- Urinary concentrations of phthalate metabolites in New Zealanders were largely comparable with those reported for other countries, with one possible exception i.e. for both adults and children the urinary concentrations of mBP, a metabolite of dibutyl phthalate (DBP), appeared to be higher than those reported for several other countries, but were comparable to the levels reported for Australia.

Associations with age

With the notable exception of antimony, for all metals the geometric means were higher for adults compared to children (1.5x higher for lead, 1.9x for mercury, 1.3x for inorganic arsenic, 2.3x for organic arsenic, 2.6x for cadmium, 1.5x for chromium, 3.6x for thallium). For lead, mercury and cadmium, positive associations with age were also observed among the adult age groups, with the oldest age group (50-64 years) having approximately 2x higher GMs compared to the youngest age groups (19-24). For antimony, the GM was higher for children compared to adults, a pattern also observed in other countries. For fluoride, the GM was similar in adults and children (particularly when comparing creatinine adjusted levels), while among children the highest GM was observed for the youngest age group of 5-7.
For the phenols and parabens, urinary concentrations in adults were generally higher than those in children. For BPA, triclosan and BP-3 the highest concentrations were

found for the 19-24 year age group. For the phthalate metabolites, urinary concentrations were typically negatively associated with age, showing the highest geometric means for the youngest age group of 5-7 years. This was not the case for mEP, a metabolite of DEP which is commonly used in personal care products, which showed a positive association with age and a peak for the 19-24 year age group.

Association with gender

For the metals lead, mercury and arsenic, higher GMs were observed for males compared to females, and for lead and mercury the same gender pattern was also observed for children. For fluoride, female adults had a higher GM compared to men, but this difference was only present for creatinine and specific gravity adjusted values. Urinary concentrations for BP-3 (a sunscreen component) and the parabens (used as antimicrobial preservatives in cosmetics), were significantly higher in females compared to males. For most phthalate metabolites, GMs were similar for males and females with the exception of mEP, a metabolite of DEP, which is commonly used in personal care products, for which the GM was higher in women compared to men.

Association with ethnicity

For organic arsenic the GMs were substantially higher for non-Māori children compared to Māori children, while no ethnic difference was observed among adults. Cotinine was detected with substantially higher frequency in Māori children compared to non-Māori children and this pattern was also observed for adults. For triclosan, non-Māori had higher urinary concentrations compared to Māori, particularly among children. For BP-3 (a sunscreen component) non-Māori had higher urinary concentrations compared to Māori, for both children and adults. For ethyl- and butylparaben (but not methyl- and propylparaben) urinary concentrations were higher in non-Māori compared to Māori (for adults only).

Association with geographic region

Both inorganic arsenic (in the form of DMA) and thallium, showed geographic variation for both children and adults, with lowest levels observed for the South Island and highest for the North of the North Island. Also for fluoride, the lowest GMs were observed for the South Island, for both adults and children. For BPA the lowest GMs were observed for the South Island, but this pattern was only observed for children, not for adults. For most other chemicals, a clear and consistent association was geographic region was not observed.

10. References

Andersen, F.A. (2008) Final Amended Report on the Safety Assessment of Methylparaben, Ethylparaben, Propylparaben, Isopropylparaben, Butylparaben, Isobutylparaben, and Benzylparaben as used in Cosmetic Products. Int J Toxicol, 27, 1-82.

Angerer, J., Ewers, U. & Wilhelm, M. (2007) Human biomonitoring: state of the art. Int J Hyg Environ Health, 210, 201-228.

Asimakopoulos, A.G., Thomaidis, N.S. & Kannan, K. (2014) Widespread occurrence of bisphenol A diglycidyl ethers, p-hydroxybenzoic acid esters (parabens), benzophenone type-UV filters, triclosan, and triclocarban in human urine from Athens, Greece. Sci Total Environ, 470-471, 1243-1249.

Barr, D.B., Wilder, L.C., Caudill, S.P., Gonzalez, A.J., Needham, L.L. & Pirkle, J.L. (2005) Urinary creatinine concentrations in the US population: Implications for urinary biologic monitoring measurements. Environmental Health Perspectives, 113, 192-200.

Bates, M., Thomson, B. & Garrett, N. (2001) Investigation of Organochlorine Contaminants in the Milk of New Zealand Women. In Health, M.o. (ed), Wellington.

Bates, M.N., Buckland, S.J., Garrett, N., Ellis, H., Needham, L.L., Patterson, D.G., Jr., Turner, W.E. & Russell, D.G. (2004) Persistent organochlorines in the serum of the non-occupationally exposed New Zealand population. Chemosphere, 54, 1431-1443.

Bates, M.N., Hannah, D.J., Simon, J.B., Taucher, J.A. & Maanen, T.v. (1994) Chlorinated Organic Contaminants in Breast Milk of New Zealand Women. Environmental Health Perspectives, 102, 211-217.

Berman, T., Goldsmith, R., Goen, T., Spungen, J., Novack, L., Levine, H., Amitai, Y., Shohat, T. & Grotto, I. (2014) Demographic and dietary predictors of urinary bisphenol A concentrations in adults in Israel. Int J Hyg Environ Health, 217, 638-644.

Buckland, S., Bates, M., Garrett, N., Ellis, H. & van Maanen, T. (2001) Concentrations of selected organochlorines in the serum of the non-occupationally exposed New Zealand population. In Ministry for the Environment (ed), Wellington.

Calafat, A.M., Ye, X., Wong, L.Y., Reidy, J.A. & Needham, L.L. (2008) Exposure of the U.S. population to bisphenol A and 4-tertiary-octylphenol: 2003-2004. Environ Health Perspect, 116, 39-44.

Canas, A.I., Cervantes-Amat, M., Esteban, M., Ruiz-Moraga, M., Perez-Gomez, B., Mayor, J. & Castano, A. (2014) Blood lead levels in a representative sample

of the Spanish adult population: the BIOAMBIENT.ES project. Int J Hyg Environ Health, 217, 452-459.

Casteleyn, L. & Aerts, D. (2015) Guest Editorial. Harmonized human biomonitoring on a European scale: experiences in seventeen countries. Environ Res, 141, 1-2.

Casteleyn, L., Dumez, B., Becker, K., Kolossa-Gehring, M., Den Hond, E., Schoeters, G., Castano, A., Koch, H.M., Angerer, J., Esteban, M., Exley, K., Sepai, O., Bloemen, L., Horvat, M., Knudsen, L.E., Joas, A., Joas, R., Biot, P., Koppen, G., Dewolf, M.C., Katsonouri, A., Hadjipanayis, A., Cerna, M., Krskova, A., Schwedler, G., Fiddicke, U., Nielsen, J.K., Jensen, J.F., Rudnai, P., Kozepesy, S., Mulcahy, M., Mannion, R., Gutleb, A.C., Fischer, M.E., Ligocka, D., Jakubowski, M., Reis, M.F., Namorado, S., Lupsa, I.R., Gurzau, A.E., Halzlova, K., Jajcaj, M., Mazej, D., Tratnik Snoj, J., Posada, M., Lopez, E., Berglund, M., Larsson, K., Lehmann, A., Crettaz, P. & Aerts, D. (2015) A pilot study on the feasibility of European harmonized human biomonitoring: Strategies towards a common approach, challenges and opportunities. Environ Res, 141, 3-14.

CDC (2012) CDC Response to Advisory Committee on Childhood Lead Poisoning Prevention Recommendations in “Low Level Lead Exposure Harms Children: A Renewed Call of Primary Prevention”. https://www.cdc.gov/nceh/lead/acclpp/cdc_response_lead_exposure_recs.pdf

CDC (2017) Fourth National Report on Human Exposure to Environmental Chemicals, Updated Tables, January 2017, Volume One. https://www.cdc.gov/exposurereport/. In CDC: Centers for Disease Control and Prevention, U.S.D.o.H.a.H.S. (ed).

Cerna, M., Krskova, A., Cejchanova, M. & Spevackova, V. (2012) Human biomonitoring in the Czech Republic: an overview. Int J Hyg Environ Health, 215, 109-119.

Cerna, M., Spevackova, V., Batariova, A., Smid, J., Cejchanova, M., Ocadlikova, D., Bavorova, H., Benes, B. & Kubinova, R. (2007) Human biomonitoring system in the Czech Republic. Int J Hyg Environ Health, 210, 495-499.

Choi, W., Kim, S., Baek, Y.W., Choi, K., Lee, K. & Yu, S.D. (2016) Exposure to environmental chemicals among Korean adults-updates from the second Korean National Environmental Health Survey (2012-2014). Int J Hyg Environ Health.

Dekant, W. & Bridges, J. (2016) Assessment of reproductive and developmental effects of DINP, DnHP and DCHP using quantitative weight of evidence. Regul Toxicol Pharmacol, 81, 397-406.

Den Hond, E., Govarts, E., Willems, H., Smolders, R., Casteleyn, L., Kolossa-Gehring, M., Schwedler, G., Seiwert, M., Fiddicke, U., Castano, A., Esteban, M., Angerer, J., Koch, H.M., Schindler, B.K., Sepai, O., Exley, K., Bloemen,

L., Horvat, M., Knudsen, L.E., Joas, A., Joas, R., Biot, P., Aerts, D., Koppen, G., Katsonouri, A., Hadjipanayis, A., Krskova, A., Maly, M., Morck, T.A., Rudnai, P., Kozepesy, S., Mulcahy, M., Mannion, R., Gutleb, A.C., Fischer, M.E., Ligocka, D., Jakubowski, M., Reis, M.F., Namorado, S., Gurzau, A.E., Lupsa, I.R., Halzlova, K., Jajcaj, M., Mazej, D., Tratnik, J.S., Lopez, A., Lopez, E., Berglund, M., Larsson, K., Lehmann, A., Crettaz, P. & Schoeters, G. (2015) First steps toward harmonized human biomonitoring in Europe: demonstration project to perform human biomonitoring on a European scale. Environ Health Perspect, 123, 255-263.

Dewalque, L., Pirard, C. & Charlier, C. (2014) Measurement of urinary biomarkers of parabens, benzophenone-3, and phthalates in a Belgian population. Biomed Res Int, 2014, 649314.

Electoral Commission (2015), Report of the Electoral Commission on the 2014 General Election. http://www.elections.org.nz/sites/default/files/bulk-upload/documents/report_of_the_ec_on_the_2014_general_election.pdf.

EFSA (2016) http://www.efsa.europa.eu/en/topics/topic/bisphenol. Bisphenol A. European Food Safety Authority.

Frery, N., Vandentorren, S., Etchevers, A. & Fillol, C. (2012) Highlights of recent studies and future plans for the French human biomonitoring (HBM) programme. Int J Hyg Environ Health, 215, 127-132.

Gobas, F., Otton, S.V., Tupper-Ring, L.F., Crawford, M.A., Clark, K.E. & Ikonomou, M.G. (2017) Chemical activity-based environmental risk analysis of the plasticizer di-ethylhexyl phthalate and its main metabolite mono-ethylhexyl phthalate. Environ Toxicol Chem, 36, 1483-1492.

Gomez Ramos, M.J., Heffernan, A.L., Toms, L.M., Calafat, A.M., Ye, X., Hobson, P., Broomhall, S. & Mueller, J.F. (2016) Concentrations of phthalates and DINCH metabolites in pooled urine from Queensland, Australia. Environ Int, 88, 179-186.

Gonzalez, H., Farbrot, A., Larko, O. & Wennberg, A.M. (2006) Percutaneous absorption of the sunscreen benzophenone-3 after repeated whole-body applications, with and without ultraviolet irradiation. Br J Dermatol, 154, 337-340.

Ha, M., Kwon, H.J., Leem, J.H., Kim, H.C., Lee, K.J., Park, I., Lim, Y.W., Lee, J.H., Kim, Y., Seo, J.H., Hong, S.J., Choi, Y.H., Yu, J., Kim, J., Yu, S.D. & Lee, B.E. (2014) Korean Environmental Health Survey in Children and Adolescents (KorEHS-C): survey design and pilot study results on selected exposure biomarkers. Int J Hyg Environ Health, 217, 260-270.

Haines, D.A., Arbuckle, T.E., Lye, E., Legrand, M., Fisher, M., Langlois, R. & Fraser, W. (2011) Reporting results of human biomonitoring of environmental chemicals to study participants: a comparison of approaches followed in two Canadian studies. J Epidemiol Community Health, 65, 191-198.

Haines, D.A. & Murray, J. (2012) Human biomonitoring of environmental chemicals--early results of the 2007-2009 Canadian Health Measures Survey for males and females. Int J Hyg Environ Health, 215, 133-137.

Haines, D.A., Saravanabhavan, G., Werry, K. & Khoury, C. (2016) An overview of human biomonitoring of environmental chemicals in the Canadian Health Measures Survey: 2007-2019. Int J Hyg Environ Health.

Han, C., Lim, Y.H. & Hong, Y.C. (2016) Ten-year trends in urinary concentrations of triclosan and benzophenone-3 in the general U.S. population from 2003 to 2012. Environ Pollut, 208, 803-810.

Hata, A., Endo, Y., Nakajima, Y., Ikebe, M., Ogawa, M., Fujitani, N. & Endo, G. (2007) HPLC-ICP-MS speciation analysis of arsenic in urine of Japanese subjects without occupational exposure. J Occup Health, 49, 217-223.

Health Canada (2015). Third report on human biomonitoring of environmental chemicals in Canada. Results of the Canadian Health Measures Survey Cycle 3 (2012-2013). Ottawa.

Health Canada (2017). Fourth Report on Human Biomonitoring of Environmental Chemicals in Canada. Results of the Canadian Health Measures Survey Cycle 4 (2014-2015). Available on: canada.ca/biomonitoring.

Heffernan, A.L., Aylward, L.L., Toms, L.M., Eaglesham, G., Hobson, P., Sly, P.D. & Mueller, J.F. (2013) Age-related trends in urinary excretion of bisphenol A in Australian children and adults: evidence from a pooled sample study using samples of convenience. J Toxicol Environ Health A, 76, 1039-1055.

Heffernan, A.L., Baduel, C., Toms, L.M., Calafat, A.M., Ye, X., Hobson, P., Broomhall, S. & Mueller, J.F. (2015) Use of pooled samples to assess human exposure to parabens, benzophenone-3 and triclosan in Queensland, Australia. Environ Int, 85, 77-83.

Heintze, S.D., Bastos, J.R. & Bastos, R. (1998) Urinary fluoride levels and prevalence of dental fluorosis in three Brazilian cities with different fluoride concentrations in the drinking water. Community Dent Oral Epidemiol, 26, 316-323.

Hinton, D., Coope, P.A., Malpress, W.A. & Janus, E.D. (1986) Trends in blood lead levels in Christchurch (NZ) and environs 1978-85. J Epidemiol Community Health, 40, 244-248.

Hoet, P., Deumer, G., Bernard, A., Lison, D. & Haufroid, V. (2016) Urinary trace element concentrations in environmental settings: is there a value for systematic creatinine adjustment or do we introduce a bias? J Expo Sci Env Epid, 26, 296-302.

Hoet, P., Jacquerye, C., Deumer, G., Lison, D. & Haufroid, V. (2013) Reference values and upper reference limits for 26 trace elements in the urine of adults living in Belgium. Clin Chem Lab Med, 51, 839-849.

Hohenblum, P., Steinbichl, P., Raffesberg, W., Weiss, S., Moche, W., Vallant, B., Scharf, S., Haluza, D., Moshammer, H., Kundi, M., Piegler, B., Wallner, P. & Hutter, H.P. (2012) Pollution gets personal! A first population-based human biomonitoring study in Austria. Int J Hyg Environ Health, 215, 176-179.

Huang, P.C., Tsai, C.H., Liang, W.Y., Li, S.S., Pan, W.H. & Chiang, H.C. (2015) Age and Gender Differences in Urinary Levels of Eleven Phthalate Metabolites in General Taiwanese Population after a DEHP Episode. PLoS One, 10, e0133782.

Jones, R.L., Homa, D.M., Meyer, P.A., Brody, D.J., Caldwell, K.L., Pirkle, J.L. & Brown, M.J. (2009) Trends in blood lead levels and blood lead testing among US children aged 1 to 5 years, 1988-2004. Pediatrics, 123, e376-385.

Kasper-Sonnenberg, M., Koch, H.M., Wittsiepe, J. & Wilhelm, M. (2012) Levels of phthalate metabolites in urine among mother-child-pairs - results from the Duisburg birth cohort study, Germany. Int J Hyg Environ Health, 215, 373-382.

Kim, N.D. (2005) Cadmium accumulation in Waikato soils. Environment Waikato Technical Report 2005/51.

Kim, S.A., Kwon, Y., Kim, S. & Joung, H. (2016) Assessment of Dietary Mercury Intake and Blood Mercury Levels in the Korean Population: Results from the Korean National Environmental Health Survey 2012-2014. Int J Environ Res Public Health, 13.

Kolossa-Gehring, M., Becker, K., Conrad, A., Schroter-Kermani, C., Schulz, C. & Seiwert, M. (2012) Environmental surveys, specimen bank and health related environmental monitoring in Germany. Int J Hyg Environ Health, 215, 120-126.

Koniecki, D., Wang, R., Moody, R.P. & Zhu, J. (2011) Phthalates in cosmetic and personal care products: concentrations and possible dermal exposure. Environ Res, 111, 329-336.

Krause, M., Klit, A., Jensen, M.B., Soeborg, T., Frederiksen, H., Schlumpf, M., Lichtensteiger, W., Skakkebaek, N.E. & Drzewiecki, K.T. (2012) Sunscreens: are they beneficial for health? An overview of endocrine disrupting properties of UV-filters. Int J Androl, 35, 424-436.

Larsson, K., Lindh, C.H., Jonsson, B.A., Giovanoulis, G., Bibi, M., Bottai, M., Bergstrom, A. & Berglund, M. (2017) Phthalates, non-phthalate plasticizers and bisphenols in Swedish preschool dust in relation to children's exposure. Environ Int, 102, 114-124.

Lee, J.W., Lee, C.K., Moon, C.S., Choi, I.J., Lee, K.J., Yi, S.M., Jang, B.K., Yoon, B.J., Kim, D.S., Peak, D., Sul, D., Oh, E., Im, H., Kang, H.S., Kim, J., Lee, J.T., Kim, K., Park, K.L., Ahn, R., Park, S.H., Kim, S.C., Park, C.H. & Lee, J.H. (2012) Korea National Survey for Environmental Pollutants in the Human Body 2008: heavy metals in the blood or urine of the Korean population. Int J Hyg Environ Health, 215, 449-457.

Lee, S.R., Lee, C.K., Im, H., Yang, W., Urm, S.H., Yu, S.D., Lee, J.H., Suh, C.H., Kim, K.H., Son, B.C., Kim, J.H., Kim, S.Y., Lee, S.W. & Lee, J.T. (2014) Secondhand smoke exposure and urine cotinine concentrations by occupation among Korean workers: results from the 2008 Korea National Survey for Environmental Pollutants in the Human Body. J Occup Environ Hyg, 11, 314-325.

Lopez-Herranz, A., Cutanda, F., Esteban, M., Pollan, M., Calvo, E., Perez-Gomez, B., Victoria Cortes, M. & Castano, A. (2016) Cadmium levels in a representative sample of the Spanish adult population: The BIOAMBIENT.ES project. J Expo Sci Environ Epidemiol, 26, 471-480.

Lye, E., Legrand, M., Clarke, J. & Probert, A. (2013) Blood total mercury concentrations in the Canadian population: Canadian Health Measures Survey cycle 1, 2007-2009. Can J Public Health, 104, e246-251.

Mannetje, A., Coakley, J., Bridgen, P., Brooks, C., Harrad, S., Smith, A.H., Pearce, N. & Douwes, J. (2013) Current concentrations, temporal trends and determinants of persistent organic pollutants in breast milk of New Zealand women. Science of The Total Environment, 458-460, 399-407.

McKelvey, W., Gwynn, R.C., Jeffery, N., Kass, D., Thorpe, L.E., Garg, R.K., Palmer, C.D. & Parsons, P.J. (2007) A biomonitoring study of lead, cadmium, and mercury in the blood of New York city adults. Environ Health Perspect, 115, 1435-1441.

Ministry for the Environment (2011). Toxicological Intake Values for Priority Contaminants in Soil. Wellington: Ministry for the Environment, Wellington.

Morck, T.A., Nielsen, F., Nielsen, J.K., Jensen, J.F., Hansen, P.W., Hansen, A.K., Christoffersen, L.N., Siersma, V.D., Larsen, I.H., Hohlmann, L.K., Skaanild, M.T., Frederiksen, H., Biot, P., Casteleyn, L., Kolossa-Gehring, M., Schwedler, G., Castano, A., Angerer, J., Koch, H.M., Esteban, M., Schoeters, G., Den Hond, E., Exley, K., Sepai, O., Bloemen, L., Joas, R., Joas, A., Fiddicke, U., Lopez, A., Canas, A., Aerts, D. & Knudsen, L.E. (2015) The Danish contribution to the European DEMOCOPHES project: A description of cadmium, cotinine and mercury levels in Danish mother-child pairs and the perspectives of supplementary sampling and measurements. Environ Res, 141, 96-105.

Morton, J., Tan, E., Leese, E. & Cocker, J. (2014) Determination of 61 elements in urine samples collected from a non-occupationally exposed UK adult population. Toxicol Lett, 231, 179-193.

Navarro Serrano, I., Llorente Ballesteros, M.T., Sanchez Fernandez Pacheco, S., Izquierdo Alvarez, S. & Lopez Colon, J.L. (2016) Total and speciated urinary arsenic levels in the Spanish population. Sci Total Environ, 571, 164-171.

Nisse, C., Tagne-Fotso, R., Howsam, M., Richeval, C., Labat, L. & Leroyer, A. (2016) Blood and urinary levels of metals and metalloids in the general adult population of Northern France: The IMEPOGE study, 2008-2010. Int J Hyg Environ Health.

Perez-Gomez, B., Pastor-Barriuso, R., Cervantes-Amat, M., Esteban, M., Ruiz-Moraga, M., Aragones, N., Pollan, M., Navarro, C., Calvo, E., Roman, J., Lopez-Abente, G. & Castano, A. (2013) BIOAMBIENT.ES study protocol: rationale and design of a cross-sectional human biomonitoring survey in Spain. Environ Sci Pollut Res Int, 20, 1193-1202.

Pino, A., Amato, A., Alimonti, A., Mattei, D. & Bocca, B. (2012) Human biomonitoring for metals in Italian urban adolescents: data from Latium Region. Int J Hyg Environ Health, 215, 185-190.

Rango, T., Vengosh, A., Jeuland, M., Tekle-Haimanot, R., Weinthal, E., Kravchenko, J., Paul, C. & McCornick, P. (2014) Fluoride exposure from groundwater as reflected by urinary fluoride and children's dental fluorosis in the Main Ethiopian Rift Valley. Sci Total Environ, 496, 188-197.

Rocha, B.A., Asimakopoulos, A.G., Barbosa, F., Jr. & Kannan, K. (2017) Urinary concentrations of 25 phthalate metabolites in Brazilian children and their association with oxidative DNA damage. Sci Total Environ, 586, 152-162.

Royal Society of New Zealand (2014). Health effects of water fluoridation: A review of the scientific evidence. A report on behalf of the Royal Society of New Zealand and the Office of the Prime Minister’s Chief Science Advisor.

Saravanabhavan, G., Werry, K., Walker, M., Haines, D., Malowany, M. & Khoury, C. (2016) Human biomonitoring reference values for metals and trace elements in blood and urine derived from the Canadian Health Measures Survey 2007-2013. Int J Hyg Environ Health.

Schober, S.E., Sinks, T.H., Jones, R.L., Bolger, P.M., McDowell, M., Osterloh, J., Garrett, E.S., Canady, R.A., Dillon, C.F., Sun, Y., Joseph, C.B. & Mahaffey, K.R. (2003) Blood mercury levels in US children and women of childbearing age, 1999-2000. JAMA, 289, 1667-1674.

Schoeters, G., Den Hond, E., Colles, A., Loots, I., Morrens, B., Keune, H., Bruckers, L., Nawrot, T., Sioen, I., De Coster, S., Van Larebeke, N., Nelen, V., Van de Mieroop, E., Vrijens, J., Croes, K., Goeyens, K. & Baeyens, W. (2012) Concept of the Flemish human biomonitoring programme. Int J Hyg Environ Health, 215, 102-108.

Schulz, C., Angerer, J., Ewers, U. & Kolossa-Gehring, M. (2007a) The German Human Biomonitoring Commission. Int J Hyg Environ Health, 210, 373-382.

Schulz, C., Conrad, A., Becker, K., Kolossa-Gehring, M., Seiwert, M. & Seifert, B. (2007b) Twenty years of the German Environmental Survey (GerES): human biomonitoring--temporal and spatial (West Germany/East Germany) differences in population exposure. Int J Hyg Environ Health, 210, 271-297.

Schulz, C., Wilhelm, M., Heudorf, U. & Kolossa-Gehring, M. (2011) Update of the reference and HBM values derived by the German Human Biomonitoring Commission. Int J Hyg Environ Health, 215, 26-35.

Serrano, S.E., Braun, J., Trasande, L., Dills, R. & Sathyanarayana, S. (2014) Phthalates and diet: a review of the food monitoring and epidemiology data. Environ Health, 13, 43.

Singh, B., Gaur, S. & Garg, V.K. (2007) Fluoride in drinking water and human urine in Southern Haryana, India. J Hazard Mater, 144, 147-151.

Solberg, H.E. (1987) Approved Recommendation (1987) on the Theory of Reference Values .5. Statistical Treatment of Collected Reference Values - Determination of Reference Limits. Clin Chim Acta, 170, S13-S32.

Sorahan, T., Pang, D., Esmen, N. & Sadhra, S. (2008) Urinary concentrations of toxic substances: an assessment of alternative approaches to adjusting for specific gravity. J Occup Environ Hyg, 5, 721-723.

Sul, D., Ahn, R., Im, H., Oh, E., Kim, J.H., Kim, J.G., Kim, P., Kim, H.A., Park, W.Y., Son, B.S., Shin, D., Shim, A.S., Yang, W., Yu, S.D., Lee, K.H., Lee, K.J., Lee, S.D., Lee, J.W., Lee, C.K., Jang, B.K., Choi, K., Han, D.H., Hwang, M.Y. & Lee, J.H. (2012) Korea National Survey for Environmental Pollutants in the human body 2008: 1-hydroxypyrene, 2-naphthol, and cotinine in urine of the Korean population. Environ Res, 118, 25-30.

't Mannetje, A., Coakley, J., Bates, M., Borman, B. & Douwes, J. (2013) Concentrations of Selected Persistent Organic Pollutants (POPs) in the Serum of New Zealanders. Technical Report No. 34. A report for the Ministry of Health, Wellington. Prepared by the Centre for Public Health Research (CPHR), Massey University, Wellington.

Tagne-Fotso, R., Leroyer, A., Howsam, M., Dehon, B., Richeval, C. & Nisse, C. (2016) Current sources of lead exposure and their relative contributions to the blood lead levels in the general adult population of Northern France: The IMEPOGE Study, 2008-2010. J Toxicol Environ Health A, 79, 245-265.

Taylor, M.P., Winder, C. & Lanphear, B.P. (2014) Australia's leading public health body delays action on the revision of the public health goal for blood lead exposures. Environ Int, 70, 113-117.

Usuda, K., Kono, K., Shimbo, Y., Fujihara, M., Fujimoto, K., Kawano, A., Kono, R., Tsuji, H., Tanida, E., Imanishi, M., Fukuda, C., Suzuki, S. & Tanaka, H. (2007) Urinary fluoride reference values determined by a fluoride ion selective electrode. Biol Trace Elem Res, 119, 27-34.

Vine, M.F., Hulka, B.S., Margolin, B.H., Truong, Y.K., Hu, P.C., Schramm, M.M., Griffith, J.D., McCann, M. & Everson, R.B. (1993) Cotinine concentrations in semen, urine, and blood of smokers and nonsmokers. Am J Public Health, 83, 1335-1338.

Wang, L., Wu, Y., Zhang, W. & Kannan, K. (2013) Characteristic profiles of urinary p-hydroxybenzoic acid and its esters (parabens) in children and adults from the United States and China. Environ Sci Technol, 47, 2069-2076.

WHO (2011) Cadmium. Safety evaluation of certain food additives and contaminants (prepared by the 73rd meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA)). WHO Food Addtive Series: 64. Geneva: World Health Organization.

WHO (2016) Arsenic: Fact Sheet. http://www.who.int/mediacentre/factsheets/fs372/en/.

Xue, J., Wu, Q., Sakthivel, S., Pavithran, P.V., Vasukutty, J.R. & Kannan, K. (2015) Urinary levels of endocrine-disrupting chemicals, including bisphenols, bisphenol A diglycidyl ethers, benzophenones, parabens, and triclosan in obese and non-obese Indian children. Environ Res, 137, 120-128.

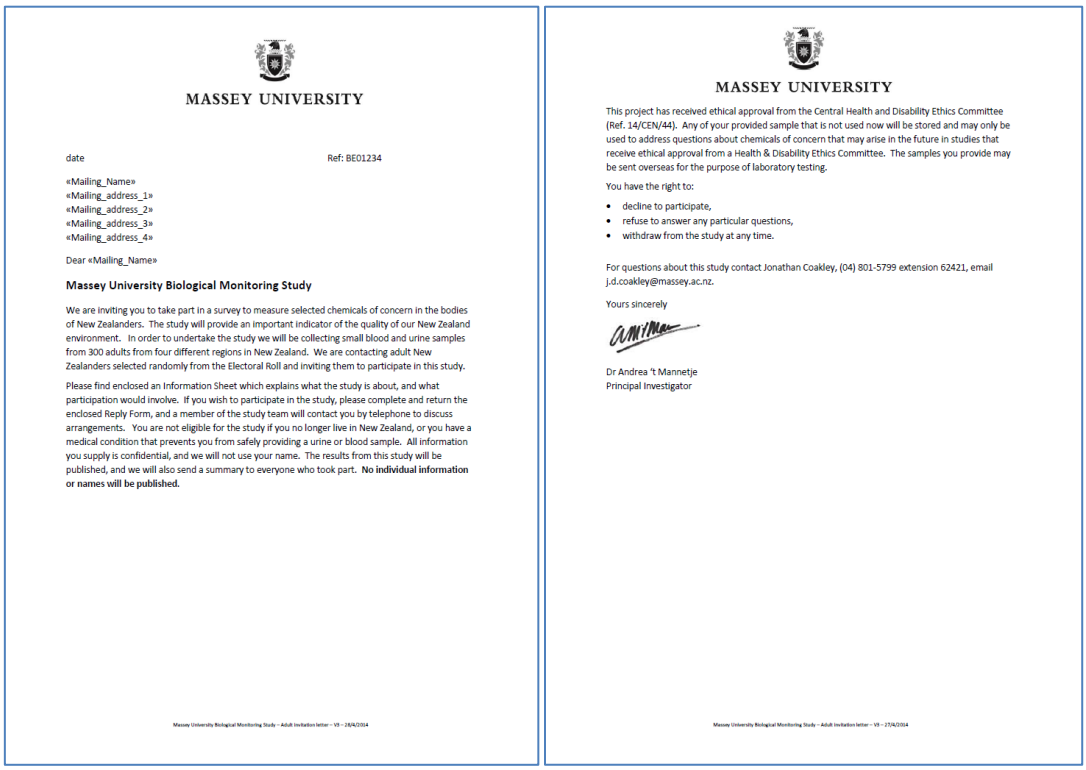
Zelenka, M.P., Barr, D.B., Nicolich, M.J., Lewis, R.J., Bird, M.G., Letinski, D.J., Metcalf, S.W. & O'Lone, R.B. (2011) A weight of evidence approach for selecting exposure biomarkers for biomonitoring. Biomarkers, 16, 65-73.

Zhang, L., Jiang, D.G., Sui, H.X., Wu, P.G., Liu, A.D., Yang da, J., Liu, Z.P., Song, Y. & Li, N. (2016) Dietary Exposure to Benzyl Butyl Phthalate in China. Biomed Environ Sci, 29, 365-373.

Appendix 1. Study materials

1.1- Adult invitation letter
1.2- Children invitation letter
1.3- Children School invitation letter
2.1- Adult Reply form
2.2- Children Reply form
3.1- Children Information Sheet
3.2- Children Parent information sheet
3.3- Adult information sheet
4.1- Adult Letter with instructions for sample collection
4.2- Children Letter with instructions for sample collection
5.1- Adult Instructions for urine collection
5.2- Children Instructions for urine collection
6.1- Adult consent form
6.2- Children consent form
7.1- Adult consent form storage future use
7.2- Children consent form storage future use
8.1- Adult Questionnaire
8.2- Children questionnaire
9.1- Adult clinical form
9.2- Children clinical form

1.1- Adult invitation letter



MASSEY UNIVERSITY

date Ref: BE01234

«Mailing_Name»
«Mailing_address_1»
«Mailing_address_2»
«Mailing_address_3»
«Mailing_address_4»

Dear «Mailing_Name»

Massey University Biological Monitoring Study

We are inviting you to take part in a survey to measure selected chemicals of concern in the bodies of New Zealanders. The study will provide an important indicator of the quality of our New Zealand environment. In order to undertake the study we will be collecting small blood and urine samples from 300 adults from four different regions in New Zealand. We are contacting adult New Zealanders selected randomly from the Electoral Roll and inviting them to participate in this study.

Please find enclosed an Information Sheet which explains what the study is about, and what participation would involve. If you wish to participate in the study, please complete and return the enclosed Reply Form, and a member of the study team will contact you by telephone to discuss arrangements. You are not eligible for the study if you no longer live in New Zealand, or you have a medical condition that prevents you from safely providing a urine or blood sample. All information you supply is confidential, and we will not use your name. The results from this study will be published, and we will also send a summary to everyone who took part. **No individual information or names will be published.**

Massey University Biological Monitoring Study – Adult invitation letter – V3 – 24/4/2014

MASSEY UNIVERSITY

This project has received ethical approval from the Central Health and Disability Ethics Committee (Ref. 14/CEN/44). Any of your provided sample that is not used now will be stored and may only be used to address questions about chemicals of concern that may arise in the future in studies that receive ethical approval from a Health & Disability Ethics Committee. The samples you provide may be sent overseas for the purpose of laboratory testing.

You have the right to:

- decline to participate,
- refuse to answer any particular questions,
- withdraw from the study at any time.

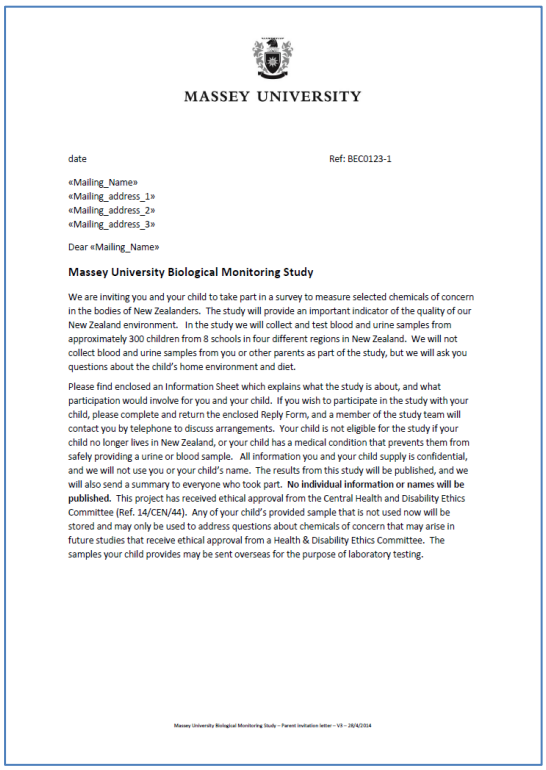
For questions about this study contact Jonathan Coakley, (04) 801-5799 extension 62421, email j.d.coakley@massey.ac.nz.

Yours sincerely

Dr Andrea 't Mannetje
Principal Investigator

Massey University Biological Monitoring Study – Adult invitation letter – V3 – 27/4/2014

1.2- Children invitation letter



MASSEY UNIVERSITY

date Ref: BEC0123-1

«Mailing_Name»
«Mailing_address_1»
«Mailing_address_2»
«Mailing_address_3»

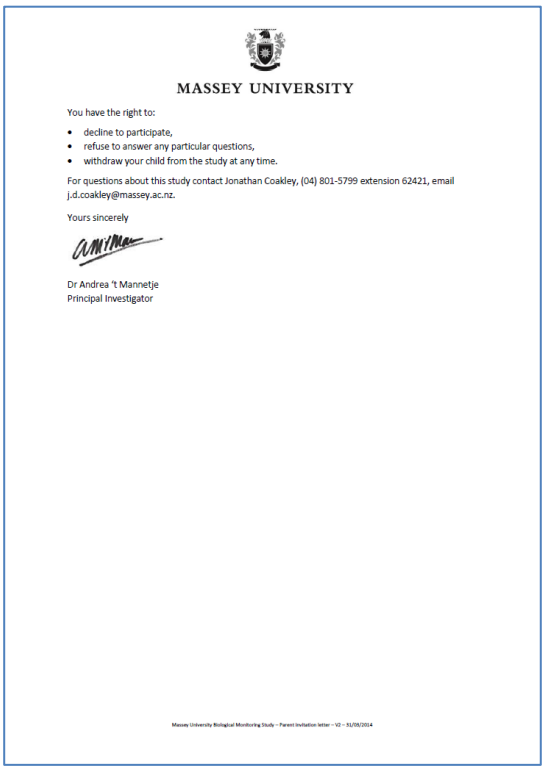
Dear «Mailing_Name»

Massey University Biological Monitoring Study

We are inviting you and your child to take part in a survey to measure selected chemicals of concern in the bodies of New Zealanders. The study will provide an important indicator of the quality of our New Zealand environment. In the study we will collect and test blood and urine samples from approximately 300 children from 8 schools in four different regions in New Zealand. We will not collect blood and urine samples from you or other parents as part of the study, but we will ask you questions about the child's home environment and diet.

Please find enclosed an Information Sheet which explains what the study is about, and what participation would involve for you and your child. If you wish to participate in the study with your child, please complete and return the enclosed Reply Form, and a member of the study team will contact you by telephone to discuss arrangements. Your child is not eligible for the study if your child no longer lives in New Zealand, or your child has a medical condition that prevents them from safely providing a urine or blood sample. All information you and your child supply is confidential, and we will not use you or your child's name. The results from this study will be published, and we will also send a summary to everyone who took part. **No individual information or names will be published.** This project has received ethical approval from the Central Health and Disability Ethics Committee (Ref. 14/CEN/44). Any of your child's provided sample that is not used now will be stored and may only be used to address questions about chemicals of concern that may arise in future studies that receive ethical approval from a Health & Disability Ethics Committee. The samples your child provides may be sent overseas for the purpose of laboratory testing.

Massey University Biological Monitoring Study – Parent invitation letter – V3 – 26/4/2014



MASSEY UNIVERSITY

You have the right to:

- decline to participate,
- refuse to answer any particular questions,
- withdraw your child from the study at any time.

For questions about this study contact Jonathan Coakley, (04) 801-5799 extension 62421, email j.d.coakley@massey.ac.nz.

Yours sincerely

Dr Andrea 't Mannetje
Principal Investigator

Massey University Biological Monitoring Study – Parent invitation letter – V2 – 31/03/2014

1.3- Children School invitation letter

MASSEY UNIVERSITY

date

[Insert Name]

Massey University Biological Monitoring Study

Massey University is organising a study into the concentrations of selected environmental chemicals in New Zealand children. In order to undertake the study we will be collecting blood and urine samples from approximately 300 children from schools in four different regions of New Zealand.

The compounds we will be testing for include metals (such as lead, mercury, arsenic), common additives to consumer products, and components of plastics. This will be the first study to measure these compounds in a representative sample of New Zealand children, and will provide an important indicator of the quality of our New Zealand environment. The results will be compared with those of other countries and will provide evidence for population health protection interventions. The study is endorsed and funded by the Ministry of Health, and has received ethical approval from the Central Health and Disability Ethics Committee (Ref. 14/CEN/44).

We are now at the stage of approaching schools to help us include 30 to 40 children from each school in the study. We would like to inform the children and their parents about the study through the school newsletter and invite them to participate by sending the study information to the parents. Please find enclosed an Information Pack which we need your help to give to parents explaining what the study is about, and what participation for them and their child will involve. To add an educational aspect to the study, we can also provide a classroom presentation related to environmental research in New Zealand.

The results of the study will be reported to the Ministry of Health and published in the scientific literature. All test results will be confidential, and names of schools and individuals will not be reported or published.

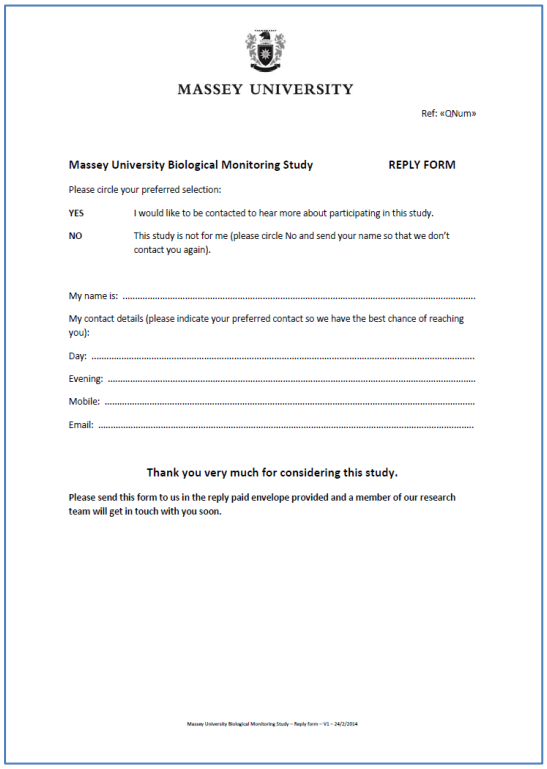
Thank you very much for considering this important study. Please contact the study coordinator Jonathan Coakley, 0800 328 284, email j.d.coakley@massey.ac.nz to discuss your school's involvement in the study, or if you have any questions or concerns.

Yours sincerely,

Jonathan Coakley
Study Coordinator

Massey University Biological Monitoring Study – School invitation letter – V3 – 28/4/14

2.1- Adult Reply form



MASSEY UNIVERSITY

Ref: «QNum»

Massey University Biological Monitoring Study **REPLY FORM**

Please circle your preferred selection:

YES I would like to be contacted to hear more about participating in this study.

NO This study is not for me (please circle No and send your name so that we don't contact you again).

My name is: .....

My contact details (please indicate your preferred contact so we have the best chance of reaching you):

Day: .....

Evening: .....

Mobile: .....

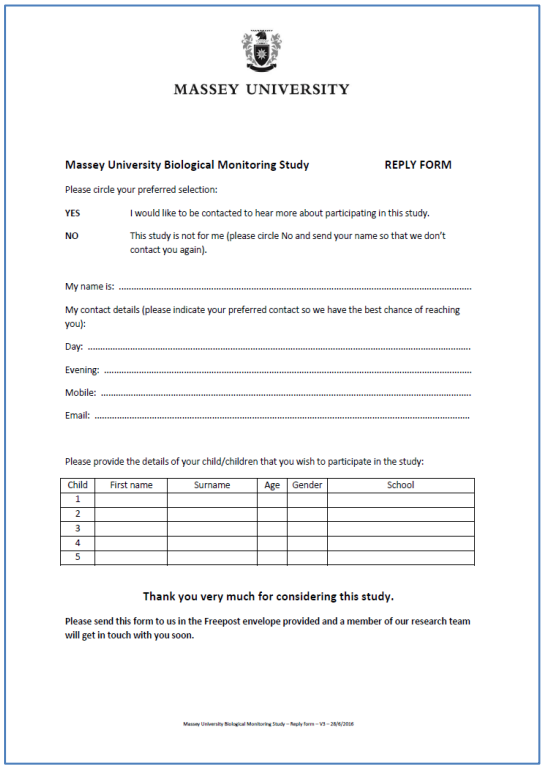
Email: .....

Thank you very much for considering this study.

Please send this form to us in the reply paid envelope provided and a member of our research team will get in touch with you soon.

Massey University Biological Monitoring Study – Reply form – V1 – 24/1/2014

2.2- Children Reply form



MASSEY UNIVERSITY

Massey University Biological Monitoring Study **REPLY FORM**

Please circle your preferred selection:

YES I would like to be contacted to hear more about participating in this study.

NO This study is not for me (please circle No and send your name so that we don't contact you again).

My name is: .....

My contact details (please indicate your preferred contact so we have the best chance of reaching you):

Day: .....

Evening: .....

Mobile: .....

Email: .....

Please provide the details of your child/children that you wish to participate in the study:

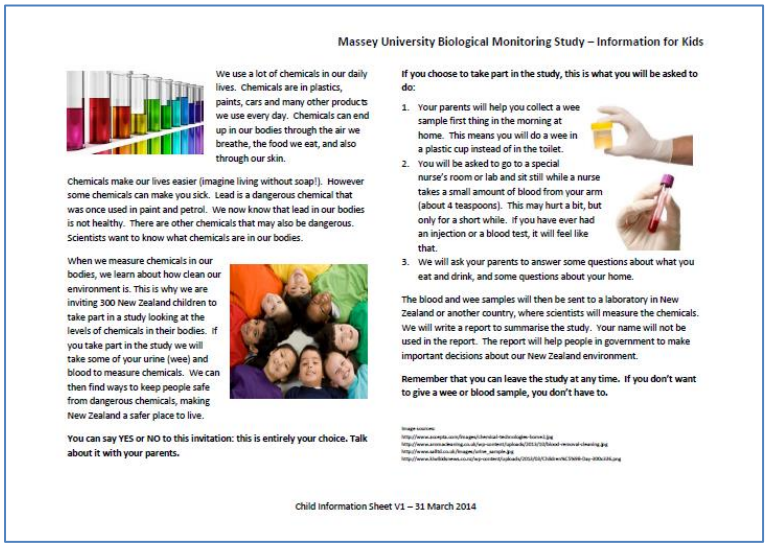
Child	First name	Surname	Age	Gender	School
1					
2					
3					
4					
5					

Thank you very much for considering this study.

Please send this form to us in the Freepost envelope provided and a member of our research team will get in touch with you soon.

Massey University Biological Monitoring Study – Reply form – V3 – 28/8/2016

3.1- Children Information Sheet



Massey University Biological Monitoring Study – Information for Kids

We use a lot of chemicals in our daily lives. Chemicals are in plastics, paints, cars and many other products we use every day. Chemicals can end up in our bodies through the air we breathe, the food we eat, and also through our skin.

Chemicals make our lives easier (imagine living without soap!). However some chemicals can make you sick. Lead is a dangerous chemical that was once used in paint and petrol. We now know that lead in our bodies is not healthy. There are other chemicals that may also be dangerous. Scientists want to know what chemicals are in our bodies.

When we measure chemicals in our bodies, we learn about how clean our environment is. This is why we are inviting 300 New Zealand children to take part in a study looking at the levels of chemicals in their bodies. If you take part in the study we will take some of your urine (wee) and blood to measure chemicals. We can then find ways to keep people safe from dangerous chemicals, making New Zealand a safer place to live.

You can say YES or NO to this invitation: this is entirely your choice. Talk about it with your parents.

If you choose to take part in the study, this is what you will be asked to do:

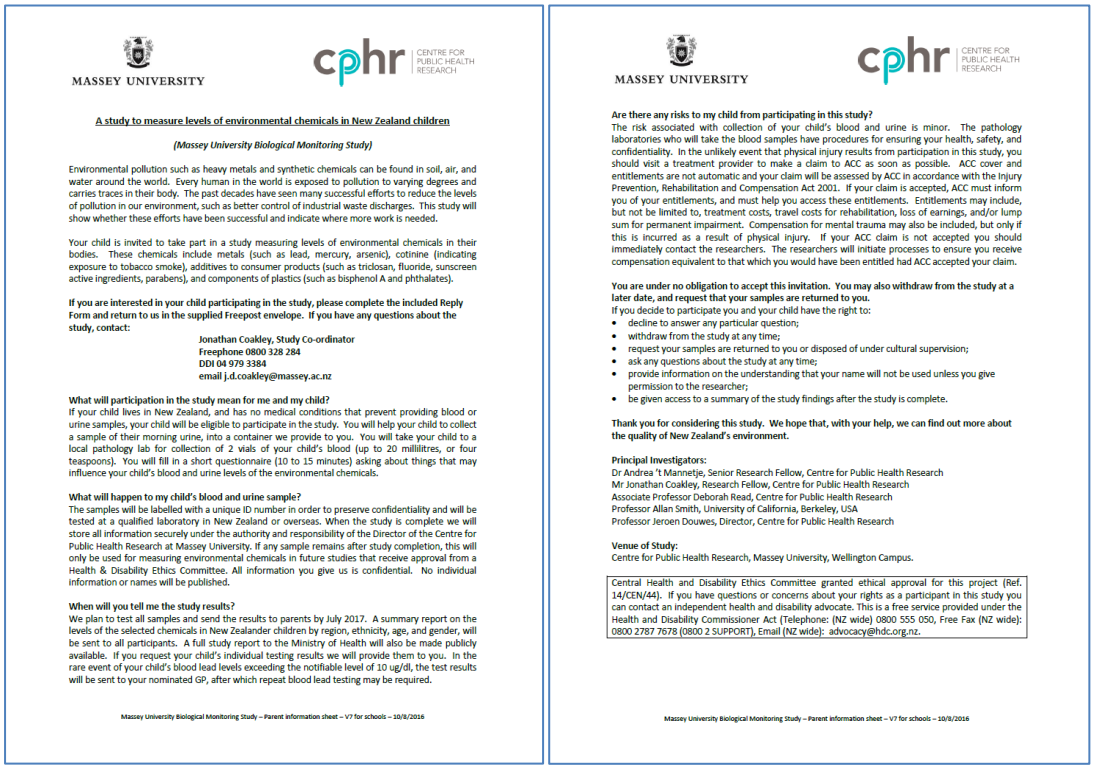
1. Your parents will help you collect a wee sample first thing in the morning at home. This means you will do a wee in a plastic cup instead of in the toilet.
2. You will be asked to go to a special nurse's room or lab and sit still while a nurse takes a small amount of blood from your arm (about 4 teaspoons). This may hurt a bit, but only for a short while. If you have ever had an injection or a blood test, it will feel like that.
3. We will ask your parents to answer some questions about what you eat and drink, and some questions about your home.

The blood and wee samples will then be sent to a laboratory in New Zealand or another country, where scientists will measure the chemicals. We will write a report to summarise the study. Your name will not be used in the report. The report will help people in government to make important decisions about our New Zealand environment.

Remember that you can leave the study at any time. If you don't want to give a wee or blood sample, you don't have to.

Child Information Sheet V1 – 31 March 2014

3.2- Children Parent information sheet



MASSEY UNIVERSITY

cphr CENTRE FOR PUBLIC HEALTH RESEARCH

A study to measure levels of environmental chemicals in New Zealand children

(Massey University Biological Monitoring Study)

Environmental pollution such as heavy metals and synthetic chemicals can be found in soil, air, and water around the world. Every human in the world is exposed to pollution to varying degrees and carries traces in their body. The past decades have seen many successful efforts to reduce the levels of pollution in our environment, such as better control of industrial waste discharges. This study will show whether these efforts have been successful and indicate where more work is needed.

Your child is invited to take part in a study measuring levels of environmental chemicals in their bodies. These chemicals include metals (such as lead, mercury, arsenic), cotinine (indicating exposure to tobacco smoke), additives to consumer products (such as triclosan, fluoride, sunscreen active ingredients, parabens), and components of plastics (such as bisphenol A and phthalates).

If you are interested in your child participating in the study, please complete the included Reply Form and return to us in the supplied Freepost envelope. If you have any questions about the study, contact:

Jonathan Coakley, Study Co-ordinator
Freephone 0800 328 284
DDI 04 979 3384
email j.d.coakley@massey.ac.nz

What will participation in the study mean for me and my child?
If your child lives in New Zealand, and has no medical conditions that prevent providing blood or urine samples, your child will be eligible to participate in the study. You will help your child to collect a sample of their morning urine, into a container we provide to you. You will take your child to a local pathology lab for collection of 2 vials of your child's blood (up to 20 millilitres, or four teaspoons). You will fill in a short questionnaire (10 to 15 minutes) asking about things that may influence your child's blood and urine levels of the environmental chemicals.

What will happen to my child's blood and urine sample?
The samples will be labelled with a unique ID number in order to preserve confidentiality and will be tested at a qualified laboratory in New Zealand or overseas. When the study is complete we will store all information securely under the authority and responsibility of the Director of the Centre for Public Health Research at Massey University. If any sample remains after study completion, this will only be used for measuring environmental chemicals in future studies that receive approval from a Health & Disability Ethics Committee. All information you give us is confidential. No individual information or names will be published.

When will you tell me the study results?
We plan to test all samples and send the results to parents by July 2017. A summary report on the levels of the selected chemicals in New Zealander children by region, ethnicity, age, and gender, will be sent to all participants. A full study report to the Ministry of Health will also be made publicly available. If you request your child's individual testing results we will provide them to you. In the rare event of your child's blood lead levels exceeding the notifiable level of 10 ug/dl, the test results will be sent to your nominated GP, after which repeat blood lead testing may be required.

MASSEY UNIVERSITY

cphr CENTRE FOR PUBLIC HEALTH RESEARCH

Are there any risks to my child from participating in this study?
The risk associated with collection of your child's blood and urine is minor. The pathology laboratories who will take the blood samples have procedures for ensuring your health, safety, and confidentiality. In the unlikely event that physical injury results from participation in this study, you should visit a treatment provider to make a claim to ACC as soon as possible. ACC cover and entitlements are not automatic and your claim will be assessed by ACC in accordance with the Injury Prevention, Rehabilitation and Compensation Act 2001. If your claim is accepted, ACC must inform you of your entitlements, and must help you access these entitlements. Entitlements may include, but not be limited to, treatment costs, travel costs for rehabilitation, loss of earnings, and/or lump sum for permanent impairment. Compensation for mental trauma may also be included, but only if this is incurred as a result of physical injury. If your ACC claim is not accepted you should immediately contact the researchers. The researchers will initiate processes to ensure you receive compensation equivalent to that which you would have been entitled had ACC accepted your claim.

You are under no obligation to accept this invitation. You may also withdraw from the study at a later date, and request that your samples are returned to you.
If you decide to participate you and your child have the right to:

- decline to answer any particular question;
- withdraw from the study at any time;
- request your samples are returned to you or disposed of under cultural supervision;
- ask any questions about the study at any time;
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- be given access to a summary of the study findings after the study is complete.

Thank you for considering this study. We hope that, with your help, we can find out more about the quality of New Zealand's environment.

Principal Investigators:
Dr Andrea 't Mannetje, Senior Research Fellow, Centre for Public Health Research
Mr Jonathan Coakley, Research Fellow, Centre for Public Health Research
Associate Professor Deborah Read, Centre for Public Health Research
Professor Allan Smith, University of California, Berkeley, USA
Professor Jeroen Douwes, Director, Centre for Public Health Research

Venue of Study:
Centre for Public Health Research, Massey University, Wellington Campus.

Central Health and Disability Ethics Committee granted ethical approval for this project (Ref. 14/CEN/44). If you have questions or concerns about your rights as a participant in this study you can contact an independent health and disability advocate. This is a free service provided under the Health and Disability Commissioner Act (Telephone: (NZ wide) 0800 555 050, Free Fax (NZ wide): 0800 2787 7678 (0800 2 SUPPORT), Email (NZ wide): advocacy@hdc.org.nz.

Massey University Biological Monitoring Study – Parent information sheet – V7 for schools – 10/8/2016

3.3- Adult information sheet

Massey University Biological Monitoring Study **INFORMATION SHEET**

Principal Investigators:
Dr Andrea 't Mannetje, Senior Research Fellow, Centre for Public Health Research
Mr Jonathan Coakley, Research Fellow, Centre for Public Health Research
Associate Professor Deborah Read, Centre for Public Health Research
Associate Professor Barry Borman, Centre for Public Health Research
Professor Allan Smith, University of California, Berkeley, USA
Professor Jeroen Douwes, Director, Centre for Public Health Research

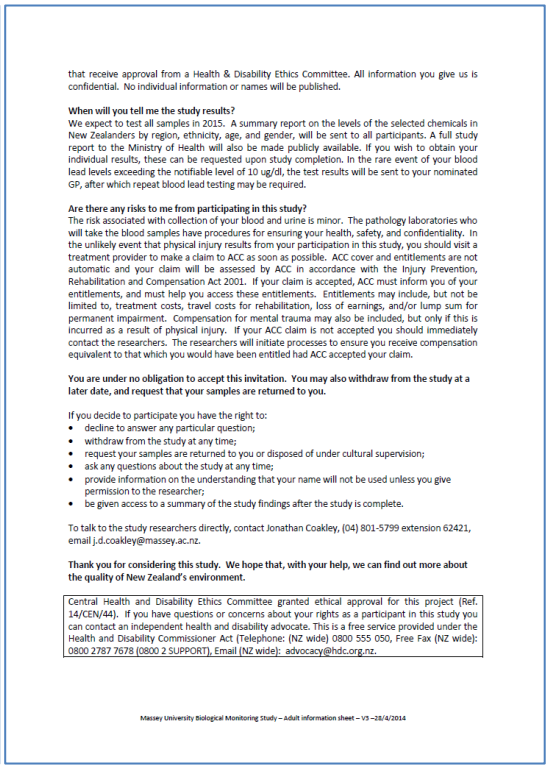
Venue of Study:
Centre for Public Health Research, Massey University, Wellington Campus.

What is this study all about?
You are invited to take part in a biological monitoring study, measuring concentrations of selected chemicals in the bodies of New Zealanders. The study will provide an important indicator of the quality of our New Zealand environment. Environmental pollution such as heavy metals and synthetic chemicals can be found in soil, air, and water around the world. Every human in the world is exposed to pollution to varying degrees and carries traces in their body. The past decades have seen many successful efforts to reduce the levels of pollution in our environment, such as better control of industrial waste discharges. This study will show whether these efforts have been successful and where more work is needed. In this study, blood and urine samples of 300 adults and 300 children from all over New Zealand will be tested for selected environmental compounds. These will include metals (such as lead, mercury, arsenic), cotinine (indicating exposure to tobacco smoke), additives to consumer products (such as triclosan, fluoride, sunscreen active ingredients, parabens), and components of plastics (such as bisphenol A and phthalates).

Why did you contact me?
We are contacting adult New Zealanders selected randomly from the most recent Electoral Roll and inviting them to participate in this study.

What will participation in the study mean for me?
If you are interested in hearing more about the study, a member of the research team will contact you by telephone to answer any questions you may have. If you live in New Zealand, and you have no medical conditions that prevent you from providing blood or urine samples, you will be eligible to participate in the study. If you are eligible and decide to participate, we will send you a package with materials for the study (e.g. urine collection container) and arrange a convenient time for you to visit a local pathology laboratory, where a nurse will collect 3 vials of blood (about 30 millilitres, or six teaspoons) from the inside of your arm. At home, you can self-collect a morning urine sample into the provided plastic container and store it in your freezer. You can bring the frozen urine sample to the pathology lab, from where both samples will be sent to Massey University. We will also ask you to complete a 15 minute questionnaire which will ask about things that may influence the blood and urine levels of common environmental compounds.

What will happen to my blood and urine sample?
Your samples will be labelled with a unique ID number in order to preserve your confidentiality. The samples will be tested at a qualified laboratory in New Zealand or overseas. When the study is complete we will store all your information securely under the authority and responsibility of the Director of the Centre for Public Health Research at Massey University. If any sample remains after study completion, this will only be used for measuring environmental chemicals in future studies



that receive approval from a Health & Disability Ethics Committee. All information you give us is confidential. No individual information or names will be published.

When will you tell me the study results?
We expect to test all samples in 2015. A summary report on the levels of the selected chemicals in New Zealanders by region, ethnicity, age, and gender, will be sent to all participants. A full study report to the Ministry of Health will also be made publicly available. If you wish to obtain your individual results, these can be requested upon study completion. In the rare event of your blood lead levels exceeding the notifiable level of 10 ug/dl, the test results will be sent to your nominated GP, after which repeat blood lead testing may be required.

Are there any risks to me from participating in this study?
The risk associated with collection of your blood and urine is minor. The pathology laboratories who will take the blood samples have procedures for ensuring your health, safety, and confidentiality. In the unlikely event that physical injury results from your participation in this study, you should visit a treatment provider to make a claim to ACC as soon as possible. ACC cover and entitlements are not automatic and your claim will be assessed by ACC in accordance with the Injury Prevention, Rehabilitation and Compensation Act 2001. If your claim is accepted, ACC must inform you of your entitlements, and must help you access these entitlements. Entitlements may include, but not be limited to, treatment costs, travel costs for rehabilitation, loss of earnings, and/or lump sum for permanent impairment. Compensation for mental trauma may also be included, but only if this is incurred as a result of physical injury. If your ACC claim is not accepted you should immediately contact the researchers. The researchers will initiate processes to ensure you receive compensation equivalent to that which you would have been entitled had ACC accepted your claim.

You are under no obligation to accept this invitation. You may also withdraw from the study at a later date, and request that your samples are returned to you.

If you decide to participate you have the right to:
- decline to answer any particular question;
- withdraw from the study at any time;
- request your samples are returned to you or disposed of under cultural supervision;
- ask any questions about the study at any time;
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- be given access to a summary of the study findings after the study is complete.

To talk to the study researchers directly, contact Jonathan Coakley, (04) 801-5799 extension 62421, email j.d.coakley@massey.ac.nz.

Thank you for considering this study. We hope that, with your help, we can find out more about the quality of New Zealand's environment.

Central Health and Disability Ethics Committee granted ethical approval for this project (Ref. 14/CEN/44). If you have questions or concerns about your rights as a participant in this study you can contact an independent health and disability advocate. This is a free service provided under the Health and Disability Commissioner Act (Telephone: (NZ wide) 0800 555 050, Free Fax (NZ wide): 0800 2787 7678 (0800 2 SUPPORT), Email (NZ wide): advocacy@hdc.org.nz.

4.1- Adult Letter with instructions for sample collection

MASSEY UNIVERSITY

date

Ref: BE01234

«Mailing_Name»
«Mailing_address_1»
«Mailing_address_2»
«Mailing_address_3»
«Mailing_address_4»

Dear «Mailing_Name»

Massey University Biological Monitoring Study

Thank you for agreeing to participate in our study! Your participation means that we will get a better picture of the level of selected chemicals of concern in New Zealanders, and will guide policy to minimise the potential risk of these chemicals in the future.

Please visit the following pathology laboratory to have your blood sample collected within 5 days of receiving this letter:

[name and address]

You do not need to fast prior to providing the blood sample. If it is not convenient for you to attend this pathology laboratory you can call us and we will find a more convenient one for you.

We have also provided you with a urine sample collection container and instructions for self-collecting a morning urine sample. Make sure that you send us the urine sample on the same day it is collected. Also complete the included Questionnaire, two Consent Forms, and Gift voucher signing slip and return to us in the provided Freepost envelope.

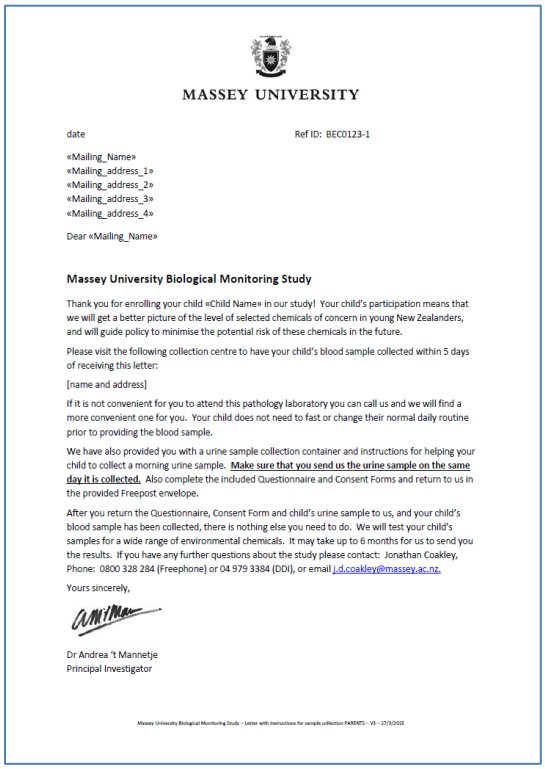
After you return the Questionnaire, Consent Forms, and self-collected urine sample to us, and your blood sample has been collected, there is nothing else you need to do. If you have any further questions about the study please contact: Jonathan Coakley, Phone: 0800 328 284 (Freephone) or 04 979 3384 (DDI), or email j.d.coakley@massey.ac.nz.

Yours sincerely

Dr Andrea 't Mannetje
Principal Investigator

Massey University Biological Monitoring Study – Letter with instructions for sample collection – V3 – 7/10/2015

4.2- Children Letter with instructions for sample collection



MASSEY UNIVERSITY

date Ref ID: BEC0123-1

«Mailing_Name»
«Mailing_address_1»
«Mailing_address_2»
«Mailing_address_3»
«Mailing_address_4»

Dear «Mailing_Name»

Massey University Biological Monitoring Study

Thank you for enrolling your child «Child Name» in our study! Your child's participation means that we will get a better picture of the level of selected chemicals of concern in young New Zealanders, and will guide policy to minimise the potential risk of these chemicals in the future.

Please visit the following collection centre to have your child's blood sample collected within 5 days of receiving this letter:

[name and address]

If it is not convenient for you to attend this pathology laboratory you can call us and we will find a more convenient one for you. Your child does not need to fast or change their normal daily routine prior to providing the blood sample.

We have also provided you with a urine sample collection container and instructions for helping your child to collect a morning urine sample. **Make sure that you send us the urine sample on the same day it is collected.** Also complete the included Questionnaire and Consent Forms and return to us in the provided Freepost envelope.

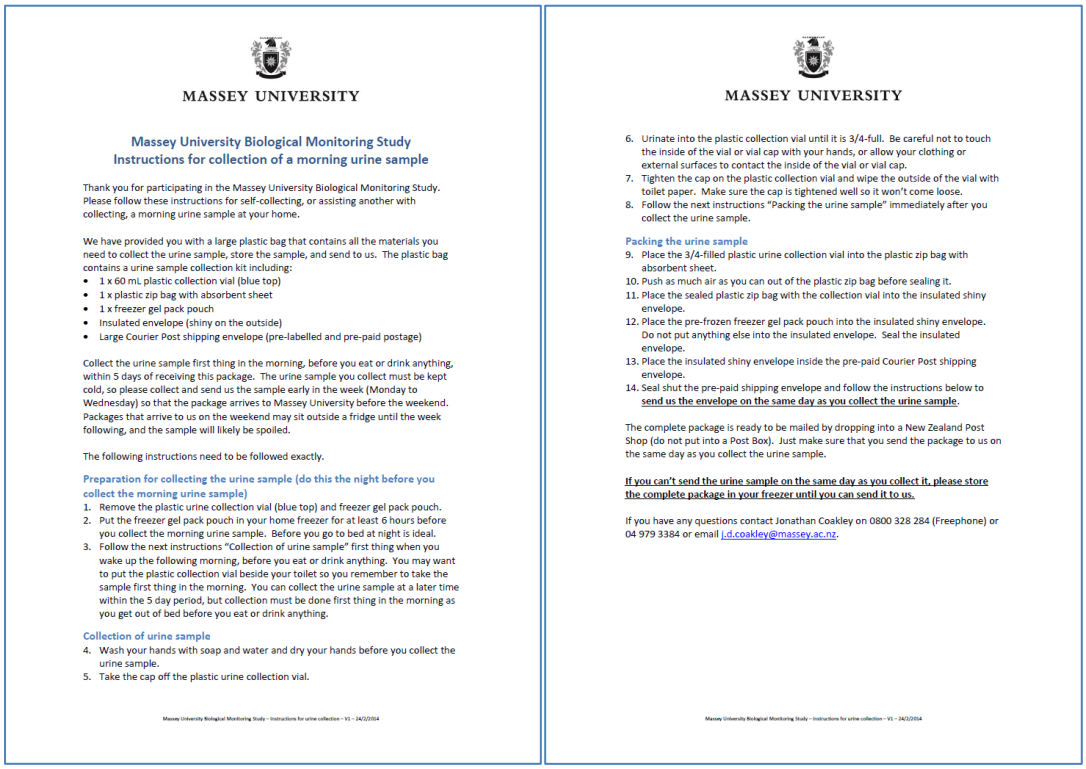
After you return the Questionnaire, Consent Form and child's urine sample to us, and your child's blood sample has been collected, there is nothing else you need to do. We will test your child's samples for a wide range of environmental chemicals. It may take up to 6 months for us to send you the results. If you have any further questions about the study please contact: Jonathan Coakley, Phone: 0800 328 284 (Freephone) or 04 979 3384 (DDI), or email j.d.coakley@massey.ac.nz.

Yours sincerely,

Dr Andrea 't Mannetje
Principal Investigator

Massey University Biological Monitoring Study – Letter with instructions for sample collection PARENTS – V3 – 27/3/2015

5.1- Adult Instructions for urine collection



MASSEY UNIVERSITY

Massey University Biological Monitoring Study
Instructions for collection of a morning urine sample

Thank you for participating in the Massey University Biological Monitoring Study. Please follow these instructions for self-collecting, or assisting another with collecting, a morning urine sample at your home.

We have provided you with a large plastic bag that contains all the materials you need to collect the urine sample, store the sample, and send to us. The plastic bag contains a urine sample collection kit including:

- 1 x 60 mL plastic collection vial (blue top)
- 1 x plastic zip bag with absorbent sheet
- 1 x freezer gel pack pouch
- Insulated envelope (shiny on the outside)
- Large Courier Post shipping envelope (pre-labelled and pre-paid postage)

Collect the urine sample first thing in the morning, before you eat or drink anything, within 5 days of receiving this package. The urine sample you collect must be kept cold, so please collect and send us the sample early in the week (Monday to Wednesday) so that the package arrives to Massey University before the weekend. Packages that arrive to us on the weekend may sit outside a fridge until the week following, and the sample will likely be spoiled.

The following instructions need to be followed exactly.

Preparation for collecting the urine sample (do this the night before you collect the morning urine sample)

1. Remove the plastic urine collection vial (blue top) and freezer gel pack pouch.
2. Put the freezer gel pack pouch in your home freezer for at least 6 hours before you collect the morning urine sample. Before you go to bed at night is ideal.
3. Follow the next instructions "Collection of urine sample" first thing when you wake up the following morning, before you eat or drink anything. You may want to put the plastic collection vial beside your toilet so you remember to take the sample first thing in the morning. You can collect the urine sample at a later time within the 5 day period, but collection must be done first thing in the morning as you get out of bed before you eat or drink anything.

Collection of urine sample

4. Wash your hands with soap and water and dry your hands before you collect the urine sample.
5. Take the cap off the plastic urine collection vial.

MASSEY UNIVERSITY

6. Urinate into the plastic collection vial until it is 3/4-full. Be careful not to touch the inside of the vial or vial cap with your hands, or allow your clothing or external surfaces to contact the inside of the vial or vial cap.
7. Tighten the cap on the plastic collection vial and wipe the outside of the vial with toilet paper. Make sure the cap is tightened well so it won't come loose.
8. Follow the next instructions "Packing the urine sample" immediately after you collect the urine sample.

Packing the urine sample

9. Place the 3/4-filled plastic urine collection vial into the plastic zip bag with absorbent sheet.
10. Push as much air as you can out of the plastic zip bag before sealing it.
11. Place the sealed plastic zip bag with the collection vial into the insulated shiny envelope.
12. Place the pre-frozen freezer gel pack pouch into the insulated shiny envelope. Do not put anything else into the insulated envelope. Seal the insulated envelope.
13. Place the insulated shiny envelope inside the pre-paid Courier Post shipping envelope.
14. Seal shut the pre-paid shipping envelope and follow the instructions below to **send us the envelope on the same day as you collect the urine sample**.

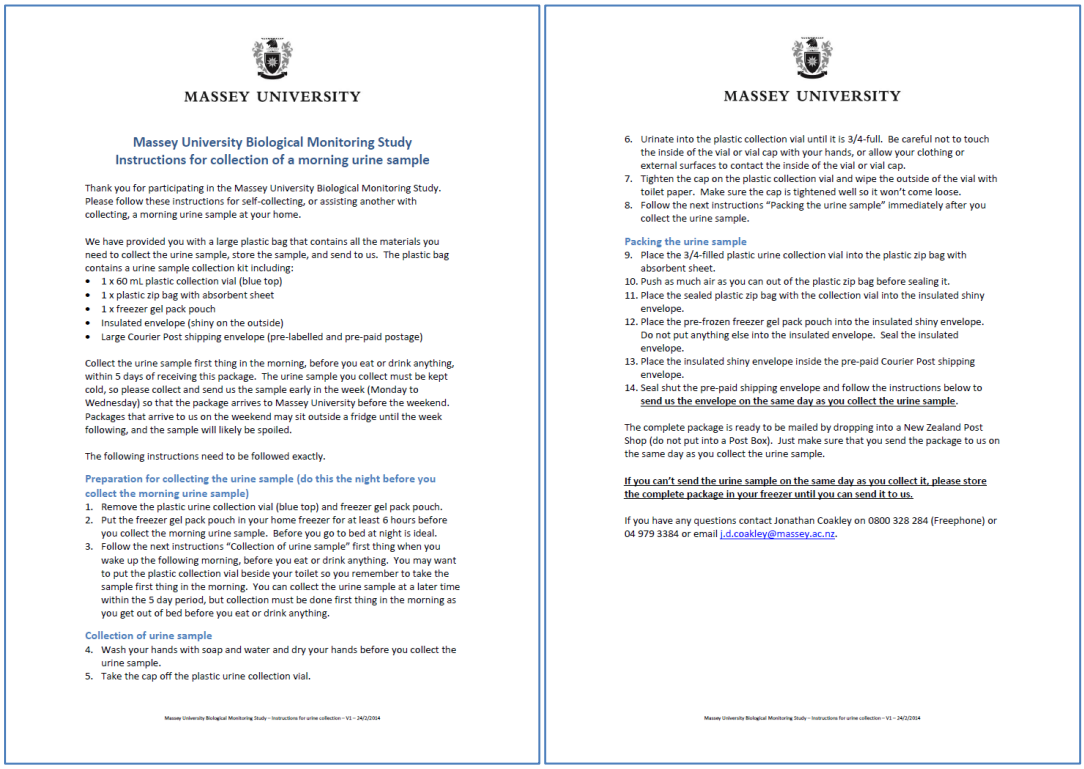
The complete package is ready to be mailed by dropping into a New Zealand Post Shop (do not put into a Post Box). Just make sure that you send the package to us on the same day as you collect the urine sample.

If you can't send the urine sample on the same day as you collect it, please store the complete package in your freezer until you can send it to us.

If you have any questions contact Jonathan Coakley on 0800 328 284 (Freephone) or 04 979 3384 or email j.d.coakley@massey.ac.nz.

Massey University Biological Monitoring Study – Instructions for urine collection – V1 – 24/2/2014

5.2- Children Instructions for urine collection



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Massey University Biological Monitoring Study
Instructions for collection of a morning urine sample

Thank you for participating in the Massey University Biological Monitoring Study. Please follow these instructions for self-collecting, or assisting another with collecting, a morning urine sample at your home.

We have provided you with a large plastic bag that contains all the materials you need to collect the urine sample, store the sample, and send to us. The plastic bag contains a urine sample collection kit including:

- 1 x 60 mL plastic collection vial (blue top)
- 1 x plastic zip bag with absorbent sheet
- 1 x freezer gel pack pouch
- Insulated envelope (shiny on the outside)
- Large Courier Post shipping envelope (pre-labelled and pre-paid postage)

Collect the urine sample first thing in the morning, before you eat or drink anything, within 5 days of receiving this package. The urine sample you collect must be kept cold, so please collect and send us the sample early in the week (Monday to Wednesday) so that the package arrives to Massey University before the weekend. Packages that arrive to us on the weekend may sit outside a fridge until the week following, and the sample will likely be spoiled.

The following instructions need to be followed exactly.

Preparation for collecting the urine sample (do this the night before you collect the morning urine sample)

1. Remove the plastic urine collection vial (blue top) and freezer gel pack pouch.
2. Put the freezer gel pack pouch in your home freezer for at least 6 hours before you collect the morning urine sample. Before you go to bed at night is ideal.
3. Follow the next instructions "Collection of urine sample" first thing when you wake up the following morning, before you eat or drink anything. You may want to put the plastic collection vial beside your toilet so you remember to take the sample first thing in the morning. You can collect the urine sample at a later time within the 5 day period, but collection must be done first thing in the morning as you get out of bed before you eat or drink anything.

Collection of urine sample

4. Wash your hands with soap and water and dry your hands before you collect the urine sample.
5. Take the cap off the plastic urine collection vial.

Massey University Biological Monitoring Study – Instructions for urine collection – V1 – 24/2/2014

MASSEY UNIVERSITY

6. Urinate into the plastic collection vial until it is 3/4-full. Be careful not to touch the inside of the vial or vial cap with your hands, or allow your clothing or external surfaces to contact the inside of the vial or vial cap.
7. Tighten the cap on the plastic collection vial and wipe the outside of the vial with toilet paper. Make sure the cap is tightened well so it won't come loose.
8. Follow the next instructions "Packing the urine sample" immediately after you collect the urine sample.

Packing the urine sample

9. Place the 3/4-filled plastic urine collection vial into the plastic zip bag with absorbent sheet.
10. Push as much air as you can out of the plastic zip bag before sealing it.
11. Place the sealed plastic zip bag with the collection vial into the insulated shiny envelope.
12. Place the pre-frozen freezer gel pack pouch into the insulated shiny envelope. Do not put anything else into the insulated envelope. Seal the insulated envelope.
13. Place the insulated shiny envelope inside the pre-paid Courier Post shipping envelope.
14. Seal shut the pre-paid shipping envelope and follow the instructions below to **send us the envelope on the same day as you collect the urine sample**.

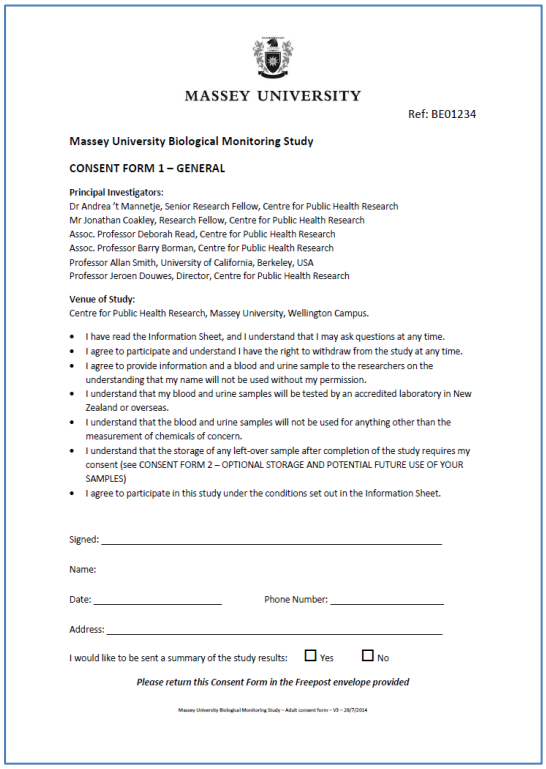
The complete package is ready to be mailed by dropping into a New Zealand Post Shop (do not put into a Post Box). Just make sure that you send the package to us on the same day as you collect the urine sample.

If you can't send the urine sample on the same day as you collect it, please store the complete package in your freezer until you can send it to us.

If you have any questions contact Jonathan Coakley on 0800 328 284 (Freephone) or 04 979 3384 or email j.d.coakley@massey.ac.nz.

Massey University Biological Monitoring Study – Instructions for urine collection – V1 – 24/2/2014

6.1- Adult consent form



MASSEY UNIVERSITY

Ref: BE01234

Massey University Biological Monitoring Study

CONSENT FORM 1 – GENERAL

Principal Investigators:
Dr Andrea 't Mannetje, Senior Research Fellow, Centre for Public Health Research
Mr Jonathan Coakley, Research Fellow, Centre for Public Health Research
Assoc. Professor Deborah Read, Centre for Public Health Research
Assoc. Professor Barry Borman, Centre for Public Health Research
Professor Allan Smith, University of California, Berkeley, USA
Professor Jeroen Douwes, Director, Centre for Public Health Research

Venue of Study:
Centre for Public Health Research, Massey University, Wellington Campus.

- I have read the Information Sheet, and I understand that I may ask questions at any time.
- I agree to participate and understand I have the right to withdraw from the study at any time.
- I agree to provide information and a blood and urine sample to the researchers on the understanding that my name will not be used without my permission.
- I understand that my blood and urine samples will be tested by an accredited laboratory in New Zealand or overseas.
- I understand that the blood and urine samples will not be used for anything other than the measurement of chemicals of concern.
- I understand that the storage of any left-over sample after completion of the study requires my consent (see CONSENT FORM 2 – OPTIONAL STORAGE AND POTENTIAL FUTURE USE OF YOUR SAMPLES)
- I agree to participate in this study under the conditions set out in the Information Sheet.

Signed: _____

Name:

Date: _____ Phone Number: _____

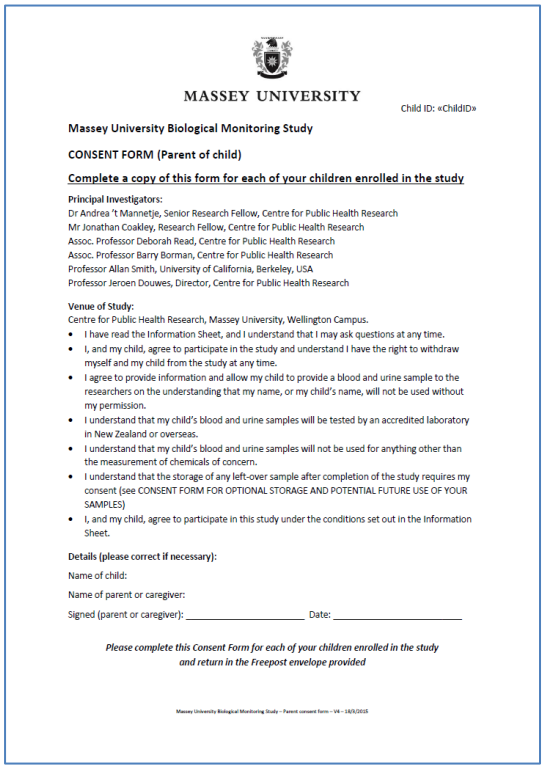
Address: _____

I would like to be sent a summary of the study results: ☐ Yes ☐ No

Please return this Consent Form in the Freepost envelope provided

Massey University Biological Monitoring Study – Adult consent form – V3 – 28/7/2014

6.2- Children consent form



MASSEY UNIVERSITY

Child ID: «ChildID»

Massey University Biological Monitoring Study

CONSENT FORM (Parent of child)

Complete a copy of this form for each of your children enrolled in the study

Principal Investigators:
Dr Andrea 't Mannetje, Senior Research Fellow, Centre for Public Health Research
Mr Jonathan Coakley, Research Fellow, Centre for Public Health Research
Assoc. Professor Deborah Read, Centre for Public Health Research
Assoc. Professor Barry Borman, Centre for Public Health Research
Professor Allan Smith, University of California, Berkeley, USA
Professor Jeroen Douwes, Director, Centre for Public Health Research

Venue of Study:
Centre for Public Health Research, Massey University, Wellington Campus.

- I have read the Information Sheet, and I understand that I may ask questions at any time.
- I, and my child, agree to participate in the study and understand I have the right to withdraw myself and my child from the study at any time.
- I agree to provide information and allow my child to provide a blood and urine sample to the researchers on the understanding that my name, or my child's name, will not be used without my permission.
- I understand that my child's blood and urine samples will be tested by an accredited laboratory in New Zealand or overseas.
- I understand that my child's blood and urine samples will not be used for anything other than the measurement of chemicals of concern.
- I understand that the storage of any left-over sample after completion of the study requires my consent (see CONSENT FORM FOR OPTIONAL STORAGE AND POTENTIAL FUTURE USE OF YOUR SAMPLES)
- I, and my child, agree to participate in this study under the conditions set out in the Information Sheet.

Details (please correct if necessary):

Name of child:

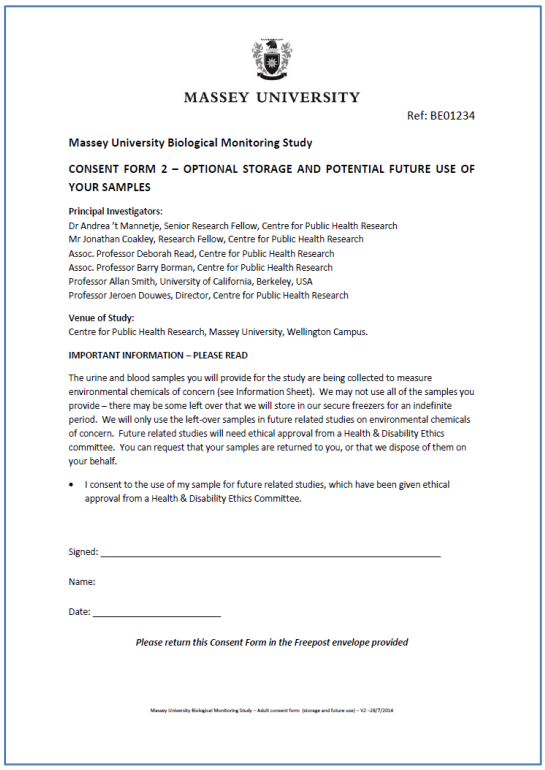
Name of parent or caregiver:

Signed (parent or caregiver): _____ Date: _____

Please complete this Consent Form for each of your children enrolled in the study and return in the Freepost envelope provided

Massey University Biological Monitoring Study – Parent consent form – V4 – 18/8/2015

7.1- Adult consent form storage future use



MASSEY UNIVERSITY

Ref: BE01234

Massey University Biological Monitoring Study

CONSENT FORM 2 – OPTIONAL STORAGE AND POTENTIAL FUTURE USE OF YOUR SAMPLES

Principal Investigators:
Dr Andrea 't Mannetje, Senior Research Fellow, Centre for Public Health Research
Mr Jonathan Coakley, Research Fellow, Centre for Public Health Research
Assoc. Professor Deborah Read, Centre for Public Health Research
Assoc. Professor Barry Borman, Centre for Public Health Research
Professor Allan Smith, University of California, Berkeley, USA
Professor Jeroen Douwes, Director, Centre for Public Health Research

Venue of Study:
Centre for Public Health Research, Massey University, Wellington Campus.

IMPORTANT INFORMATION – PLEASE READ

The urine and blood samples you will provide for the study are being collected to measure environmental chemicals of concern (see Information Sheet). We may not use all of the samples you provide – there may be some left over that we will store in our secure freezers for an indefinite period. We will only use the left-over samples in future related studies on environmental chemicals of concern. Future related studies will need ethical approval from a Health & Disability Ethics committee. You can request that your samples are returned to you, or that we dispose of them on your behalf.

- I consent to the use of my sample for future related studies, which have been given ethical approval from a Health & Disability Ethics Committee.

Signed: _____

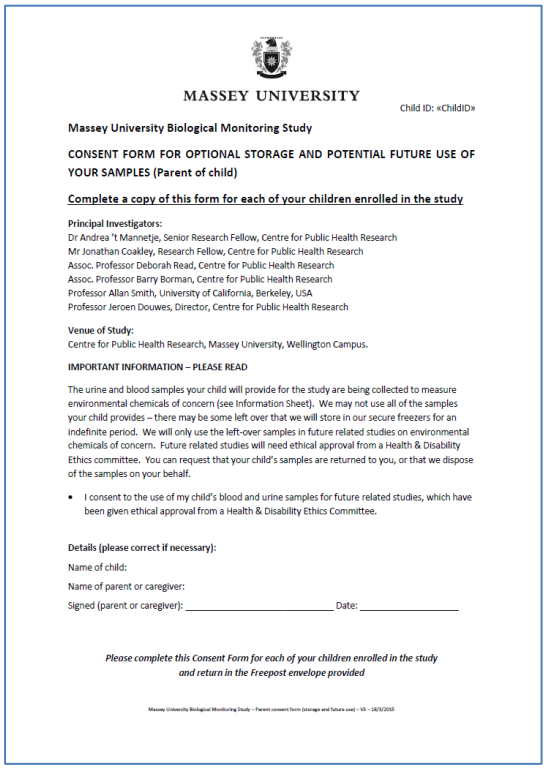
Name:

Date: _____

Please return this Consent Form in the Freepost envelope provided

Massey University Biological Monitoring Study – Adult consent form (storage and future use) – V2 –28/7/2014

7.2- Children consent form storage future use



MASSEY UNIVERSITY

Child ID: «ChildID»

Massey University Biological Monitoring Study

CONSENT FORM FOR OPTIONAL STORAGE AND POTENTIAL FUTURE USE OF YOUR SAMPLES (Parent of child)

Complete a copy of this form for each of your children enrolled in the study

Principal Investigators:
Dr Andrea 't Mannetje, Senior Research Fellow, Centre for Public Health Research
Mr Jonathan Coakley, Research Fellow, Centre for Public Health Research
Assoc. Professor Deborah Read, Centre for Public Health Research
Assoc. Professor Barry Borman, Centre for Public Health Research
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Venue of Study:
Centre for Public Health Research, Massey University, Wellington Campus.

IMPORTANT INFORMATION – PLEASE READ

The urine and blood samples your child will provide for the study are being collected to measure environmental chemicals of concern (see Information Sheet). We may not use all of the samples your child provides – there may be some left over that we will store in our secure freezers for an indefinite period. We will only use the left-over samples in future related studies on environmental chemicals of concern. Future related studies will need ethical approval from a Health & Disability Ethics committee. You can request that your child's samples are returned to you, or that we dispose of the samples on your behalf.

- I consent to the use of my child's blood and urine samples for future related studies, which have been given ethical approval from a Health & Disability Ethics Committee.

Details (please correct if necessary):

Name of child:

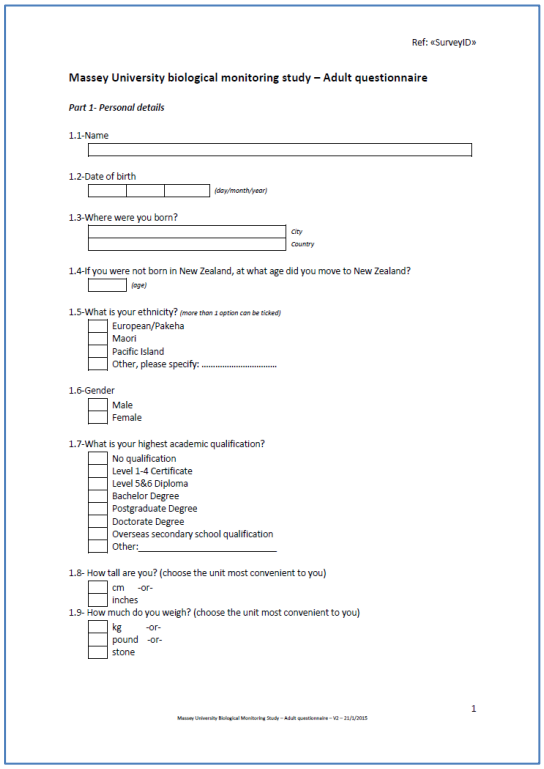
Name of parent or caregiver:

Signed (parent or caregiver): _____ Date: _____

Please complete this Consent Form for each of your children enrolled in the study and return in the Freepost envelope provided

Massey University Biological Monitoring Study – Parent consent form (storage and future use) – V3 – 18/3/2015

8.1- Adult Questionnaire



Ref: «SurveyID»

Massey University biological monitoring study – Adult questionnaire

Part 1- Personal details

1.1-Name

1.2-Date of birth
(day/month/year)

1.3-Where were you born?
City
Country

1.4-If you were not born in New Zealand, at what age did you move to New Zealand?
(age)

1.5-What is your ethnicity? *(more than 1 option can be ticked)*
- European/Pakeha
- Maori
- Pacific Island
- Other, please specify: .....

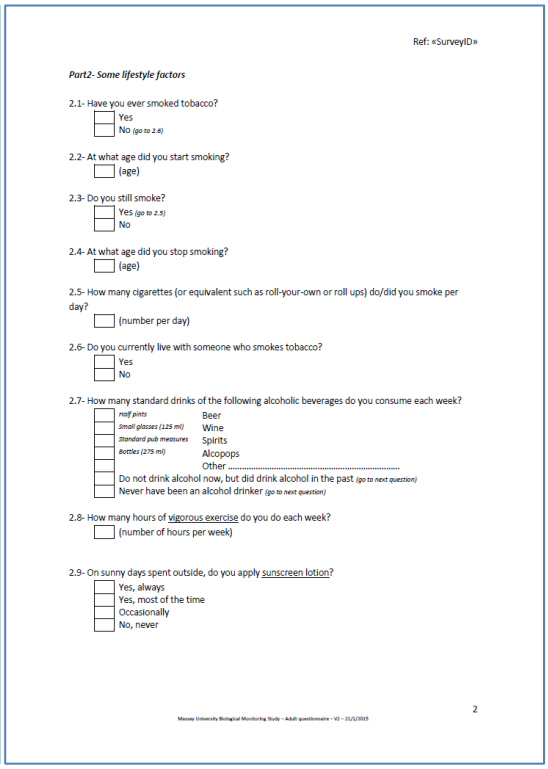
1.6-Gender
- Male
- Female

1.7-What is your highest academic qualification?
- No qualification
- Level 1-4 Certificate
- Level 5&6 Diploma
- Bachelor Degree
- Postgraduate Degree
- Doctorate Degree
- Overseas secondary school qualification
- Other:_____

1.8- How tall are you? (choose the unit most convenient to you)
- cm -or-
- inches

1.9- How much do you weigh? (choose the unit most convenient to you)
- kg -or-
- pound -or-
- stone

Massey University Biological Monitoring Study – Adult questionnaire – V2 – 21/1/2015 1



Ref: «SurveyID»

Part2- Some lifestyle factors

2.1- Have you ever smoked tobacco?
- Yes
- No *(go to 2.6)*

2.2- At what age did you start smoking?
- (age)

2.3- Do you still smoke?
- Yes *(go to 2.5)*
- No

2.4- At what age did you stop smoking?
- (age)

2.5- How many cigarettes (or equivalent such as roll-your-own or roll ups) do/did you smoke per day?
- (number per day)

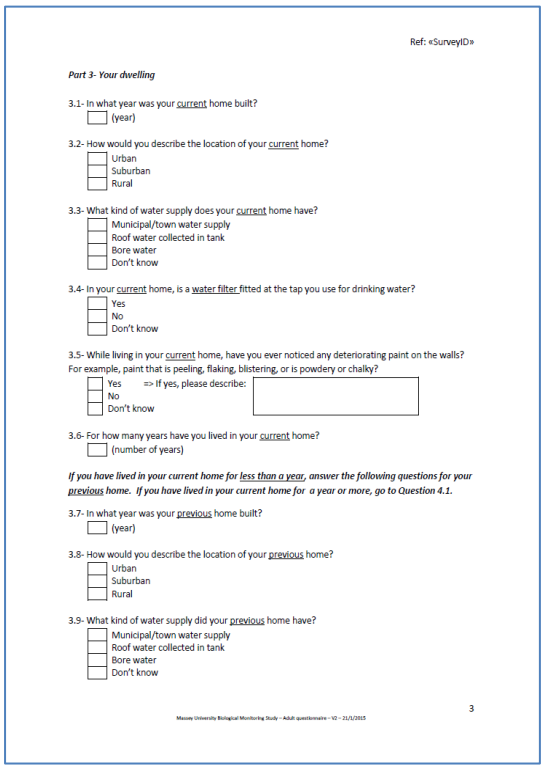
2.6- Do you currently live with someone who smokes tobacco?
- Yes
- No

2.7- How many standard drinks of the following alcoholic beverages do you consume each week?
- *Half pints* Beer
- *Small glasses (125 ml)* Wine
- *Standard pub measures* Spirits
- *Bottles (275 ml)* Alcopops
- Other .....
- Do not drink alcohol now, but did drink alcohol in the past *(go to next question)*
- Never have been an alcohol drinker *(go to next question)*

2.8- How many hours of vigorous exercise do you do each week?
- (number of hours per week)

2.9- On sunny days spent outside, do you apply sunscreen lotion?
- Yes, always
- Yes, most of the time
- Occasionally
- No, never

Massey University Biological Monitoring Study – Adult questionnaire – V2 – 21/1/2015 2



Ref: «SurveyID»

Part 3- Your dwelling

3.1- In what year was your current home built?
- (year)

3.2- How would you describe the location of your current home?
- Urban
- Suburban
- Rural

3.3- What kind of water supply does your current home have?
- Municipal/town water supply
- Roof water collected in tank
- Bore water
- Don't know

3.4- In your current home, is a water filter fitted at the tap you use for drinking water?
- Yes
- No
- Don't know

3.5- While living in your current home, have you ever noticed any deteriorating paint on the walls?
For example, paint that is peeling, flaking, blistering, or is powdery or chalky?
- Yes => If yes, please describe:
- No
- Don't know

3.6- For how many years have you lived in your current home?
- (number of years)

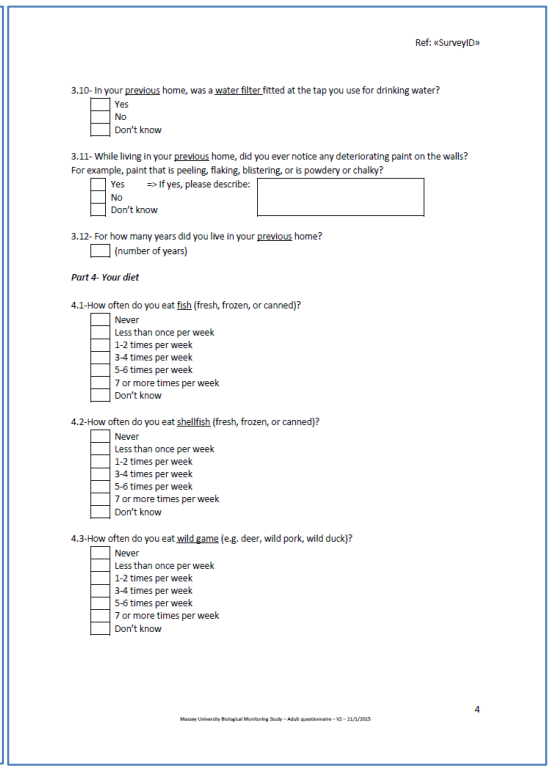
If you have lived in your current home for less than a year, answer the following questions for your previous home. If you have lived in your current home for a year or more, go to Question 4.1.

3.7- In what year was your previous home built?
- (year)

3.8- How would you describe the location of your previous home?
- Urban
- Suburban
- Rural

3.9- What kind of water supply did your previous home have?
- Municipal/town water supply
- Roof water collected in tank
- Bore water
- Don't know

Massey University Biological Monitoring Study – Adult questionnaire – V2 – 21/1/2015 3



Ref: «SurveyID»

3.10- In your previous home, was a water filter fitted at the tap you use for drinking water?
- Yes
- No
- Don't know

3.11- While living in your previous home, did you ever notice any deteriorating paint on the walls?
For example, paint that is peeling, flaking, blistering, or is powdery or chalky?
- Yes => If yes, please describe:
- No
- Don't know

3.12- For how many years did you live in your previous home?
- (number of years)

Part 4- Your diet

4.1-How often do you eat fish (fresh, frozen, or canned)?
- Never
- Less than once per week
- 1-2 times per week
- 3-4 times per week
- 5-6 times per week
- 7 or more times per week
- Don't know

4.2-How often do you eat shellfish (fresh, frozen, or canned)?
- Never
- Less than once per week
- 1-2 times per week
- 3-4 times per week
- 5-6 times per week
- 7 or more times per week
- Don't know

4.3-How often do you eat wild game (e.g. deer, wild pork, wild duck)?
- Never
- Less than once per week
- 1-2 times per week
- 3-4 times per week
- 5-6 times per week
- 7 or more times per week
- Don't know

Massey University Biological Monitoring Study – Adult questionnaire – V2 – 21/1/2015 4

4.4-How often do you drink milk?
- ☐ Never
- ☐ Less than once per week
- ☐ 1-2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 7 or more times per week
- ☐ Don't know

4.5-How often do you eat cheese?
- ☐ Never
- ☐ Less than once per week
- ☐ 1-2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 7 or more times per week
- ☐ Don't know

4.6-How often do you eat rice?
- ☐ Never
- ☐ Less than once per week
- ☐ 1-2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 7 or more times per week
- ☐ Don't know

4.7-How often do you eat tofu or soy-based protein?
- ☐ Never
- ☐ Less than once per week
- ☐ 1-2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 7 or more times per week
- ☐ Don't know

4.8-How often do you eat potatoes/kumara (including boiled, baked or fried)?
- ☐ Never
- ☐ Less than once per week
- ☐ 1-2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 7 or more times per week
- ☐ Don't know

4.9-How often do you take dietary supplements (vitamins, minerals, herbal or other dietary supplements)?
- ☐ Never
- ☐ Less than daily
- ☐ Daily
- ☐ Don't know

4.10-How often do you take fluoride supplements (e.g. fluoride tablets)?
- ☐ Never
- ☐ Less than daily
- ☐ Daily
- ☐ Don't know

4.11-How often do you eat canned food (or food prepared with canned ingredients)?
- ☐ Never
- ☐ Less than once per week
- ☐ 1-2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 7 or more times per week
- ☐ Don't know

4.12- What type of salt is used for cooking meals at your home?
- ☐ Iodised salt
- ☐ Non-iodised salt
- ☐ Don't know
- ☐ Salt is never used in meals or added to meals at my home

4.13- How often do you eat hot food that has been stored, cooked or re-heated in plastic containers (e.g. take-away meal, ready-made meal, leftovers heated or stored in plastic containers)?
- ☐ Never
- ☐ Less than once per week
- ☐ 1-2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 7 or more times per week
- ☐ Don't know

4.14- How much water do you drink from the tap (including water used to make tea, coffee, cordial etc.)?
- ☐ Litres of tap water per day (number) or, ☐ Glasses per day (number)
- ☐ Litres of tap water per week (number) or, ☐ Glasses per week (number)
- ☐ Never/rarely drink water from the tap
- ☐ Don't know

4.15- How much water do you drink from a plastic bottle (including from water coolers)?
- ☐ Litres of bottled water per day (number) or, ☐ Glasses per day (number)
- ☐ Litres of bottled water per week (number) or, ☐ Glasses per week (number)
- ☐ Never/rarely drink water from plastic bottles
- ☐ Don't know

4.16- How many drinks (other than water) do you drink from a plastic bottle?
- ☐ Litres per day (number) or, ☐ Glasses per day (number)
- ☐ Litres per week (number) or, ☐ Glasses per week (number)
- ☐ Never/rarely drink from plastic bottles
- ☐ Don't know

Part 5- Some questions related to health

5.1-How many metallic (silver) dental fillings do you have?
- ☐ (number)

5.2-Do you have any metallic joint replacements ?
- ☐ Yes
- ☐ No

5.3-Have you ever had a stroke?
- ☐ Yes
- ☐ No

The following 4 questions are for women only (if you are a man go to Question 5.8)

5.4-How many children have you given birth to?
- ☐ (number)

5.5- Have your periods stopped permanently (menopause)?
- ☐ Yes
- ☐ No
- ☐ Don't know

5.6- Do you have thin bones (osteoporosis)?
- ☐ Yes
- ☐ No
- ☐ Don't know

5.7- Have you ever taken hormone replacement therapy prescribed by a doctor?
- ☐ Yes, for how long? ☐
- ☐ No
- ☐ Don't know

The following questions are for everyone to complete

5.8- Name and address of your current GP (General Practitioner):

5.9- In case the blood test result for lead that will be conducted as part of this study is elevated, I consent for my test results to be sent to my General Practitioner.
- ☐ Yes
- ☐ No

signature

Part 6- Your occupation

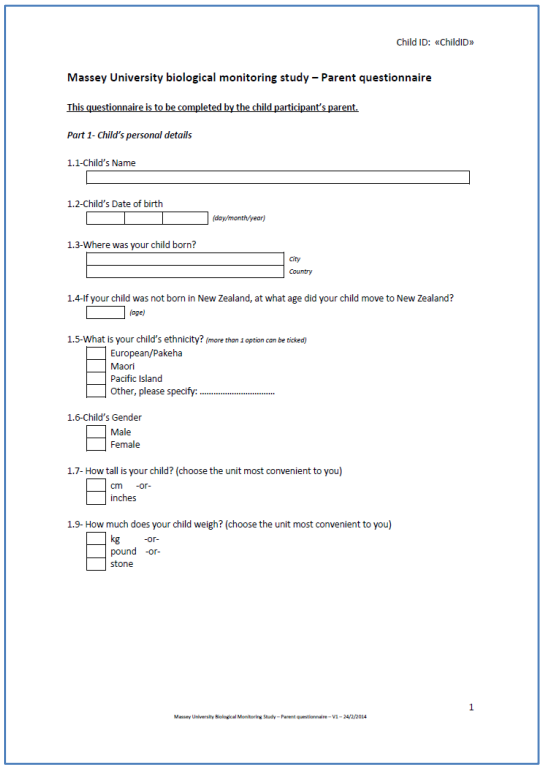
6.1-What is your current job (occupation)?

6.2-Please tick if you ever worked in any of the following jobs (occupations):
- ☐ Paint removal or repair/renovation of houses or other buildings
- ☐ Demolition of buildings or structures such as bridges
- ☐ Metal smelter or foundry
- ☐ Welding
- ☐ Battery making or recycling
- ☐ Plumbing
- ☐ Panel beating or car painting
- ☐ Paint manufacture
- ☐ Pottery making
- ☐ Jewellery making or repairing
- ☐ Shipbuilding, repair or painting
- ☐ Working in a glass factory
- ☐ Working in a chemical plant that uses lead
- ☐ Dentistry including dental nurses
- ☐ Fluorescent bulb crushing and recycling
- ☐ Chloralkali plant worker
- ☐ Hard metal alloy production
- ☐ Electroplating
- ☐ Timber treatment and preservation
- ☐ Leather tanning
- ☐ Bricklaying, masonry, concrete finishing
- ☐ Mining, ore processing
- ☐ Manufacture of rodenticides (e.g. rat poison)
- ☐ The military

END - Thank you for taking the time to complete this Questionnaire.

Please return this completed Questionnaire in the Freepost envelope with the Consent Forms.

8.2- Children questionnaire



Child ID: «ChildID»

Massey University biological monitoring study – Parent questionnaire

This questionnaire is to be completed by the child participant's parent.

Part 1- Child's personal details

1.1-Child's Name

1.2-Child's Date of birth
(day/month/year)

1.3-Where was your child born?
City
Country

1.4-If your child was not born in New Zealand, at what age did your child move to New Zealand?
(age)

1.5-What is your child's ethnicity? *(more than 1 option can be ticked)*
- European/Pakeha
- Maori
- Pacific Island
- Other, please specify: .....

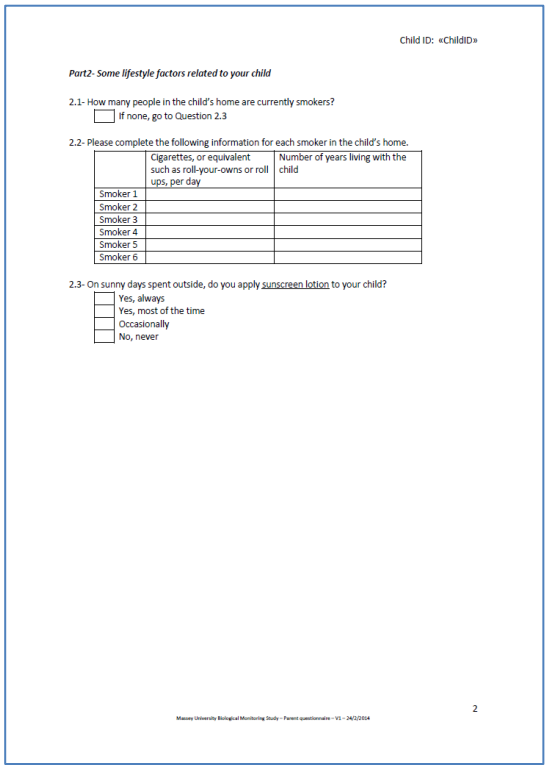
1.6-Child's Gender
- Male
- Female

1.7- How tall is your child? (choose the unit most convenient to you)
- cm -or-
- inches

1.9- How much does your child weigh? (choose the unit most convenient to you)
- kg -or-
- pound -or-
- stone

1

Massey University Biological Monitoring Study – Parent questionnaire – V1 – 24/2/2014



Child ID: «ChildID»

Part2- Some lifestyle factors related to your child

2.1- How many people in the child's home are currently smokers?
If none, go to Question 2.3

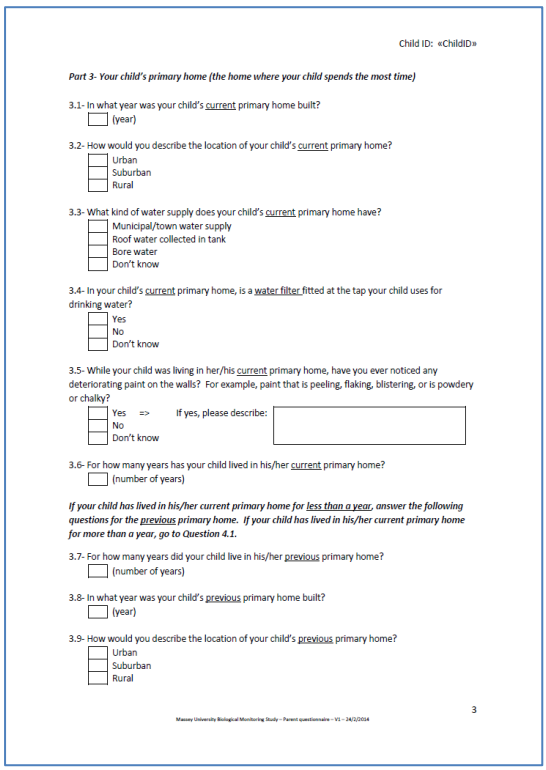
2.2- Please complete the following information for each smoker in the child's home.

	Cigarettes, or equivalent such as roll-your-owns or roll ups, per day	Number of years living with the child
Smoker 1		
Smoker 2		
Smoker 3		
Smoker 4		
Smoker 5		
Smoker 6		

2.3- On sunny days spent outside, do you apply sunscreen lotion to your child?
- Yes, always
- Yes, most of the time
- Occasionally
- No, never

2

Massey University Biological Monitoring Study – Parent questionnaire – V1 – 24/2/2014



Child ID: «ChildID»

Part 3- Your child's primary home (the home where your child spends the most time)

3.1- In what year was your child's current primary home built?
(year)

3.2- How would you describe the location of your child's current primary home?
- Urban
- Suburban
- Rural

3.3- What kind of water supply does your child's current primary home have?
- Municipal/town water supply
- Roof water collected in tank
- Bore water
- Don't know

3.4- In your child's current primary home, is a water filter fitted at the tap your child uses for drinking water?
- Yes
- No
- Don't know

3.5- While your child was living in her/his current primary home, have you ever noticed any deteriorating paint on the walls? For example, paint that is peeling, flaking, blistering, or is powdery or chalky?
- Yes => If yes, please describe:
- No
- Don't know

3.6- For how many years has your child lived in his/her current primary home?
(number of years)

If your child has lived in his/her current primary home for less than a year, answer the following questions for the previous primary home. If your child has lived in his/her current primary home for more than a year, go to Question 4.1.

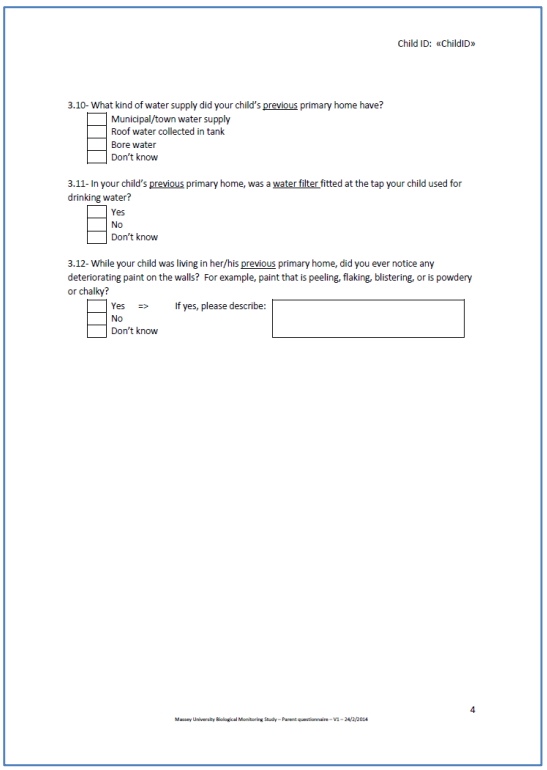
3.7- For how many years did your child live in his/her previous primary home?
(number of years)

3.8- In what year was your child's previous primary home built?
(year)

3.9- How would you describe the location of your child's previous primary home?
- Urban
- Suburban
- Rural

3

Massey University Biological Monitoring Study – Parent questionnaire – V1 – 24/2/2014



Child ID: «ChildID»

3.10- What kind of water supply did your child's previous primary home have?
- Municipal/town water supply
- Roof water collected in tank
- Bore water
- Don't know

3.11- In your child's previous primary home, was a water filter fitted at the tap your child used for drinking water?
- Yes
- No
- Don't know

3.12- While your child was living in her/his previous primary home, did you ever notice any deteriorating paint on the walls? For example, paint that is peeling, flaking, blistering, or is powdery or chalky?
- Yes => If yes, please describe:
- No
- Don't know

4

Massey University Biological Monitoring Study – Parent questionnaire – V1 – 24/2/2014

Child ID: «ChildID»

Part 4- Your child's diet

4.1-How often does your child eat fish (fresh, frozen, or canned)?
- ☐ Never
- ☐ Less than once per week
- ☐ 1-2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 7 or more times per week
- ☐ Don't know

4.2-How often does your child eat shellfish (fresh, frozen, or canned)?
- ☐ Never
- ☐ Less than once per week
- ☐ 1-2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 7 or more times per week
- ☐ Don't know

4.3-How often does your child eat wild game (e.g. deer, wild pork, wild duck)?
- ☐ Never
- ☐ Less than once per week
- ☐ 1-2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 7 or more times per week
- ☐ Don't know

4.4-How often does your child drink milk?
- ☐ Never
- ☐ Less than once per week
- ☐ 1-2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 7 or more times per week
- ☐ Don't know

4.5-How often does your child eat cheese?
- ☐ Never
- ☐ Less than once per week
- ☐ 1-2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 7 or more times per week
- ☐ Don't know

4.6-How often does your child eat rice?
- ☐ Never
- ☐ Less than once per week
- ☐ 1-2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 7 or more times per week
- ☐ Don't know

4.7-How often does your child eat tofu or soy-based protein?
- ☐ Never
- ☐ Less than once per week
- ☐ 1-2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 7 or more times per week
- ☐ Don't know

4.8-How often does your child eat potatoes/kumara (including boiled, baked or fried)?
- ☐ Never
- ☐ Less than once per week
- ☐ 1-2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 7 or more times per week
- ☐ Don't know

4.9-How often does your child take dietary supplements (vitamins, minerals, herbal or other dietary supplements)?
- ☐ Never
- ☐ Less than daily
- ☐ Daily
- ☐ Don't know

4.10-How often does your child take fluoride supplements (e.g. fluoride tablets)?
- ☐ Never
- ☐ Less than daily
- ☐ Daily
- ☐ Don't know

4.11-How often does your child eat canned food (or food prepared with canned ingredients)?
- ☐ Never
- ☐ Less than once per week
- ☐ 1-2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 7 or more times per week
- ☐ Don't know

4.12- What type of salt is used for cooking meals that your child eats at your home?
- ☐ Iodised salt
- ☐ Non-iodised salt
- ☐ Don't know
- ☐ Salt is never used in meals or added to meals eaten by my child

4.13- How often does your child eat hot meals that have been stored, cooked, or re-heated in plastic containers (e.g. take-away meal, ready-made meal, leftovers heated or stored in plastic containers)?
- ☐ Never
- ☐ Less than once per week
- ☐ 1-2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ 7 or more times per week
- ☐ Don't know

4.14- How much water does your child drink from the tap (incl. water used to make tea, coffee, cordial etc.)?
- ☐ Litres of tap water per day (number) or, ☐ Glasses per day (number)
- ☐ Litres of tap water per week (number) or, ☐ Glasses per week (number)
- ☐ Never/rarely drink water from the tap
- ☐ Don't know

4.15- How much water does your child drink from a plastic bottle (including from water coolers)?
- ☐ Litres of bottled water per day (number) or, ☐ Glasses per day (number)
- ☐ Litres of bottled water per week (number) or, ☐ Glasses per week (number)
- ☐ Never/rarely drink water from plastic bottles
- ☐ Don't know

4.16- How many drinks (other than water) does your child drink from a plastic bottle?
- ☐ Litres per day (number) or, ☐ Glasses per day (number)
- ☐ Litres per week (number) or, ☐ Glasses per week (number)
- ☐ Never/rarely drink from plastic bottles
- ☐ Don't know

Part 5- Some questions related to your child's health

5.1-How many metallic (silver) dental fillings does your child have?
- ☐ (number)

5.2-Does your child have any metallic joint replacements ?
- ☐ Yes
- ☐ No

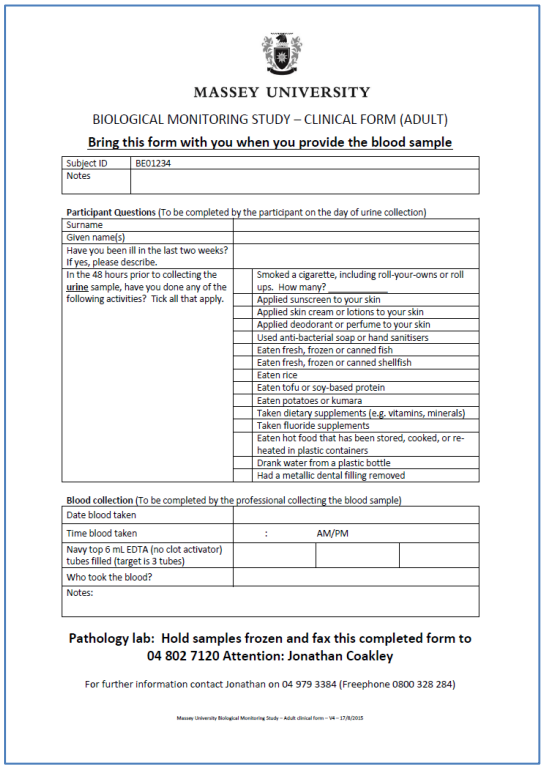
5.3- Name and address of your child's current GP (General Practitioner):

5.4- In case the blood test for lead that will be conducted as part of this study is elevated, I consent for my child's test results to be sent to my child's General Practitioner.
- ☐ Yes
- ☐ No

signature

END - Thank you very much for completing this questionnaire.

9.1- Adult clinical form



MASSEY UNIVERSITY

BIOLOGICAL MONITORING STUDY – CLINICAL FORM (ADULT)

Bring this form with you when you provide the blood sample

Subject ID	BE01234
Notes	

Participant Questions (To be completed by the participant on the day of urine collection)

Surname		
Given name(s)		
Have you been ill in the last two weeks? If yes, please describe.		
In the 48 hours prior to collecting the urine sample, have you done any of the following activities? Tick all that apply.		Smoked a cigarette, including roll-your-owns or roll ups. How many?
		Applied sunscreen to your skin
		Applied skin cream or lotions to your skin
		Applied deodorant or perfume to your skin
		Used anti-bacterial soap or hand sanitisers
		Eaten fresh, frozen or canned fish
		Eaten fresh, frozen or canned shellfish
		Eaten rice
		Eaten tofu or soy-based protein
		Eaten potatoes or kumara
		Taken dietary supplements (e.g. vitamins, minerals)
		Taken fluoride supplements
		Eaten hot food that has been stored, cooked, or re-heated in plastic containers
		Drank water from a plastic bottle
		Had a metallic dental filling removed

Blood collection (To be completed by the professional collecting the blood sample)

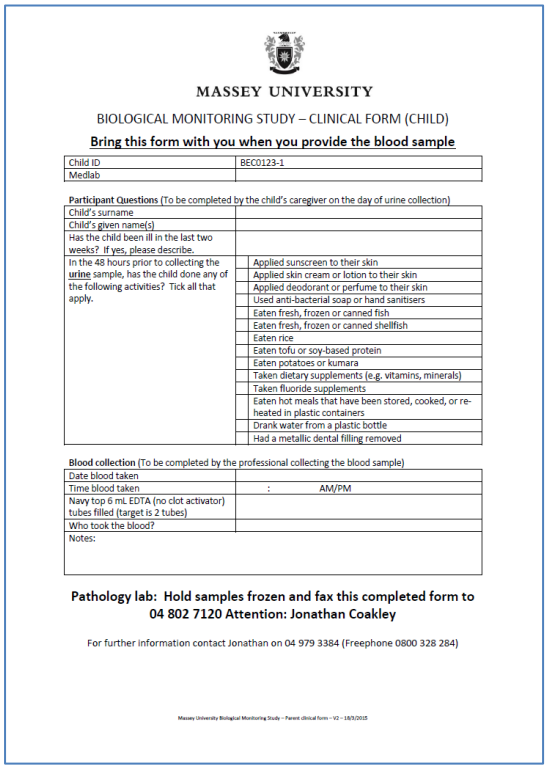
Date blood taken			
Time blood taken	: AM/PM		
Navy top 6 mL EDTA (no clot activator) tubes filled (target is 3 tubes)			
Who took the blood?			
Notes:			

Pathology lab: Hold samples frozen and fax this completed form to 04 802 7120 Attention: Jonathan Coakley

For further information contact Jonathan on 04 979 3384 (Freephone 0800 328 284)

Massey University Biological Monitoring Study – Adult clinical form – V4 – 17/8/2015

9.2- Children clinical form



MASSEY UNIVERSITY

BIOLOGICAL MONITORING STUDY – CLINICAL FORM (CHILD)

Bring this form with you when you provide the blood sample

Child ID	BEC0123-1
Medlab	

Participant Questions (To be completed by the child's caregiver on the day of urine collection)

Child's surname	
Child's given name(s)	
Has the child been ill in the last two weeks? If yes, please describe.	
In the 48 hours prior to collecting the **urine** sample, has the child done any of the following activities? Tick all that apply.	☐ Applied sunscreen to their skin
	☐ Applied skin cream or lotion to their skin
	☐ Applied deodorant or perfume to their skin
	☐ Used anti-bacterial soap or hand sanitisers
	☐ Eaten fresh, frozen or canned fish
	☐ Eaten fresh, frozen or canned shellfish
	☐ Eaten rice
	☐ Eaten tofu or soy-based protein
	☐ Eaten potatoes or kumara
	☐ Taken dietary supplements (e.g. vitamins, minerals)
	☐ Taken fluoride supplements
	☐ Eaten hot meals that have been stored, cooked, or re-heated in plastic containers
	☐ Drank water from a plastic bottle
	☐ Had a metallic dental filling removed

Blood collection (To be completed by the professional collecting the blood sample)

Date blood taken	
Time blood taken	: AM/PM
Navy top 6 mL EDTA (no clot activator) tubes filled (target is 2 tubes)	
Who took the blood?	
Notes:	

Pathology lab: Hold samples frozen and fax this completed form to 04 802 7120 Attention: Jonathan Coakley

For further information contact Jonathan on 04 979 3384 (Freephone 0800 328 284)

Massey University Biological Monitoring Study – Parent clinical form – V2 – 18/3/2015

Appendix 2. Conversion factors

chemical group	specific analyte		g/mol
metals	total lead	Pb	207.20
	total mercury	Hg	200.59
	arsenobetaine (organic arsenic)	AB	177.9975
	dimethylarsinic acid (inorganic arsenic)	DMA	137.9977
	monomethylarsonic acid (inorganic arsenic)	MMA	139.970
	Arsenite (inorganic arsenic)	AsIII	129.91
	Arsenate (inorganic arsenic)	AsV	138.921
	cadmium	Cd	112.41
	chromium	Cr	51.9961
	thallium	Tl	204.3833
	antimony	Sb	121.76
phenols	bisphenol A (2,2-bis[4-hydroxyphenyl] propane)	BPA	228.29
	Triclosan (2,4,4'-trichloro-2'-hydroxyphenyl ether)	TCS	289.54
	Benzophenone-3	BP-3	228.24
	4-tert-octylphenol	tOP	206.329
	Butyl Paraben		194.227
	Ethyl Paraben		166.176
	Methyl Paraben		152.149
	Propyl Paraben		180.203
phthalates	Monomethyl phthalate	mMP	180.157
	Monoethyl phthalate	mEP	194.186
	Monobutyl phthalate	MBP	222.24
	Monobenzyl phthalate	mBzP	256.257
	Mono-2-ethylhexyl phthalate	mEHP	278.344
	Mono-(2-ethyl-5-oxohexyl) phthalate	mEOHP	292.33
	Mono-(2-ethyl-5-hydroxyhexyl) phthalate	mEHHP	294.34
	Mono-cyclohexyl phthalate	MCHP	248.27
	Mono-(3-carboxypropyl) phthalate	MCPP	252.222
	Mono-iso-nonyl Phthalate	MiNP	292.37
tobacco	cotinine		176.22
fluoride	fluoride	F^-	18.9984
other	creatinine		113.118

Appendix 3. Results for creatinine and specific gravity

Table A3.1. Urinary creatinine in g/L (adults).

		n	n< LOD	GM g/L	95%	CI	(R2) p-value
all	all	304	0	1.25	1.17	1.34	(0.244)
age	19-24	53	0	1.56	1.33	1.83	
	25-34	65	0	1.57	1.40	1.76	
	35-49	83	0	1.26	1.10	1.44	
	50-64	103	0	0.96	0.86	1.07	**<0.0001**
gender	male	140	0	1.56	1.43	1.69	
	female	164	0	1.03	0.94	1.14	**<0.0001**
ethnicity	Māori	115	0	1.27	1.13	1.42	
	non-Māori	189	0	1.24	1.13	1.35	0.205
region	Northland/Auckland	67	0	1.24	1.06	1.45	
	Waikato/BoP	84	0	1.43	1.25	1.64	
	lower North Island	78	0	1.21	1.06	1.37	
	South Island	75	0	1.12	0.99	1.26	0.109

95%CI: 95% confidence interval of the geometric mean; R^2: R-squared of the multivariate linear regression model; *:p<0.05

Table A3.2. Urinary creatinine in g/L (children)

		n	n< LOD	GM g/L	95%	CI	(R2) p-value
all	all	300	0	1.16	1.09	1.23	(0.124)
age	5-7	64	0	0.97	0.86	1.07	
	8-10	120	0	1.03	0.95	1.11	
	11-18	116	0	1.40	1.25	1.55	**<0.0001**
gender	male	144	0	1.21	1.09	1.32	
	female	156	0	1.12	1.02	1.21	0.089
ethnicity	Māori	87	0	1.23	1.07	1.38	
	non-Māori	213	0	1.13	1.05	1.21	0.133
region	Northland/Auckland	50	0	1.42	1.23	1.60	
	Waikato/BoP	48	0	1.23	0.95	1.50	
	lower North Island	172	0	1.07	1.00	1.15	
	South Island	30	0	1.13	0.95	1.32	0.140

95%CI: 95% confidence interval of the geometric mean; R^2: R-squared of the multivariate linear regression model; *:p<0.05

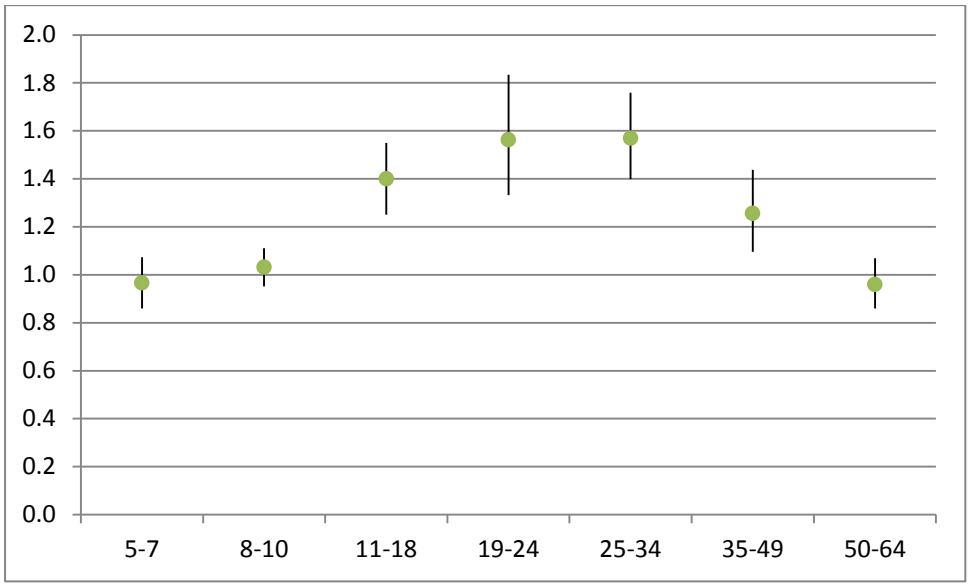


Figure A3.1. Geometric means and 95% Confidence Intervals of urinary creatinine in g/L (y axis), by age group (x axis).

Table A3.3. Urinary specific gravity (adults)

		n	n< LOD	AM	95%	CI	(R2) p-value
all	all	304	0	1.018	1.017	1.018	(0.136)
age	19-24	53	0	1.019	1.017	1.021	
	25-34	65	0	1.019	1.018	1.021	
	35-49	83	0	1.018	1.016	1.019	
	50-64	103	0	1.016	1.015	1.017	**0.027**
gender	male	140	0	1.020	1.019	1.021	
	female	164	0	1.016	1.015	1.017	**<0.0001**
ethnicity	Māori	115	0	1.018	1.017	1.019	
	non-Māori	189	0	1.017	1.016	1.018	0.159
region	Northland/Auckland	67	0	1.017	1.016	1.019	
	Waikato/BoP	84	0	1.019	1.018	1.020	
	lower North Island	78	0	1.018	1.016	1.019	
	South Island	75	0	1.016	1.015	1.018	0.744

95%CI: 95% confidence interval of the arithmetic mean; R^2: R-squared of the multivariate linear regression model; *:p<0.05

Table A3.3. Urinary specific gravity (children)

		n	n< LOD	AM	95%	CI	(R2) p-value
all	all	300	0	1.020	1.020	1.021	(0.024)
age	5-7	64	0	1.021	1.020	1.022	
	8-10	120	0	1.020	1.019	1.021	
	11-18	116	0	1.020	1.019	1.021	0.810
gender	male	144	0	1.021	1.020	1.022	
	female	156	0	1.020	1.019	1.021	0.106
ethnicity	Māori	87	0	1.021	1.020	1.022	
	non-Māori	213	0	1.020	1.019	1.021	0.144
region	Northland/Auckland	50	0	1.021	1.019	1.022	
	Waikato/BoP	48	0	1.020	1.018	1.022	
	lower North Island	172	0	1.020	1.019	1.021	
	South Island	30	0	1.022	1.020	1.024	0.481

95%CI: 95% confidence interval of the arithmetic mean; R^2: R-squared of the multivariate linear regression model; *:p<0.05

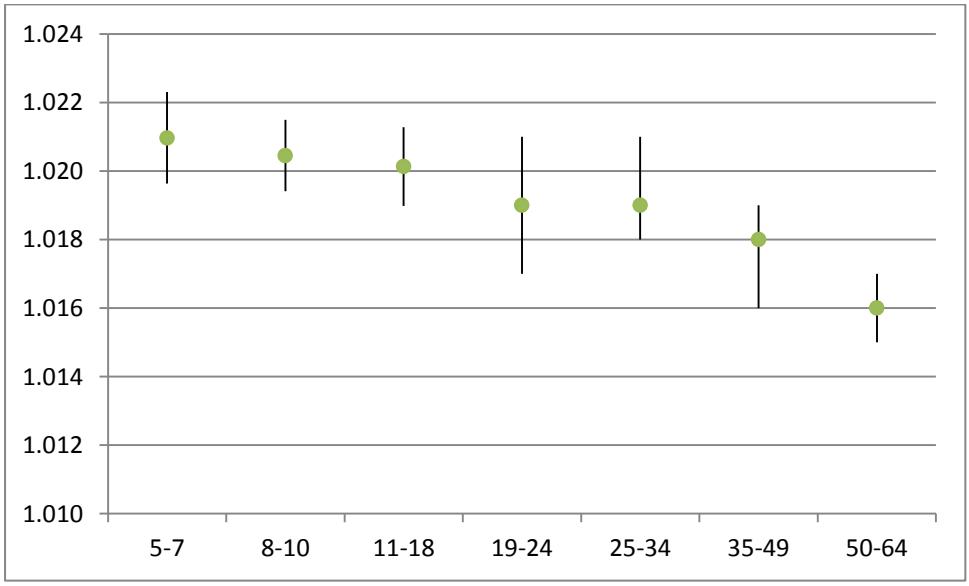


Figure A3.2. Arithmetic means and 95% Confidence Intervals of urinary specific gravity (y axis), by age group (x axis).