Air Toxics Monitoring in British Columbia

Douglas D. Johnson
BC Environment
Skeena Region
P.O. Box 5000, Smithers, British Columbia CANADA VOJ 2N0

Keywords: air quality, air quality monitoring, air toxics, British Columbia, metals, Skeena Region.

Abstract: **There is increasing concern about the great diversity of chemicals and other contaminants released into the environment. In the past ten years, the issue of inhalable particulate matter has exploded as a public health issue. Currently, there is focus on interaction between atmospheric contaminants and the human immune system. When released to the atmosphere, contaminants enter a pathway by which large areas and populations may be exposed to these substances. It is critical that regulatory agencies, such as BC Environment, inventory these contaminants, both in response to acute incidents and for chronic exposure. Skeena Region has traditionally emphasised monitoring and assessment of PAHs. Recent studies have been expanded to include metals. The current status of these programmes is reviewed and monitoring results of the Kitimat metals programme, in the middle of its minimum duration, are presented.**

Data capture has been good for the programme to date. Concentrations less than minimum detection limits are typical for beryllium, cadmium, lead, nickel in the residential areas, selenium, and approximately one-quarter of the silicon samples. Preliminary Screening Level exceedences occur at all sites for barium, copper, manganese (except for the Kitimat residential areas), and zinc (except Terrace). Exceedences for nickel occur only at the Haul Road and Kitimat Rail sites, the stations close to the valley west wall. Barium, vanadium, and zinc have exposure patterns of greatest exceedence frequencies closest to the major industrial sources (Haul Road). These contaminants also have the greatest mean concentrations closest to the industrial sources. The Kitimat Rail (Service Centre) site has the highest mean concentrations of chromium, iron, manganese, and nickel. Manganese and nickel have the highest exceedence frequencies at the Rail site. Riverlodge has the greatest mean copper concentrations and the greatest copper exceedence frequencies. Generally, Terrace has the fewest exceedence frequencies. The sites north of the industrial area (Haul Road and Kitimat Rail) have the greatest exceedence frequencies for nickel, selenium, vanadium, and zinc. There is a mixed spatial pattern for barium, copper, and manganese.

Introduction

Generally, toxic air pollutants (also known as air toxics or hazardous air pollutants) are defined as those known or suspected to cause serious health problems. A variety of industrial sources and motor vehicles emit “routine” toxic air pollutants. In addition to routine releases, sudden accidental air releases of toxics threaten many Canadians. Toxic air pollutants include metals, other particles, and certain vapours from fuels and other sources.

The emission of toxic substances into the air can cause chronic and acute damage to human health and the environment. Human exposure to these contaminants at sufficient concentrations and durations can result in cancer, poisoning, and rapid onset of sicknesses such as nausea or difficulty in breathing. Other less measurable effects include immunological, neurological, reproductive, developmental, and respiratory problems. Pollutants deposited onto soil or into lakes and streams affect ecological systems and eventually human health through consumption of contaminated food. Some researchers (e.g., Colborn 1996) see evidence that industrial chemicals in the environment, including metals, harm endocrine (regulating) systems of fish, birds and mammals.

Below is an overview of the definition of air toxics in British Columbia. Subsequently presented are the interim results of the Kitimat airborne metals monitoring programme. The presentation of the interim assessment is an example of an application of air toxics monitoring in British Columbia.

Definition of Air Toxics and Hazardous Air Pollutants in British Columbia

Much of the work on defining air toxics in British Columbia has been done by the Subcommittee for the Definition of Toxic and Persistent Substances of the Criteria Policy and Regulation Review Committee (Environmental Protection Department). The committee released a guidance document for the definition of a “persistent toxic substance” in 1995. This document was prepared to provide guidance to BC Environment staff regarding the definition of the terms “toxic and persistent” for the development of programs, regulations, strategies, technical criteria, and other measures necessary for the protection of the environment. This document by itself, however, does not represent the position or policy of BC Environment respecting any specific substance or product. Much of this section is drawn from the work of the subcommittee.

The definition of toxic substances is usually: (i) a general narrative definition, (ii) impact criteria, and/or (iii) a list of specified substances. The Canadian Environmental Protection Act (CEPA section 11) uses the following narrative statement:

> a substance is toxic if it is entering or may enter the environment in a quantity or concentration or under conditions;
>
> a) having or that may have an immediate or long-term harmful effect on the environment,
>
> b) constituting or that may constitute a danger to the environment on which human life depends, or
>
> c) constituting or that may constitute a danger in Canada to human life or health.

In order to consistently develop criteria and programs for the protection of the environment, BC Environment requires a definition for toxic and persistent substances. Definition of these terms may also be necessary for a number of other regulatory purposes. For example, lists of toxic and persistent substances may be generated for use in:

- Determining waste discharge permit fees.
- Establishing environmental quality criteria and standards.
- Establishing Provincial "targets" to reduce the production rate of toxic wastes (e.g., pollution prevention programs).
- Establishing high priority "ban and phase-out" lists for toxic substances.

The Criteria Policy and Regulation Review Committee have recommended the following regarding the definition of a “persistent toxic substance”:

- The terms toxic and persistent should not be generically defined solely as a simple list of "toxic and persistent" substances. Rather, such definition should be based on both a narrative definition and specific technical criteria, capable of application to any substance.
- The recommended definition criteria are to be solely based on toxicological and environmental fate characteristics of the substances *per se* without additional consideration of aspects relating to the discharge itself such as the volume or time of discharge, location in which the discharge will occur, economic considerations, existence of regulatory requirements or feasibility of engineering controls, etc.
- An additional specific criteria-based definition is thought to have several advantages. For example unlike most narrative definitions, it is relatively precise. Furthermore, it is scientifically defencible, unlike simple lists of substances that are often perceived to be arbitrary. Determination of toxic and persistent substances under a criteria based definition is documentable and thus would lend itself to any consultative process which BC Environment may wish to use regarding future development or revision of regulations. Finally, such a definition may allow BC Environment to set priorities

regarding the urgency for regulatory actions based on the relative ranking of various toxic and persistent substances.

- To be considered for definition as a chronic toxic substance, said substance should elicit either:
  - a) carcinogenic, mutagenic or teratogenic effects, or
  - b) provoke other well documented toxic effects of proven etiology following long term exposure to sub-acute dose.
- Only IARC group 1 and 2A agents be considered for definition as carcinogenic substances in humans; in the case of animals, group 2B agents should be considered potential carcinogenic substances, subject to confirmation based on review of IARC rationale documents.
- Agents known to be either carcinogenic or teratogenic should also be assumed to be mutagenic.
- Teratogenicity be included only as a supplementary criteria for consideration in the definition of toxic substances.

The remainder of this paper contains a report on the application of one of Skeena Region's air toxic assessment programmes.

Skeena Monitoring Programmes

In the past, monitoring and assessment programmes in Skeena Region (Figure 1) focused on traditional 'criteria' air contaminants. Increased attention to inhalable particulate matter and air toxics has occurred in recent years. Outlined briefly below are current monitoring programmes, largely concentrated in the Highway 16/37 South corridor. Figure 2 depicts, in detail, the communities of the Highway 16/37 South area (Bulkley/Skeena and Kitimat drainage basins).

Figure 1. Skeena Region, British Columbia.
Presented is Skeena Region's location relative to British Columbia's political and coastal boundaries.

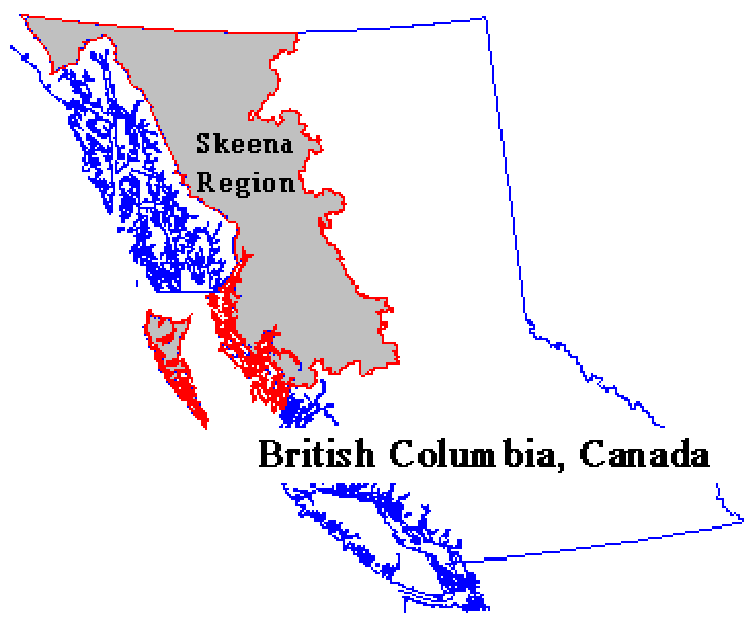
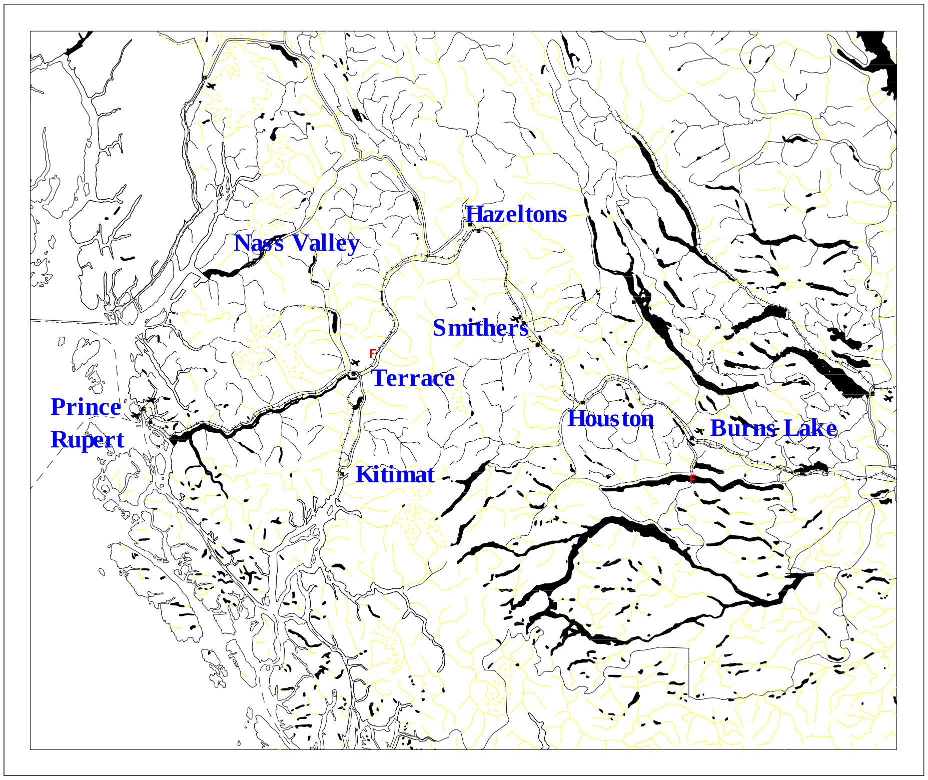


Figure 2. Highway 16/37 South Corridor, Skeena Region, British Columbia. The Highway 16/37 South corridor is the primary geographic focus of air quality monitoring and assessment work in Skeena Region. This corridor contains all communities depicted below, except for the Nass Valley.



As a result of confined valleys, significant combustion sources, and occasionally poor dispersion meteorology, there are episodes of poor inhalable particulate air quality in Skeena Region's interior. As a result, much of BC Environment's monitoring and assessment resources were allocated to establish an interior community network of continuous, real-time inhalable particulate (PM_{10}) monitors. PM_{10} TEOMs are currently deployed in Burns Lake, Houston, Quick, Smithers, and Terrace. BC Environment solely supports the Burns Lake and Quick TEOMs; the remainder are partnerships with industry and local government. Future plans are to have industry fund TEOMs in Telkwa, Kitimat, and Prince Rupert, leaving the Hazeltons as the only significant gap in the network.

Much of the heavy industrial development (pulp mills, smelter) in Skeena Region occurs in the coastal communities of Kitimat and Prince Rupert. These have traditionally participated in monitoring of criteria air contaminants, but have been reluctant to upgrade particulate monitoring to continuous PM_{10}.

A number of monitoring programmes have been implemented to assess the significance of toxic air contaminants. Presented below is a detailed assessment of the interim results of the Skeena metals monitoring programme. The Skeena PAH sampling and assessment programme has been presented elsewhere (Johnson, 1995). Other assessment programmes have included short-duration research into ozone exposure.

Kitimat Metals Programme

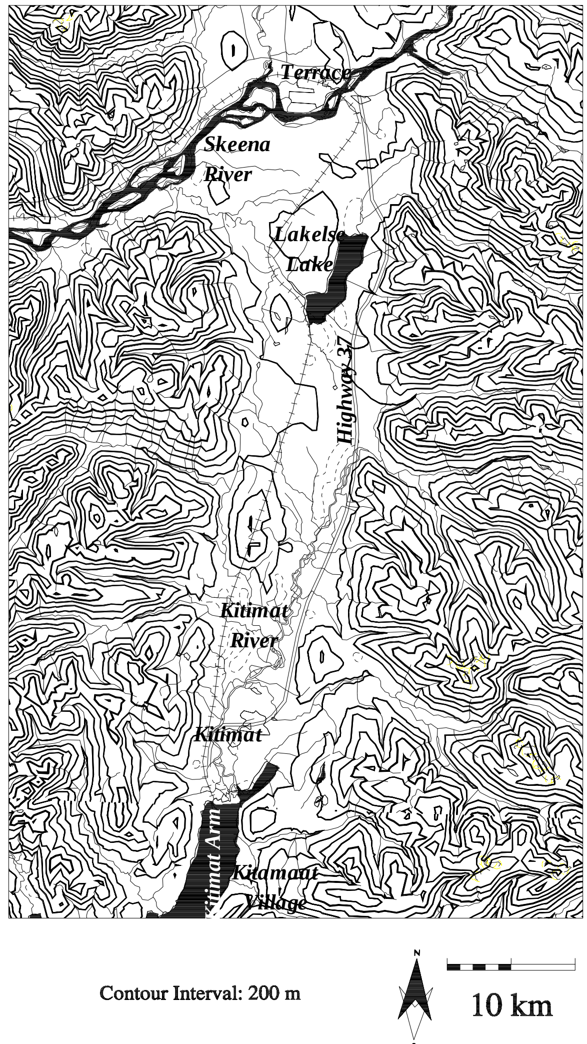
In response to questions raised regarding the concentrations of toxic metals in the atmospheric environment originating from Kitimat industrial operations, BC Environment initiated a process to assess this issue. BC Environment Air Resources Branch (Suzuki, 1994) developed preliminary screening criteria to complement a sampling and analysis programme negotiated with Alcan Smelters and Chemicals Ltd. This sampling programme is now approximately half complete.

The focus of Kitimat metals monitoring and assessment programme is the Kitimat-Terrace corridor. Notable emissions are those associated with the aluminium smelter (Alcan Smelting and Chemicals Limited), the paper mill (Eurocan Pulp and Paper Company), and the methanol and ammonia plant (Methanex Corporation). As part of their air emissions permits, these companies are required to monitor and report to BC Environment air contaminant concentrations in the ambient environment.

Study Area

The name Kitimaat ("People of the Snow") is a Tsimshian name given to the Haisla native Indians who made their home at the head of Douglas Channel, a long, broad fjord that connects to Hecate Strait and the Pacific Ocean (Figure 2). Today Kitimat is a municipal district that marks the point where the Kitimat River drains into Kitimat Arm fjord (Figure 3).

Figure 3. The Geography of the Kitimat Valley.



The Kitimat and Lakelse river valley bottoms form low and generally simple terrain anchored by the City of Terrace on the Skeena River some 60 km north of the Municipal District of Kitimat. The divide between the two drainage basins is only 200 m above sea level and occurs approximately 30 km up-valley from Kitimat. The surrounding terrain is complex post-glacial, including steep mountainous areas with peaks in the 1700 m elevation range, as depicted in Figure 3. Moderately dense to dense coniferous forest dominates the landscape, characterised by western hemlock, amabalis fir, and mountain hemlock. Closer to the coast, scrub, western hemlock, western red cedar, yellow cedar, and shore pine are present. (Smith, 1996).

The Kitimat townsite originated to house workers for the Aluminium Company of Canada (now known as Alcan Aluminium Limited) when construction of its Kitimat Works smelter began in the early 1950s. The CN Rail line to Kitimat opened in 1954; a highway connection to Terrace was complete in 1957 (Kitimat's Tourism Information Directory, 1995).

The Municipal District of Kitimat has a current population of approximately 11 700 people. The industrial sites are at the southern end of the Kitimat River valley, along the west wall of the valley (Figure 4). Figure 5 depicts the industrial setting as viewed from Kitimat Arm just north of Kitamaat Village.

Figure 4. Kitimat Geography.
The main residential areas of Kitimat are in the centre-top portion of the image (only major roads are shown). To the South of Highway 37 (runs North-South in top-right and centre-left and East-West in centre-top) is the Riverlodge subdivision. To the North on the bench are the Whitesail and Nechako subdivisions. Inflow (southerly) winds follow the valley orientation, resulting in industrial emissions passing over the Sandhill (just north of Eurocan) and the Service Centre (north-northeast of the Sandhill). Monitoring station locations are depicted with associated contaminants (HF - hydrogen fluoride, NO_x - nitrogen oxides, SO_2 - sulphur dioxide, PM_{10} - inhalable particulate, TRS - total reduced sulphur, and W_x - meteorology). Metals and PAHs, which may be of interim duration, are also located at the four contaminant monitoring sites; ozone is located at the Kitimat Rail site.

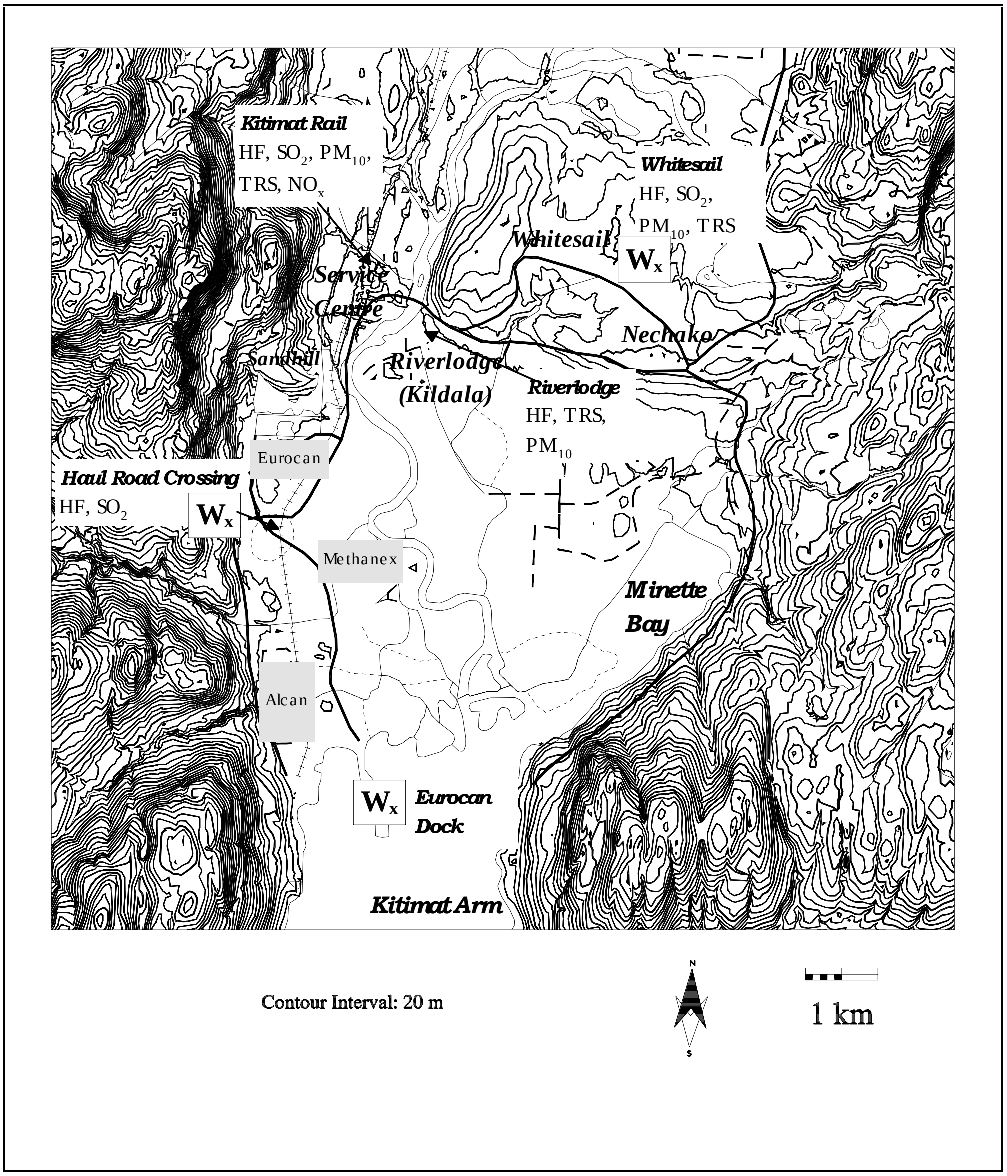


Figure 5. The Kitimat Industrial Setting.
Image is looking west from just north of Kitamaat Village. The smelter complex (left) and the visible point sources emission associated with Eurocan (right) are evident. The Kitimat River estuary is in the foreground and the Coast Range mountains are in the background.

In summer, prevailing inflow (southerly) winds blow the industrial area plumes up the Kitimat River valley towards Terrace. Visible industrial emissions during inflow conditions are frequently observed travelling over the Sandhill and following a ridge 365 m ASL 1-1½ km west of the Service Centre. On occasion, a lee vortex draws down visible (primarily Eurocan plume) and other emissions into the Service Centre. In winter, outflow (northerly) winds from the interior of the province funnel the plume out Kitimat Arm (Figure 3). Atmospheric conditions also include a variable mixing layer and diurnal wind variation.

Kitamaat Village is located 5 km southwest of the industrial area (on the opposite side of Kitimat Arm from the industrial sites) and the main residential areas of Kitimat (Whitesail, Nechako, and Kildala (Riverlodge) subdivisions) are 5 km northeast of the smelter and 2.5 km east-northeast of Eurocan (Figure 4). Thus, the Kitimat industrial area is geographically and meteorologically well-sited relative to populated areas for minimising the potential for environmental impacts on human health. The Service Centre, a largely light industrial-commercial-service area (with some residents in the Kitimat Hotel), is 5 km north of the smelter and 2 km north of Eurocan. Between the Service Centre and the industrial areas is 'the Sandhill', a 180 m above sea level easterly topographic intrusion into the valley. The greatest potential for air emission-related impacts are, therefore, in the terrestrial and aquatic environments; impacts may occur in the main residential areas only during calm and fumigation conditions. The Terrace airport recorded calm wind 19% of the time for the 1951-1980 climate normal averaging period. As a result of probably frequent sea breezes, significantly fewer calms are expected in Kitimat.

Monitoring Sites

Figure 4 (above) depicts the Kitimat monitoring sites: Haul Road, Kitimat Rail (Service Centre), Riverlodge (Kildala), and Whitesail. The intent of the Haul Road Crossing site is to capture the near-industrial area ambient conditions. There are no humans residing, normally working, nor recreating in this area. Kitimat Rail represents exposures in a commercial sector, however, a small number of people do reside here. Riverlodge and Whitesail are the two residential stations. A ridge and Highway 37 divide the two neighbourhoods. Terrace is the intermediate control site[1].

Method

A measured volume of ambient air is drawn at a constant flow rate through a high volume sampler. A 0.3 μm Teflon coated borosilicate glass fibre filter collects particulate in the air sample. Particles are collected on the filter(s) during a 7 day sampling period[2]. The collected material constitutes total particulate.

The filter is subsequently digested in a nitric/perchloric acid to bring the metals into solution. Following acid digestion, aqueous solutions of metals are converted to aerosols in a ICP nebulizer and injected directly into a high temperature plasma (6000 to 8000°K). This highly efficient ionisation produces ionic emission spectra at wavelengths specific to the elements of interest that can be monitored either simultaneously or sequentially.

---

[1] It is possible that Kitimat contaminants could reach Terrace. However, a study in the summer of 1994 did not detect any hydrogen fluoride, sulphur dioxide, or total reduced sulphur compounds at the Terrace-Kitimat airport. Complementary data from Smithers and Quick will be used in the final report to assess the significance of any metals found common to the Terrace-Kitimat environment.

[2] A seven day collection period, rather than the normal 24 hours, was chosen to ensure that enough particulate were collected relative to those contained in the filter itself and the analytical method detection limit.

Metals Assessment Criteria

Table 1 depicts the screening criteria used to assess the metals data. Provincial objectives are used to derive most criterion (unshaded). However, no provincial screening criteria were provided for aluminium, iron, magnesium, silicon, or titanium. For the purposes of this paper, a measure of central tendency of impact assessment criteria from other jurisdictions was used to develop an interim screening criterion for these contaminants. Magnesium was the exception for which the provincial Level A total suspended particulate criterion is used. As such, these represent neither the most conservative (protective) nor "official" provincial objectives. When the sampling is complete (fall 1997), a more comprehensive assessment will be undertaken of these interim screening criteria. Also note that the screening levels are for an integration period of one day. The samples collected have integrations of approximately seven days. This results in a less conservative assessment.

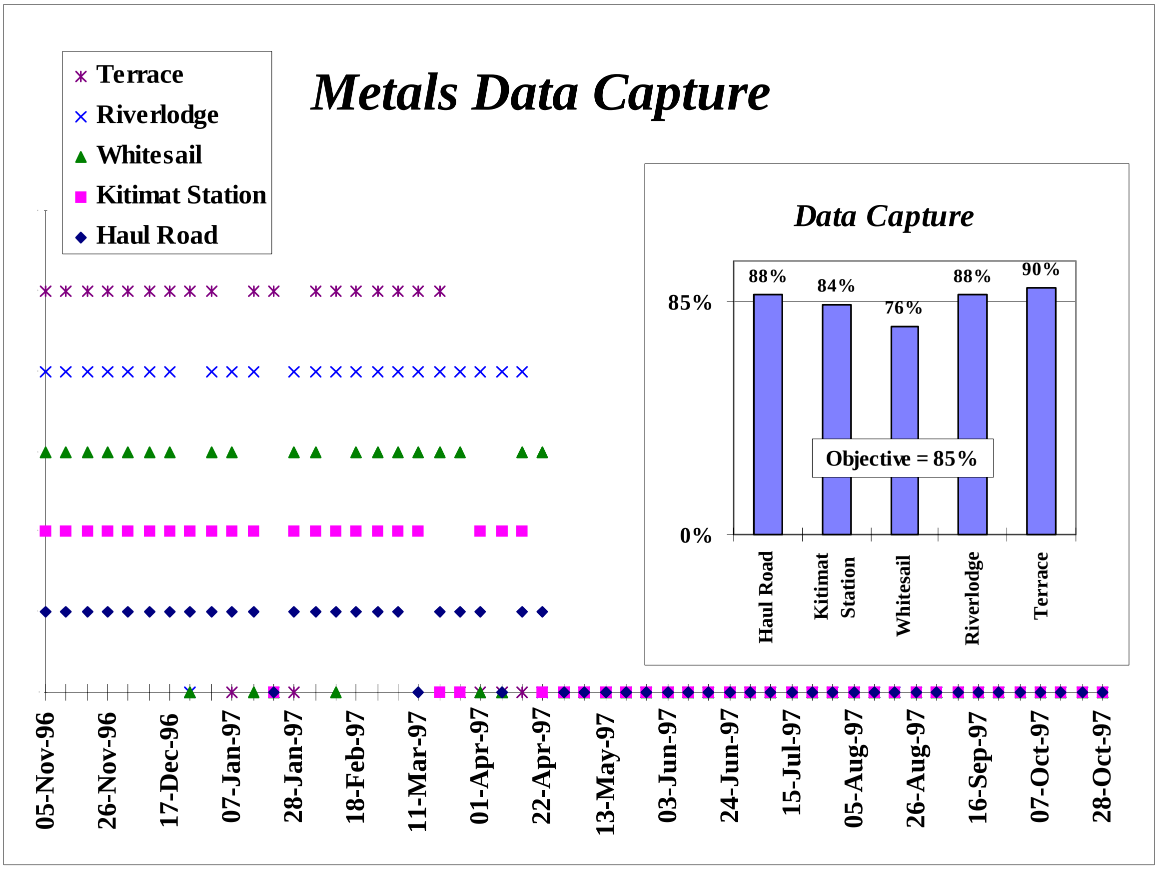
Table 1. Preliminary Screening Levels. Shaded boxes depict interim regional screening criteria based on a measure of central tendency of regulatory standards drawn from a variety of other jurisdictions. Clear boxes represent Provincial Preliminary Screening levels.

Contaminant	Screening Criterion ($\mu g\ m^{-3}\ d^{-1}$)
Aluminium (Al)	28.5
Barium (Ba)	0.50
Beryllium (Be)	0.005
Cadmium (Cd)	0.05
Chromium (Cr)	0.05
Copper (Cu)	0.25
Iron (Fe)	10.5
Lead (Pb)	1
Magnesium (Mg)	150
Manganese (Mn)	0.05
Nickel (Ni)	0.01
Selenium (Se)	0.1
Silicon (Si)	97
Titanium (Ti)	35
Vanadium (V)	0.05
Zinc (Zn)	1

Data Capture

This sampling programme is intense as the samplers are run continuously. Figure 6 depicts the data capture statistics of the interim metals sampling programme. Note that most statistics are within the BC Environment data capture guidelines of 85% of all samples.

Figure 6. Metals Sampling Programme Interim Data Capture Statistics.
The BC Environment objective is 85%. Data are current to the most recently available. The X-axis depicts week sampled. The Y-axis represents samples captured.



Results

Of primary concern to BC Environment is whether or not observed metals concentrations meet the screening criteria (Table 1). Figure 7 presents the screening criteria exceedence frequency for each contaminant at each sample site. As indicated in Figure 7, there are a number of exceedences of the 24 hour screening criteria, even for the Terrace ‘control’ site.

Figure 7. Screening Criteria Exceedence Frequencies.

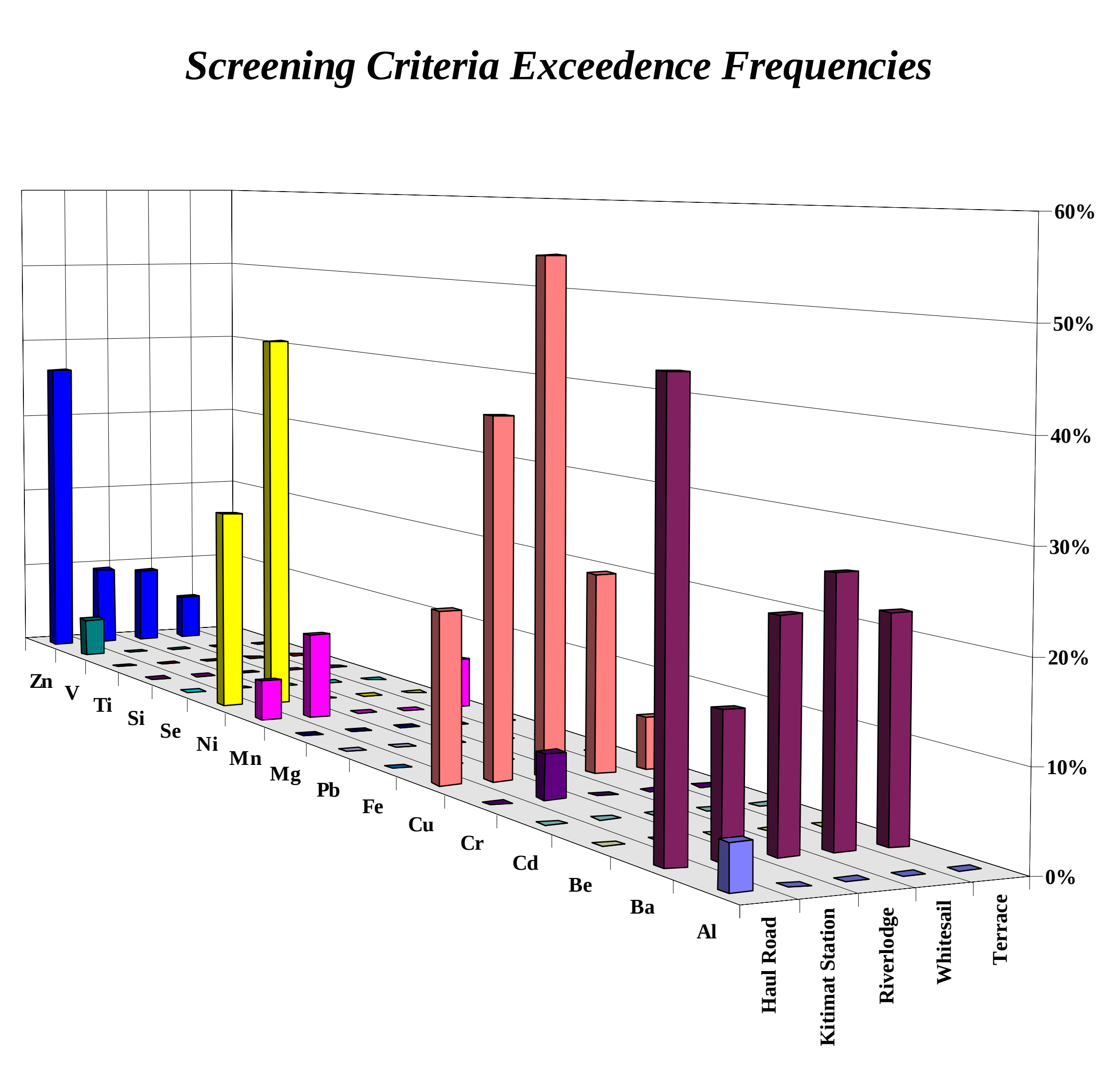
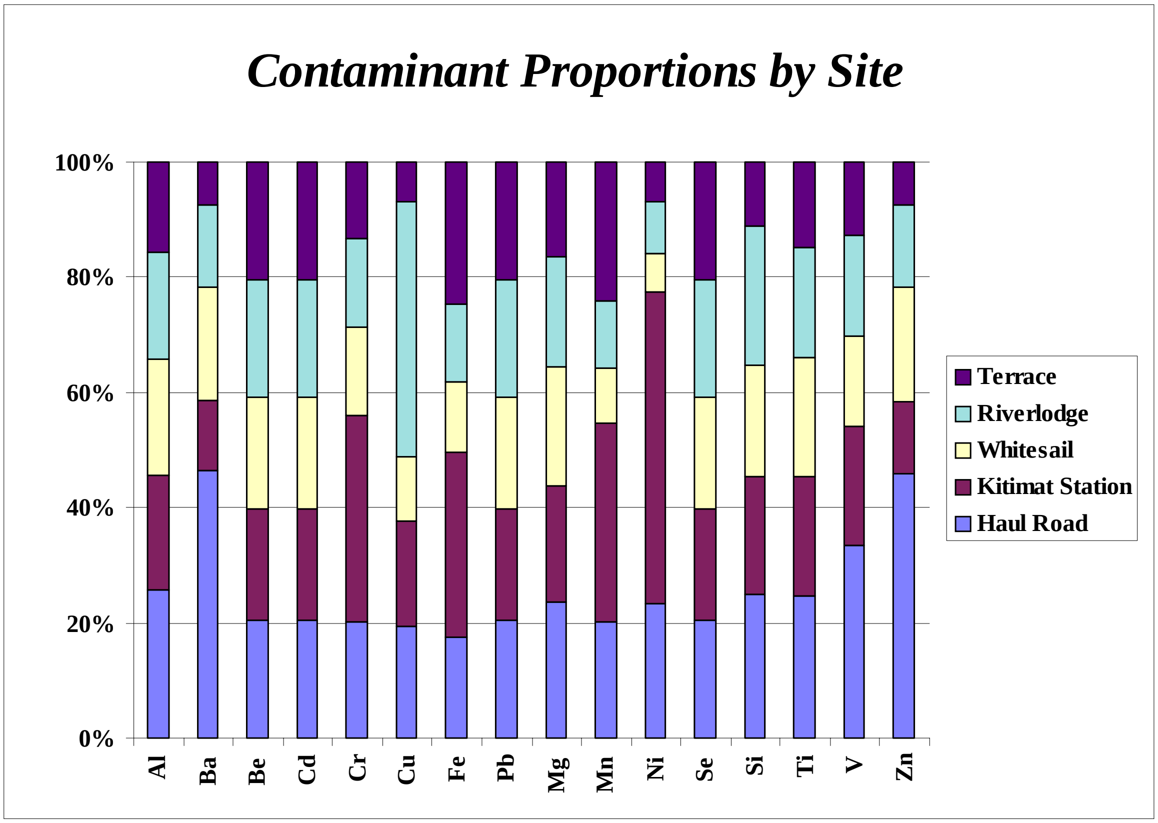


Figure 8 summarises the environmental metals exposure in a different manner. The average concentrations for all sites are summed, by contaminant, and then expressed as a relative frequency between sites (relative frequencies, as opposed to absolute means, allow plotting of all contaminants on the same chart). Thus, if metals were equally ubiquitous at all sites, one would expect their proportions to equal 20% at each site (i.e., one of five sites).

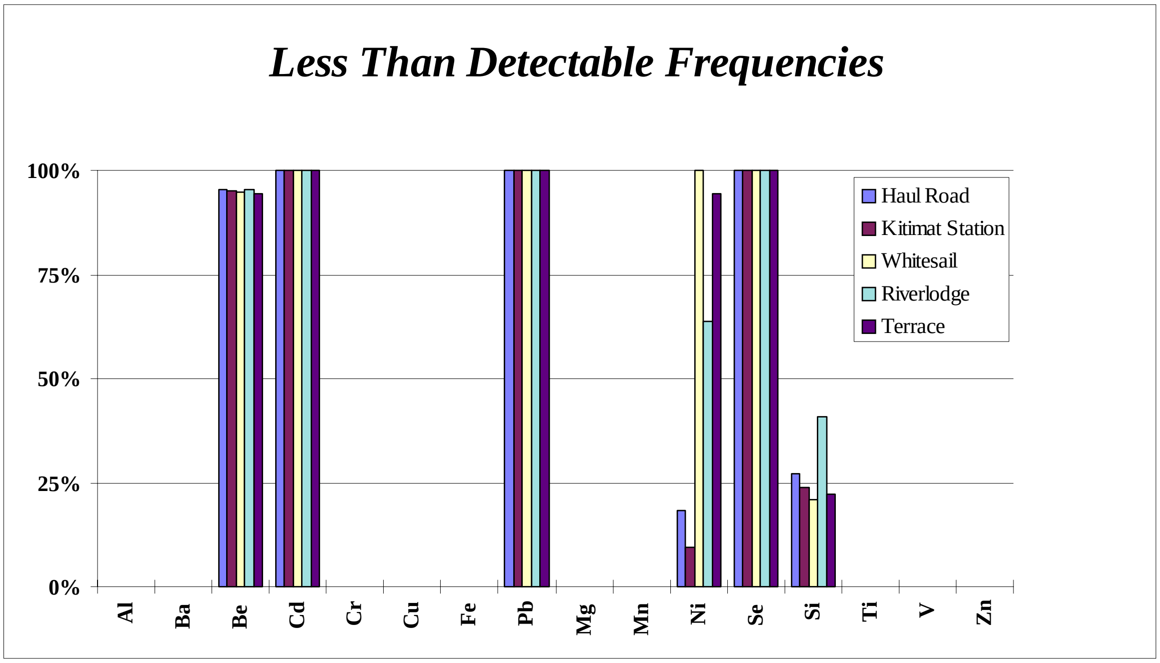
Figure 8. Contaminant Proportions By Site.



Clearly, there is not an even distribution of metals exposure between all sites. The Haul Road appears to have an abundance of aluminium, barium, vanadium, and zinc relative to other sites. Kitimat (Rail) Station has more chromium, iron, manganese, and nickel. Riverlodge has a lot of copper. Average concentrations in Terrace are generally at or less than other sites.

Figure 9 depicts the analytical procedure less than detectable sample frequency (including the metals contained in the filter). Beryllium, cadmium, lead , nickel (Whitesail and Terrace only), and selenium are 'absent' in atmospheric particulate matter.

Figure 9. Frequencies of Less Than Detectable Observations.

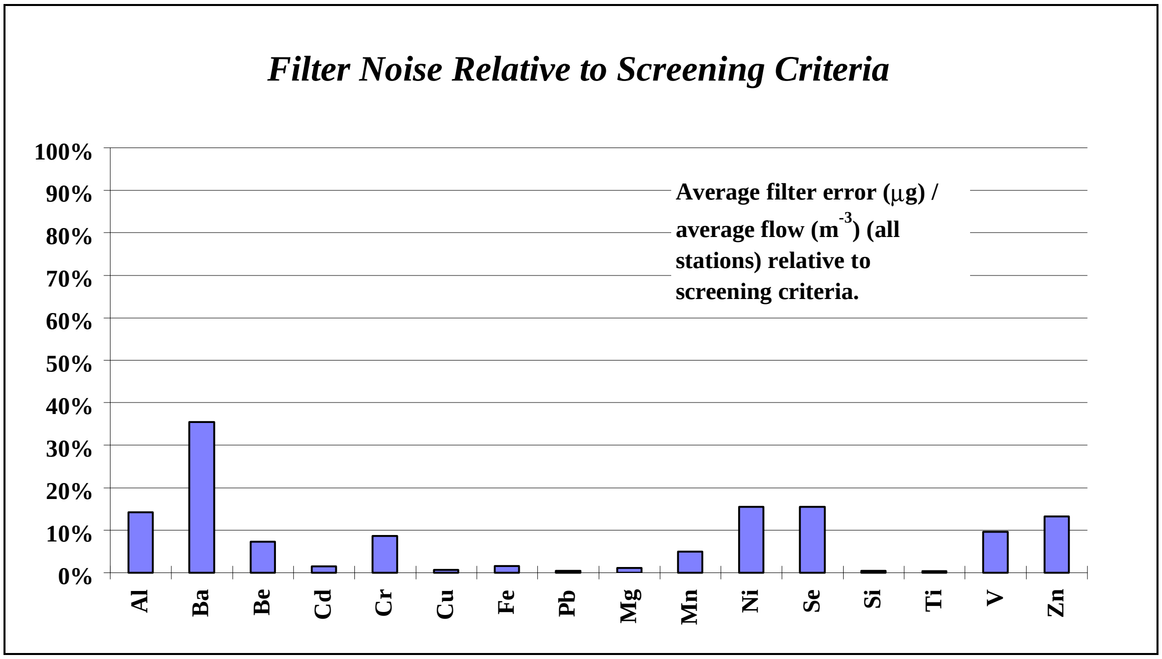


Given the exceedences of the screening criteria (Figure 7) and the differences in metals distribution between sites (Figure 8), we need to look more closely at these data. Corrections are necessary to account for sampling and filter error to determine if exceedences are still significant.

Data Correction

Figure 10 depicts the sampling error (filter noise component) relative to the screening criteria. Filter noise (metal content (µg)) was converted to units comparable to screening criteria (µg m^{-3}) by taking the average filter metal content (µg, by contaminant) and dividing it by the average high volume sampler flow (m^{-3}).

Figure 10. Filter Noise Relative to Screening Criteria.



A number of contaminants are present on the blank sample filters in quantities that are high relative to the screening criteria. In particular, aluminium, barium, beryllium, chromium, manganese, nickel, selenium, vanadium, and zinc are present in quantity.

Figure 11 presents the amount of laboratory error (the method error), expressed as a percentage of the filter error (Figure 10). It is clearly much less significant than the error associated with filter contamination. Figure 12 explicitly demonstrates this by presenting total error (and the variability about the mean blank error as one standard deviation error bars). In absolute terms, filters have large quantities of aluminium and magnesium on them.

Figure 11. Method Error Relative to Filter Blank.

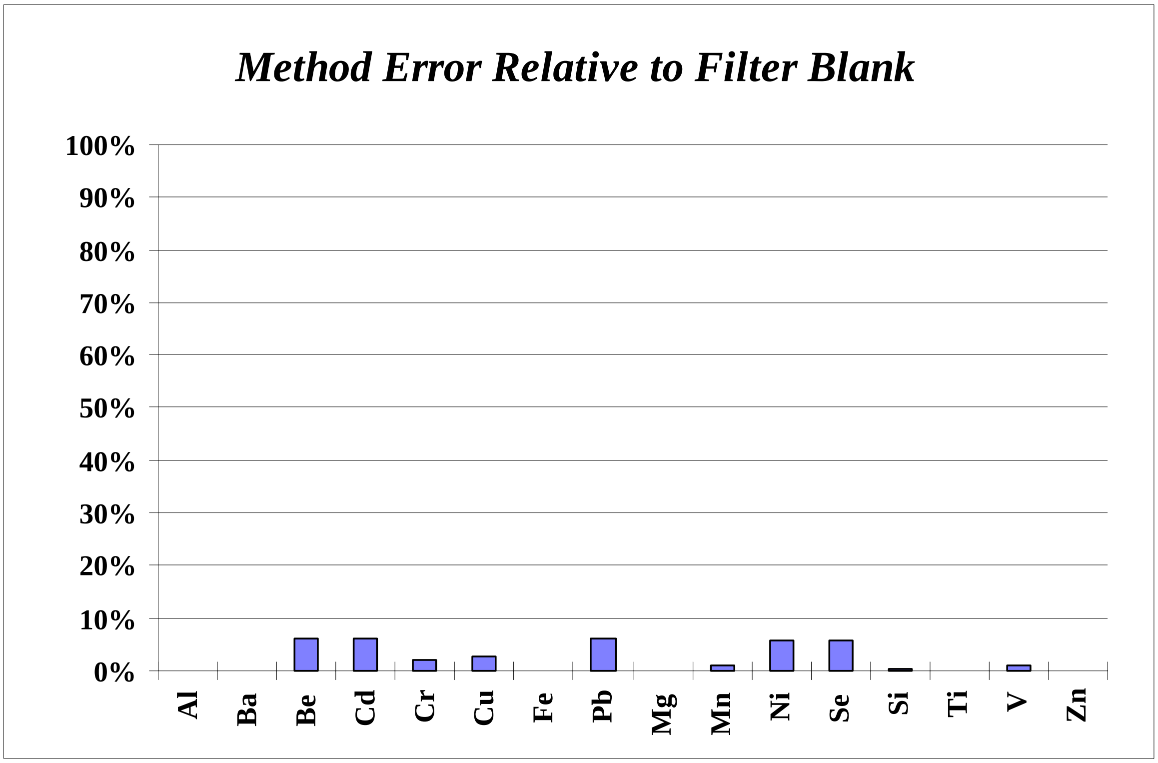
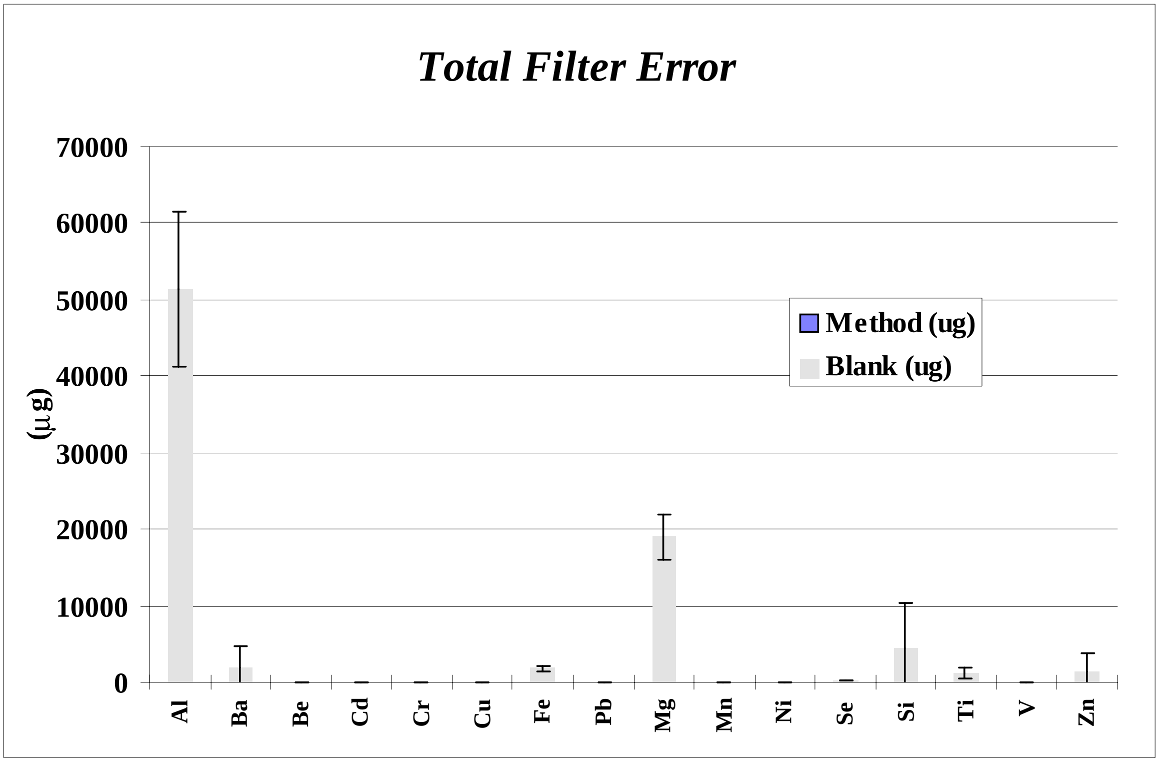


Figure 12. Total Error.

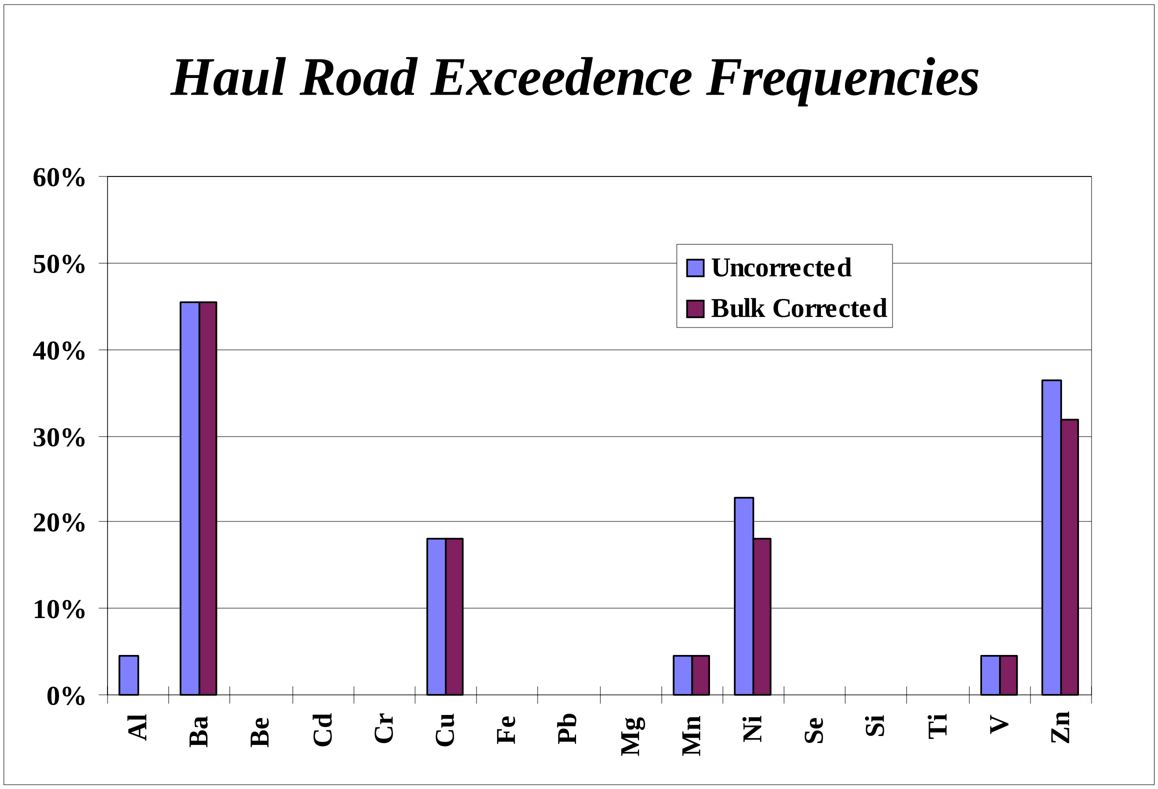


As a result of the potentially significant error inherent in the sampling protocol, a bulk error correction is applied by subtracting, from each individual observation, a bulk error term defined by the equation below:

$$Error_c\left(\mu g\, m^{-3}\right) = \frac{TotalFilter\, Error_c\left(\mu g\right)}{Flow\left(m^3\right)}$$

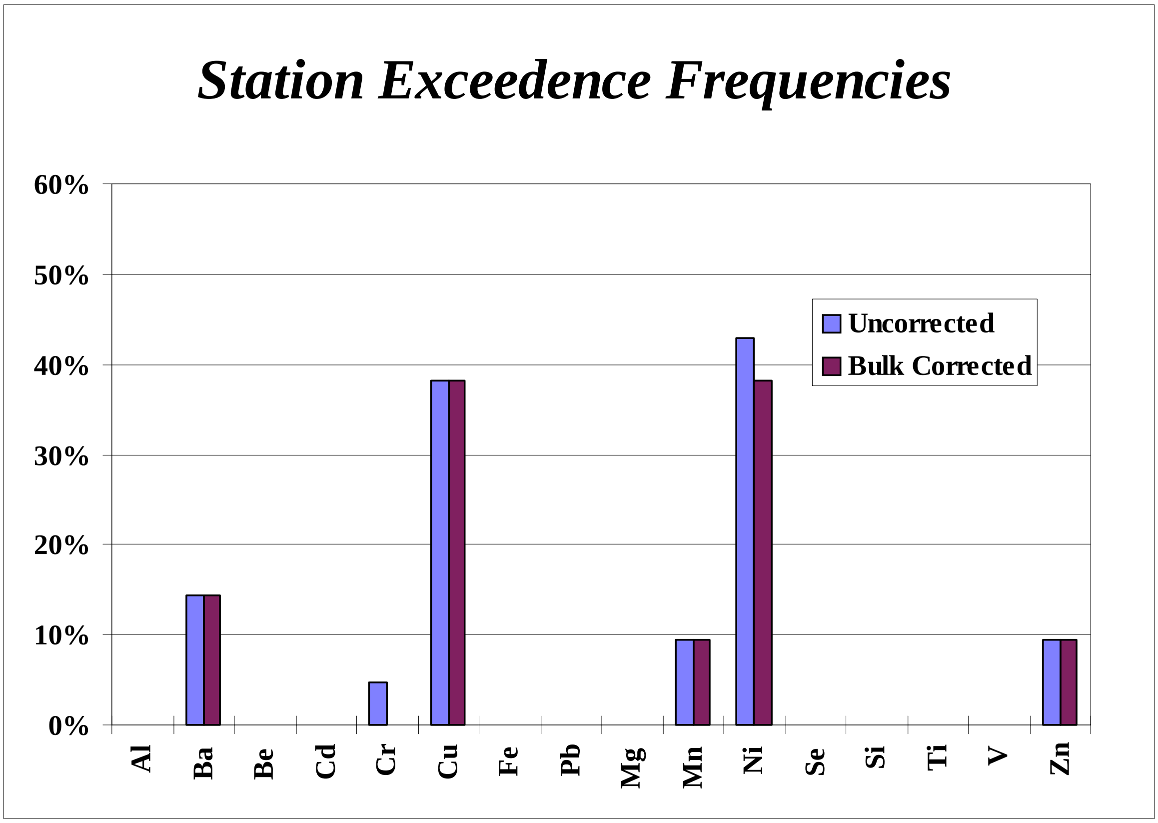
where total filter error (sum of the filter contamination and method error) and flow are both averages for all samples. Presented below is the significance of these corrections on Preliminary Screening Level exceedence frequency for each of the Haul Road (Figure 13), Kitimat Rail (Figure 14), Riverlodge (Figure 15), Whitesail (Figure 16), and Terrace (Figure 17) sample sites.

Figure 13 Haul Road Exceedence Frequencies.



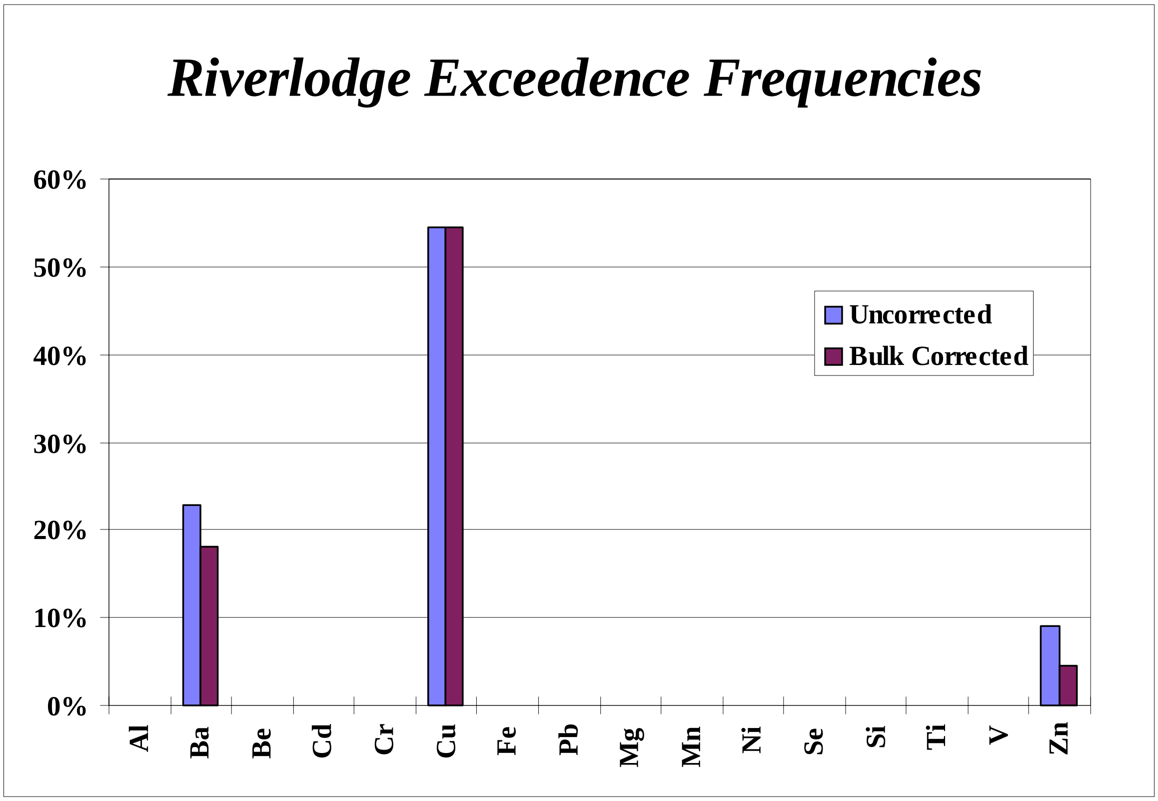
The Haul Road site, closest to the industrial sources and downwind of the pulp mill and gas plant during outflow (but upwind of the smelter), saw its aluminium exceedences drop to zero after correction. Exceedence frequencies of nickel and zinc dropped slightly. Other exceedence frequencies were unchanged. After correction, exceedences occur for barium, copper, manganese, nickel, vanadium, and zinc.

Figure 14. Kitimat Rail Exceedence Frequencies.



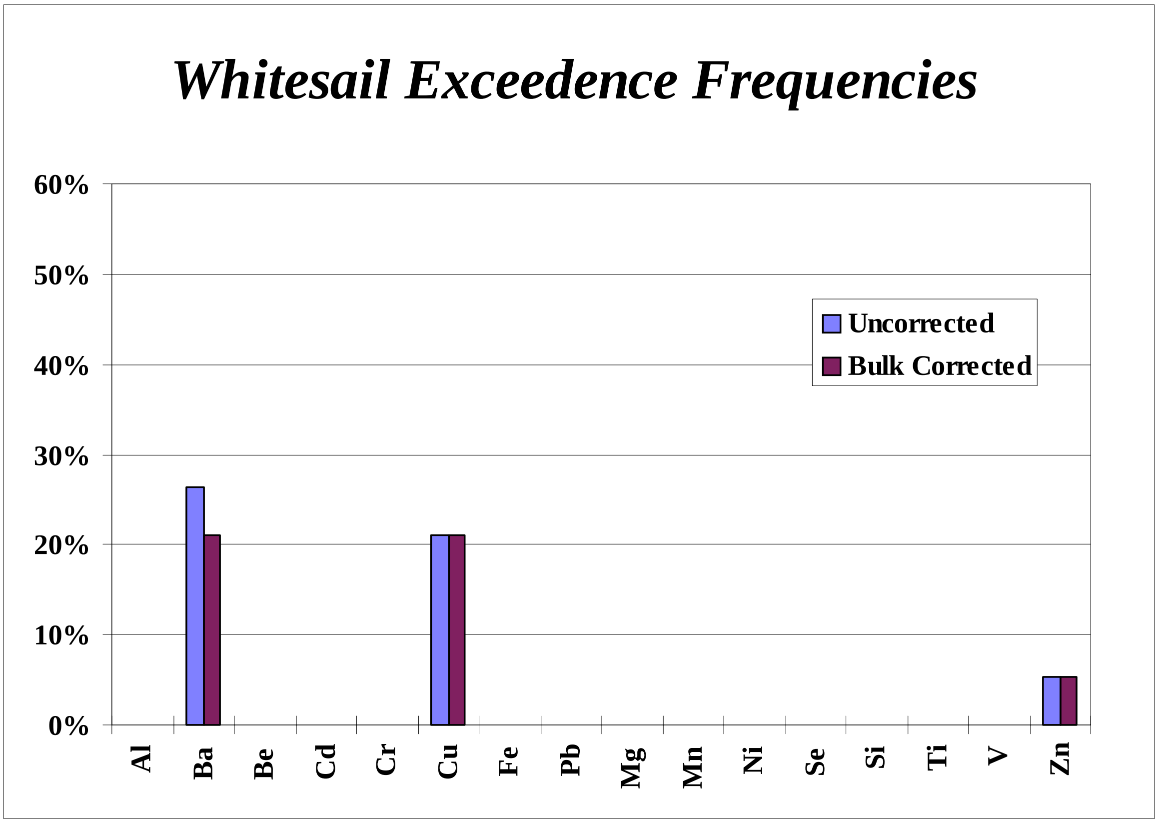
Kitimat Station, directly north of the industrial sites, had chromium exceedence frequencies drop to zero after correction; nickel declined slightly. Exceedences occur for barium, copper, manganese, nickel, and zinc.

Figure 15. Riverlodge Exceedence Frequencies.



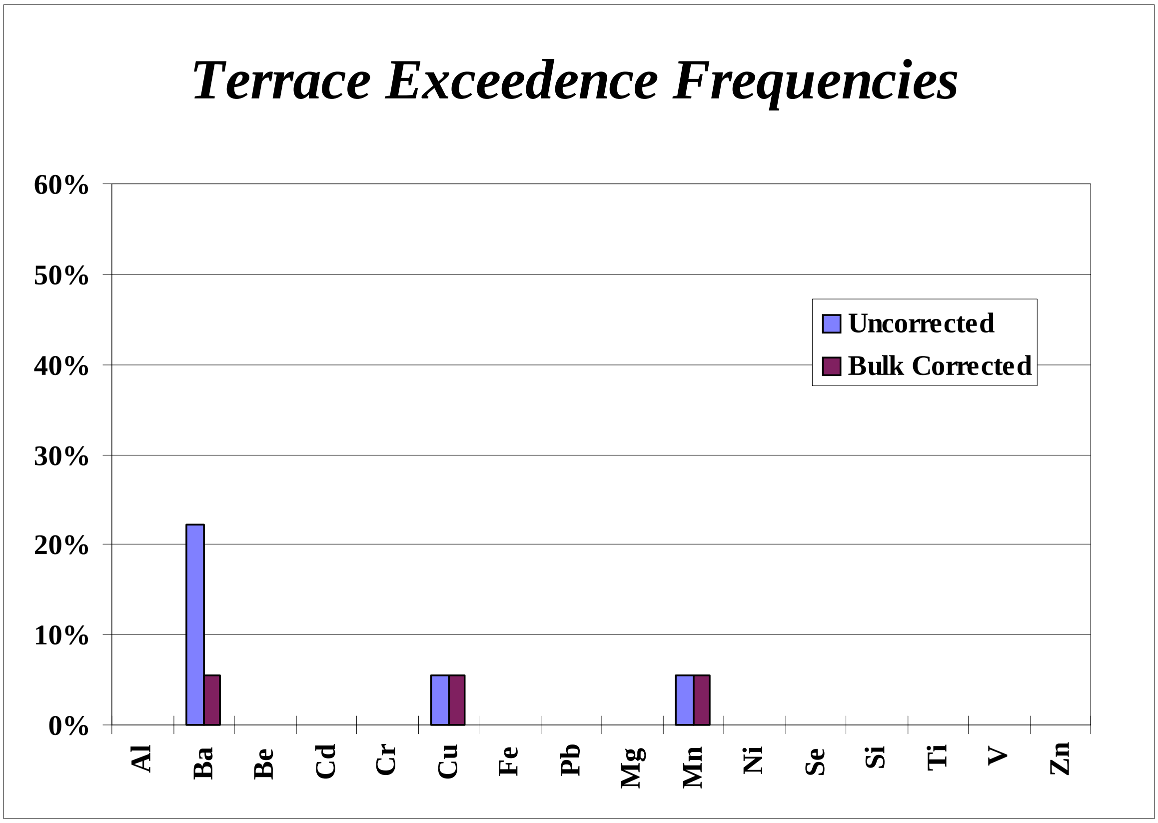
Riverlodge, the low-elevation residential area northeast of the industrial sources, saw barium and zinc exceedence frequencies decline slightly upon correction. Exceedences occur for barium, copper, and zinc.

Figure 16. Whitesail Exceedence Frequencies.



Whitesail, the higher-elevation residential area northeast of the industrial sources, had barium exceedence frequencies decline slightly after correction. Exceedences occur for barium, copper, and zinc.

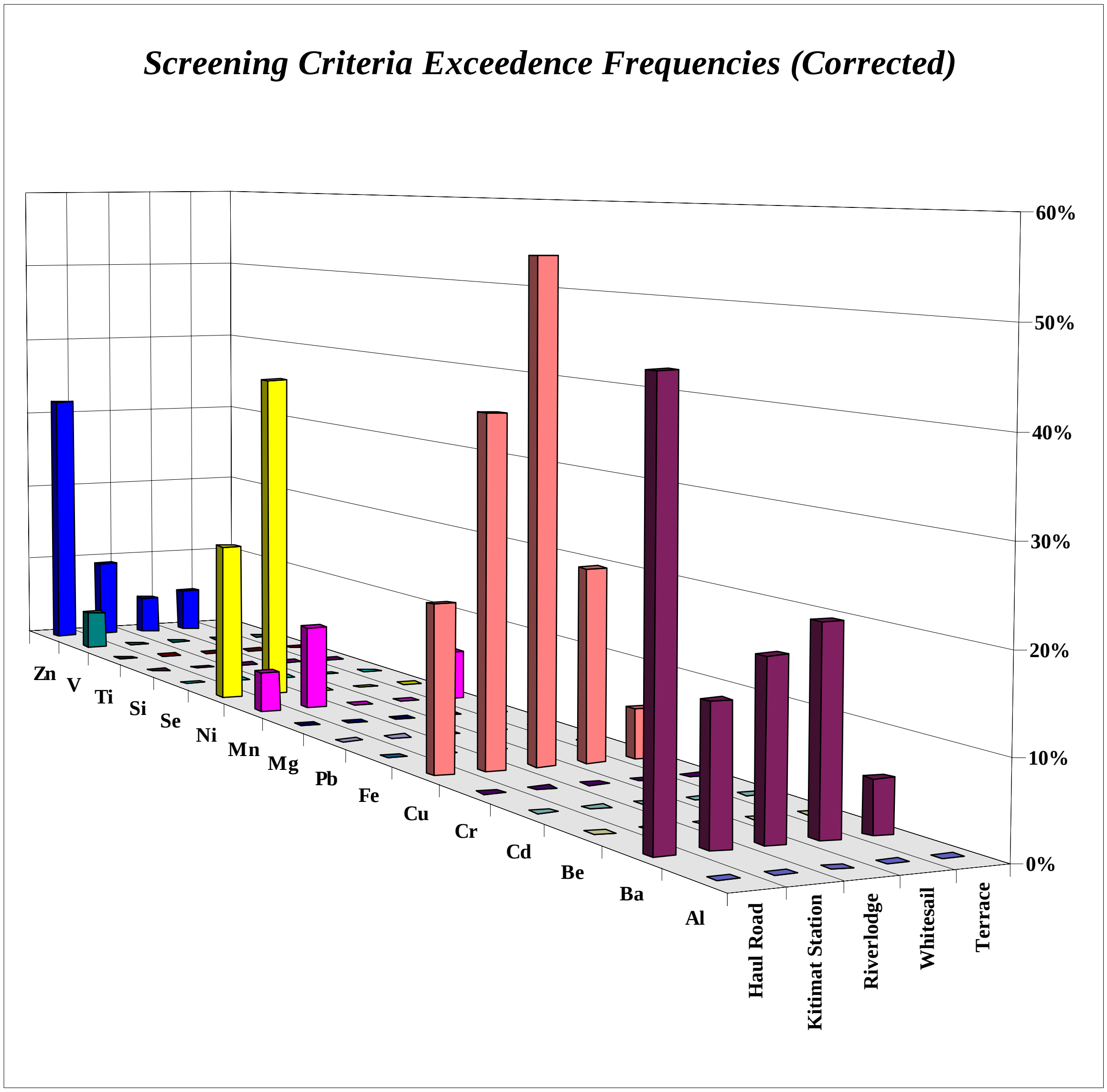
Figure 17. Terrace Exceedence Frequencies.



Terrace, the community 60 km north of Kitimat, saw its barium exceedences decline drastically after correction. Barium, copper, and magnesium exceeded the screening criteria occasionally (approximately 5% of samples).

Figure 18 presents the screening criteria exceedence frequencies corrected for errors by contaminant and site.

Figure 18. Screening Criteria Exceedence Frequencies Corrected for Error.



Comparing with the uncorrected chart (Figure 7), the pattern for barium and zinc change: the Terrace barium exceedence frequencies have dropped markedly and Whitesail now has the lowest zinc exceedences (Terrace had the lowest uncorrected zinc exceedences). Otherwise, the patterns are similar. Generally, Terrace has the fewest exceedence frequencies. The industrial sites (Haul Road and Kitimat Rail) have the greatest exceedence frequencies for zinc, vanadium, selenium, and nickel. There is a spatial pattern for barium and copper.

Meteorology

Generally, Kitimat experiences outflow winds from November to March. October and April are transition months. Inflow winds dominate May-September. Presented below are windroses for three meteorological stations are covering the sampling period.

Figure 19. Terrace Meteorology.

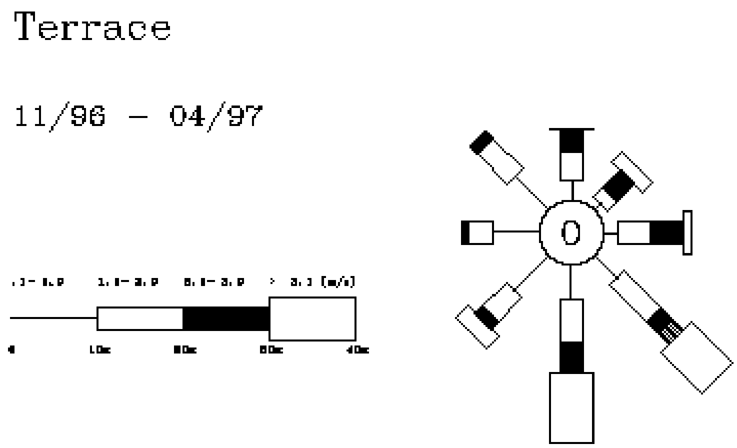


Figure 20. Kitimat (Eurocan Dock) Meteorology.

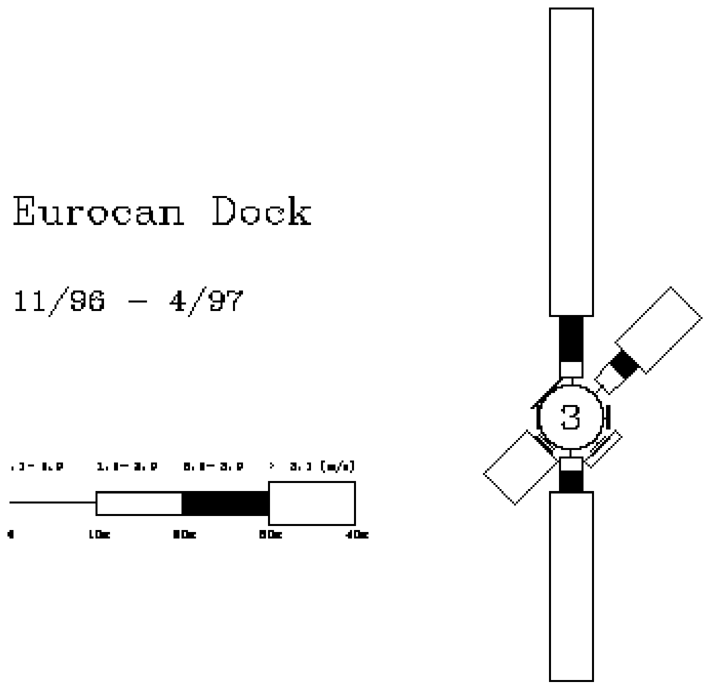
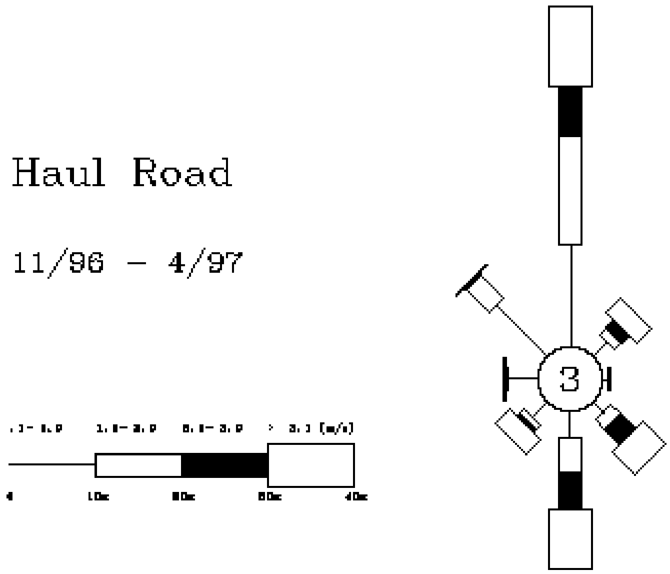


Figure 21. Kitimat (Haul Road) Meteorology.



Terrace appeared to have inflow winds most of the sample period. However, given the station siting (north of the Skeena river), one cannot conclude this represents a vector from Kitimat. It is likely the Skeena River (east-west orientation, see Figure 3) affects any inflowing emissions from Kitimat. Strong outflow winds, representing valley-scale meteorology, dominate the Eurocan Dock site. However the site also has a strong inflow sub-component. Less intense winds characterise the Haul Road site as it is much closer to the valley wall. It had a strong outflow component.

Summary and Conclusions

Data capture has been good for the programme to date. As such, the samples may generally be considered representative of their sites. Concentrations less than minimum detection limits are typical for beryllium, cadmium, lead, nickel in the residential areas, selenium, and approximately one-quarter of the silicon samples. Preliminary Screening Level exceedences occur at all sites for barium, copper, manganese (except for the Kitimat residential areas), and zinc (except Terrace). This is significant given that inflow winds do not dominate the meteorological regime and the Preliminary Screening Criteria represent daily averages (whereas the samples are weekly averages). Exceedences for nickel occur only at the Haul Road and Kitimat Rail sites, the stations close to the valley west wall. Barium, vanadium, and zinc have exposure patterns of greatest exceedence frequencies closest to the industrial sources (Haul Road). These contaminants also have the greatest mean concentrations closest to the industrial sources. The Kitimat Rail (Service Centre) site has the highest mean concentrations of chromium, iron, manganese, and nickel. Manganese and nickel have the highest exceedence frequencies at the Rail site. Riverlodge has the greatest mean copper concentrations and the greatest copper exceedence frequencies. Generally, Terrace has the fewest exceedence frequencies. The sites directly north of the industrial area (Haul Road and Kitimat Rail) have the greatest exceedence frequencies for nickel, selenium, vanadium, and zinc. There is a mixed spatial pattern for barium, copper, and manganese.

Future assessment work includes episode analysis to determine the wind vectors which dominated a screening criteria exceedence. Summer 1997 data may contrast the winter data with respect to more prevailing inflow winds. If industrial emissions are contributing to metal loadings in the environment, we would expect to see increases in exposures during the summer months. Examination of the metals data collected this summer in Smithers and Quick will provide a contrast to the Kitimat and Terrace data. A more comprehensive emissions inventory is necessary to assess which point sources, if any, are emitting metals in significant quantities.

References

BC Environment. 1995. Persistent Toxic Substance Definition. Subcommittee for the Definition of Toxic and Persistent Substances. Environmental Protection Department. *The Environmental Protection Compendium* (http://www.env.gov.bc.ca/epd/cpr/policy/ptsd.html). 25 January 1995.

Colborn, T., D. Dumanoski, and J. Peterson Myers. 1996. *Our Stolen Future*. Dutton. New York, USA.

Johnson, D.D. 1995. *PAHs: Ambient Air Quality Monitoring in British Columbia.* Presentation to Environment Canada Workshop. Simon Fraser University (Downtown Campus), Vancouver, British Columbia. 6 March 1995.

Kitimat's Tourism Information Directory, 1995. 12 December 1995. http://www.sno.net/tourist.html

Smith, J. 1996. *Emissions and Vegetation Monitoring in the Kitimat Valley: A Review With Notes on Proposed Biomonitoring Programs.* March 1996 Draft. Prepared for Prince Rupert Forest Region Research Branch. 59 pp.

Suzuki, N. 1994. *Sampling and Impact Assessment* Criteria *for the Kitimat Metals In Air Ambient Monitoring Programme*. Memo to Richard Bennett, Air Resources Branch. 3 October 1994.