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Children's Exposure to Metals – A Community Initiated Study

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Abstract:
In 2007, it had been shown that the shipping of lead through Esperance Port in Western Australia resulted in contamination and elevated blood lead concentrations in children. A clean-up strategy was implemented, however little attention was given to other metals. In consultation with the community, a cross-sectional exposure study was designed. Thirty nine children aged 1-12 years provided a sample of hair, urine, drinking water, residential soil and dust. Concentrations of nickel and lead were low in biological and environmental samples. Hair aluminium (Al) (<DL-251µg/g) and copper (Cu) (7-415µg/g), and urinary aluminium (<DL-210µg/L), manganese (Mn) (<DL-550µg/L) and copper (<DL-87µg/L) were elevated for a small number of participants. Concentrations of nickel (Ni) in urine, soil and dust decreased with increasing distance from the Port, as did soil lead (Pb) concentrations. The results suggest exposure to nickel and lead was limited in children at the time of sampling in 2009. Further investigation is required to determine the source(s) and significance of other elevated metals concentrations.

Key words:

Metals exposure, children, urine, hair, lead

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The authors declare they have no competing financial interests.

Ethics approval was obtained for this study from the Edith Cowan University Human Research Ethics Committee (approval #3439)

List of abbreviations:

ADWG Australian Drinking Water Guidelines

ICP-OES Inductively coupled plasma optical emission spectrometry

Word count: 4012

Introduction

The town of Esperance lies on the southern coast of Western Australia and is home to one of the largest shipping ports in the region. In April 2005 the Esperance Port Authority began shipping lead carbonate from the Magellan Metals mine through Esperance Port (Western Australia Government Committee of Inquiry Education and Health Standing Committee, 2007). Between December 2006 and January 2007 the deaths of a large number of birds in the area prompted an investigation which discovered high levels of lead in the kidneys, livers and bones of the birds (Gulson et al., 2009; Western Australia Government Committee of Inquiry Education and Health Standing Committee, 2007). Although it was later determined that lead was unlikely to have been responsible for the deaths of the birds in Esperance, the presence of elevated concentrations of the metal in the birds alerted government authorities to the possibility of public health issues arising from contamination. The Esperance Port Authority put an immediate stop on the export of lead carbonate through the Port (Heyworth & Mullan, 2009; Western Australia Government Committee of Inquiry Education and Health Standing Committee, 2007).

Between March 2007 and August 2007 blood lead testing was offered to residents of Esperance by the WA Department of Health (Western Australia Government Committee of Inquiry Education and Health Standing Committee, 2007). Of the 404 blood samples collected from children aged under 5 years, seven (1.7%) were found to have lead concentrations of ≥100µg/l. Subsequent isotopic analysis confirmed that the Magellan lead made a contribution of between 27% and 93% (median 71%) to the total blood lead concentrations detected in samples from young children from the area (Gulson et al., 2009).

The testing of 1539 rainwater tanks in Esperance revealed that a number had concentrations of lead and nickel which exceeded the Australian Drinking Water Guidelines, with 369 and 285 exceeding the guideline for nickel and lead, respectively (Department of Health WA, 2007). This prompted the implementation of a clean up operation. Rainwater tanks were subsequently re-tested to evaluate the procedure (Heyworth, 2008c; Heyworth & Mullan, 2009). Although the concentrations of both metals in rainwater tanks were found to have declined, 20% of the tanks re-tested remained above the ADWG (Heyworth & Mullan, 2009). Limited testing of biological and environmental samples for other metals occurred despite the presence of iron ore shipping and nickel continuing to be shipped through the Port.

Children are more vulnerable to health effects associated with elevated metals exposure due to a less developed blood-brain barrier (Jarup 2003). They have a larger surface area to body mass ratio than adults (Selevan et al., 2000), breathe more air, and consume more food per unit weight than adults (Moya et al., 2004; Selevan et al., 2000). These factors can result in children having increased exposure to environmental contaminants. In addition specific behavioural tendencies that children exhibit, such as hand to mouth activity, can further increase their level of exposure (Moya et al., 2004).

Metals are known for their detrimental health impacts at elevated concentrations. Lead is neurotoxic and young children are particularly vulnerable to the deleterious effects of exposure (Landrigan 2000; Weiss 2000). There is increasing evidence of the negative health effects of low lead exposure (i.e. <100µg/l) and to date no threshold has been identified at which lead exposure is safe to the developing nervous system (Gilbert & Weiss, 2006). The negative health impacts of other metals include skin irritation, sensitivity and respiratory effects, including asthma (nickel) (Patnaik 2007), renal dysfunction (cadmium), intellectual impairment, cognitive and behavioural changes including ADHD and developmental delay (mercury, manganese, aluminium, arsenic), (Bouchard et al., 2007; Jarup, 2003; Liu et al., 2010), gastrointestinal problems (cadmium, arsenic and copper), (Jarup, 2003; Nordberg, 2004) and skeletal damage (cadmium), (Jarup, 2003). Of great concern is the fact that subtle changes associated with many of these health impacts have been observed in children at low doses, below those concentrations considered acceptable (de Burbure et al., 2006; Jarup, 2003).

The community of Esperance expressed concern about on-going contamination of the environment and wished to consider non-invasive measures of exposure in their children, to eliminate the stress of providing blood samples. The community were made aware of the limitations of the study and specifically the use of hair and urine samples as measures of exposure for selected metals. The community did not wish to have their children traumatised again with the taking of more blood samples and approached researchers at Edith Cowan University to undertake an opportunistic community research project aimed at investigating children’s exposure to metals in Esperance. It was aimed to investigate the contribution of proximity to the Port, as well as other factors, in determining environmental and biological metals concentrations.

Materials and Methods

Study Design

This study was a cross-sectional survey of metals exposure in 39 children living in and around the town of Esperance at varying distances from the Esperance Port. Ethics approval was obtained for this study from the Edith Cowan University Human Research Ethics Committee (approval #3439). The metals investigated were aluminium, arsenic, cadmium, cobalt, chromium, copper, manganese, mercury, nickel and lead.

Participant recruitment

Information leaflets inviting families with children aged 1-12 years of age to participate in the study were distributed to the local community via local organisations such as Locals for Esperance Development, the local media and by door knocking. Participants were originally required to have resided in the area for at least one year however as recruitment proceeded and the rate of recruitment was low, recruitment criteria were relaxed to a minimum of one month in order to be eligible to participate. Written informed consent was received from the parents of participating children prior to data collection. All recruitment and data collection occurred during a two week period in April 2009.

Questionnaire

Parents were asked to complete a questionnaire with, or on behalf of, their child. The questionnaire collected demographic information as well as information regarding lifestyle or activities that may affect a child's exposure to metals, such as the occurrence of smoking at the household and recent renovations to the property. Specific information was also collected regarding the amount of time the child spent playing with soil or water in their garden, the existence of any medical conditions and the usual diet of the child, including the consumption of home grown vegetables.

Biological Samples: Urine and hair

One first morning void urine sample was requested from each participating child into provided polyethylene containers. Samples were frozen at −20°C prior to analysis. The parents of participating children were asked to collect hair samples from their child. Full strands of hair were cut from at least three locations on the nape of the neck, with parents instructed to cut as close as possible to the scalp. Parents subsequently selected the first 3cm of hair and placed this section into plastic sample bags provided. . Hair samples were stored at 4°C prior to analysis.

Environmental Samples: Drinking Water, soil and dust

Each participant collected a sample of drinking water from the main source of drinking water at their residence. Sample bottles were 500 ml polyethylene and were 1M Nitric acid washed prior to sample collection. Samples were frozen at −20°C prior to analysis. Parents were requested to collect surface soil samples (at least a full dessert spoon) from four locations around their property. They were instructed that samples should be collected from bare areas of soil where the participating child plays. The four discrete samples were combined into a single composite sample and stored at 4°C prior to analysis. Participants were asked to provide dust samples by emptying the contents of their vacuum cleaner bags into the sample collection bag provided. Collected samples were stored at 4°C prior to analysis.

Sample Treatment and Chemical Analysis

Dust samples were filtered through a sieving tower in order to extract the <60µm fraction, then air dried and weighed. Rocks and large debris were removed from composite soil samples which were then dried at 35°± 5°C, ground to a particle size of 750µm and weighed before analysis. Dust and soil samples were digested with nitric acid and hydrogen peroxide as per US EPA method 3050b (United States Environmental Protection Agency, 2002) prior to analysis. Hair samples were washed five times in acetone, three times in water and then again in acetone. The samples were dried for 4 hours at 35°± 5°C. Samples were digested in nitric acid and hydrogen peroxide in accordance with Sreenivasa Rao et al., (2002). Dust, soil and hair samples were analysed at the ECU laboratory using inductively coupled plasma optical emission spectroscopy (ICP-OES). The Quality Assurance and Quality Control (QA/QC) procedures employed were derived from US EPA guidelines (United States Environmental Protection Agency, 1992).

Metal concentrations in urine and drinking water samples (Al, As, Cd, Co, Cu, Hg, Ni, Mn, and Pb) were analysed by the ChemCentre of Western Australia, a NATA accredited facility, using Agilent Inductively Coupled Plasma - Mass Spectrometry 7500cs (which included collision cell) and internal standards. Creatinine in urine samples was analysed by a discrete autoanalyser (Labmedics/Thermo Fisher Aquakem) using colorimetric determination and caustic/picric acid solutions.

Statistical Methods and Analysis

The biological and environmental concentrations of metals were not normally distributed and were highly skewed to the right as assessed by Shapiro-Wilk tests, Q-Q plots and skewness values >0. Concentrations below the detection limits were assigned a value of half the respective detection limit (Liu et al., 1997). Comparisons between categories of children's socio demographic characteristics, lifestyles and activities were undertaken using Mann-Whitney tests. Spearman's Rank correlations were calculated to investigate relationships between environmental and biological measures of exposure. All skewed variables were natural log-transformed and those variables which were associated with an increase in metals concentrations were entered listwise into a multiple linear regression to explore the influence of demographic, lifestyle factors and environmental metals concentration on urinary and hair metals concentrations. Linear regression was performed with the natural log transformed urinary or hair metal concentration as the dependent variable, using forced entry of independent variables. After the initial run of multiple linear regression, the model was re-run multiple times, removing variables with insignificant beta coefficients and confidence intervals. All statistical analysis was undertaken using SPSS version 17.0 software.

Results

Basic demographics

Descriptive information about 39 participating children from 36 households is presented in Table 1. There were a roughly equal number of males and females aged between 1 and 11 years (Table 1). Forty seven percent lived in a home in which a smoker resided (Table 2). The children spent on average over 3 hours per day outside and over 75% of participants were reported to spend 1 hour or more per week undertaking activities that brought them into contact with soil (Table 2).

The harvesting and use of rainwater is quite common in Esperance, and consistent with this 47% of children were from homes where current rainwater consumption was reported (Table 3). Fifty-five per cent of participants were from households that were either currently using, or had previously used, rainwater as a source of drinking water (Table 3). Growing fruit and vegetables was also popular amongst participants with 58% of children reported to consume home grown produce, with most participants washing produce prior to consumption (Table 3).

Drinking water metals concentrations

All drinking water samples recorded metals concentrations below World Health Organisation Guidelines for Drinking Water Quality (3rd Edition, 2008) and most were below the National Health and Medical Research Council's (NHMRC) Australian Drinking Water Guidelines

(2004), (Table 4). There were two samples that were either close to, or above the NHMRC guideline for nickel, 18 and 32µg/L, respectively (Table 4). Concentrations of Hg were below the limit of detection in all water samples analysed.

Residential Soil and Dust Metals Concentrations

Most soil samples had metals concentrations that were considerably lower than the Australian National Environment Protection Council, Schedule B Health Based Investigation Levels for residential Soil (NEPC 1999). There was one soil sample with an elevated cadmium concentration of 3.96µg/g, which although well below current health based investigation levels, is above the ecological investigation level of 3µg/g (Table 4). No significant correlations were observed between the concentrations of metals in drinking water and those in either soil or dust. However, Spearman's rank correlations were positive for concentrations of Al, Ni and Mn in soil and the corresponding metal concentration in dust (Al $r_s = .471$, $p < 0.01$, Ni $r_s = .399$, $p < 0.05$, Mn $r_s = .363$, $p < 0.05$). No other relationships between soil and dust were observed.

Concentrations of Metals in Urine and Hair

Thirty seven participants provided a urine sample. Urine samples were analysed for all metals including chromium and mercury, however both these metals were below the limit of detection. Both uncorrected and creatinine corrected urinary metals concentrations were determined (Table 5). Creatinine corrections were made when the participant's creatinine concentration was above 0.3g/L (n=32). This approach was more conservative than the standard protocol of adjusting using creatinine values ≥0.3g/L, however with a number of younger participants with creatinine concentrations of ≤0.3g/L this approach was warranted to reduce the likelihood of artificially elevated corrected results. Spearman's rho revealed significant positive correlations between the observed and creatinine corrected urinary concentrations of metals (Al r_s = 1.000, As $r_{s=}$ .957, Cd $r_{s=}$ .997, Cu $r_{s=}$ .736, Mn $r_{s=}$ 1.000, Ni $r_{s\,=}$ .874, Pb $r_{s=}$ .945, p <0.001 for all metals) and therefore to maximise the data available only uncorrected urinary metals concentrations were utilised in the subsequent data analysis.

The concentrations of metals in hair samples are shown in Table 5. There were a large number of samples recording less than the detection limit for arsenic, cadmium, cobalt and manganese. Some of the masses of the hair samples were also very low due to the age of the child and this affected detection and the reliability of the result and hence these samples were excluded.

Factors influencing urinary and hair metals concentrations

Noting the small sample numbers, demographic, lifestyle, activities and environmental factors were examined for their potential influence on urinary and hair metals concentrations. There were no correlations observed between environmental and biological concentrations with the exception of copper. The Spearman correlation between soil Cu concentration and urinary Cu concentration was positive and significant (r_s = .400, p <0.05).

Children who were exposed to cigarette smoke at home (regardless of where smoking occurred) had higher concentrations of hair lead than those who were not (median 1.6µg/g vs. 0.1µg/g U=91, p < 0.05, r = .466). Fifty eight percent of participating children consumed home grown produce and these children were also found to have higher concentrations of copper in their hair samples than those who did not (median 125.0µg/g vs. 16.5µg/g, U=99, p < 0.01, r = -.577).

All metals soil concentrations and five dust metals (As, Cd, Cu, Ni, Pb) concentrations decreased with increasing distance of the participants' residence from the Port. The relationship reached significance for soil Cu ($r_s = -.387$, $p < 0.05$), Ni ($r_s = -.571$, $p < 0.001$) and Pb ($r_s = -.373$, $p < 0.05$) concentrations and also dust Ni concentrations ($r_s = -.521$, $p < 0.01$). Similarly, concentrations of nickel in urine and hair were higher in those residing less than 2km from Esperance Port compared with those who resided ≥2km away, however these relationships did not reach significance (urine median 3.0µg/L vs <LOD, U=121, p =.303, r = -.187; hair median 0.46 µg/g vs <LOD, U=35, p =.322, r = -.237).

A number of factors were investigated for their relationship with selected urinary and hair metals concentrations using linear regression. Only metals that were detected in more than 60% of biological samples were selected for regression modeling, namely Cu, Ni and Pb. Environmental (residential soil, indoor dust and drinking water) demographic (age and gender) and other characteristics (distance of residence from the Port, consumption of home grown produce and the presence of a smoker at the property) were entered into the regression model (Table 6). For urinary metal concentrations regressions were run with the observed concentrations as the dependent variable and again with creatinine adjusted concentrations. When observed urinary concentrations were used, creatinine was added into the model as an independent variable (Barr et al., 2005)

Soil copper concentrations, age and creatinine concentrations were the variables that explained the highest percentage of urinary copper concentrations in children. However these factors accounted for approximately 28% of the variation (Table 6). When the regression was run with creatinine corrected urine copper concentrations as the dependent variable the age of the child was the only significant predictor remaining (Table 6). The only significant predictor of observed urine nickel concentrations was creatinine, indicating the high correlation between nickel and creatinine concentrations in urine (r =.577, $p < .001$). However when creatinine adjusted concentrations were used as the dependent variable, the distance of the participants' home from the Port and the drinking water nickel concentrations were found to influence urine nickel concentrations, accounting for approximately 26% of the variation. (Table 6). No significant predictors of observed or creatinine adjusted urinary lead concentrations were identified.

The consumption of home grown produce by children explained approximately 32% of the variation in hair Cu concentrations (Table 6).The occurrence of smoking at the property accounted for 19% of the variation of hair Pb concentrations and was found to be the only significant predictor (Table 6). No significant predictors of hair nickel concentrations were identified.

Discussion

The metals concentrations in all soils tested were lower than available guideline values and generally lower than those reported in other communities. In comparison with studies conducted overseas, the concentrations of metals in household dust in Esperance were generally lower, with the exception of copper and nickel (Rasmussen et al., 2001; Turner & Simmonds, 2006). The median dust concentrations of cadmium and lead in this study were the same as the geometric mean concentrations reported in another Australian study of household dust in Sydney, however the concentrations of copper, manganese and nickel were higher in Esperance than Sydney (Chattopadhyay et al., 2003). It is worth noting that although the median lead concentration found in household dust in Esperance was similar, a much larger range in concentrations was observed in Sydney, an area impacted by heavy traffic therefore it would be expected that historical leaded fuel would contribute to this result (Laidlaw & Taylor, 2011). Esperance on the other hand is a rural location with a small population and, other than the Port, does not have heavy industry.

Urinary and hair metals concentrations for most children were considered low. When compared with the results of a biomonitoring study of metals in the urine of 72 unexposed German children aged 2-17 years, the concentrations of Co, Cr, Ni and Pb in this study were within the range or lower than the previously reported values (Heitland & Köster, 2006). Two participants had urinary elevated As concentrations, however as the analysis reported on total As, as opposed to inorganic As, it is likely that this could be attributable to fish consumption prior to sample collection. The Cu concentrations in this study were below concentrations reported in Germany (Heitland & Köster, 2006), with the exception of one participant. A small number of elevated urinary Mn concentrations were detected, with one extreme value of 550µg/L. It is difficult to find comparison ranges for urinary Al in children in the literature. A French study of 100 unexposed adults reported a reference range of 0.16-11.2µg/l (5^{th}-95^{th} percentile) for urinary Al (Goullé et al., 2005). Three participants in this study had Al concentrations outside this range, two of which were considerably elevated (68µg/L and 210µg/L, respectively).

Concentrations of Cd, Mn, Ni and Pb were low in hair samples and were below previously reported comparison ranges for metals in the hair of children (Senofonte et al., 2000; Wright et al., 2006) and non-occupationally exposed children and adults (Wang et al., 2009). The concentration of hair Al of one participant in this study far exceeded previously reported concentrations (Goullé et al., 2005; Senofonte et al., 2000), however hair Al is not considered a good measure of exposure (Wilhelm & Idel, 1996). A small number of elevated concentrations of As and Cu in hair samples were also detected that exceeded those previously reported for non-exposed individuals (Senofonte et al., 2000; Goullé et al., 2005). Non-standard scissors were utilised by parents for hair collection which may have resulted in possible contamination to samples, however the washing procedures undertaken prior to hair sample analysis should have been sufficient to remove any external contamination.

The occurrence of smoking at the property was found to increase children's hair Pb concentrations. This finding is consistent with that of Conrad and colleagues who identified increased blood Pb concentrations in children exposed to environmental tobacco smoke (Conrad et al., 2010). The Conrad study also identified an increase in urinary Cd concentrations in children residing with a smoker (Conrad et al., 2010). In this study, the concentrations of cadmium in hair and urine samples were low, with the majority of concentrations below the limit of detection (84% and 91% of samples <LOD for urine and hair Cd, respectively). This precluded any determination of whether exposure to tobacco smoke caused an increase in Cd concentrations in this population.

The age of children was found to be a significant predictor of urinary Cu concentrations, with young children having the highest concentrations. This finding is consistent with that of a previous study in Greece in which a negative association between children's serum Cu concentrations and age was identified (Arvanitidou et al., 2007). Urinary Cu concentrations were higher amongst participants with higher soil Cu concentrations, and similarly hair Cu concentrations were higher amongst participants who consumed home grown produce, suggesting that in addition to contact with soil, the uptake of the metal from the soil by edible plants could be an additional route of human exposure in the area.

The elevated concentrations of urine and hair Al and Mn seen in few participants were not explained by the variables collected. This suggests that either these samples had some contamination introduced or that dietary intake may be the significant pathway of exposure to these metals.

There are a number of limitations of this study, specifically the small sample size and the use of only non-invasive biological samples. Blood is considered to provide a better assessment of body burden and exposure for some metals, most notably Pb, however this study was designed following consultation with the community and it was clear that the requirement of the collection of blood from young children would have greatly reduced the number of families wishing to participate.

Conclusions

Although a small number of elevated concentrations were observed, generally low concentrations of metals were found in both environmental and biological samples suggesting contamination from the Port appears to no longer be causing high community exposure in Esperance in this group of children. The results cannot be generalised to the general community due to insufficient sample size and the cross sectional design. The results are consistent with Department of Health follow up blood testing in 2008 (Department of Health WA, 2008a&b) which revealed that blood lead levels in children in the region had decreased following the clean up operation. However, the increase in soil (Cu, Ni and Pb) and dust metals (Ni) concentrations in proximity to the Port suggests that some degree of environmental contamination remains. Furthermore, the distance of a participant's home from the Port was found to be a predictor of adjusted urinary nickel concentrations, despite the urinary concentrations of nickel being low.

Esperance Port no longer ships lead carbonate, however, nickel continues to be shipped, along with other materials. In order to prevent similar contamination occurring in the future, measures must be taken to ensure that adequate monitoring of the transport and loading of materials occurs at Ports, particularly at those close to town sites where communities are at risk of exposure should contamination occur. Further work is needed to establish the sources of the small number of elevated metals concentrations in biological samples and the potential for associated health risks.

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Table 1: Demographic Characteristics of Participants (n=39)

Characteristic	
Mean Age (in years)	5.6
Range (in years)	1-11
Males (%)	48.7
Mean years family resided in area	4.2
Range	0.08-12
Diet (%)	
No special diet	81.6
Vegetarian	5.3
Lactose free	5.3
Other	7.8

Table 2: Self Reported Lifestyle and Activities of Participants (n=38)

Lifestyle/ Activity	Percent of Participants
Smoker at residence (%)	47.4[a]
Frequency of smoking (%)	(n=18)
Daily	44.4
Few days per week	11.1
Few days per month	22.2
< Few days per month	22.2
Renovations to home in past year (Y) (%)	23.7
Child plays in garden/assists with gardening (Y) (%)	89.5
Hours per week of soil contact (%)	(n=34)
0-1 hours	23.5
1-5 hours	55.9
>5 hours	20.6
Hours spent outside per day (mean)	3.2
Range	1-10
Hours windows open per day during summer (%)	
0-1 hours per day	5.6
2-5 hours per day	36.1
6-10 hours per day	36.1
>10 hours per day	22.2

[a] 88.9% of households where smoking occurs reported outdoor smoking only.

Table 3 Drinking water and consumption of home grown produce (n=38).

Activity and Frequency	% of participants
Consume home-grown produce (Y)	57.9
Frequency of consumption of home-grown produce	(n=22)
Daily	13.6
Few days a week	36.4
Few days a month	18.2
< Few days a month	31.8
Wash home-grown fruit and vegetables always (Y)	63.6
Peel home-grown fruit and vegetables always (Y)	22.7
Used fertilisers	44.7
Current use of rain water tank	47.4
Frequency of rain water use (%)[a]	(n=18)
Every day	66.7
2-3 times a week	5.6
4-5 times a week	11.1
Once a week	11.1
None	5.6
Current or previous use of rain water as:	
Drinking water	55.3
Cooking	44.7
Washing fruit or vegetables	31.6

[a] Frequency of use for the week prior to questionnaire completion

Table 4: Concentrations of Metals in Drinking Water, Residential Soil and Dust samples

	Drinking Water (µg/L) n= 38			Soil (µg/g) n=37			Household Dust (µg/g) n=35	
Metal	**Median**	**Range**	**Guideline[a]**	**Median**	**Range**	**Guideline[b]**	**Median**	**Range**
Al	<LOD	<LOD-11.0	200	2293.59	727.69-7439.38	N/A	16,728.52	2662.59-39,333.00
As	<LOD	<LOD	7	<LOD	<LOD-4.03	100	6.55	<LOD -39.84
Cd	<LOD	<LOD-0.4	2	0.48	<LOD-3.96	20	1.94	<LOD -9.43
Co	<LOD	<LOD	N/A	0.33	<LOD -0.92	100	0.56	<LOD -6.11
Cu	22.0	3.0-220.0	2000	3.09	<LOD -13.74	1000	136.79	0.93-2030.22
Mn	<LOD	<LOD-7.0	500	15.84	4.14-29.61	1500	97.97	3.76-252.01
Ni	<LOD	<LOD-32	20	2.88	<LOD -30.23	600	68.86	1.67-268.47
Pb	<LOD	<LOD-0.6	10	<LOD	<LOD -54.31	300	82.99	25.24-377.52

[a]National Health and Medical Research Council, Australian Drinking Water Guidelines (2004)

[b] National Environmental Protection Council (NEPC), Assessment of Site Contamination Measure (Schedule B(7a) Health Based Investigation Levels (NEPC, 1999).

<LOD Below Limit of Detection

Table 5: Concentrations of Metals in Urine and Hair samples

	Urine					Hair concentrations (µg/g) n=22		
	Observed concentrations (µg/L) n=37			Creatinine Adjusted concentrations n=32 (µg/g creatinine)				
Metal	**% <LOD**	**Median**	**Range**	**Median**	**Range**	**% <LOD**	**Median**	**Range**
Al	86.5	<LOD	<LOD- 210.0	<LOD	<LOD-262.50	63.6	<LOD	<LOD -250.89
As	21.6	10.0	<LOD - 700.0	12.92	<LOD-583.33	95.5	<LOD	<LOD -2.10
Cd	83.8	<LOD	<LOD - 1.0	<LOD	<LOD-1.67	90.9	<LOD	<LOD -0.34
Co	78.4	<LOD	<LOD - 2.0	<LOD	<LOD-2.00	100	<LOD	<LOD
Cu	2.7	12.0	<LOD - 87.0	13.33	<LOD-96.00	0	56.27	7.11-415.23
Mn	86.5	<LOD	<LOD - 550.0	<LOD	<LOD -1100.00	95.5	<LOD	<LOD -0.21
Ni	40.5	3.0	<LOD - 9.0	3.54	<LOD -8.00	40.9	0.38	<LOD -1.52
Pb	43.2	1.0	<LOD - 3.0	1.10	<LOD -5.0	54.5	<LOD	<LOD -5.66

Table 6: Effects of environmental concentrations, distance from Port and lifestyle factors on concentrations of Cu, Ni and Pb in observed and creatinine adjusted urine and hair using regression analysis.

Metal in Urine	**Predictors[b]**	**Standardised Coefficient**			**95% Confidence Interval for Beta**		**Model Summary**	
		Beta	**t**	**Sig.**	**Lower Bound**	**Upper Bound**	**R^2**	**Adj R^2**
Cu Observed (n=35)	Constant		9.678	.000	1.992	3.056	.347	.284
	Ln Soil Cu	.357	2.437	.021	.025	.278		
	Age	-.459	-2.840	.008	-.190	-.031		
	Creatinine	.351	2.184	.037	.040	1.179		
Cu Adjusted (n=31)	Constant		11.954	.000	2.561	3.619	.147	.118
	Age	-.384	-2.238	.033	-.164	-.007		
Ni Observed (n=37)	Constant		-.518	.608	-.634	.367	.333	.313
	Creatinine	.577	4.167	.000	.622	1.799		
Ni Adjusted (n=30)	Constant		7.256	.000	.954	1.706	.308	.257
	Ln Drinking water Ni	.370	2.296	.030	.027	.483		
	Ln Distance to Port	-.462	-2.863	.008	-.889	-.147		
Metal in Hair								
Cu (n=22)	Constant		8.650	.000	2.290	3.745	.348	.315
	Eat HGP[a]	.590	3.266	.004	.535	2.428		
Pb (n=22)	Constant		-4.272	.000	-2.603	-.895	.233	.194
	Smoking at property	.482	2.461	.023	.217	2.633		

[a]HGP – Home grown produce. [b]Predictors entered into models were continuous with the exception of consumption of home grown produce and occurrence of smoking at property which were both categorical variables (Yes/No).