



2009 Report on Nickel Dust Monitoring in Esperance

Summary

This report was prepared by the Environmental Health Hazards Unit-Toxicology (Department of Health) as part of ministerial condition (DOH ref:25-09211) to monitor trends in nickel dust concentration in Esperance. This is the annual report for 2009 and contains:

- Details of the air-monitoring network.
- Summary of the network operations protocol during 2009 and notable events.
- Monthly concentration levels of nickel at the monitoring sites and performance against the annual Department of Health guideline for Nickel in ambient air.
- A highlight of exceedances, interpretation of data and discussion of trends across the monitoring network.
- Implications of a guideline exceedance on the health of the population.

During 2009

- The annual average for nickel was exceeded at 4 out of 5 monitoring sites.
- Site 2 consistently reported the higher concentration relative to the other sites.
- Compared to disparate data from 2008 there has been a significant reduction in fugitive nickel emissions from the port in 2009.

Recommendations

- Additional monitors are required in residential areas most vulnerable to port emissions.
- The nickel concentration in PM10 instead of TSP should be measured in the residential areas.
- The characteristics and activities at site 2 should be investigated.

1 Introduction

Bulk nickel loading at the port of Esperance is the single major contributor to fugitive nickel dust in the town of Esperance. The *Esperance Ports Sea & Land Licence 5099/1974/12* (the licence) issued by the Department of Environment (DEC) on the 6th of January 2009 (the licence) requires the Esperance Port Authority (EsPA) to monitor and report nickel concentrations in ambient air.

Monitoring is necessary for several reasons, including: to measure the exposure of the population to nickel; to assess compliance against short term and long term health based guidelines set by the Department of Health (DOH) and to assess the effectiveness of abatement strategies. In order to meet these requirements the nickel concentration was measured at multiple sites.

This is the Annual Report for the Esperance nickel air monitoring network for 2009 and compares monitoring results against the DOH long term health based guideline of 0.003 µg/m³. The report contains:

- Details of the network and network re-organisation required to supply exposure specific data.
- Summary of the network operations protocol during 2009 and notable events.
- Measured monthly concentration levels of nickel at all monitoring sites in the network.
- Performance against the annual guideline.
- A highlight of exceedances, interpretation of data and discussion of trends across the monitoring network.
- The health implications of exceeding the guideline.

2 The Air Monitoring Network

The EsPA manages the air monitoring network and reports the monitoring results monthly as required by the licence. These are published on the Esperance Port Authority website: <http://www.esperanceport.com.au/>

- A network of 5 air-quality monitoring stations surrounds the port. Monitoring sites were chosen based on wind direction, wind speed and historical dust dispersion data. The EsPA follow a monitoring protocol approved by the DEC and the DOH.
- The fifth monitoring station was introduced to the network in July 2009. Site 5 is located at the Council Chambers and while not part of the ports licence requirements is nevertheless managed by the EsPA.

- Between January and June 2009 the lead shed at the port was dismantled and removed. During the removal the network was used to monitor lead dust and Site 5 was originally located behind the port in line with the lead shed. Nickel data captured during this time has not been included in this report.
- Each monitoring station in the network samples TSP. High Volume Samplers (HVS) draw air through a filter paper at a measured rate. The filter papers are analysed for nickel concentration for compliance against both the 24-h and the annual DOH nickel guidelines for ambient air.
- Four stations sample PM₁₀ with TEOMs (Tapered Element Oscillating Microbalance monitors) co-located with the HVS at Sites 1-4. PM₁₀ concentration is monitored for compliance against the national PM₁₀ standard. The TEOM monitoring system does not produce a testable dust sample hence the need for the HVS monitors.

3 Monitoring and Analysis

The role of the EsPA is to inspect the monitoring data for breaches of the licence and record any actions taken to address the breaches. EsPA commissioned SKM and ENV environmental consultants to compile the monthly reports for the DEC who independently audit the data before its published on the EsPA website.

3.1 Monitoring Sites

The monitoring for health convention dictates that monitoring sites should be positioned in a way that enables the population exposure to a pollutant to be best determined. The reality is that the design of any monitoring network needs to consider more than one purpose for the data. The Esperance monitors were placed downwind of the port so to measure the maximum concentration of fugitive dust emissions from the port entering the community while enabling the port to use the data to monitor compliance with their licence.

Additional monitors are required in residential areas to ensure that the risk to the population is properly assessed and to enable any statements about comparison of measured levels with the target value to be made with confidence.

3.2 Sampling

The TSP sampling frequency protocol was determined by prevailing winds. Daily sampling was required during the summer months when winds are on-shore with less frequent sampling during the winter months when winds are off-shore. TSP was required to be sampled daily during ship loading of the nickel concentrate and whenever meteorological criteria as set out in the licence were triggered. Sampling began with every third day between 2 January and 20 January until the sampling protocol was established.

In total 1300 TSP samples across the network were collected between 2/1/2009 and 31/12/2009.

3.3 Analysis

The EsPA commissioned the Analytical Reference Laboratory (ARL) to analyse the HVS filter papers for TSP & nickel between 1 January and 19 January 2009.

However their standard laboratory method for analysing nickel in TSP did not allow nickel to be detected at the very low concentrations required by the guideline. The inherent limits of their chemical analytical method meant that very small concentrations above the background could not be precisely measured. These small concentrations are said to be below the 'limit of detection' (LOD), various LODs exist. The most appropriate analytical method is the one that yields the smallest LOD relative to its intended use.

ARL reported an unacceptable LOD of $0.005 \mu\text{g}/\text{m}^3$ compared to the guideline of $0.003 \mu\text{g}/\text{m}^3$. Only two samples were less than the LOD during the sample period hence the influence on the monthly mean was not a factor.

MPL laboratories analysed the HVS filter papers between 20 January and 31 December 2009. Their limit of detection was reported as the Lower Quantitation Limit (LQL) The LQL is usually significantly higher than the LOD therefore the LQL is more likely to be a real value and not a random fluctuation however LQLs still need to be as low as possible to report a concentration with a reasonable degree of accuracy and precision. MPL reported an LQL of $0.003 \mu\text{g}/\text{m}^3$ before it was reduced to $0.002 \mu\text{g}/\text{m}^3$ in September. Currently standardised analytical procedures for nickel particulates do not allow for a smaller limit of detection.

3.4 Measurement Uncertainty

No measurement is exact. The measured concentration of nickel in the dust sample will be subject to a variety of influences. One such influence is the LOD, discussed in section 3.3; others are discussed below.

Correct functioning of the monitors over the sampling period is required to yield meaningful analytical results. Overall monitor function was >95% of their operational time therefore monitor function did not present a source of uncertainty.

Sampling occurred every third day for the first 19 days in January instead of daily sampling. Another 10 days of data was lost across the network but neither at the same time nor site. Despite data lost it did not represent a significant uncertainty in the annual mean because the potential error was contained to relatively few days spread across the network or at non-critical sites.

LODs are a characteristic of all analytical analysis as already discussed. In simple statistical analyses, values reported as less than the LOD (censored values) could be interpreted as missing values and not present a problem when they occur infrequently and at random. However censored values are not in fact missing they are just imprecise at some value less than the LOD. An accepted practice is to substitute the censored value with a constant value,

such as half the LOD or, the LOD divided by the square root of 2 ($DL/\sqrt{2}$) or, the LOD value or zero. Although there is no single universally accepted method for replacing the censored values, half the LOD is often used although substitution with ($DL/\sqrt{2}$) has been reported as a better compromise between the LOD, half the LOD and zero.

The censored values are extraordinarily small; however they can still have a large effect on the distribution of the entire set of observations when they occur frequently. The magnitude of the uncertainty depends upon the percentage of censored values in the data. As the number of substituted values exceeds 25% the greater is the uncertainty in the mean. Across the network in Esperance, 45% of the samples analysed during 2009 were below the detection limit and hence the uncertainty in the annual mean is dominated by analytical uncertainty.

This uncertainty does not preclude the analytical method because it is inevitable that measurements must be made at very low levels. Instead, some caution is required in interpreting the measurements so as not to invalidate the entire dataset at the convenience of statistical analysis.

4 Data Quality & Processing

4.1 Ratification

The DEC ratified the concentration data each month in their role as the State regulator. DEC officers plotted the daily concentration of nickel at each site in a time series and displayed the data in a continuous list of values that could be easily compared. One aim of the ratification was to distinguish between changing ambient concentrations and analytical discrepancies.

The data was inspected visually for any obvious discrepancies, if reasons were found for any discrepancies such as incorrect transcription or analytical error the dataset was corrected before it was sent to DOH for an independent health based audit.

4.2 Data Processing

Processing the data for statistical analysis requires that only measurements that pass quality assurance criteria for data capture and time coverage are included in the statistical analysis. Time coverage of 50% is typically acceptable for monitoring annual trends provided the 50% captures all the data of interest. Given the sensitivity around the dust emissions in Esperance, DOH expected a data capture of at least 75%. Overall data capture across the network for the HVS was >90%.

Analytical analysis of the network samples produced concentration values over a 24 hour period. Censored values were replaced by a calculated $DL/\sqrt{2}$ value. The data were then treated in the following ways:

- The monthly concentration mean for each site was derived from the mean of the 24 hour values recorded at each site.

- Annual means for each site were derived by averaging the monthly means for each site.
- A network wide annual mean was derived by averaging the annual means.

Only measurements where the valid sampling period was greater than 75% of the required 24-h sampling period were counted. This accounted for more than 90% of the sample.

4.3 Measured Uncertainty of Annual Average

Since the data capture across the HVS network was very high, uncertainty caused by data capture was not a significant factor.

Shorter monitoring period influence the network wide mean so Site 5's contribution to the annual mean has been weighted accordingly to decrease its contribution to the mean proportionally.

5 Network Data

5.1 Daily & Monthly concentrations.

The average monthly nickel concentration as TSP at sites 1-5 (see attachment) is plotted in figure 1 as a column chart. The line plot shows the corresponding TSP concentrations at site 2.

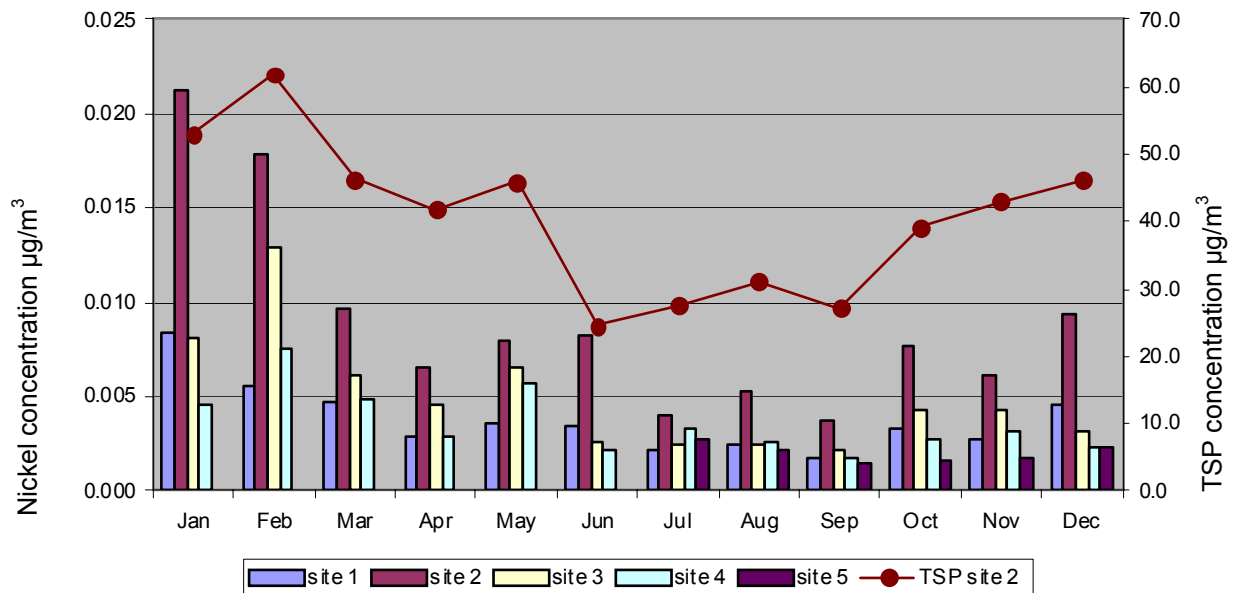


Figure 1: Measured monthly mean concentration of nickel at individual sites plus TSP concentration at site 2.

The monthly fluctuations in nickel concentration are strongly associated with seasonal wind direction. On-shore winds, south & south-east, dominate during the warmer months and blow across the port towards the town and residential areas. North and north-west off-shore winds dominate during the winter. The strong association between summer wind direction and elevated nickel concentrations during summer confirms the port as the main source of nickel laden dust. No other source of bulk nickel is present in Esperance to account for these observations.

Monitoring wind direction is critical to managing fugitive dust emissions from ship loading. The ship loading protocol requires loading to stop temporarily when winds blow from the south to north-easterly directions. In May (10-13) and November (9-12) nickel concentrations spiked when ship-loading occurred during on-shore winds. During these days winds were highly variable making ship loading more difficult to manage.

Nickel concentration fluctuates daily at each monitoring site and shares 3 characteristic features:

- 1) Nickel concentrations spike during ship loading activity.
- 2) In-between ship loading activity spikes nickel concentration drops to below detection.
- 3) Infrequent random spikes occur across the network in-between ship loading activities.

A spike is defined as any concentration above the guideline. Ship loading, nickel ore handling and transport to the port are likely to contribute to the random spikes during the year. The interval between spikes and the magnitude of the spikes are closely associated with the seasonal wind direction and ship loading activities. Random spikes are bigger and more frequent during the warmer months and smaller and fewer during winter months. During the summer months nickel concentration spikes from 1 to 5 days, depending on the location of the monitors. In-between spikes the nickel concentration tends to fall below the level of detection in contrast to the winter months where intervals, of non-detects, last from days to months or longer.

Site selection is a very important part of any air quality monitoring programme. Air quality at a site is strongly influenced by local air flow and local activity and this is a likely explanation for the higher concentration of nickel at site 2. The pattern of nickel concentrations at this site shares similar characteristics to the other sites except that daily TSP and nickel concentrations are consistently higher relative to the other sites. For example, concentration spikes are highest and below detection intervals are shortest throughout the year at this monitor. The site is closest to the port these observations may be due to local dust funnelled from the port, the entrance road and the railroad.

During January and February, 70 and 46 trucks of nickel ore respectively were received at the port in addition to the usual rail deliveries of nickel concentrate. The truck deliveries were made daily except for 6 days out of each month. Maximum nickel concentrations occurred during this period however the relationship between truck movement and nickel concentration may be coincidental.

Other factors such as port clean-up, infrastructure and improvements in the loading process also played a role in reducing nickel concentrations in subsequent months.

Nickel concentrations have been consistently very low at site 5 for the six months the monitor has been in commission. This gives some confidence that nickel concentration decreases with increased distance from the port. Additional monitors in the residential areas to the north and north east of the port will provide a measure of local exposure in those directions and a better representative overall measure of community exposure.

5.2 Trend

Changes in the monthly mean nickel concentration for 2009 and 2010 is shown in figure 2. Data is lacking for a trend analysis however when compared to disparate dust data from 2008 there has been a significant reduction in nickel concentration suggesting that dust abatement strategies put in place during 2009 at the port are working. The absence of exceedances of the 24-h guideline during 2009 and 2010 to date supports this supposition.

The seasonal pattern in nickel concentration is clearly visible as is the reduction in nickel concentration in the first 5 months of 2010 compared with 2009. Analysis of the data from January to May 2010 shows that nickel concentrations at sites 1-4 have fallen in comparison to the same period in 2009 in spite of increased truck movements. This suggests other local influences, such as the port clean-up have played a significant role in the reducing the nickel concentrations at site 2.

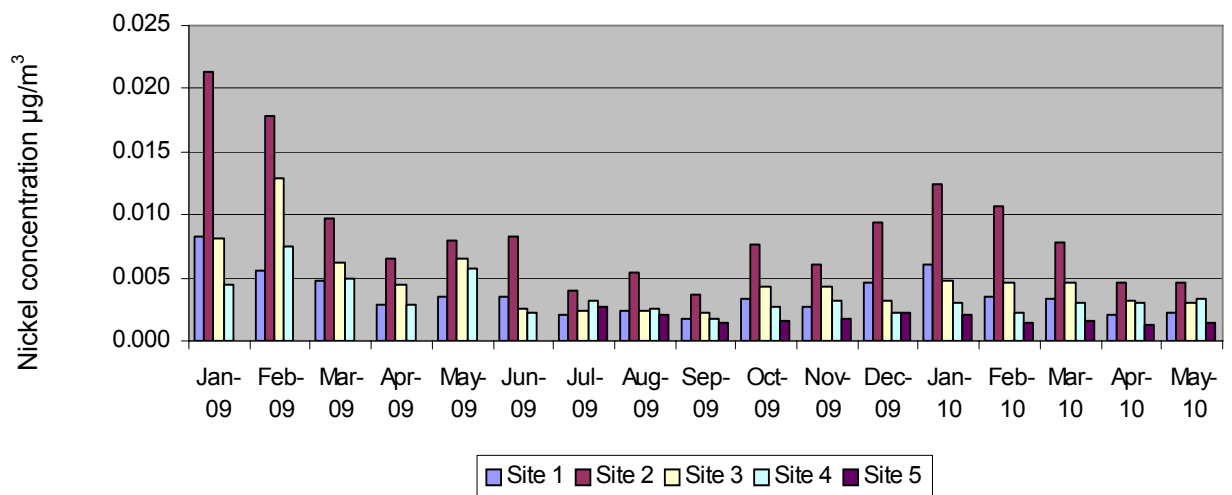


Figure 2: Changes in the monthly mean nickel concentration for 2009 - 2010

5.3 Annual concentration

The annual mean nickel concentration at individual sites and over the whole network is given in table 1 and figure 3. The means for Sites 1 - 4 exceed the target annual guideline. The highest annual mean value for nickel was found at site 2 which greatly influences the network wide annual mean. As discussed previously dust impacts around site 2 are probably localised given its proximity to the port and transport routes. Further planned monitoring and continued improvements in port hygiene will help to better define the zone of influence of the port emissions in this area.

Table 1: 2009 annual mean nickel concentrations

Site	Annual mean concentration $\mu\text{g}/\text{m}^3$	DOH nickel target guideline value $\mu\text{g}/\text{m}^3$
1	0.0038	0.003
2	0.0090	
3	0.0050	
4	0.0036	
5	0.0020	
Network wide weighted mean	0.0047	

For compliance purposes the average of the entire network is usually compared against a recommended guideline. The network weighted mean is $0.0047 \mu\text{g}/\text{m}^3$ however it does not represent the mean population exposure but the maximum population exposure on the basis that the monitor locations for sites 1-4 are designed to capture source emissions as well as population exposure.

Consequently given wind and rain dispersion, the ambient air concentration of nickel is theoretically expected to be progressively lower as distance from the port increases.

The network individual monitor means are compared against the DOH guideline in figure 3.

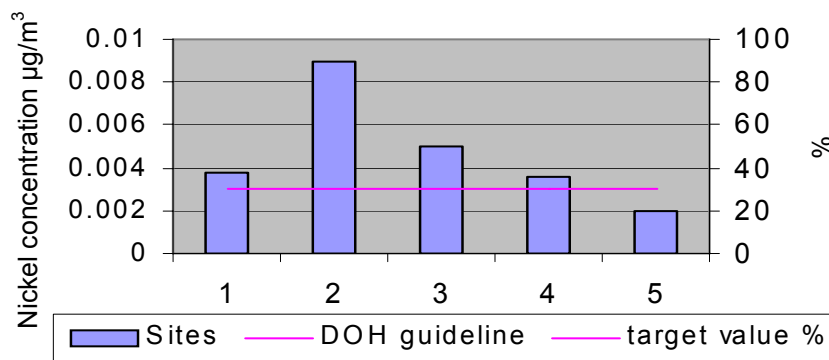


Figure 3: Network individual annual concentration with respect to the DOH guideline.

It is worth bearing in mind that the fraction of TSP that is fine enough to be inhaled is contained within the PM_{10} fraction. Assuming that all the nickel in TSP is evenly distributed and that 50% of TSP is PM_{10} then half of the nickel concentration

measured at sites 1-5 would be in PM₁₀. The true population exposure could be better defined by measuring nickel in the PM₁₀ fraction.

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Data from planned additional monitors will give a better indication of the distribution of nickel between the port and the outer monitors and provide a better indication of exposure. Meanwhile port hygiene during ship loading and dust reduction strategies and are expected to continue to improve until all boundary monitor nickel levels have consistently met the guidelines.

6 Relevance to Health

The DOH guideline is highly conservative and based on 70 years of continuous daily exposure at levels above 0.003 µg/m³. It was set to protect against significant health effects like lung cancer. Nickel particulates must be fine enough to be deeply inhaled, retained in the lung and be in a form that enables transportation across the cell wall to exert a health effect.

This does not mean that exposure to concentrations above the guideline will lead to health effects or cancer because the DOH guideline has large in built safety factors. In comparison; the United Kingdom and the European Community countries recently reviewed the toxicity of nickel and recommended a revision to their annual guidelines to 0.02 µg/m³ and 0.01 µg/m³ respectively, measured in the PM₁₀ fraction.

The type of nickel transported through Esperance is cleared rapidly from the body regardless of its source. This means the body excretes excess nickel in the same way whether it comes from the daily diet (nickel is a natural to many foods) or from inhalation exposure. The concentration of nickel in the air was below the limit of detection 45% of the year. This means that although the annual guideline was exceeded, the large number of days with nickel below the guideline provided sufficient time for excess nickel to be excreted from the body.

7 Recommendations

Additional monitors are needed in residential areas to better understand the distribution of nickel dust and population exposure.

Assuming some nickel is distributed in the PM₁₀ fraction and given that PM₁₀ by virtue of size has great buoyancy and travels further than TSP then it is important to also measure nickel in PM₁₀ to better understand the potential for respiratory exposure.

Concentrations of nickel at Site 2 exceed the guideline. The site location should be investigated for local influences and the mitigation strategies investigated and implemented.

(First published in 2010; reviewed 2011)



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