

Retesting of Lead and Nickel Levels in Rainwater Tanks at Esperance

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ABBREVIATIONS

ADWG	Australian Drinking Water Guidelines
EspPA	Esperance Port Authority
mg/L	Milligrams per litre

BACKGROUND

In 2004 the Esperance Port Authority (EspPA) began shipping lead carbonate through the Port. The lead arrived at the Port via rail from a mine site almost 900km away. In the summer of 2006/07 the reporting of a significant number of bird deaths linked to lead poisoning led to an investigation by Government authorities into the public health impacts of lead contamination in the community.

As part of the investigation, the Department of Health, in conjunction with the Shire of Esperance, tested 1539 rainwater tanks for heavy metals. There are a large number of domestic rainwater tanks within Esperance and this enabled sampling in all residential areas. The testing of rainwater tanks provided information to community members on the safety of their drinking water sources and also gave investigators details on the geographic extent of the contamination. However, it should be noted that the primary source of drinking water in Esperance is scheme water provided by the Water Corporation. The scheme water is monitored regularly and is in compliance with all health guideline values set by the Australian Drinking Water Guidelines (ADWG). Tank rainwater is also used as a source of drinking water by some Esperance households.

The results of the first batch of tank rainwater testing showed that lead levels in rainwater exceeded the ADWG values in 285 (19%) of tanks. As a result of testing for other metals, it was discovered that nickel levels in 369 (24%) of rainwater tanks also exceeded the Australian Drinking Water Guidelines. Further information on this survey can be found at <http://www.health.wa.gov.au/envirohealth/hazards/esperance.cfm>.

These results were presented in both tabular and map format to all interested parties, including the community. The maps covered the Esperance town site with various shadings from highest to lowest levels. Subsequently, the EspPA coordinated the cleaning of rainwater tanks and gutter systems for residences with high results in their tank rainwater sample or in an area deemed by the Department of Health as more likely to have been impacted. A total 423 tanks were cleaned by the EspPA as a part of this program. The protocol for cleaning is attached as Appendix 1.

Once the cleaning program was completed the Department of Health conducted a pilot survey to provide an indication on whether the cleaning program had been effective in reducing lead levels below the ADWG. Twelve tanks were selected for sampling in this initial pilot survey with eight of these samples selected on the basis that their original lead levels were the highest of the samples taken. The results of this pilot survey showed that four of the samples still exceeded the ADWG, albeit marginally. All four samples were located in close proximity to the Port, and had shown very high levels on the first sampling.

Consequently a further investigation was designed to determine whether cleaning of rainwater tanks had been successful in reducing the lead and nickel levels to below the ADWG for lead (0.01mg/L) and nickel (0.02mg/L) and, if the levels were still high, what were the contributing factors to those elevated levels.

AIMS

The aims of the retesting program were:

1. To determine whether the lead and/or nickel concentrations in rainwater tanks have reduced since tanks have been cleaned;

and, if concentrations were found to have remained high,

2. To describe the factors associated with concentrations of lead and/or nickel.

METHODS

Study population

Rainwater tanks in Esperance from a population of rainwater tanks previously tested were sampled. Tanks in the suburb of Castletown were excluded in this follow-up investigation as this area is outside the area of greatest interest to the Department of Health. The sample of tanks was drawn from those tanks with an exact known location. The final study area contained 806 rainwater tanks that were eligible for retesting.

The study region was stratified by a 1 km square grid over the study area, resulting in 25 cells (Figure 1). A sample of tanks was randomly selected from each grid. The number from each grid varied proportional to the number of rainwater tanks initially tested in that grid. Also approximately 100 tanks were to be sampled from 423 tanks that had been cleaned by the EspPA.

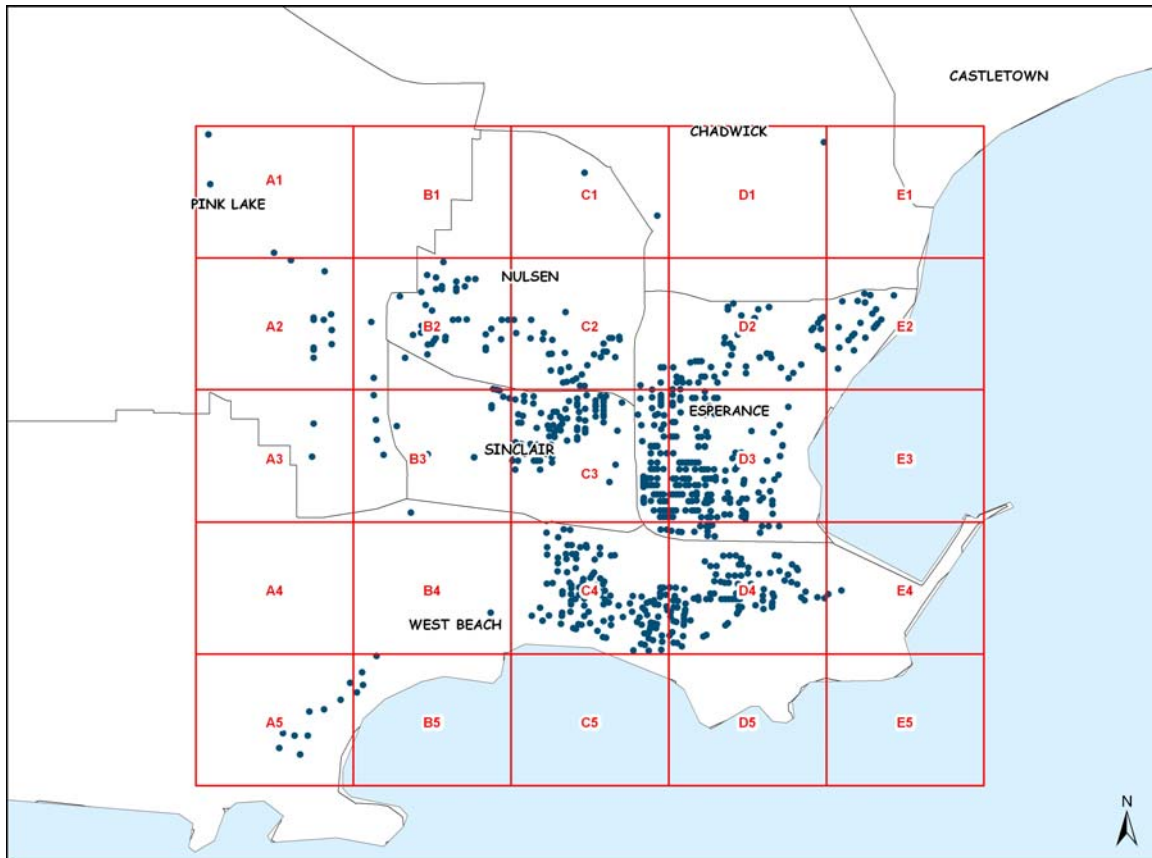


Figure 1 Location of rainwater tanks that were eligible for re-sampling, Esperance October 2007

Tank selection

The tanks were classified into three groups based on a combination of lead or nickel concentrations and whether or not the EspPA reported that the tank had been cleaned. These groups were defined as:

Group 1- those tanks that exceeded the ADWG for either lead or nickel and since have been cleaned by the EspPA.

Group 2- those tanks that exceeded the ADWG for either lead or nickel and have not been cleaned by the EspPA.

Group3 -those tanks that did not exceed the ADWG for either lead or nickel and have not been cleaned by the EspPA.

Table 1 shows the numbers of tanks that were randomly selected for sampling for each Group. It was not always possible to gain consent to undertake further tank rainwater sampling from households. In some cases consent was given but the tank could not be accessed. Hence table 1 also show the number of tanks that were included in the study.

Figure 2 shows the location of tanks in Group 1, Group 2 and Group 3 within the study area.

Table 1 Tanks selected for sampling and the number of samples obtained by Group.

	Group 1	Group 2	Group 3
Number of tanks selected for sampling	128	67	41
Number of tanks actually sampled	97	49	30

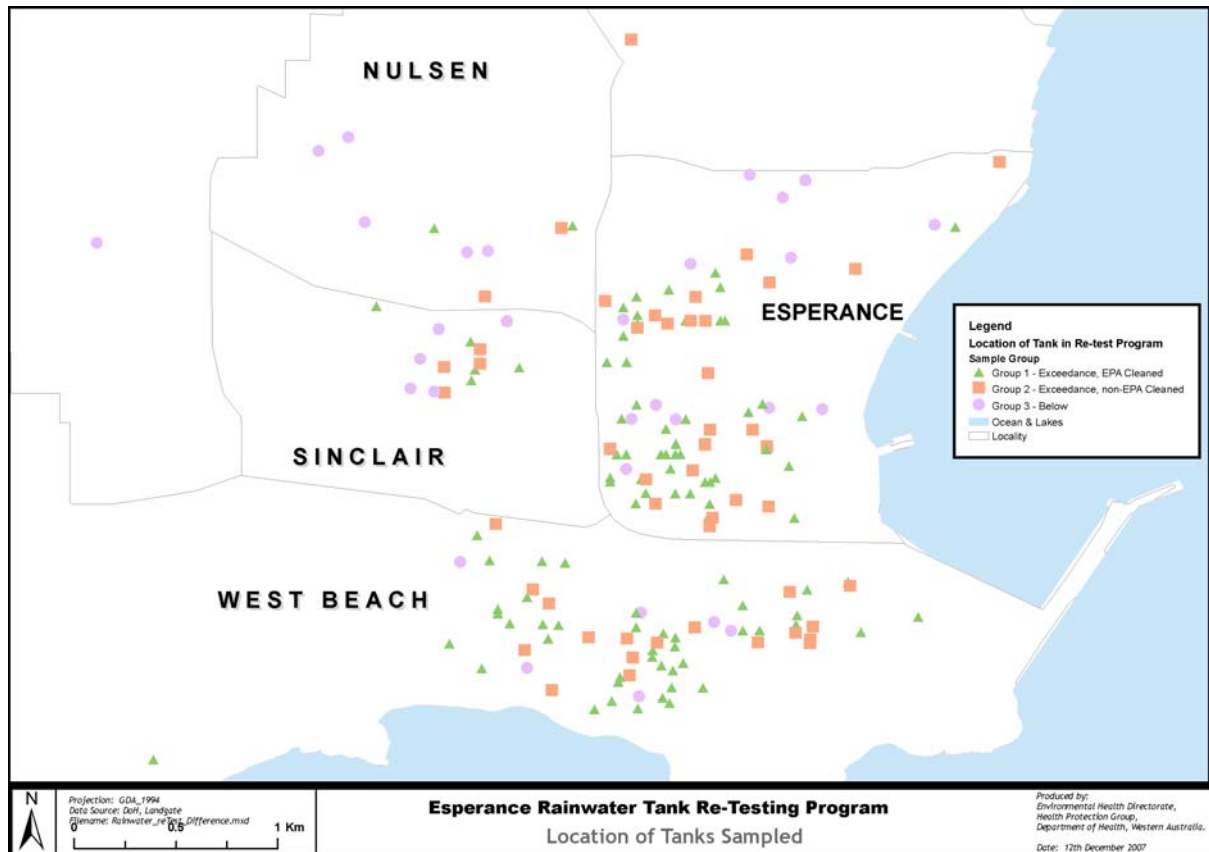


Figure 2 Location of rainwater tanks for retesting by Group, Esperance 2007

Water sampling and analysis

Baseline sampling

Water samples that were collected by the Department of Health and the Shire of Esperance between April and June 2007 are referred to as the *baseline* samples.

Follow-up sampling

Water samples that were collected as part of this investigation and after rainwater tanks had been cleaned by EspPA are referred to here as the *follow-up* samples. These samples were taken by the Department of Health and the Shire of Esperance from 15 to 29 October 2007.

The sampling protocol was the same for baseline and follow-up sampling and the protocol is attached in Appendix 2.

Questionnaire data

When the baseline samples were collected, data regarding the tank and catchment characteristics were obtained by officer taking the sample. Where possible, the householder/resident was also surveyed to obtain additional information on cleaning regimes etc. If these data had not been collected at baseline, the data were collected at the time of follow-up samples. Information collected included:

- i. Location
- ii. Type of roof – tile, asbestos cement, Colourbond, Zinalume
- iii. Condition of roof as observed by sampler
- iv. Type of gutters
- v. Type of tank – Zinalume, galvanised iron, plastic, concrete , otherwise
- vi. Capacity of tank
- vii. Presence of first flush diverter, opening on tank roof
- viii. Routine cleaning frequencies for gutter, roofs and tanks
- ix. Other possible sources of lead including lead flashing, gutter type, etc.
- x. Date on which the tank was last cleaned, if not cleaned by EspPA.

It was not always possible to interview the residents and/or home owner and so there was a high proportion of missing data for several of these variables. At most there were tank and roof catchment data for 143 out of the 175 tanks in the sample.

Water analysis

All samples were analysed for lead and nickel concentrations by the NATA accredited Chemistry Centre (WA) using method, 3120B Inductively Coupled Plasma Method from the Standard Method for the Examination of Water and Wastewater (American Public Health Association, 1998).¹

Statistical Analysis

All data were provided to The University of Western Australia by the Department of Health.

Aim 1: to determine whether lead and nickel concentrations have reduced since tanks have been cleaned

Descriptive statistics for lead and nickel concentrations and changes over time were determined. Medians were determined as well as means because the data were not normally distributed, but skewed to the left (see Appendix 3 and 4). These results were compared with the AGWG, which are 0.01mg/L for lead and 0.02mg/L for nickel.

The Department of Health provided maps of the results using the ESRI ArcMap software. Smooth grids of the testing results were achieved with ESRI Spatial Analyst, more specifically the kernel density tool which transforms point results into a grid via a moving window technique.

¹ Reference: American Public Health Association (1998). Standard Method for the Examination of Water and Wastewater. 20th Edition. Method 3120B Inductively Coupled Plasma Method.

The concentrations of lead and nickel in tank rainwater were then compared by cleaning status of the rainwater tanks.

Aim 2 to describe the factors that are associated with higher concentrations of lead and/or nickel.

Tank and roof characteristics, cleaning status and distance from the Port were compared across lead and nickel samples above and below the ADWG. The relationships between the lead and/or nickel concentrations at follow-up and cleaning status and distance from the Port, adjusting for baseline lead or nickel concentration, were modelled using linear regression.

The relationship between follow-up lead and nickel concentrations with rainwater tank and roof catchment characteristics were also modelled.

The natural logarithms of the lead and nickel levels were used in all models as these data were highly skewed. The dependent variable was the follow-up lead reading. Distance was modelled in kilometres and as a continuous variable. Cleaning was modelled as a dichotomous variable (1= yes, 0=no). Because the initial metal concentration influenced the degree of change, the first metal reading was included in the model. Thus the independent effects of cleaning and distance from the Port are adjusted for first metal reading.

The statistical analysis was conducted using SPSS V15 (Chicago) and STATA (Texas) statistical packages.

RESULTS

These results are structured to address Aim 1 first, that is provide a description of lead and nickel concentrations over time and by cleaning status. These results determined whether further analysis was required. If it was shown that lead or nickel levels did not reduce substantially after cleaning, then analyses were undertaken to describe the factors associated with the second metal reading (Aim 2). These factors included roof and tank characteristics, cleaning status and distance from the Port. To address Aim 2, roof and tank characteristics are first summarised and comparisons made by lead and/or nickel concentrations. Lead and/or nickel concentrations by distance from the Port are also presented. Finally linear regression models of the relationship between follow-up lead and/or nickel concentrations and cleaning status, distance from the Port and roof catchment and rainwater tank characteristics, are presented.

Aim 1: to determine whether lead and nickel concentrations have reduced as a result of tank cleaning

Descriptive analysis of lead and nickel concentrations

Group characteristics at baseline

In total 176 rainwater tanks were re-sampled; 97 in Group 1, 49 in Group 2 and 30 in Group 3.

Of the 97 samples taken in Group 1, 62 samples (64%) were above the ADWG for lead and 70 (72%) over the ADWG for nickel. Among these, 35 samples were above both

lead and nickel standards (Table 2). In Group 2, 24 samples were above the ADWG for lead (49%) and 40 (82%) were above the ADWG for nickel, out of a total of 49 samples. All samples in Group 3 were below the ADWG.

Table 2 Proportion of samples above the ADWG for lead and nickel guidelines at baseline, Esperance March- June 2007 (n=146).

	NUMBER OF TANKS	ABOVE LEAD		ABOVE NICKEL		ABOVE BOTH	
		ADWG ONLY		ADWG ONLY		ADWG	
		N	%	N	%	N	%
Group 1	97	62	27.8	70	72.2	35	36.1
Group 2	49	24	49.0	40	81.6	15	30.6

Lead and nickel concentrations at baseline and follow-up sampling.

The mean and median concentrations of both lead and nickel decreased between baseline and follow-up samples (Table 3). At baseline the overall mean and median concentrations for both lead and nickel were above the ADWG, that is 0.01mg/L for lead and 0.02mg/L for nickel. At follow up, both had reduced to below their respective ADWG, but the percentage reduction was greater for nickel (85%) compared with lead (55%) (Table 3).

Figures 3 and 4, provided by the Department of Health, present smoothed maps of lead concentrations in the study area at baseline and follow-up. They depict a visual summary of the spatial distribution of lead levels. Figures 5 and 6, also provided by the Department of Health, are smoothed maps of nickel concentrations in the study area as at baseline and follow-up.

Table 3 Lead and nickel concentrations in tank rainwater at baseline and follow-up, Esperance 2007 (n=176)

Sample time	Lead			Nickel		
	Mean	Median	Range	Mean	Median	Range
Baseline	0.018	0.010	0.001-0.160	0.047	0.027	0.001-0.700
Follow up	0.008	0.004	0.0004-0.100	0.007	0.003	0.000-0.110

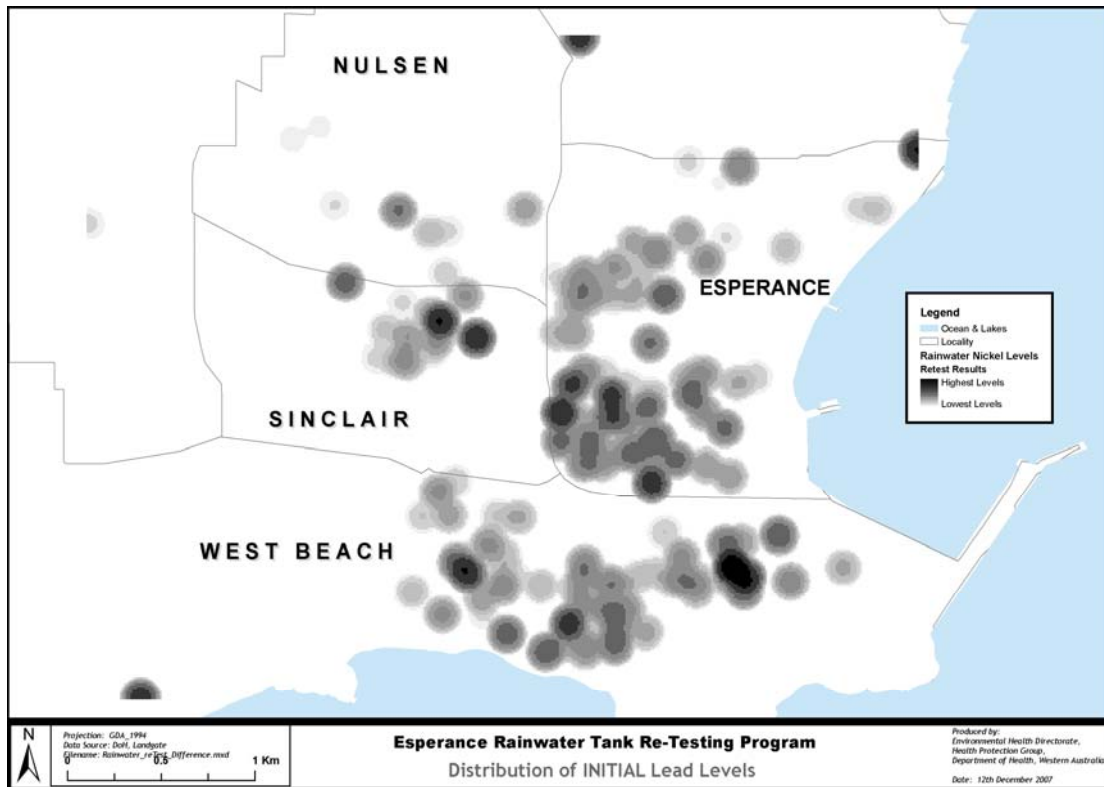


Figure 3 Spatial Distribution of Lead Levels in Rainwater Tanks at Baseline, Esperance March- June 2007

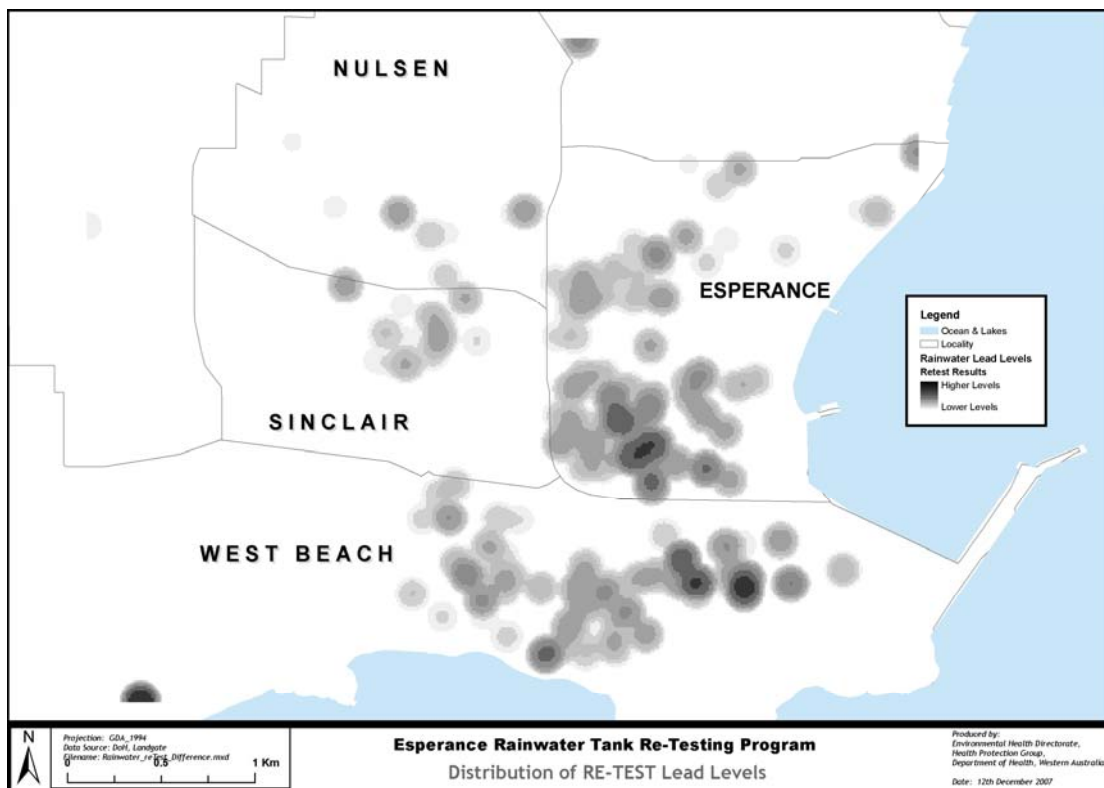


Figure 4 Spatial Distribution of Lead Levels in Rainwater Tanks at Follow-up, Esperance, October 2007

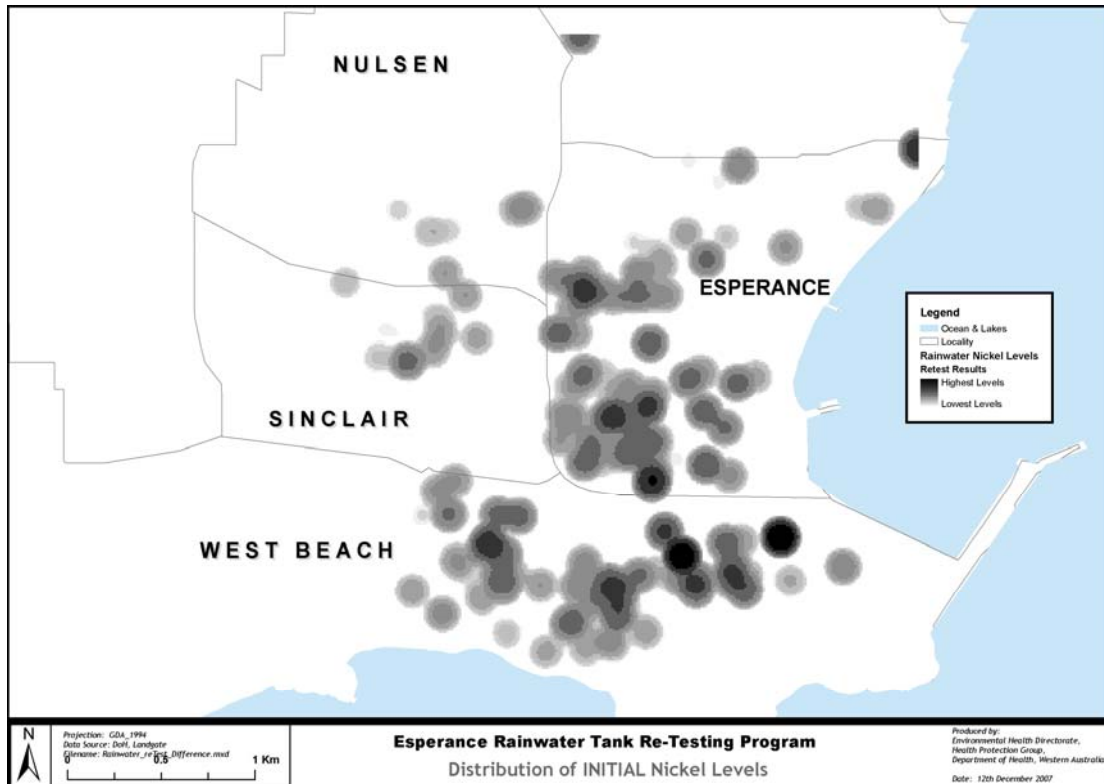


Figure 5 Spatial Distribution of Nickel Levels in Rainwater Tanks at Baseline, Esperance March- June, 2007

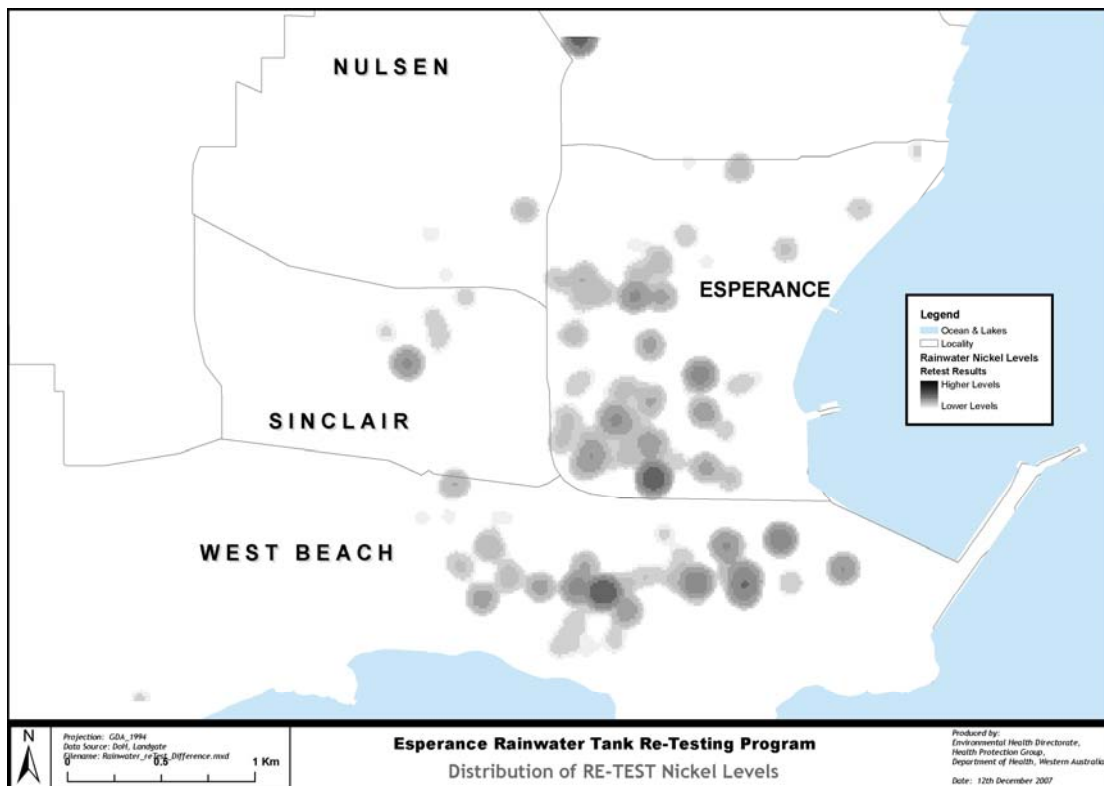


Figure 6 Spatial Distribution of Nickel Levels in Rainwater Tanks at Follow-up, Esperance, October 2007

Cleaning of tanks

EspPA provided dates of cleaning for the 97 tanks in Group 1. These tanks were cleaned between May and August, 2007.

In the survey of residents (n =143), an additional 29 tanks were reported to have been cleaned by the household. Among respondents from Group 2, 26 (63%) out of 41 reported that they had cleaned their tank, while three (13%) out of the 24 respondents in Group 3 reported that they had cleaned their tanks. Tanks were reported by residents to have been cleaned between March and September of 2007.

The time between cleaning and the second sample ranged from 6 to 33 weeks, with a mean of 19 weeks.

Lead and nickel concentrations by group and cleaning status.

Table 4 presents the mean, median and range of lead and nickel concentrations at baseline by Group and also by cleaning status for Group 2. Group 2 has been subdivided into Group 2a for tanks cleaned by household and Group 2b for tanks not cleaned.

For lead, the concentrations in Groups 1, 2a and 2b declined over time and for Group 3 stayed approximately the same. The means are below the ADWG at follow up for all Groups except Group 2b, the not-cleaned subgroup. In this subgroup the median is just above the ADWG. The per cent reduction in means for each group was similar; Group 1 55%, Group 2a, 60% and Group 2b, 54%. The median values, which better reflect the skewed nature of these data, indicate that the reduction in not-cleaned Group 2b was less. The per cent reduction in median values for each group was; Group 1 62%, Group 2a, 56% and Group 2b, 25%.

For nickel there were decreases in mean concentrations in all Groups and all were below the ADWG at follow up. The decreases in mean concentrations on Groups 1 and 2a were around 90%, whereas for Group 2b the decrease was 36%. The decreases in median concentrations were similar in each group, Group 1 91%, Group 2a, 85% and Group 2b, 84%.

These results indicate that the nickel levels have reduced to a greater extent than lead between March and October 2007. Cleaning of tanks appears to have had a greater influence on reducing the nickel concentrations rather than lead concentrations.

Table 4 Lead concentrations in tank rainwater by Group, Esperance 2007

Lead	n	Baseline samples			Follow up samples		
		Mean	Median	Range	Mean	Median	Range
Group 1 Exceeded lead or nickel standard and cleaned by EspPA ¹	97	0.020	0.013	0.001-0.160	0.009	0.005	0.000-0.100
Group 2a² Exceeded lead or nickel standard and cleaned by household	26	0.020	0.009	0.001-0.100	0.008	0.004	0.001-0.028
Group 2b Exceeded lead or nickel standard and not cleaned	15	0.024	0.012	0.001-0.100	0.011	0.009	0.001-0.038
Group 3 did not exceed either standard and not cleaned by EspPA	30	0.003	0.002	0.001-0.009	0.002	0.002	0.000-0.007
Nickel							
Group 1 Exceeded lead or nickel standard and cleaned by EspPA	97	0.048	0.032	0.001-0.680	0.005	0.003	0.000-0.037
Group 2a² Exceeded lead or nickel standard and cleaned by household	26	0.086	0.040	0.003-0.700	0.009	0.006	0.001-0.038
Group 2b Exceeded lead or nickel standard and not cleaned	15	0.045	0.037	0.002-0.110	0.029	0.006	0.001-0.110
Group 3 did not exceed either standard and not cleaned by EspPA	30	0.007	0.006	0.002-0.019	0.002	0.002	0.001-0.006

1. EspPA=Esperance Port Authority

2. Data on cleaning for 8 tanks not available and these data have been excluded.

Because of the proportion of cleaned tanks in Group 2, the subsequent analyses will consider only cleaned versus not cleaned tank samples rather than comparisons across Groups. As the cleaning status was available for 161 out of the 175 tanks, the sample size for these data is 161. For reference, the results by Groups are presented in Appendix 5.

Comparisons by cleaning status

There were substantial reductions in mean and median lead and nickel concentrations in both tanks that were cleaned and those not cleaned (Table 5).

The reduction was greatest for nickel in cleaned tanks. The percentage reduction in median nickel concentrations was 88%, whereas for those tanks not cleaned the reduction in nickel concentration was 63%. For lead there was little difference in the reduction between the cleaned tanks and not-cleaned tanks; the reductions in the median concentrations were 58% and 60% respectively.

The difference in lead concentration between follow-up and baseline was not significantly associated with cleaning status (p=0.266). In contrast, the difference in nickel concentrations between follow-up and baseline was significantly associated with cleaning status (p=0.009), with the difference being greater in the cleaned group.

Table 5 Lead concentrations in tank rainwater by cleaning status, Esperance 2007 (n=161)

Tanks cleaned by EspPA ¹ or household (n=125)				Tanks not cleaned (n=36)		
Lead	Mean	Median	Range	Mean	Median	Range
Baseline	0.020	0.012	0.001-0.160	0.012	0.005	0.001-0.100
Follow up	0.009	0.005	0.001-0.110	0.006	0.002	0.000-0.038
Nickel						
Baseline	0.055	0.032	0.001-0.680	0.023	0.008	0.002-0.110
Follow up	0.006	0.004	0.002-0.700	0.013	0.003	0.001-0.110

1. EspPA- Esperance Port Authority

In Table 6 the percentages at or above the ADWGs for lead and nickel for cleaned and not-cleaned rainwater tanks, at the two time points are presented. Histograms of the distributions of lead and nickel concentrations at baseline and follow up are shown in Appendices 2 and 3.

At baseline 80 (50%) of all lead samples (n=161) were at or above the ADWG for lead of 0.01mg/L, whereas at follow up this had reduced to 34 (21%). For nickel the reduction was greater, with 103 (64%) of all samples at or above the ADWG of 0.02 mg/L at baseline and 13 (8%) at follow up. While there are small numbers in the not-cleaned group, they provide an indication of the reduction that would have occurred without

cleaning. For lead the proportion above the ADWG reduced by 61% in the cleaned group compared with 33% in the not-cleaned group. For nickel, the proportion above the ADWG reduced by 92% compared with 50% in the not-cleaned group.

Table 6 Proportion of tanks with lead and/or nickel concentrations at or above the standard by cleaning and time, Esperance 2007

Lead	Total	Baseline samples at or above ADWG		Follow-up samples at or above ADWG	
		n	%	n	%
Cleaned by EspPA ¹ or household	125	72	57.6	28	22.4
Not cleaned	36	9	25.0	6	16.7
Total	161	81	50.3	34	21.1

Nickel					
Cleaned by EspPA ¹ or household	125	91	72.8	7	5.6
Not cleaned	36	12	33.3	6	16.7
Total	161	103	64.0	13	8.1

1. EspPA= Esperance Port Authority

When the cleaned tanks were stratified by date of cleaning, that is the period, March to June, compared with July onwards, the follow up means and medians were the same as for the cleaned group as a whole (as shown in Table 5).

Summary of Analysis for Aim 1

In summary, these data indicate that there have been reductions in both lead and nickel concentrations, but that the reduction has been greater for nickel concentrations. The reduction in nickel concentration was significantly associated with cleaning status. Hence the analysis for Aim 2, that is to describe the factors associated with concentrations at follow-up, is limited to lead levels.

Aim 2 To describe the factors associated with continuing higher concentrations of lead.

Characteristics of tanks sampled

The characteristics of the tanks and their roof and gutter catchment areas are shown in Table 7 and Table 8. Data were available for a maximum of 143 tanks only, with varying amounts of data missing within that group. When there were considerable missing data, these variables were not included in further analyses. These variables were, with the number of missing data in parentheses: age of house (90) households; age of roof (36); area of catchment (80), age of tank (75) tank cleaning routine (73), roof cleaning routine (61) and tank volume (50).

Tanks were predominantly made of Zinalume and plastic and there were no concrete tanks. Nearly all tanks (96%) were reported to be in good condition. Five per cent of tanks had a first flush diverter, and most did not have an opening on the tank roof. Over half the tanks (55%) had a screened inlet. The usual tank cleaning routine was available for only half of the tanks and for the majority of these (74%) cleaning occurred irregularly or never.

The most common roof material was Colourbond, followed by tile. For gutters Colourbond was the most common material. Of the 132 tanks for which the roof condition was noted, 86% were in a good condition (Table 8). Eighty two households answered the question about cleaning the roof catchment and 77% indicated that they never or irregularly cleaned the roof catchment area. For gutters, 44% of households cleaned their gutters at least annually, whereas 56% never or irregularly cleaned gutters.

Table 7 Characteristics of rainwater tanks, Esperance 2007 n=143

Characteristic	Number	Percentage
<i>Rainwater tank material</i>		
Zinalume	53	37.9
Colourbond	30	21.4
Plastic	45	32.1
Fibreglass	12	8.6
Missing	3	
<i>Condition of rainwater tank</i>		
Poor	0	0
Fair	6	4.3
Good	135	95.7
Missing	2	
<i>First flush device installed</i>		
Yes	7	4.9
No	136	95.1
Missing	0	
<i>Opening on tank roof</i>		
Yes	25	17.5
No	118	82.5
Missing	0	

Table 8 Characteristics of catchment roof and gutters, Esperance 2007 (n=143)

Characteristic	Number	Percentage
<i>Material- Roof catchment area</i>		
Zincalume	25	17.8
Colourbond	61	43.7
Asbestos cement	9	6.4
Tile	45	32.1
Missing	3	-
<i>Condition of roof catchment area</i>		
Poor	1	0.8
Fair	17	12.9
Good	114	86.4
Missing	11	-
<i>Material- gutters</i>		
Zincalume	41	18.2
Colourbond	70	49.0
Plastic	6	4.2
Other	26	18.2
Missing	0	-

Lead concentrations by tank and catchment characteristics

Comparisons were made of lead concentrations at follow-up sampling by tank or roof catchment characteristics for those variables for which there were minimal missing data and some variation in the distribution. For example first flush diverters were not considered as 95% of tanks did not have a diverter. The regular cleaning routine for tanks was not compared as data were not available for 71 tanks.

There were no significant differences in the distribution of lead concentration by tank and catchment characteristics.

Table 9: Cross-tabulation of tank and catchment characteristics by proportion of samples above and below 0.01µg/L lead (n= 143)

Tank and roof characteristics ¹		LEAD CONCENTRATION AT FOLLOW UP			
		<0.01mg/L		≥0.01mg/L	
		n	%	n	%
Tank material	Zincalume	43	39.1	10	33.3
	Colourbond	23	20.9	7	23.3
	Plastic	34	30.9	11	36.7
	Fibreglass	10	9.1	2	6.7
Roof material	Zincalume	19	17.3	6	20.0
	Colourbond	51	46.4	10	33.3
	Asbestos cement	5	5.4	3	10.0
	Tile	34	30.9	11	36.7
Gutter material	Zincalume	32	28.3	9	30.0
	Colourbond	54	47.4	16	53.3
	Plastic	5	4.4	1	3.3
	Other	22	19.5	4	13.3
Opening in tank roof	No	94	83.2	24	80.0
	Yes	19	16.8	6	20.0
Condition of roof	Poor/average	17	16.3	1	3.6
	Good	87	83.7	27	96.4

1.Total may not add to 143 due to missing data

Lead concentrations at follow up by distance from the Port

The distribution of lead concentrations by distance from the Esperance Port is shown in Table 10. This analysis includes data from all 176 samples, but the same pattern was seen when the data were limited to the 161 samples for which cleaning status was known. Samples that were above the lead ADWG tended to be from tanks closer to the Port. Seventy per cent of these samples were within 1.5 kms compared with 54% of samples below the standard being within 1.5kms. These differences were statistically significant ($\chi^2_{(3 \text{ df})} = 9.4, p=0.025$).

Just 13 samples were at or above the nickel ADWG at follow-up, six of these were within 1 km of the Port , 5 between 1.01 km and 1.5 km and 2 more than 2 km.

Table 10 Lead concentrations by distance from the Esperance Port (n=176).

DISTANCE FROM PORT	LEAD CONCENTRATION AT FOLLOW-UP				
	Total	<0.01mg/L		≥0.01mg/L	
		n	%	n	%
0-1.00 km	26	15	10.7	11	30.6
1.01- 1.50 km	75	61	43.6	14	38.9
1.51- 2.00km	44	38	27.1	6	16.7
More than 2.00 km	31	26	18.6	5	13.9

Linear Regression Models

The influence of cleaning and distance from the Port on the follow-up lead levels were modelled for the dataset of 161 samples, for which data on cleaning status of tanks were available. A secondary analysis that included the tank and catchment characteristics was then undertaken on the dataset of 143 samples.

The regression model looking at the effect of cleaning and distance from the Port, adjusted for the initial lead reading, is shown in Table 11. Distance from the Port was significantly related to the second lead reading. As distance from the Port increases the lead concentration decreases.

Cleaning status had no significant influence on the second lead reading. While the descriptive analysis in Aim 1 suggested that cleaning may have reduced lead levels, when adjustment is made for the baseline lead reading and distance from the Port, cleaning no longer has a significant effect on the follow-up lead reading.

Table 11 Linear Regression Model: Effect of cleaning, distance from Port and baseline lead reading on follow up lead concentration (n=161)

	Coefficient	95% Confidence Interval		P-value
Constant	-2.825			
LnPb1- Baseline	0.437	0.320	0.554	<0.001
Cleaned versus not cleaned	0.106	-0.232	0.444	0.537
Distance in kilometres	-0.426	-0.654	-0.177	0.001

Model 1: $\text{LnPb}_2 = 0.437(\text{LnPb}_1) + 0.106 (\text{Cleaned}) - 0.426 (\text{Distance in km}) - 2.825$.
R- square = 0.376

To illustrate this model, if a tank was located one kilometre from the Port, had been cleaned and the initial lead reading was 0.01mg/L (the natural logarithm equals -4.605), the second lead reading is predicted to be:

$$\begin{aligned} \text{LnPb}_2 &= 0.437(-4.605) + 0.106(1) - 0.426(1) - 2.825 \\ \text{LnPb}_2 &= -5.157 \end{aligned}$$

Hence the predicted second lead reading would be 0.006mg/L.

If all factors are kept equal, that is the baseline reading is 0.01mg/L and the tank is cleaned, the predicted follow up levels decrease with distance, but each is below the lead standard (Table 12). If the baseline reading is 0.02mg/L and the tank within 0.5kms of the Port the predicted follow-up reading is 0.01mg/L.

Table 12 Predicted follow-up lead reading based upon model by varying distance from the Port for cleaned tanks, Esperance 2007

Distance from Port	Baseline lead level	Predicted second lead level
	mg/L	mg/L
0.5kms	0.01	0.007
1.0kms	0.01	0.006
1.5kms	0.01	0.005
2.0kms	0.01	0.004
0.5kms	0.02	0.010
1.0kms	0.02	0.008
1.5kms	0.02	0.006
2.0kms	0.02	0.005

The next model includes the tank and catchment characteristics. Because of missing values for some variables, there were 138 complete observations out of the dataset of 143 samples. Again the model adjusted for the baseline lead concentration.

The significant predictor in this model was distance from the Port. None of the tank characteristics were significant predictors of the second lead reading. Cleaning of the tanks again was not associated with the second lead reading. Hence, given the data available, Model 1 is adequate for predicting the follow up lead concentration.

Table 13 Linear Regression model 2- Effect of cleaning, distance from Port, baseline lead reading and tank and catchment characteristics on follow up lead concentration (n=138)

	Coefficient	95% confidence interval		P-value
Constant	-2.41			
LnPb- sample 1	0.486	0.351	0.621	<0.001
Cleaned vs. not cleaned	0.077	-0.303	0.458	0.689
Distance in kilometres	-0.399	-0.660	-0.138	0.003
Tank material (reference Zincalume)				0.368
Colourbond	0.054	-0.351	0.460	
Plastic	0.005	-0.365	0.376	
Fibreglass	0.429	-0.082	1.067	
Roof material (reference Zincalume)				0.369
Tile	0.261	-0.720	0.199	
Asbestos cement	0.168	-0.587	0.923	
Colourbond	-0.292	-0.789	0.205	
Gutter material (reference Zincalume)				0.679
Colourbond	0.003	-0.430	0.435	
Other ¹	-0.170	-0.651	0.311	
Opening on tank roof	0.101	-0.316	0.518	0.633

1. plastic combined with other.

Summary of Analysis for Aim 2

The analyses undertaken here indicate that the lead levels have reduced but the reduction is less with increasing distance from the Port. Cleaning status, tank and roof characteristics did not significantly influence the follow-up lead concentrations.

The effect of the variable “distance from the Port” on follow- up lead levels could reflect one of three possibilities. It may be that :

1. The Port is a source of ongoing lead contamination. While lead carbonate is no longer handled the Esperance Port, the buildings, railway lines and the ground surrounding the areas where the lead carbonate was unloaded from kibbles and loaded onto ships may still be contaminated with lead. This lead could then be re-entrained into the air and contaminate tanks closer to the Port. The extent and success of any cleaning programs undertaken at the Port

- as a result of environmental notices issued by the Department of Environment and Conservation need further consideration;
2. The existing contamination in the surrounding environment is still circulating and being deposited into tank rainwater. It may be that trees and shrubs and possibly soil in the local environment are still contaminated with lead and this is being re-entrained by wind into the air and then deposited on roof catchments;
 3. It is a combination of the above.

The cleaning protocol for rainwater required that the “bottom part of the roof” be cleaned (see Appendix 1). Cleaning of the roof catchment may not have adequately removed lead from this environment, with those closest to the Port having the higher levels of lead deposition in the past. With time this contamination has been washed into the rainwater tanks.

The main tank and roof characteristics were investigated and they did not influence follow-up lead concentrations.

DISCUSSION

Various types of summary statistics have been used to describe the level of lead and nickel contamination. The mean, median and range were extracted, as was the proportion above the Australian Drinking Water Guidelines for both metals of interest. The relationship between the follow-up lead readings and cleaning status and distance from the Port was also modelled. These provide us with information on the current status of rainwater tanks in the town of Esperance.

The key findings of this study are:

- Lead and nickel levels have decreased between baseline and follow-up;
- Cleaning of tanks impacted upon nickel concentrations, to the extent that only 8% of the follow-up sample remain above the guideline;
- Cleaning of tanks had minimal impact on the follow-up lead concentrations.
- Follow-up lead concentrations were related to distance from the Port. As distance from the Port increased the follow-up lead concentrations decreased. Distance from the Port could reflect ongoing contamination from the Port or it could be a proxy for re-mobilisation of existing lead contamination in the environment or residual roof contamination.

The baseline tank rainwater samples were taken between April and June and the follow-up samples were taken in October. During the autumn period between samples the prevailing winds in the morning were from the North/ North-West and North-East and in the afternoon they were from the South-East and South. In winter period between sampling the prevailing winds were from the North-West/ North and West for both morning and afternoon (http://www.bom.gov.au/climate/averages/wind/selection_map.shtml). The winds most likely to pick up contamination, if present, from the Port and the surrounding areas and then transport this across the town site would be from the North through to the South-East. Hence it is possible that rainwater tanks have been re-

contaminated. In summer, the prevailing winds are from the North-East and South-East and potentially this contamination of the local environment, if it exists, will be continuing.

It is noted that Department of Environment and Conservation has issued an environmental protection notice under Section 65 of the Environmental Protection Act 1986, requiring the Port Authority to undertake extensive sampling across the Esperance Port in order to develop and implement clean-up plans for the reduction of lead contamination at the Port. The Port has undertaken this sampling and developed a clean-up plan (for further details see http://www.esperanceport.com.au/downloads/env/Lead_Sampling_Clean_Up_and_Validation_Pt_1.pdf). The early implementation of this clean-up plan would minimise any further contribution of lead into the Port area into the environment.

There are a number of reasons as to why nickel may not have re-contaminated tanks and for levels to have reduced to a greater extent than lead. Nickel has been handled at the Port for about 30 years and any cleaning of the Port environment would have removed deposits that have built up over a long period of time. The concentrate is about 8%-15% nickel, whereas for lead, the concentrate is in the order of 65% lead. There has been a number of engineering upgrades at the Port to reduce the potential for nickel dust. The EspPA has specified the minimum moisture content and pH of nickel arriving at the Port and maintained the moisture content during storage in sheds at the wharf. There has been a presence of Department of Environment and Conservation officers monitoring nickel concentrate loaded onto ships.

CONCLUSIONS

The most important factor influencing the follow-up lead readings was the distance from the Port. As the distance from the Port increased, the follow-up lead concentration decreased. On the other hand whether a tank was cleaned had no apparent effect on the follow-up lead concentration. These findings suggest that there may be ongoing contamination of rainwater tanks from the environment. The lead levels may be a result of ongoing contamination arising from the Port environment, the re-mobilisation of existing lead contamination of the environment, the difficulties in removing residual lead from the roof catchment areas or a combination of these.

Nickel levels have been reduced substantially as a result of the rainwater tank cleaning program.

As a result of these findings it is recommended that people in Esperance continue to be advised not to drink rainwater. In addition, it is recommended that there is further investigation of lead levels in the Port environs, the surrounding residential areas and roofs to identify and address any environmental sources of lead.

Further sampling of tank rainwater may be required to assess whether there is continuing contamination of tank rainwater by lead and/or nickel and to evaluate any interventions to reduce lead exposure.

APPENDIX 1 ESPERANCE PORT AUTHORITY RAINWATER TANK CLEANING PROCEDURE

This document was provided by the Esperance Port Authority and is available on the Department of Health website.

APPENDIX 2 SAMPLING PROTOCOL

Purpose of Activity: To ascertain the quality of rainwater collected in rainwater tanks in the Esperance town site area.

Sampling protocols have been designed to ensure the integrity of the collected samples and may not meet the necessary requirements for regulatory purposes.

Rainwater Tank Sample Request

- 1.1. Receive request to sample rainwater tank by phone or in person (constitutes consent to take rainwater tank sample)
- 1.2. Shire personnel to request permission to enter property in the absence of resident, or arrange a suitable time to meet at the property.
- 1.3. Notification of request posted in Rainwater Tank Sampling data base

Rainwater Tank Sample Procedure

- 1.4. Shire personnel to attend residence and locate rainwater tank
- 1.5. Rainwater tank samples to be collected in the supplied Chemistry Centre (WA) receptacles for Domestic Suite Analysis (consisting of two sample bottles) only.
- 1.6. Shire personnel to write details of water sample to be taken on labels of both Chemistry Centre (WA) supplied bottles:

SAMPLE TYPE: domestic suite

SAMPLE ID: location details/address

DATE/TIME:

CLIENT/CONTACT: Shire of Esperance

Collection of sample

- 1.7. Remove any filtration devices or cloth material used as such from the rainwater tank tap outlet.
- 1.8. Turn on tap of rainwater tank and allow a steady stream of rainwater to flow for 15-30sec.
- 1.9. Undo lids of sample receptacles.

- 1.10. Hold opening of bottle under the water stream.
- 1.11. Fill bottles completely minimising air pockets that may result whilst filling.
- 1.12. Re-cap bottles immediately.
- 1.13. Bottles to be placed in chilled esky as soon as possible (within 2-5 minutes).

Complete Rainwater Tank Survey form.

- Note roof material – tiles, colorbond steel, galvanized steel, asbestos, and other.
- Note tank material – colorbond steel, galvanized steel, fibreglass, polyethylene plastic
- Note presence or absence of a first flush diversion apparatus.
- Note observations on survey form.

If owner is present, ask the following questions to complete survey.

- What are the uses of the rainwater?
- How old is the roof material?
- How old is the tank?
- When was the tank last cleaned?
- When was the tank last flushed?
- When were the gutters last cleaned?
- Were the gutters cleaned before the last heavy rainfall (January 2007)?

Packing of bottles for courier transport.

1.14. On return to the Shire of Esperance office, sample bottle pairs are joined together with elastic bands and placed in Environmental Health Services fridge (located in the Staff Room) or packed in an esky with an appropriate number of ice bricks to maintain a chilled temperature.

1.15. Eskies prepared for transport are to be appropriately secured and labelled for transportation. Individual Esky labels to include sender details, recipient details, and individual item number of total item number. Shire of Esperance personnel to complete 'Chemistry Centre (WA) Chain of Custody' form for the samples they have collected.

Complete 'Chemistry Centre (WA) Chain of Custody' form

1.16. Information to be written on 'Chemistry Centre (WA) Chain of Custody' form shall include:

'Sample ID' – address/location (as written on sample bottle label)

'Date' - of sample collection

'Test Required' - Domestic Suite Analysis

Check 'Water – Other' column

Note 'Rainwater' in 'Comments' column.

'Courier Name' - Courier Australia

'Client' -Shire of Esperance

'Sampled by' - samplers name

1.17. Chain of Custody form to be duplicated and the hard copy filed in the water sampling records folder. The original is sealed in a plastic zip lock bag and packed with the water samples for delivery to the Chemistry Centre (WA).

1.18. Shire of Esperance Records department are to be consulted for information of 'Courier Australia' daily collection timetable. If required contact Courier Australia (Phone No 131 885) to arrange for collection.

1.19. 'Courier Australia' consignment note to be addressed to:

Jenny McGuire, Chemistry Centre (WA), 125 Hay Street, East Perth 6004

1.20. Samples are collected by courier as soon as practicable for direct transport to the Chemistry Centre (WA).

Rainwater Testing Data Base Data Entry

1.21. Rainwater Tank Survey information to be entered daily into 'Rainwater Testing' data base by Shire of Esperance personnel performing the sampling procedure.

1.22. Create 'excel' spreadsheet of sampled locations from data base program.

1.23. Forward 'sampled locations' spreadsheet to the appropriate Chemistry Centre (WA) personnel, and appropriate Department of Health personnel by email.

END OF DOCUMENT

APPENDIX 3 HISTOGRAMS OF LEAD CONCENTRATIONS AT BASELINE AND FOLLOW-UP SAMPLING

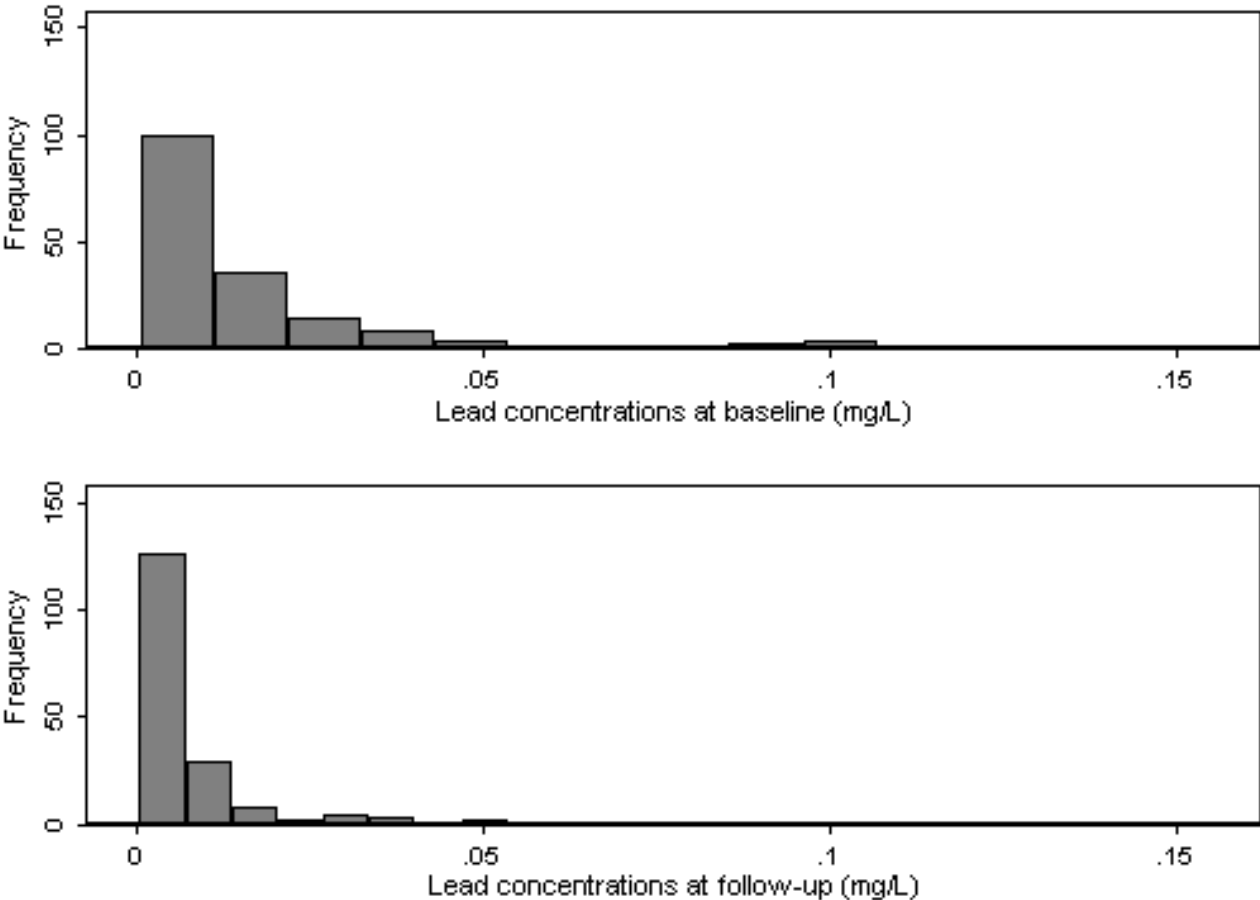


Figure 7 Distribution of lead concentrations at baseline and follow-up

APPENDIX 4 HISTOGRAMS OF NICKEL CONCENTRATIONS AT BASELINE AND FOLLOW-UP SAMPLING

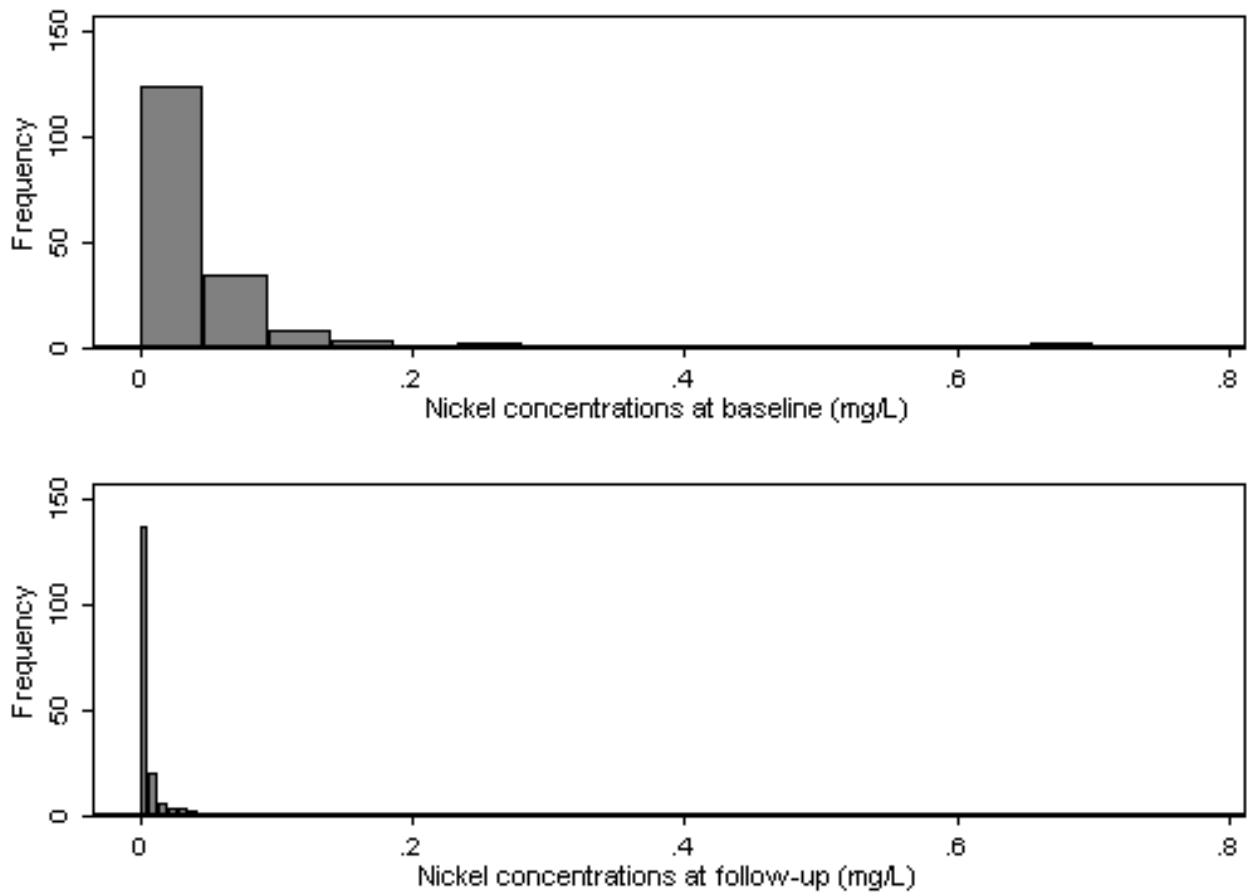


Figure 8 Distribution of nickel concentrations at baseline

APPENDIX 5 RESULTS BY GROUP

Table 14 Lead concentrations in tank rainwater by Group, Esperance, 2007

Lead	n	Baseline samples			Follow up samples		
		Mean	Median	Range	Mean	Median	Range
Group 1 Exceeded lead or nickel standard and cleaned by EspPA ¹	97	0.020	0.013	0.001-0.160	0.009	0.005	0.0007-0.1000
Group 2 Exceeded lead or nickel standard and not cleaned by EspPA	49	0.022	0.010	0.001-0.110	0.008	0.0050	0.0005-0.0380
Group 3 did not exceed either standard and not cleaned by EspPA	30	0.003	0.002	0.001-0.009	0.002	0.002	0.0004-0.0074
Total	176	0.018	0.010	0.001-0.160	0.008	0.004	0.0004-0.1000
Nickel							
Group 1 Exceeded lead or nickel standard and cleaned by EspPA	97	0.048	0.032	0.001-0.680	0.005	0.003	0.000-0.037
Group 2 Exceeded lead or nickel standard and not cleaned by EspPA	49	0.071	0.037	0.002-0.700	0.015	0.007	0.001-0.110
Group 3 did not exceed either standard and not cleaned by EspPA	30	0.007	0.006	0.002-0.019	0.002	0.002	0.001-0.006
Total	176	0.047	0.027	0.001-0.700	0.007	0.003	0.000-0.110

1. EspPA= Esperance Port Authority

Table 15 Proportion of tanks with lead and/or nickel concentrations at or above the standard for Groups 1 and 2 by time, Esperance 2007

		Baseline samples at or above ADWG ¹		Follow up samples at or above ADWG	
Lead	n	n	%	n	%
Group 1 Exceeded lead or nickel standard and cleaned by EspPA	97	62	63.9	21	21.6
Group 2 Exceeded and not cleaned by EspPA	49	24	49.0	15	30.6
Total²	146	86	58.9	36	24.7
Nickel					
Group 1 Exceeded lead or nickel standard and cleaned by EPA	97	70	72.2	3	3.1
Group 2 Exceeded lead or nickel standard and not cleaned by EspPA	49	40	81.6	10	20.4
Total¹	146	110	75.3	13	8.9

¹ADWG= Australian Drinking Water Guideline

²Total of Groups 1 and 2 only as there were no samples exceeding the standards in Group 3.

Table 16: Proportion of tanks for which lead and/or nickel concentrations decreased or remained the same by Group, Esperance 2007

Group	n	Lead		Nickel	
		n	%	n	%
Concentrations remained same or decreased					
Group 1 Exceeded lead or nickel standard and cleaned	97	75	77.3	92	94.8
Group 2 Exceeded lead or nickel standard and not cleaned	49	35	71.4	45	91.8
Group 3 did not exceed either standard and not cleaned	30	23	76.7	29	96.7
Total	176	133	75.6	166	94.3

