FRASER RIVER ACTION PLAN

Wet Concentrations and Depositions of Organic Compounds and Inorganic Substances in the Ambient Air Surrounding Burnaby Lake, B.C. for 1996

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Wet Concentrations and Deposition Rates of Organic Compounds and Inorganic Substances in the Ambient Air Surrounding Burnaby Lake, B.C. for 1995

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I. Abstract

A sampling program was initiated, as a part of Environment Canada's Fraser River Action Plan, to measure the influence of the atmospheric deposition process to the watershed containing Still Creek-Burnaby Lake-Brunette River. This river system enters into the Fraser River and carries the impacts of urban atmospheric deposition to the estuary. Measurements were made to assess the concentration and deposition of metals and polyaromatic hydrocarbons to this area. Rain samplers were used to collect precipitation samples during a year-long sampling program. The concentrations of some metals and polyaromatic hydrocarbons exceeded Canadian drinking water or aquatic freshwater guidelines. Although these concentrations are not consistently high, there may be a shock value to the aquatic system. The concentrations of polyaromatic hydrocarbons in the rainwater exceeded values reported for similar ecosystems in Europe and the United States.

Résumé

Un programme d'échantillonnage a été mis en oeuvre, dans le cadre du Plan d'action du Fraser d'Environnement Canada, en vue de mesurer l'effet du processus de dépôt atmosphérique dans le bassin versant comprenant le ruisseau Still, le lac Burnaby et la rivière Brunette. L'eau de ce réseau hydrographique se jette dans le fleuve Fraser et entraîne avec elle jusque dans l'estuaire les dépôts atmosphériques d'origine urbaine. Des mesures ont été effectuées pour évaluer la concentration et le taux de dépôt de métaux et d'hydrocarbures polyaromatiques dans cette région. On a utilisé des collecteurs de pluie pour prélever des échantillons de précipitation dans le cadre d'un programme d'échantillonnage d'une durée d'un an. Les concentrations de certains métaux et d'hydrocarbures polyaromatiques sont supérieures aux limites fixées dans les recommandations canadiennes concernant l'eau potable ou le milieu aquatique d'eau douce. Bien qu'elles ne soient pas uniformément élevées, ces concentrations peuvent constituer un choc pour le système aquatique. Les concentrations d'hydrocarbures polyaromatiques dans l'eau de pluie étaient supérieures aux valeurs signalées pour des écosystèmes semblables en Europe et aux États-Unis.

II. Introduction

An eco-system is affected by a number of sources of pollution introduced through various delivery pathways. Often, the only pathways considered are those related to solid and liquid sources. However the air pathway has also been shown to be a significant contributor to the total deposition of pollutants to an area. It was this air pathway that was studied to examine the impact of air pollution on the Burnaby Lake watershed. This watershed contains Still Creek, Burnaby Lake and the Brunette River areas. This watershed drains into the Fraser River near New Westminster, B.C. Any pollution in the Burnaby Lake watershed could thereby flow into and have an impact on the Fraser River estuary.

Urban sources in the area are too diverse and numerous to enumerate. The commonly expected pollutants are metals and polyaromatic hydrocarbons (PAHs), which are also listed in the Canadian Priority Substances List (PSL) for control or removal from the environment.

The metals assessed in this study were common elements that included: silver, aluminum, arsenic, boron, barium, calcium, cadmium, chromium, copper, iron, mercury, magnesium, manganese, sodium, nickel, lead, sulphur, selenium, silicon, strontium, titanium, and zinc.

The PAHs included: naphthalene, acenaphthalene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(c)phenanthrene, benz(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(j)fluoranthene, benzo(a)pyrene, indeno(1,2,3-c,d)pyrene, dibenz(a,h)anthracene, and benzo(g,h,i)perylene.

III. Site Description

The site used for this sampling program is located at Burnaby Lake in central Burnaby. The samplers were located on the roof of the Burnaby Lake Pavilion, situated on the southwest side of the lake. The building was situated over the lake on pilings and was away from any local sources of pollution. Burnaby Lake was chosen for its proximity to the traffic corridors, as well as its distance from any particular point source. Because the site was free of any physical obstructions to wind flow, the transportation of any pollutants to the samplers should have resulted in samples that were representative of the area. Pollutant levels from traffic sources on the major highways and various other local sources would be diluted with ambient air before reaching the sampling site; hence, this site was considered to be a ‘back ground’ site.

The lake is positioned between two ridges that run laterally for several kilometers in an approximately east-west direction on the north and south sides of the lake. Inflow and outflow streams are located on the west and east sides of the lake: Still Creek, the principal inflow source to Burnaby Lake, flows from the west into the lake; Brunette River flows west and south to the Fraser River, where it enters at New Westminster. The total area of the watershed is 7200 hectares. Because of the topography, the natural flow of winds through the lake basin is either from either the east or the west. The west side of the lake has a large density of small industrial businesses (mechanical, shipping, transportation and manufacturing). The east side of the lake has a complex mix of uses (a residential area, a business area and an industrial area).

A variety of small light and heavy duty businesses were located to the west. These industries vary in activity from mechanical repairs to dairy processing to manufacturing, and may be the source of diverse pollutants.

Of the several different types of point and non-point sources in the region, the most common urban source was from vehicular traffic. The incomplete combustion of fuels from such traffic was assumed to be responsible for the discharge of organic and inorganic substances, polyaromatic hydrocarbons (PAHs) and metals, directly to the atmosphere and indirectly to the watershed. Two of the busiest traffic corridors in the Lower Mainland are located within close proximity to the Burnaby Lake area. Highway 1 lies directly to the south of the lake and parallels it for the majority of its length, at some points coming within 100–200 meters of the lake. Highway 7 (Lougheed Hwy.) is positioned on the northern ridge at a distance of approximately 3–4 kilometers. Both major thoroughfares come together at the east end of the lake in a major intersection (Figure 1).

IV. Sampling Methods

Two types of rainfall samplers were situated on the rooftop, and care was given to ensure that they were away from any objects that were within three times the object’s height. Both samplers conformed to CAPMoN standards (Vet *et al*, 1987) for precipitation sampling, and field procedures conformed to CAPMoN protocols (CAPMoN, 1985).

A. Wet Inorganic Sampler

A precipitation sampler from the M.I.C. corporation was used to collect rainfall for inorganic chemical analyses. The sampler utilized a heated moisture sensor that operated a closure lid so that it was open when there was precipitation and closed during dry periods. It consisted of a plastic bucket 31.5 cm in diameter (inside) and 51.0 cm deep (collection area of 0.0779 m^2) with an open polyethylene bag placed inside the bucket to collect the rainwater. The polyethylene bag was removed after a week's sampling, and was taken to the lab for metals analyses.

B. Wet Organic Sampler

A second M.I.C. precipitation sampler was used to collect rainfall for the organic components. This sampler was similar in construction to the inorganic sampler in that concept and method of operation was identical, but the collection device was different. The sampler consisted of a Teflon-coated 46 cm square, 38 cm deep stainless steel collection funnel supported by a fabricated aluminum body. The collection area was 0.212 m^2. The collection funnel and the underside of the lid were Teflon-coated to reduce the possibility of sample loss through chemical or physical reaction with the sampler.

A white Teflon tube was attached to the bottom of the collection funnel via a Nalgene™ connector. The tube contained XAD-2 resin to absorb any organic compounds that were in the rain samples. Rain samples were collected for a week and then the Teflon tube containing the XAD-2 resin was removed and sent to the lab for PAH analyses.

V. Meteorological Data

Meteorological monitoring equipment was also located on the roof of the Burnaby Lake rowing club pavilion building to measure wind speed and direction, temperature, relative humility, atmospheric pressure, and rainfall.

Rainfall information was collected in two forms: a tipping bucket rain gauge to assess rainfall intensity; and an Environment Canada standard rain gauge to measure amount. The standard rain gauge (SG) measured the total amount of rainfall during the sampling period. This data was used for calculations of concentrations and deposition rates of the organic and inorganic components of this sampling program. The tipping bucket gauge (TRG) was used to assess the intensity of precipitation and the total amount of rainfall. The data collected from the TBRG was captured on a data logger from Campbell Scientific. Both gauges measured their values in millimeters.

Wind speed and direction were measured using an RM Young anemometer. This instrument was mounted on a 3 meter tower. Wind speed was measured in knots while wind direction was measured in degrees. The temperature was measured using an RM Young thermistor sensor that was attached at a point about 2 metres above ground on the meteorological tower. The temperature was recorded in degrees Celsius (°C). The relative humidity was measured with an RM Young hygrometer that was attached at a point about 2 metres above ground on the meteorological tower. The relative humidity was recorded in percent relative humidity (% RH). The station pressure was measured with a Setra Systems aneroid barometer and was recorded in millibars (mb). Data is shown in Table 1.

VI. Quality Assurance

A. Meteorological Data

To ensure the meteorological devices were performing to standard, they were periodically evaluated for accuracy. Rain data from the tipping bucket rain gauge (TBRG) was collected for later evaluation of the effect of rainfall intensity. This gauge was accurate to ± 0.2 mm of rain; the TBRG was certified before sampling, and is normally re-checked yearly. The standard Environment Canada rain gauge has an accuracy of ± 0.1 mm of rain.

The RM Young anemometers were evaluated yearly using manufacturer procedures to ensure that they performed accurately and within the manufacturer's specifications. The accuracy of the wind speed was ±0.1 knot over the threshold limit of 1.0 knot over a range of 0 to 60 knots. The wind direction accuracy was within 5 degrees of true north after being sited with a compass at setup.

The RM Young thermistors (temperature sensors) were evaluated yearly using manufacturer procedures to ensure that they performed accurately and within the manufacturer's specifications of ±0.4° C.

The RM Young humidity meters were evaluated yearly using manufacturer procedures to ensure that they performed accurately and within the manufacturer's specifications of ±3% RH over a range of 0-100%.

The RM Young pressure sensors were evaluated yearly using manufacturer procedures to ensure that they performed accurately and within the manufacturer's specifications.

B. Field Sampling Procedures

The most important aspect of the field procedures was to ensure that samples were collected properly and were not contaminated. Documented sample handling protocols were established prior to sampling to ensure that no contamination by the personnel or other outside sources was possible.

Because PAHs and metals are commonly found in cigarette smoke, it was imperative that non-smoking personnel were employed in the sample handling program. Also, sampling personnel were required to wear polyethylene gloves during sample handling.

1. Wet Inorganic Sampler

The polyethylene bags were visibly checked for any obvious contamination before they were used. Also, sample bags containing a known amount of distilled water were submitted to assess the bags for contaminants. Plastic gloves were worn at all times when handling any part of the sample or sample collector to ensure that the inside of the polyethylene bag that used to collect the sample remained contaminant free. Human perspiration was considered to be a possible source of metal contamination for sodium, calcium and magnesium. The removal of the polyethylene bag from the bucket was done with caution to prevent sample loss from bag breakage. Because there were several periods when there was unusually high rainfall amounts, abnormally high stress was put on the bag strength. During the sampling program, bag breakage did occur, resulting in loss of sample. All dates and setup and removal times of were noted on both the polyethylene sample bag and in a data logbook.

2. Wet Organic Sampler

Similar measures to those required for metals were taken to ensure that the samples remained free from contamination for PAHs.

Care was taken when removing the Teflon tube from the rain sampler. It was imperative that no contamination of the sample or its container occurred during either the attachment or removal of the Teflon tube/ XAD-2 resin. After placing the rain sampler lid in the open position and shutting off the power, the inside Teflon coated collection area (funnel) of the sampler was rinsed down with a small amount of de-ionized water. The collection area was again rinsed down with de-ionized water and at the same time a Kimwipe® was used to wipe down the walls of the funnel in order to remove any remaining fine particulate or organic residue. The Kimwipe® was considered a part of the sample and was placed in an clean amber glass container for combined analyses. After cleaning the sampler funnel, the tube was removed from the sampler and the exposed end sealed with chemically clean aluminum foil for transport to the lab. The entire collection area of the rain sampler was then thoroughly brushed and rinsed down to remove any final residual contaminants that might affect the following week's sample. A new Teflon tube with fresh XAD-2 resin was attached to the rain funnel connector and de-ionized water was passed through to check for leaks between connectors. If leaks were found, the tube was removed and the threaded joints were re-wrapped with Teflon tape before being re-attached. The process was repeated until no leaks were observed. The sampler was then turned on.

Special shipping requirements for the Teflon tube/ XAD resin sample and the polyethylene sample bag were not required because the samples were taken immediately to the lab. Once the samples arrived at the lab they were stored at a temperature of 5°C.

C. Sampling Media - Quality Assurance

The Quality Assurance (QA) media program included both field and lab elements for blanks and spikes. Those were performed according to standard operating protocol at Zenon labs (Jeffrey D, 1994).

1. Blanks

Field blanks were used to confirm the quality and accuracy of the methods involved in the transportation, collection and handling of a particular sample. A field blank was obtained by performing normal installation procedures and removing the sampling media (either Teflon tube of polyethylene bag) without sampling. The blank samples were then returned to the laboratory for analysis. Metal field blank results are shown in Table 2**,** and PAH field blank results are shown in Table 3**.**

2. Spikes

Laboratory sample spikes for PAHs were used throughout the duration of the study period to assess the laboratory sample extraction efficiencies. A known amount of a surrogate substance chemically similar to the other analytes was added to the sample media before sample extraction. The chemicals used in spiking samples and sample media were deuterated naphthalene, acenaphthene, phenanthrene, chrysene and perylene.

Field spikes were used to assess the accuracy of the sampling method of PAHs. Field spikes (d12-fluoranthene and d12-benzo(g,h,i)perylene) were prepared in the lab by adding a known amount to the sample media, before they were taken to the Burnaby Lake site for routine sampling. After the normal sample period, the sampling media was removed and taken to the lab for analyses.

3. Lab Procedures

Normal operating procedures requires the use of lab blanks, standards, spikes and replicate analyses, as a part of the labs quality assurance/ control program. The lab blanks were used to assess reagents, methods, standards, instruments and calibrations. Replicates were performed to assess the precision and repeatability of the analytical procedure.

VII. Data

A. Meteorological Data

The sampling program ran from January 31 to December 5, 1995. During that period there 36 sets of data recorded for the meteorological conditions at the sampling site. The weekly averaged meteorological data for sampling period is shown in Table 1.

Figure 2 provides a picture of variation of the amount of rainfall, according to the standard EC rain gauge, over time. Rainfall for the study period ranged from 0.0 - 140.0 mm according to the standard EC rain gauge and 0.0 - 131.4 mm according to the tipping bucket rain gauge.

Figure 3 shows average weekly wind speeds for the study period. Prevalent wind direction was determined by the frequency and average speed of the wind in an compass octant. The octant directions used were: North, North-East, East, South-East, South, South-West, West and North-West (N, NE, E, SE, S, SW, W, NW). Wind speeds ranged from 2.5-5.2 knots, and direction varied from day to day.

Maximum weekly temperatures are shown in Figure 4**.** Mean weekly temperatures ranged from 2.7 - 21.2 ºC and are shown in Figure 5. Average weekly atmospheric pressure values for the study period ranged from 1002-1023 Mb. Average weekly relative humidity values for the study period ranged from 64.6-98.8 % saturation.

B. Chemical Data

The chemicals measured during this sampling program, PAHs and metals, were chosen primarily because of their ubiquitous nature and suspected origins from local sources.

1. Metal Data

Metals analyses were performed by Zenon Analytical Services. Analyses for metals were performed on an Inductively Coupled Plasma Atomic Absorption Spectrophotometer (ICP-AAS), and data was reported (Tables 4) in terms of concentrations of each analyte present in the sample.

Concentration values below the minimum detection concentration (MDC) were shown as 'less than' (<) and set to zero for purposes of data assessment. Beryllium, bismuth, cobalt, potassium, molybdenum, phosphorous, antimony, tin, tellurium, thallium, vanadium and zirconium were not detected in the samples during the study period and were excluded from discussion.

Field blanks, taken during the study period, proved to be free of contamination, with the exception of mercury, as shown in Table 2. The sample concentrations for mercury were blank corrected by subtracting the blank value. The blank-corrected data is shown in Table 5.

Because the rate of emission of pollutants from various sources is not constant, weekly samples were taken over the period of about a year to assess average concentrations and to calculated average deposition rates.

The blank-corrected data was multiplied by the volume of the sampler to reflect the deposition in weights, then divided by the area of the sampler and the time period of the sample . The calculated deposition rates in milligrams per square meter per day ($mg/m^2/d$) are show in Table 6.

2. PAH Data

PAHs are a family of related cyclic aromatic compounds of two to six six-member carbon rings. These compounds exhibit a range of physical properties, as shown in Table 7 (Budavari *et al*, 1989), (Lewis, R., 1991), (Lide, D., 1992).

PAHs can be grouped as low molecular weight and high molecular weight compounds. Low molecular weight PAHs are those with weights of less than 200 atomic mass units (a.m.u.) and include naphthalene, acenaphthene, acenaphthene, fluorene, phenanthrene and anthracene. These chemicals appear to have higher volatility compared to the heavy molecular weight PAHs. Low molecular weighted PAHs are normally present in the samples in higher quantities than the high molecular weight PAHs.

Because the samples were extracted with solvents to concentrate the PAHs and thereby increase the sensitivity of the measurements, the laboratory data was reported terms of total micrograms (µg) found of each analyte. This concentration data, with recoveries and blanks are shown in Table 8.

Any values below the minimum detection limit were set to zero for reporting purposes. 7,2-dimethyl benzo(a)anthracene, 3-methylcholanthrene, dibenzo(a)pyrene, and dibenz(a,h)anthracene were not detected in the samples, and were excluded from further discussion.

PAH field blanks were used during the study period and results were used to blank correct the sample data. Naphthalene had a high blank value and this may have been due to presence of acidic compounds (nitrates) that can cause de-polymerization of the XAD resin to form break down compounds that interfere with naphthalene analysis (Jenkins, B. M., *et al*, 1996). The blank-corrected values were then evaluated with respect to the recoveries of specifically spiked compounds.

Lab spikes were included throughout the study period. The chemicals used for spikes were chosen to represent the range of volatilities in the PAHs being measured. If a spike showed poor recovery, then the chemicals with equal or higher volatility would then be suspect. On February 21, the lab recoveries were unacceptable and data for that day was excluded from further calculations.

Field spikes were used to assess field sampling procedures. If the recovery for a field spike PAH chemical was unacceptable, sample results for PAHs with a volatility equal or greater than the spike PAH were considered suspect and removed from further consideration.

To calculate concentration and deposition values, the area of the organic sampler (in square millimeters, mm^2) was calculated and multiplied by the measured rainfall (in millimeters, mm) for each sample period to obtain the amount of rainfall that passed through the sampling tube in liters (Table 9). This calculated volume was used with the analyses weights reported by the laboratory to calculate concentrations. The concentration data (µg/L) was calculated after blank correction (Table 10); the shaded areas denote data that became suspect because of poor spike results. Deposition rates were calculated ($\mu g/m^2/d$) from the calculated concentrations, sampler area, and sample period (Table 11).

VIII. Discussion

A. Meteorological Data

Meteorological data was collected throughout the study period. Average weekly data was calculated for the duration of each sampling period, usually seven days. This data was then used with the sample data to evaluate trends in the concentrations and deposition rates.

Some meteorological data was lost or suspect for several reasons: datalogger overload; violent storms that flooded equipment or knocked it over; and, freezing conditions. During the period of August 29 to October 2 and October 17 to October 31 some wind data was suspect as the datalogger reported that on those days, the maximum and minimum wind speeds were the same.

Rainfall varied throughout the study period, but the most rainfall occurred during the winter weeks (Figure 2) showing a seasonal pattern, with the summer having the lowest rainfall and the winter having the highest.

Wind patterns appeared to be predominantly from the east during the study period. Some seasonal trends were observed, where the wind is prevalently from the southeast in the winter, east in the spring and summer, and north to southeast in the fall. Northwest winds were not observed at any time (Figure 3). Because the weekly wind direction was evaluated from frequency patterns, there was often difficulty in determining a “prevailing” wind direction, especially when daily wind direction predominated in two or more different octants in the same week.

B. Chemical Data

1. Metals

Metals are emitted into the atmosphere through a wide variety of manufacturing processes, and this diversity of sources makes identification of any one source difficult. Zinc, for example, is used in the metal galvanizing industry and can be emitted as a metal fume during manufacturing processes; it is also used in the manufacture of rubber tires, and as tires wear microscopic amounts of tire dust are released to the atmosphere. The diverse anthropogenic sources contribute varying amounts of metals to the urban atmosphere.

a) Field Sampling

The study period for metals ran from January 31, 1995 to December 5, 1995. Samples were normally taken over a week from Tuesday to Tuesday, except for two weeks when the samplers were running 6 days and 8 days respectively: August 8 - 13 and August 14 - 21. The weekly schedule was established for economic reasons, and to make sure that the expected low levels of chemicals would be in sufficient quantities to be measurable. On occasion a weekly sample was not submitted to the laboratory because there had been no measurable rainfall during the sampling week. The sample media was left in the field for second week, or until measurable rainfall did occur, no longer than three weeks. Contrarily, some weeks had so much precipitation that the weight of the precipitation caused bag breakage, resulting in a loss of sample. In the cases where no precipitation occurred samples were only considered to have occurred during the week of precipitation. Hence, the deposition rates reported are minimum values, and could have been higher if lost samples were included.

b) QA

(1) Blanks

Two field metal blanks were performed (March 7 and June 6). With the exception of presence of mercury on March 7, no background contamination was detected in the blanks. The relative and uniform absence of contamination in the blanks indicated that lack of more field blanks was acceptable.

c) Sample Data

The study period was intended to provide a representative sample data set for the year, to evaluate the effect of annual atmospheric deposition on the Burnaby Lake area. A broad group of metals was measured to determine which metals were present and in what quantities. Of the thirty-five metals analyzed, twenty-two were found in measurable quantities; the metals that were not detected were excluded from further evaluation: beryllium, bismuth, cobalt, potassium, molybdenum, phosphorous, antimony, tin, tellurium, titanium, thallium, vanadium, and zirconium.

The metals that were found included: silver, aluminum, arsenic, boron, barium, calcium, cadmium, chromium, copper, iron, mercury, magnesium, manganese, sodium, nickel, lead, sulphur, selenium, silicon, strontium, titanium, and zinc.

(1) Statistics

Table 12 provides a summary of the concentrations (mg/l), with maximums, minimums, and means. The most predominant metals found in this study were sulphur, sodium, calcium, magnesium, silicon, iron, aluminum, and zinc, respectively. Sulphur, with a minimum concentration of 100 µg/L, was present throughout the study period.

Table 13 is a summary of the maximum, minimum, and mean values for deposition rates for metals in mg/m^2/d. Tables 14 and 15 show deposition in mg/m^2/yr and kg/ha/yr, respectively. The most predominant metals in terms of deposition rates in this study are sulphur, sodium, calcium, magnesium, zinc, and silicon, in that order.

(2) Trends and Standards

Data for the weekly-taken samples presented in the tables and figures is shown with the start date for the seven day sample.

Health Canada (HC) has established standards (Health Canada, 1995) for the concentrations of metals that are allowable in drinking water, and for aquatic life in freshwater. The standards for silver, arsenic, boron, barium, cadmium, chromium, mercury, lead, and selenium are shown in Table 16 with a summary of the maximum and average values measured at the Burnaby Lake site. Also included are the B.C. Environment working criteria for water quality (B.C. Environment, 1994).

Silver (Figure 6) was detected on three days: May 16 (0.1 µg/L), June 6 (0.2 µg/L), and August 14 (0.1 µg/L). The Health Canada Freshwater Aquatic Life guidelines of 0.0001 mg/L were exceeded in these three rainfall events. There was moderate rainfall on June 6 and August 14, and very little rainfall on May 16. The daily mean temperature did not exhibit maxima or minima on those three days, and the only peak in maximum temperature was on June 6. The wind came from the southwest on May 16, and from the east on June 6 and August 14. Sources of silver are few; it is used in jewelry, electronics and in some anti-fungal treatments. No assessment of sources was possible.

Aluminum is associated with diverse sources related to soil, canning, metal finishing, metal recovery, etc. Aluminum (Figure 7) showed four peaks in concentration (April 18, May 16, June 13, and September 12) over the spring, summer, and autumn months. Aluminum was not measurable during the winter months. The HC aluminum concentration guideline for freshwater aquatic life was 0.005 mg/L, which was exceeded each time it was detected. There was moderate rainfall on June 13 and very little rainfall on April 18, May 16, and September 12. The wind direction varied: from the west on April 18; from the southwest on May 16; from east-southeast on June 13; and from the northeast on September 12. The only correlation between meteorological events and concentration or deposition values was with a prevailing easterly wind and possible sources to the east. Changes in atmospheric temperature values appeared to have had no impact on aluminum concentration levels. There were four peaks in deposition rate in the spring and summer (April 11, May 16, June 13, and August 29). There was moderate rainfall on April 11 and June 13, and very little rainfall on May 16 and August 29. The wind came from the southwest on April 11 and May 16, east-southeast on June 13, and east on August 29. The wind speeds were average; there were no storms that might have carried ground soil, a source of aluminum.

Arsenic is a toxic substance often associated with smelting, refining and recycling of metals. Arsenic (Figure 8) was detected on eight days: March 28; June 13; July 4; July 11; August 1; September 12; November 7; and November 28. Higher concentration peaks appear early in the study period (March 28, June 13, and July 4) when rainfall amounts were low, resulting in higher concentrations. High deposition rate peaks appear throughout the study period (March 28, June 13, July 4, August 1, and November 7) regardless of rainfall amount, indicating a consistent nearby source of emissions . The wind direction on the days with peaks was mainly from the east; however, on other days when the wind also came from the east there was no detectable peak in concentration or deposition. The wind speeds were of average magnitude on those days. It may be that the low-level concentration days had more air dilution or that emission sources were shut down. No sample concentrations were over the Drinking Water Guideline (0.025 mg/L) or the Freshwater Aquatic Life objective level of 0.05 mg/L (Health Canada, 1995).

Boron (Figure 9) was detected on four days: April 18, April 25, May 16, and September 12. There may be a correlation with wind direction, as the wind came from a west/southwest direction on the days (April 18, April 25, and May 16). On September 12, when there was less deposition, the wind came from the northeast. There may be a source of boron to the south-west of the Burnaby lake area. Boron is often associated with fertilizers and metal refining. Boron shows a maximum concentration of 0.05 mg/l and an average of 0.0033 mg/l. The concentrations found are not near the maximum drinking water guideline of 5.0 mg/l.

Barium (Figure 10) shows a repeating concentration pattern or trend with peak concentrations around the second or third week of each month, except in February, July, and October. The wind direction varied during the days with significant peaks (from the east on Mar 21: west on April 18, east-southeast on June 13, south on August 22; and northeast on September 12), consequently no consistent source direction could be determined. Barium had a maximum concentration of 0.004 mg/l and an average concentration of 0.0079 mg/l. These concentrations are low compared to the HC drinking water guideline of 1.0 mg/l, and there is no perceived concern for barium concentrations. On November 7, although the concentration was not as high as on other days, because the rainfall amount was high, a large and notable deposition-rate peak occurs; unfortunately wind data is missing for this date.

Calcium concentrations showed a trend (Figure 11) similar to that for barium, with a cyclic pattern of peaks occurring around the 14th to 20th of each month, except in July and October. Significant peaks occur on August 22 and September 12, with the winds coming from the south and the northeast respectively. Wind direction varied on other days for other concentration peaks: east on March 21, west on April 18, south on May 2, southwest on May 16, and southeast on June 20; no repeatable wind direction and source could be observed. Calcium is normally found in atmospheric aerosols carried from marine environments, such as the Pacific Ocean, and because of the size of this nearby source there was no one predominant source direction. Health Canada has established a freshwater aquatic life guideline level of 0.00006 mg/L; all samples measured (0.005 to ~1.55 mg/L) were above this level. Aside from a major peak on November 7, the deposition rate for calcium was between 0.0 and 1.5 $mg/m^2/d$ for the study period.

Cadmium (Figure 12) had a series of concentration maxima on March 21, May 2, June 20, October 17 and November 2; maximum at 0.003 mg/L. There are fifteen different events that have concentration levels at or above the Health Canada freshwater aquatic life guideline of 0.0002-0.0018 mg/L level; they are, however, below the drinking water guideline of 0.005 mg/L. The wind direction varied for those days, coming from the east on March 21, the south on May 2, the east-south-east on June 20 and the north on October 17. Wind speed, rainfall and temperature were moderate during these events. Cadmium shows one major deposition rate peak on November 7, but wind direction values were unavailable for source evaluation.

Chromium (Figure 13) was measurable only during the last two weeks of the study period, with a peak on November 21 at 0.14 mg/L. The wind was from the southeast for those two days and temperatures were moderate. However, chromium did not appear in detectable quantities on days when the winds also came from the southeast. Wind speeds are higher than the average at 3.3 knots on November 21, and 4.6 knots on November 28. A source to the south east of the sampling site is likely; chromium is often associated with industries related to plating and metal refining. Health & Canada (HC) guidelines for maximum drinking water levels are at 0.05 mg/L, well above levels measured in rainwater samples, but guidelines for freshwater aquatic life were at 0.002-0.020 mg/L and these two rainfall events exceeded that lower level.

Copper (Figure 14) had measurable concentrations on March 21, April 4, 11, 18, 25, May 2, 16 and August 22; all values except the last date have concentration levels above the HC freshwater aquatic guideline of 0.002-0.004 mg/L. The HC drinking water guideline is $\leq$ 1.0 mg/L. Except for the peak on March 21, when the wind came from the east, the peaks occurred on days when winds come from the south/ southwesterly direction. However, copper was not detected on July 25 and August 22, when the wind was also from the south. Again, pollutant sources may have shut down, or transport from long distance sources may have been impeded. Copper had one major deposition rate peak on November 7 but wind data was not available for assessment.

Iron (Figure 15) had cyclic concentration peaks throughout the sampling period, with peaks March 21, April 4, 11, May 2, 16, June 13, 20, September 12 and November 14 and 21. Winds during these periods varied from northeast, east, east-south-east, south-east, south, southwest and west, but primarily from the south and east sectors. HC's freshwater aquatic life guideline is 0.3 mg/L which is well above any values measured. Iron shows a major deposition rate peak on November 21 associated with a heavier rainfall amount.

Mercury (Figure 16) was measured once in the sampling period on March 7, during a minor rain event, at a concentration of 0.02 μg/L, well below the HC freshwater aquatic life guideline value of 0.1 μg/L. The wind was from the southeast at 4.4 knots and the temperature was moderate.

Magnesium (Figure 17) displayed a trend roughly similar to that of barium and calcium, where notable concentration values appear mid-month, except in July when there was no rainfall at the time. Significant concentration peaks occurred on February 28, April 18, and September 12, when the winds came from the southeast, west, northeast, and southeast respectively. Magnesium is another 'sea salt' that is often found in locations near the ocean. There are no HC guidelines for magnesium. Deposition rate peaks followed the same general pattern, with two notable peaks on November 7 and November 28. The meteorological data was missing for November 7, but on November 28 the wind was from the southeast.

Manganese (Figure 18) had a major concentration peak on September 12 and deposition rate peak on September 26, with winds from the northeast. Temperatures were moderate on those two days. There was little rainfall on September 12 and moderate rainfall on September 26. Other minor concentration peaks occur throughout the study period, but the wind direction varied from southwest to southeast. Manganese is associated with gasoline and steel. There may be two different sources of manganese in the area. The HC drinking water objective for manganese is ≤ 0.05 mg/L. The highest manganese concentration is about half that value.

Sodium (Figure 19) had concentration peaks occurring on April 18 and September 12. There was very little rainfall on April 18 and September 12 and temperatures were moderate. The wind came from the west on April 18 and from the northeast on September 12, showing little consistency related to source direction. The HC drinking water guideline for sodium is ≤ 200 mg/L. The maximum sodium concentration found was 2.65 mg/L, well below this guideline indicating no perceived concern for sodium. A major deposition rate peak occurred on November 28, and slightly smaller peaks occur on October 10 and October 24. Winds were from the southeast on October 10, north on October 24, and southeast on November 28. Wind directions on days with other minor peaks were from the east/ southeasterly direction. Sodium is a major constituent of ‘sea salt’ and the random source direction observed is consistent with the presence of nearby ocean sources.

Nickel (Figure 20) was only found in one sample (0.02 mg/L), on November 21, when the wind was from the southeast at 3.3 knots and temperatures were moderate. A rain event occurred during the week. This concentration is just below the HC Freshwater Aquatic Life guideline of 0.025-0.15 mg/L.

Lead (Figure 21) was detected five times during the study period on April 11, 18, May 2, 16, and August 29. With the exception of August 29, when deposition was lower and the wind was from the east, lead was measured when the wind blew from the south-to-west quadrant. Concentrations varied from 0.001 to 0.006 mg/L; the HC drinking water guideline is 0.01 mg/L and the freshwater aquatic life guideline is 0.001-0.007 mg/L (changes with hardness). For aquatic life, these rain events appear to exceed guidelines and may have a ‘shock’ value on aquatic life.

Values for sulphur (Figure 22) varied throughout the study period. Notable concentration peaks occurred on August 14 and September 12, when winds were from the east and the northeast respectively. Notable deposition rate peaks occurred on August 14, October 10, and 24 when winds were from the east, the southeast, and the north respectively. Although it appears that deposition events are related to easterly winds, no significant peaks occur on other days with northeast/east/southeast winds. In terms of other meteorological data, temperatures were moderate and rainfall ranged from little to moderate. Levels of sulfur measured do not appear to be of concern as HC guidelines for sulfur as sulfate (≤ 500 mg/L) are higher than rainfall concentrations measured. The deposition rate of sulfur, as reported in Table 15, showed an average deposition rate of 8.4 kg/ha/yr as sulfur or 25.2 kg/ha/yr as sulfate; maximum values of 53.7 kg/ha^2/yr as sulfur or 161. kg/ha/yr as sulfate. The target loading of 20 kg/ha/yr is the federal government precipitation objective (LRTAP, 1990), in order to reduce acid rain. This limit is exceeded for both average and maximum amounts.

Selenium (Figure 23) was detected six times in measurable quantity during the study period, with a notable peak on September 26 of 0.007 mg/L. HC guidelines for freshwater aquatic life are 0.001 mg/L, and all measured values are near or above that value. Wind direction varied during these events, coming from the east on February 28 and August 14, the south on August 22, the northeast on September 26, the southeast on October 10, and the north on October 24. Generally, there was an eastern flow pattern and pollutant sources could be expected in that area.

Silicon (Figure 24) showed six values on April 4, 11,18, 25, May 2, August 22 and September 12. Concentration peaks occurred on April 4, 18, and September 12. The wind came from the east on April 4, the west on April 18, and the northeast on September 12. There was moderate rainfall on April 4 and very little rainfall on April 18 and September 12. There was one major peak in deposition rate on April 4. Silicon is associated with soil sources and spring and fall winds, picking up soil, may have caused these peaks. There are no health guidelines associated with silicon.

Strontium (Figure 25) showed one major concentration peak on September 12. The wind came from the east on March 21 and April 4, the northeast on September 12, and the southeast on November 28. Notable deposition rate peaks occur on March 21, April 4, September 12, and November 28. The wind direction tended to be from easterly directions when significant deposition occurred, and may be related to the source(s) of strontium. Again, on other days with similar wind direction there was no measurable strontium. There are no HC guidelines available for strontium concentrations.

Titanium (Figure 26) was detected five times during the study period: on April 12, 25, May 2, June 13, and September 12. The winds were from the southwest, west, south, east-southeast, and the northeast respectively. No titanium was detected in the winter months, hence summer source-related activities are expected. The concentration values are all about 0.003 mg/L, and the deposition rate values varied due to different amounts of rainfall. Titanium is associated with metallurgical process, cosmetics and paint production. There are no HC guidelines available for titanium concentrations.

Zinc (Figure 27) concentration peaks occurred on April 11, March 21, and May 9. Deposition rate peaks occurred on January 31, April 11, May 9, November 7, and November 21; they follow the rough mid-month peak trend noted before, except in April, May, July, September, and October. The wind direction was from the east/southeast, except on April 11 when it was from the southwest. The HC guideline for freshwater aquatic life is 0.03 mg/L and seven rainfall events had concentrations above this limit; there may be a short-term ‘shock’ effect on aquatic systems during these rainfall events.

There are no currently recognized standards for deposition rates, but in his proposal for Environment Canada’s Atmospheric Environment Service (AES) air toxics program, R. M. Hoff has proposed “an interim program target to determine the regions in Canada where … trace elements (except Hg) fluxes exceed ± 100 $\mu g/m^2/y$” and where “Mercury fluxes exceed ± 10 $\mu g/m^2/y$.” (Hoff, R.M., 1996). Table 14 shows that almost all the metals measured have deposition rates above that limit, with the exception of silver and mercury. Calcium, sodium, magnesium, silicon and sulphur are not considered toxic; sulfur, however, as sulfate does contribute to acid rain.

(3) Comparisons with other Studies

Similar rainfall studies (Poissant, L. *et al,* 1992), (Atteia, O., 1994), (Barrie, L. *et al*, 1987) have been done in other areas. Results from those studies are shown in Table 17, in comparison with results from this study. The ‘remote sites’ (Enewetak, N. Pacific, Remote Bermuda, Bermuda, NW Ontario, and Northern Sweden) are listed in order of increasing proximity to urban areas.

Although there is comparable data for most metals, similar data for silver, aluminum, mercury, sulphur, and titanium were not found in other studies.

Arsenic data was found for a study in Dorset, Ontario (Barrie, L. *et al*, 1987) and the concentration of arsenic from this study was found to be higher, though within the same order of magnitude.

Data for boron, barium, iron, sodium, silicon, and strontium had only one study which sampled for the same chemicals (Atteia, O., 1994). Boron, barium, silicon, and strontium concentrations from the Burnaby Lake (BL) data were lower than that of Switzerland; boron and strontium were of the same order of magnitude, and barium and silicon concentrations were one order of magnitude lower than that of Switzerland. Iron and sodium concentrations from BL were higher than that of Switzerland, though within the same order of magnitude.

Calcium at BL is comparable to the results from Villeroy and Switzerland. All three studies show within the same order of magnitude, and the Burnaby Lake concentrations are between the lower Villeroy concentrations and higher Switzerland concentrations.

Cadmium concentrations from this study were higher than those of other studies. The results from Villeroy, Southern Sweden, SW Ontario, and Lewes, Delaware are within the same order of magnitude; results from the other studies are lower by at least one order of magnitude.

Burnaby Lake chromium concentrations are higher than Switzerland and Dorset data, and fall within the Sudbury result range.

Copper concentrations from the BL study are lower but within the same order of magnitude for Switzerland, Southern Sweden, Northern Sweden, SW Ontario, Sudbury, Ontario, Dorset, Ontario, NW Ontario, and Northern Sweden (as reported in Barrie et al). The Burnaby Lake concentrations were higher than those from the remote sites.

Magnesium data, compared to results from Villeroy and Switzerland, show all three data sets within the same order of magnitude, and the Burnaby Lake concentrations are between the lower Villeroy concentrations and higher Switzerland concentrations.

Manganese concentrations from this study are within the same order of magnitude as all the other studies except for Enewetak, N. Pacific, Remote Bermuda, and Bermuda. The average concentration is lower than that of Switzerland, Southern Sweden, Northern Sweden, SW Ontario, Dorset, NW Ontario, and Northern Sweden.

Nickel concentrations are comparable to results from other studies, where results were within the same order of magnitude.

The average lead concentration from this study is significantly lower than that of other studies, with the exception of Enewetak and N Pacific.

The Villeroy study also sampled for selenium, and results are similar to those for the Burnaby Lake study.

2. PAHs

PAHs are a group of toxic chemicals on the Canadian Priority Substances list (PSL, 1994) under the Canadian Environmental Protection Act (CEPA). They are unique chemicals that are usually produced from the incomplete combustion of organic materials, or in manufacturing other organic chemicals. The multiple-bonded planar structures exhibit an ability to react and π-bond to organic surfaces. They can attach themselves to ash or fine particulate and then be transported great distances from the source before being washed out of the air by precipitation.

Several of these PAH compounds are considered carcinogenic. The PAHs assessed in this sampling program are classified as light and heavy molecular weight species. One of these compounds, benzo(a)pyrene (BaP), is considered to be the most toxic and has been given a toxic equivalent factor (TEF) of 1.0 (B.C. Waste Management Act, 1992), (PSL, 1994), (Collins *et al*, 1991) and other PAHs have been compared to it (Table 18).

a) Field Sampling Discussion

The weekly PAH sampling period coincided with that for the metals sampling program. In weeks with no precipitation, no sample was submitted to the laboratory. The sampling period was typically seven days but there were two periods with a 6 and 8 day duration. The samples were analyzed as soon as possible after sampling; if there were a delay, they were kept at 5º C in the laboratory to prevent any sample degradation.

b) QA Discussion

(1) Blanks

During the study period three field blanks were taken. The results are shown in Table 3. Due to the ubiquitous nature of naphthalene in the atmosphere, or from possible XAD resin breakdown (discussed earlier) the blank values for this particular chemical were higher than expected.

(2) Lab Spikes

Lab spikes were performed with each sample set submitted. The majority of the lab recoveries fell within the accepted recovery range of 60% - 140%. The only exceptions were on June 20, where the recovery of the highly volatile naphthalene fell slightly below the accepted parameters, and on February 21, where, due to an error in the lab, the recovery values were unacceptable for further calculations. That suspect data was discarded.

(3) Field Spikes

Chemicals chosen for field spikes were intended to be representative of a range in PAH volatility. One exception noted is for benzo(g,h,i)perylene where compared to fluoranthene, the molecular weight is higher, but with a lower sublimation temperature; hence, it is considered more volatile (Table 7). Field spikes were performed fifteen times (44% of the samples).

87% of the fluoranthene d1 recoveries and 53% of the benzo(g,h,i)pyrene d12 recoveries fell within acceptable parameters of 60-140% recovery. Sample data for the corresponding chemicals on the days with low recoveries were not used in further calculations. Similarly, data for chemicals with higher volatility's than the chemicals in question was also excluded from further calculations. Shaded data shown in Table 10 is considered suspect.

On August 14 and 29, 1995, recoveries for both field spike chemicals were unusually low. The problem may be due to the condition of the XAD-2 resin column. Sample resin columns may have been 'aged' from extended storage before usage. Consequently, the spiked chemicals may have had a longer resident time and may be more completely adsorbed to the resin, making them more difficult to extract, and thus reducing spike efficiencies. Or, a second reason may be due to high daytime temperatures (27-29° C) could have caused volatilization of the spikes from the sample media. Maximum temperatures for those weeks were plotted (Figure 28) in comparison to the average recoveries during the time which field spikes were performed. The relationship was an inverse one, where at high temperatures, the recoveries were at their lowest. Also, the elevated temperatures may have resulted in a drying of XAD-2 tube resin which was supposed to be kept wet at all times, so as to reduce channeling or to keep the active site of the chemicals active. If the XAD-2 resin did indeed dry out, it may have led to a reduction of its adsorption efficiency or a more permanent bonding of the spikes to the resin itself. Results on these days may be low.

c) Data Discussion

The data was reported from the laboratory in terms of total micrograms found of each analyte because the sample was concentrated on the XAD-2 resin before being extracted.

Of the twenty-three PAHs measured, eighteen were found in measurable quantity; 7,2-dimethyl benzo(a)anthracene, 3-methylcholanthrene, dibenzo(a)pyrene, and dibenz(a,h)anthracene were not detected in the samples and were excluded from discussion.

(1) Statistics

A summary of the concentrations (Table 19) of the detected PAHs, with maximums, minimums and means showed that: the most predominate low molecular weight PAHs were naphthalene, phenanthrene, fluorene, and acenaphthene, in that order; the most predominate high molecular weight PAHs were fluoranthene, pyrene, chrysene, and benzo(b)fluoranthene, in that order. Acenaphthene, fluorene, phenanthrene, fluoranthene, and pyrene were present throughout the study period.

Table 20 shows a summary of the deposition rates of the detected PAHs (with maximums, minimums and means) in µg/m^2/d. Deposition rates in g/ha/yr are shown in Table 21. The deposition rate magnitude is similar that for concentrations.

(2) Trends and Standards

Guideline concentrations for naphthalene, acenaphthene, fluorene, phenanthrene, pyrene, and benzo(a)pyrene (Table 22) were found in a supporting document for Environment Canada's Priority Substance List (Germain, A., *et al*, 1993) prepared for the Canadian Council of Ministers of the Environment (CCME).

Naphthalene (Figure 29) is a ubiquitous chemical, that showed erratic peaks in concentration and in deposition rate throughout the study period. There seems to be some correlation between most peak concentrations (April 25, June 20, and August 8, and August 22) and wind direction from the south and east. Temperatures were moderate, and rainfall ranged from little to moderate during these events. Significant deposition rate amounts occurred on May 9, July 4, and August 8 when rainfall amount was higher than for other weeks. The wind was from the east on all three days. Naphthalene showed concentrations that surpassed the expected CCME guidelines stated in the PSL supporting document of 0.8 µg/L on April 25, May 2, June 20, and August 8. The concentration obtained on August 22 (0.781 µg/L) almost reached the recommendation of 0.8 µg/L. On April 25, the concentration of naphthalene (1.51 µg/L) was almost twice as high as the guideline. There is however, some concern about possible sample contamination from breakdown of the XAD resin when exposed to acidic solutions (Jenkins, B. M., et al, 1996).

Acenaphthalene (Figure 30) and acenaphthene (Figure 31), had highest concentration peaks on April 18 when the wind was from the west, but there was very little rainfall on that date. Acenaphthene had a minor concentration peak on May 2. Acenaphthene concentrations, with a maximum of 0.063 µg/L and an average of 0.015 µg/L, were well below the guideline of 6.0 µg/L recommended by British Columbia Ministry of Environment Lands and Parks (B.C. MoELP) for the protection of freshwater aquatic life (Napgal, N. K., 1993). The deposition rate peaks were on February 7, March 7, and on November 7. The wind came from the northeast on February 7 and the southeast on March 7. Meteorological data was missing for November 7 due to datalogger malfunction. There was moderate rainfall on February 7 and March 7, and heavy rain on November 7. Acenaphthylene and acenaphthene had higher deposition rates in the winter months than in any other season.

Fluorene (Figure 32) had a major concentration peak on April 18 and a minor concentration peak on May 2. On April 18, there was very little rainfall, the wind came from the west and temperature was moderate. On May 2, the wind came from the south and precipitation and temperature were moderate. Fluorene, had a maximum concentration of 0.110 µg/L and an average of 0.019 µg/L which was well below the guideline of 11. µg /L recommended by British Columbia Ministry of Environment Lands and Parks (B.C. MoELP) for the protection of freshwater aquatic life (Napgal, N. K., 1993). Ontario has proposed an interim water quality guideline of 0.2 µg/L (OMOEE, 1994). The deposition rate peaks were similar to those for acenaphthalene and acenaphthene on February 7, March 7, and November 7. For these events, winds were: northeast on February 7; southeast on March 7. Meteorological data was missing for November 7 due to datalogger malfunction, however there was heavy rain on November 7. Rainfall for February 7 and March 7 was moderate.

Phenanthrene (Figure 33) had significant concentrations on April 18 and April 25. Precipitation was low for April 18 and moderate for April 25, temperatures were moderate, and the wind was from the west on both days. However, on July 11, when the wind was also from the west, there was no similar peak in concentration. Phenanthrene had a maximum concentration of 0.343 µg/L (and an average of 0.073 µg/L), which was above the guideline of 0.3 µg /L recommended by British Columbia Ministry of Environment Lands and Parks (B.C. MoELP) for the protection of freshwater aquatic life (Napgal, N. K., 1993). The Ontario recommended provincial water quality objective was 0.03 µg/L (OMOEE, 1994). Significant depositions occurred on February 7, March 7, August 1, October 3,10 and November 7. The respective wind patterns were: northeast on February 7; southeast on March 7. Meteorological data was missing for November 7 when there was heavy rain; rainfall for February 7 and March 7 was moderate. Phenanthrene had higher deposition rates in the winter months than in any other season.

Anthracene (Figure 34) showed significant concentrations on April 18 and April 25. Precipitation was low for April 18 and moderate for April 25, temperatures were moderate, and the wind came from the west on both days. However, on July 11, a similar west wind had no measurable anthracene. On April 18 and 25, the concentrations were 0.018 µg/L and 0.014 µg/L, respectively. B.C. recommended water quality criteria are 4 µg/L and 0.1 µg/L to protect freshwater aquatic life from chronic and photo-induced effects (Napgal, N. K., 1993). Ontario has proposes an interim Provincial Water Quality Objective of 0.0008 µg/L (OMOEE, 1994). Levels found were above the OMOEE guidelines but below the B.C. guidelines. Deposition rate peaked on February 7, March 7, August 1, October 3, 24, and November 7. Winds were predominantly from an eastern direction: northeast on February 7, southeast on March 7, east on August 1 and October 3, and southeast on October 10 and November 14. Temperatures were mainly moderate, and precipitation ranged from little rainfall to moderate rainfall.

Benzo(g,h,i)perylene (Figure 35) had a major concentration peak on April 18. On that day, there was very little rainfall, the wind came from the west and the temperature was moderate. Deposition rates were erratic throughout the study period. Significant peaks in deposition rates occurred on March 7, 14, April 4, 18, May 9, August 1, October 3, 10, and November 14. Wind patterns were mostly from the east and southeast during the major deposition events. Temperatures and precipitation varied from low to high during these events. There are no available guideline criteria for benzo(g,h,i)perylene.

Fluoranthene (Figure 36) showed significant concentrations on April 18, with a peak on April 25. Precipitation was low for April 18 and moderate for April 25. Temperatures were moderate. The wind came from the west on both days. However, on July 11, when the wind was also from the west, there was no significant peak in concentration. B.C. recommended water quality criteria are 4 µg/L and 0.2 µg/L to protect freshwater aquatic life from chronic and photo-induced effects (Napgal, N. K., 1993). Ontario has proposes an interim Provincial Water Quality Objective of 0.0008 µg/L (OMOEE, 1994). Fluoranthene had a maximum of 0.304 µg/L and an average of 0.035 µg/L in the BL study. Concentrations usually exceeded the CEPA administrative threshold, the Ontario objective and the B.C. value for photo-induced toxicity. High deposition rates occurred on February 7, March 7, March 14, October 3, October 10, and November 7. Wind direction seemed mainly easterly, with a northeast wind on February 7, an east wind on October 3, and southeast winds on March 7, March 14, and October 10. Meteorological data was missing for November 7.

Pyrene (Figure 37) showed significant concentrations on April 18 and 25. Precipitation was low for April 18 and moderate for the 25th. Temperatures were moderate and the wind came from the west on both days. Pyrene showed concentrations above the B.C. recommended water quality criteria (of 0.02 µg/L to protect freshwater aquatic life from photo-induced effects (Napgal, N. K., 1993)) on April 18 (0.136 µg/L), April 25 (0.174 µg/L), and August 22 (0.056 µg/L). High deposition rates occurred on February 7, March 7, 14, April 25, October 3, 10, 24, and November 7. There seems to be no correlation to meteorological events as wind direction, rainfall, and temperature were inconsistent. The wind came from the northeast on February 7, southeast on March 7, southeast on March 15, west on April 25, east on October 3, southeast on October 10, and north on October 24. Meteorological data was missing for November 7. Precipitation and temperature ranged from low to high. Pyrene had higher deposition rates in the winter months than in any other season.

Benzo(c)phenanthrene (Figure 38) showed concentration peaks on April 25, May16, June 13 and August 22. The wind direction was from the west on April 25, southwest on May 16, east on June 13 and south on August 22. Temperatures were high, and rainfall was moderate. Erratic deposition rates occurred, with significant depositions on March 7, April 25, June 6, August 1, 22, October 3, 10, and November 7. Temperature was moderate for those days except on June 6 and August 1, when temperatures were high. The wind direction varied, although the winds came mainly from the easterly direction: southeast on March 7, west on April 25, east on June 6, east on August 1, south on August 22, east on October 3, and southeast on October 10. Meteorological data is missing for November 7.

Benz(a)anthracene (Figure 39) showed a notable concentration peak occurred on April 18, at 0.059 µg/L. There was very little rainfall on that day, the wind came from the west and the temperature was moderate. B.C. recommended water quality criteria are 0.1 µg/L to protect freshwater aquatic life from chronic and photo-induced effects (Napgal, N. K., 1993). Ontario has proposes an interim Provincial Water Quality Objective of 0.0004 µg/L (OMOEE, 1994). Concentrations are near the B.C. limit. Deposition rates peaked on February 7, August 1, October 3, 24, and November 7. Wind direction was predominantly from the north and east. The wind came from the northeast on February 7, from the east on August 1 and October 3, and from the north on October 24. Meteorological data is missing for November 7. Temperatures ranged from low to moderate, and three rain events coincided with some of those days (August 1, October 3, November 7).

Chrysene (Figure 40) showed a notable concentration peak (0.15 µg/L) occurred on April 18. There was very little rainfall on that day, the wind was from the west and the temperature was moderate. Deposition rates peaked on February 7, March 14, October 3, 24, and November 7. The wind direction varied on those days, generally coming from northeast to southeast. Meteorological data is missing for November 7. Temperatures ranged from low to moderate, and rainfall varied, with moderate to high precipitation.

Benzo(b)fluoranthene (Figure 41) also had a notable concentration peak (0.19 µg/L) occur on April 18. There was very little rainfall on that day, the wind came from the west, and the temperature was moderate. Deposition patterns were similar to those of benzo(a)anthracene, with deposition rate peaks on February 7, March 14, April 18, October 3, 10, 24, and November 7. The wind direction varied on those days, coming generally from the northeast to the southeast. Meteorological data is missing for November 7. Temperatures ranged from low to moderate, and rainfall varied, with moderate to heavy precipitation.

Benzo(k)fluoranthene (Figure 42) had a major concentration peak (0.045 µg/L) occur on April 18. There was very little rainfall on that day. The wind came from the west and the temperature was moderate. Depositions seemed mainly limited to winter and autumn months. Significant deposition rate peaks occurred on March 14, April 18, August 1, October 3, 10, 24, and November 7. Wind direction was generally from the southeast. Meteorological data is missing for November 7. Temperature and rainfall varied in magnitude.

Benzo(j)fluoranthene (Figure 43) was detected twice during the study period: March 14 and August 14. The wind came from the southeast on March 14 and from the east on August 14. Temperatures and rainfall were moderate.

Benzo(a)pyrene (Figure 44) was detected nine times during the study period: February 21, 28, March 14, April 18, August 1, October 24, November 7, and 14. A major concentration peak occurred on April 18 (0.08 µg/L), however, there was very little rainfall that day. The wind was from the west and the temperature was moderate. High deposition rates occurred on February 28, March 7, and April 18. The wind came from the southeast on four days, and from the west on one day. Temperature for these two episodes ranged from low to moderate, precipitation was low on February 28 and April 18 with a rain event on March 7. Meteorological data is missing for November 7. Benzo(a)pyrene showed concentrations above the International Joint Commission for the Great Lakes (IJC) objective (Germain, A., *et al*, 1993) on February 28 (0.014µg/L) and April 18 (0.081 µg/L). The Great Lakes Science Advisory Board (GLSAB, 1983) and the B.C. MoELP (Napgal, N. K., 1993) have recommended a water quality criterion of 0.01 µg/L BaP for the protection of freshwater aquatic life.

Dibenz(a,h)anthracene (Figure 45) was detected four times during the study period: February 21, March 7, 14, and August 14. The winds on those days came generally from a south and easterly direction. Rainfall and temperature varied.

Indeno(1,2,3-c,d)pyrene (Figure 46) showed a major concentration peak occurred on April 18. There was very little rainfall on that day, the wind came from the west, and the temperature was moderate. High deposition rates occurred on March 14, April 18, August 1, October 3, and 10. Temperature was moderate, rainfall varied and the wind generally came from the east and southeast - except on April 18, when the wind came from the west.

(3) Comparisons to other studies

PAHs have been examined in other studies (Brun, G., 1989 as found in Ringuette, S., *et al*, 1993), (Kelly, T. J., *et al*, 1991), (Leister, D. L., and J. E. Baker, 1994), (Ligocki, M. C. *et al*, 1985), (Poster, D. L. and J. E. Baker, 1996), (Ringuette, S. A., *et al*, 1993). These studies employed sampling techniques similar to those in this study. The results from this study are compared to previous research and results are shown in Table 23.

Results for fluorene from the Burnaby Lake study (BL) were shown to be higher than that of Chesapeake Bay, Portland, and Prince Edward Island (PEI). Results from Burnaby Lake and PEI are within the same order of magnitude, and are higher an order of magnitude compared to Chesapeake Bay, and two orders of magnitude higher compared to Portland.

Phenanthrene results from the BL study are higher than other studies, but within the same order of magnitude as Villeroy, and higher by one order of magnitude compared to Chesapeake Bay and Portland.

The anthracene average concentration from the BL study is lower than the Villeroy results by one order of magnitude, and is comparable to Chesapeake Bay results.

Benzo(g,h,i)perylene concentrations in the BL study are within the same order of magnitude as results from Chesapeake Bay and Portland.

The average concentration for fluoranthene in the BL study was higher than Villeroy, Chesapeake Bay, and Portland by one order of magnitude.

The average pyrene concentration from the BL study is higher but comparable to that of Chesapeake Bay and is higher than Villeroy and Portland by one order of magnitude.

The average benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, and indeno(1,2,3-c,d)pyrene concentrations from the BL study are higher but comparable to those of the other studies which tested for these chemicals.

The average chrysene concentration from the BL study is higher than the results from Chesapeake Bay and Portland by one order of magnitude.

Data from other studies relating to the PAHs naphthalene, acenaphthalene, acenaphthene, benzo(c)phenanthrene, and benzo(j)fluoranthene were not found.

IX. Conclusions

The air pathway is responsible for the atmospheric deposition of metals and PAHs to the Burnaby Lake watershed area. The rainfall amount is highly variable from season to season, and the resultant washing of the air to remove gaseous and particulate forms of chemicals can result in aquatic solutions that vary in concentration.

The wind patterns in the area follow the geographically limited corridor of the river valley, generally from east to west. The wind patterns associated with rainfall events when metal or PAH levels were high, indicate sources in both directions. No attempt was made to discover those individual sources as it was beyond the scope of this study. Several possible sources exist in the area: the traffic corridors surrounding the lake area; small industries exist to the west, and to the southeast; large transportation and warehouse facilities exist to the southeast, near the mouth of the Brunette River; and to the north, on Burnaby Mountain, there are gas pipeline and oil tank storage facilities as well as a major university complex.

Of the 35 metals in the survey, 22 were found in measurable quantities in the rainfall. Of these, sulfur was present in all samples.

Some of these concentrations exceed guidelines for drinking water or aquatic freshwater life forms for metals. Those chemicals that have been observed to exceed one or both of these guidelines are: silver, aluminum, arsenic, calcium, cadmium, chromium, lead, selenium and zinc. Nickel was measured at levels just below a guideline. Although these concentrations may only be present in rainfall for short periods of time, there may be a potential shock to aquatic environments that could have long term impacts. Measured concentrations of metals in rainfall were similar to those found elsewhere in the world.

Some of these metal species (calcium, magnesium, sodium, strontium, and sulphur) are typically from a marine environment and are naturally carried in the wind and clouds from the ocean to inland areas where they are deposited. These species are not generally considered to be toxic. The average deposition rate of 25.2 kg/ha/y (maximum at 161. kg/ha/y) measured for sulfate to this watershed is above the Canadian standard of 20 kg/ha/y and indicated an acidifying environment.

The deposition criteria of ± 100 $\mu g/m^2/y$ for the Great Lakes (Hoff, R.M., 1996) have been exceeded for: aluminum, arsenic, boron, barium, calcium, cadmium, chromium, copper, iron, magnesium, manganese, sodium, nickel, lead, sulfur, selenium, silicon, strontium, titanium and zinc. Table 24 shows the total deposition of metals that may be introduced into the Burnaby Lake watershed in a year, along with the best case/worst case scenarios (maximum/ minimum). The accumulation of these deposited materials in the water, sediments and aquatic life forms may impact the ecosystem. Table 25 shows the total yearly deposition of PAHs into the Burnaby Lake watershed, with respective maximums and minimums.

For the PAHs, 18 of the 23 chemicals were detected in the samples. PAHs are on the Canadian government's priority substances list as they are considered toxic and carcinogenic. Recommended guideline concentrations were used in this evaluation but no known accepted standards exist at this time. Of the 18 PAHs found, those that exceeded one or more of the recommended guidelines included: naphthalene, phenanthrene, anthracene, fluoranthene, pyrene, benz(a)anthracene and benzo(a)pyrene.

Episodes appear to have occurred when numerous chemicals showed simultaneous concentration peaks indicating a possible common source of PAHs (acenaphthene, acenaphthalene, phenanthrene, anthracene, benzo(g,h,i)perylene, pyrene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene and indeno(1,2,3-c,d)pyrene) somewhere to the west of the site.

PAHs were found in significantly higher rainwater concentrations than at other referenced sites in Europe or the United States. Deposition levels are far in excess of levels suggested for the Great Lakes area. Most of the PAHs, with the exceptions of benzo(c)phenanthrene, benzo(j)fluoranthene, and dibenz(a,h)anthracene, exceed the proposed deposition standard.

The deposition rates for acenaphthalene, acenaphthene, phenanthrene, and pyrene had higher deposition rates in the winter months than in any other season. This is probably due to temperature inversions in the lake valley and the presence of nearby residential areas where wood fireplace emissions occur during the colder winter months.

The deposition criteria of ± 100 $\mu g/m^2/y$ for the Great Lakes (Hoff, R.M., 1996) have been exceeded for: naphthalene, acenaphthalene, acenaphthene, fluorene, phenanthrene, anthracene, benzo(g,h,i)perylene, fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, and indeno(1,2,3-c,d)pyrene (Table 26).

X. Acknowledgments

1. Greater Vancouver Regional District staff for field support: Fred Prystar, Michio McGaughey and Al Percival
2. Zenon Environmental Laboratory (B.C.) Ltd. For laboratory analyses: Mr. Shawn Heier
3. Environment Canada for weather data: Mr. Bruce Lohnes

XI. References

Atteia, O., Major and Trace Elements in Precipitation on Western Switzerland, *Atmospheric Environment*, **1994,** *Vol. 28*, No. 22, pp 3617-24 12

B.C. Environment, Approved and Working Criteria for Water Quality - 1994, **1994** 8

Barrie, L.A., S.E. Linfberg, W.H. Chan, H.B. Ross, R. Arimoto and T.M. Church, On the Concentration of Trace Metals in Precipitation, *Atmospheric Environment*, **1987,** *Vol. 21*, No. 5, pp. 1133-35 12

Budavari, S., M. O'Neil, A. Smith, P.E. Heckelman, Eds The Merck Index: *An Encyclopedia of Chemicals Drugs and Biologicals*, 11th Edition, Rahway, N.J.: Merck & Co. Inc., **1989** 6

Collins, J., J. Brown, S. Dawson, and M. Marty. *Risk Assessment for Benzo(a)pyrene*, Regulatory Toxicology and Pharmacology. Vol 13, pp 170-184, **1991** 13

Germain, A., F. Perron, and R. Van Coillie, *Fate, Ecotoxicity, and Regulations. Environment Canada*, Environmental Protection Branch, Quebec Region, Montreal, **1993** 14, 17

Government of Canada, Canadian Environmental Protection Act - Priority Substances List Assessment Report: Polycyclic Aromatic Hydrocarbons. Ottawa, **1994** 13

Great Lakes Science Advisory Board (GLSAB), *Annual Report: Report of the Aquatic Ecosystem Objectives Committee, Report to the International Joint Commission*, Windsor, Ontario, p.32-56, **1983**17

Health Canada, *Canadian Water Guidelines: Summary of Guidelines for Water Quality in Canada*, **1995**
Hoff, R.M., Proposal for Air Toxics Program: Understanding Environmental Cycling of Airborne Toxics, March **1996** 12, 19

Jeffrey D, Zenon Environmental Laboratories Inc., BC Division, *Quality System Manual*, **1994** 4

Jenkins, B. M., A. D. Jones, S. C. Turn and R. B. Williams, Emission Factors for Polycyclic Aromatic Hydrocarbons for Biomass Burning, *Environ. Sci. Technol.*, **1996,** *30*, 2462-2469 6, 15

Kelly, T.J., J.M. Czuczwa, Atmospheric and Tributary Inputs of Toxic Substances to Lake Erie, *Jour. Great Lake Res. 17(4)*: 504-516, **1991** 17

Leister, D.L., and J.E. Baker, Atmospheric Deposition of Organic Contaminants in Chesapeake Bay, *Atmospheric Environment*, **1994,** *Vol. 28*, No. 8, pp. 1499-1520 17

Lewis, R., Hazardous Chemicals Desk Reference. 2nd Edition. New York: Van Nostrand Reinhold, **1991** 6

Lide, D., ed. CRC Handbook of Chemistry and Physics, 73rd Edition, Florida: CRC, **1992** 6

Ligocki, M., C. Leuenberger, J. Pankow. \Trace Organic Compounds in Rain - III. Particle Scavenging of Neutral Organic Compounds\, *Atmospheric Environment*. **1985,** *Vol 19*, No. 10, PP 1619-1626 17

LRTAP, Federal/Provincial Research and Monitoring Committee (RMCC), The 1990 Canadian Long-Range Transport of Air Pollutants and Acid Deposition Assessment Report, Part 1, Executive Summary, **1990** 11

Napgal, N. K.,Ambient *Water Quality Criteria for Polycyclic Aromatic Hydrocarbons (PAHs)*, Water Quality Branch, Ministry of Environment, Lands and Parks, **1993** 15, 16, 17

Ontario Ministry of Environment and Energy (OMOEE), *Water Management: Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of Environment and Energy*, ISBN 0-7778-3494-4, 31p, **1994** 15, 16

PAH Toxic Equivalency Factors, B.C. Waste Management Act, Special Waste-Schedule 1.1, BC Reg.132/92.s. 34 **1992** 13

Poissant, L, J-F. Koprivnak and B. Harvey, Atmospheric Contribution to the St. Lawrence River Pollution (Quebec Canada), On-going research, **1992** 12

Poster, D.L., and J. E. Baker, Influence of Submicron Particles on Hydrophobic Organic Contaminants in Precipitation. 1. Concentrations and Distriubtions of Polycyclic Aromatic Hydrocarbons and Polychlorinated Biphenyls in Rainwater, *Environmental Science and Technology*, **1996,** *Vol. 30*, pp 341-348 17

Ringuette, S., A. Germain, C. Gonthier, and F. Perron. *Presence of PAHs in the Canadian Environment - An Overview*. Environment Canada, Quebec Region, **1993** 17

Site Operations Reference Manual - Precipitation (CAPMoN), April **1985** 2

Vet, R.J., W.B. Sukloff, M.E. Still, C.S. McNair, J.B. Martin, W.F. Kobelka and A.J. Gaudenzi, *Canadian Air and Precipitation Monitoring Network (CAPMoN) - Precipitation Data Summary*, **1987**, Report: ARD 89-1; Table 2.2 2

Figure 1: Sampling Area

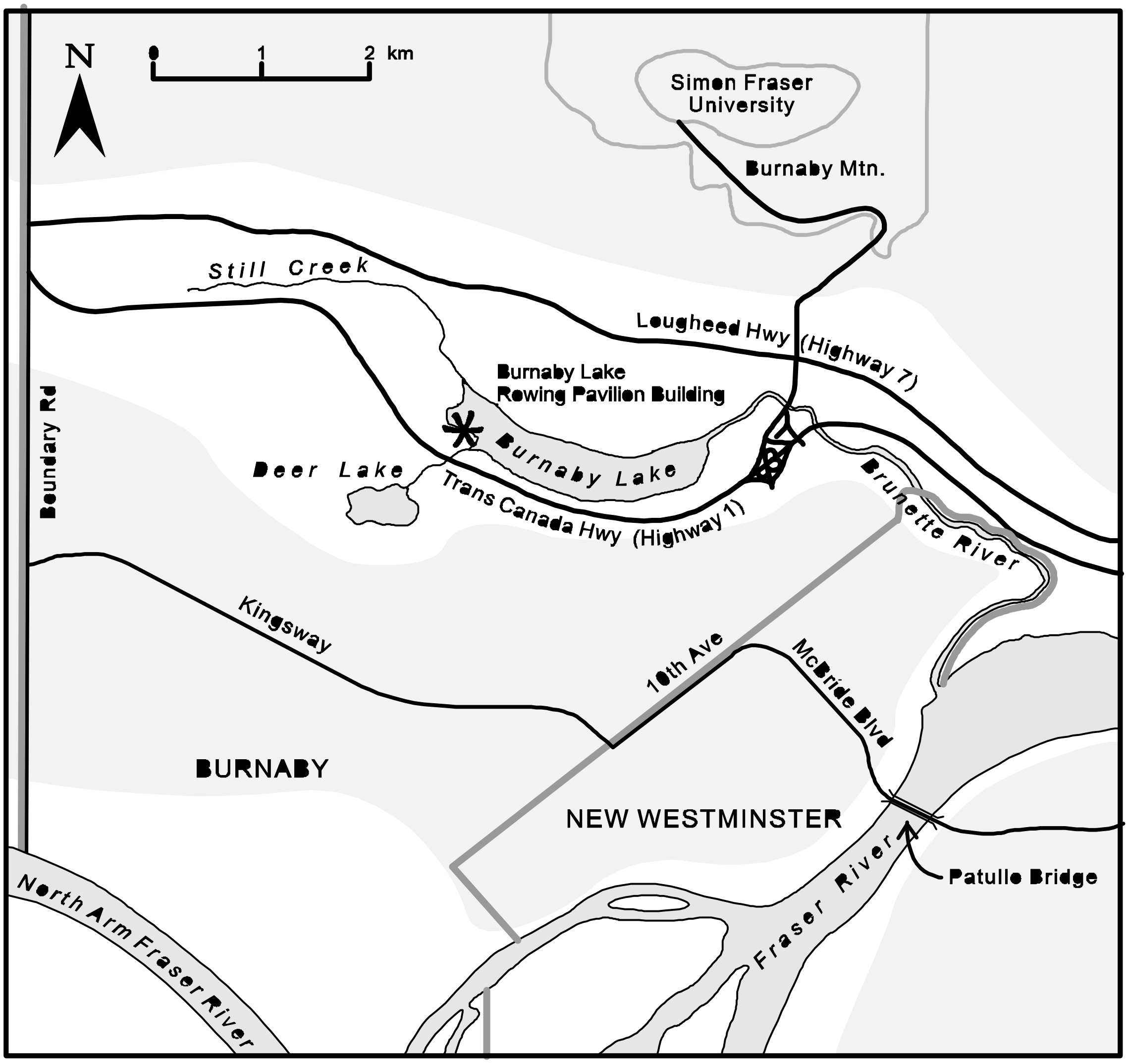


Figure 2: Rainfall at Burnaby Lake

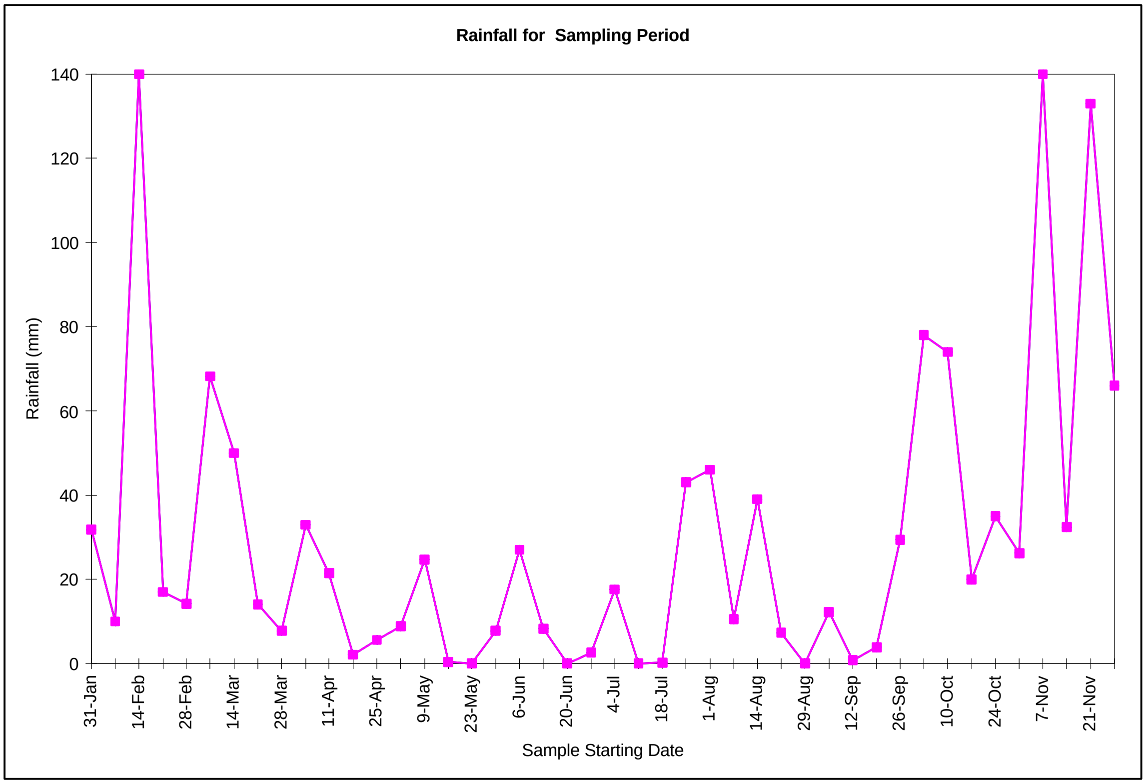


Figure 3: Weekly wind direction at Burnaby Lake

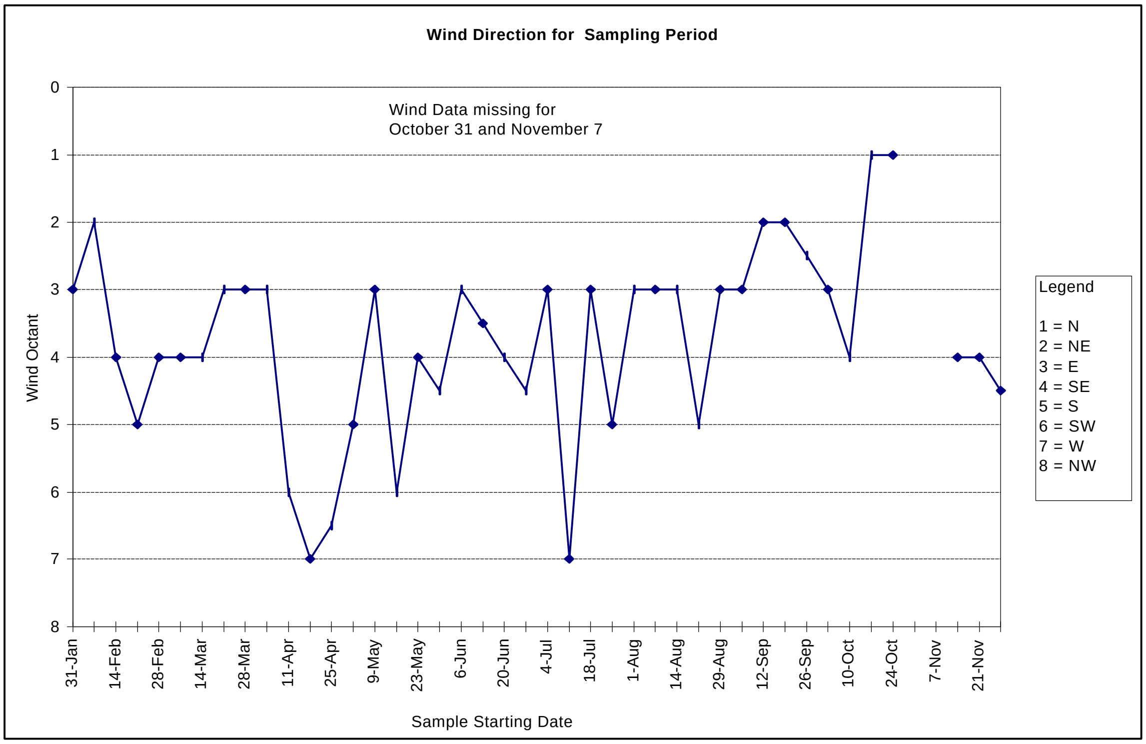


Figure 4: Maximum temperatures at Burnaby Lake

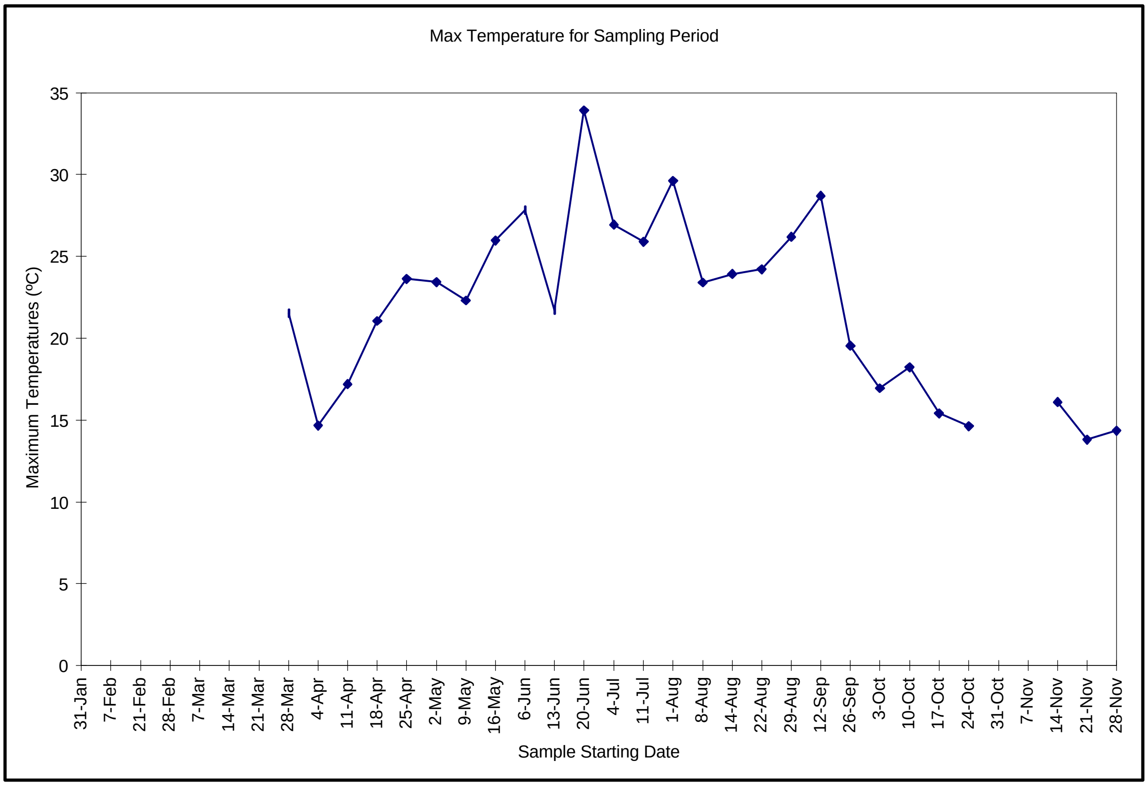


Figure 5: Mean sampling temperatures at Burnaby Lake

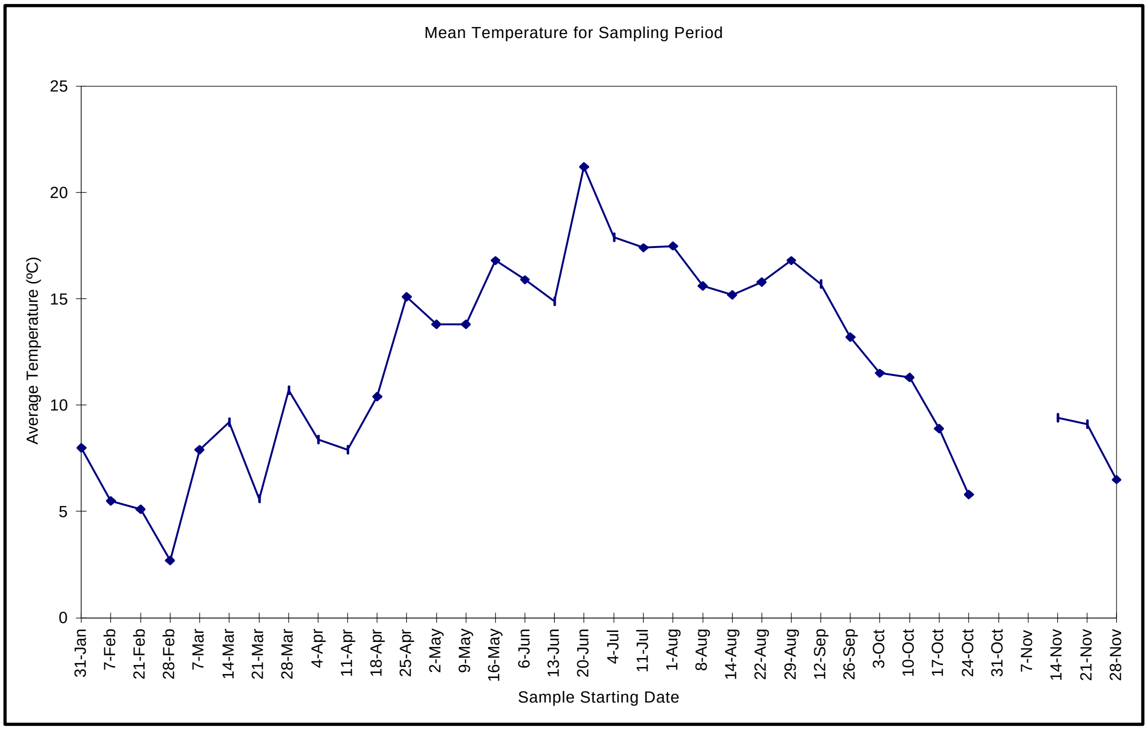


Figure 6: Silver in rainfall

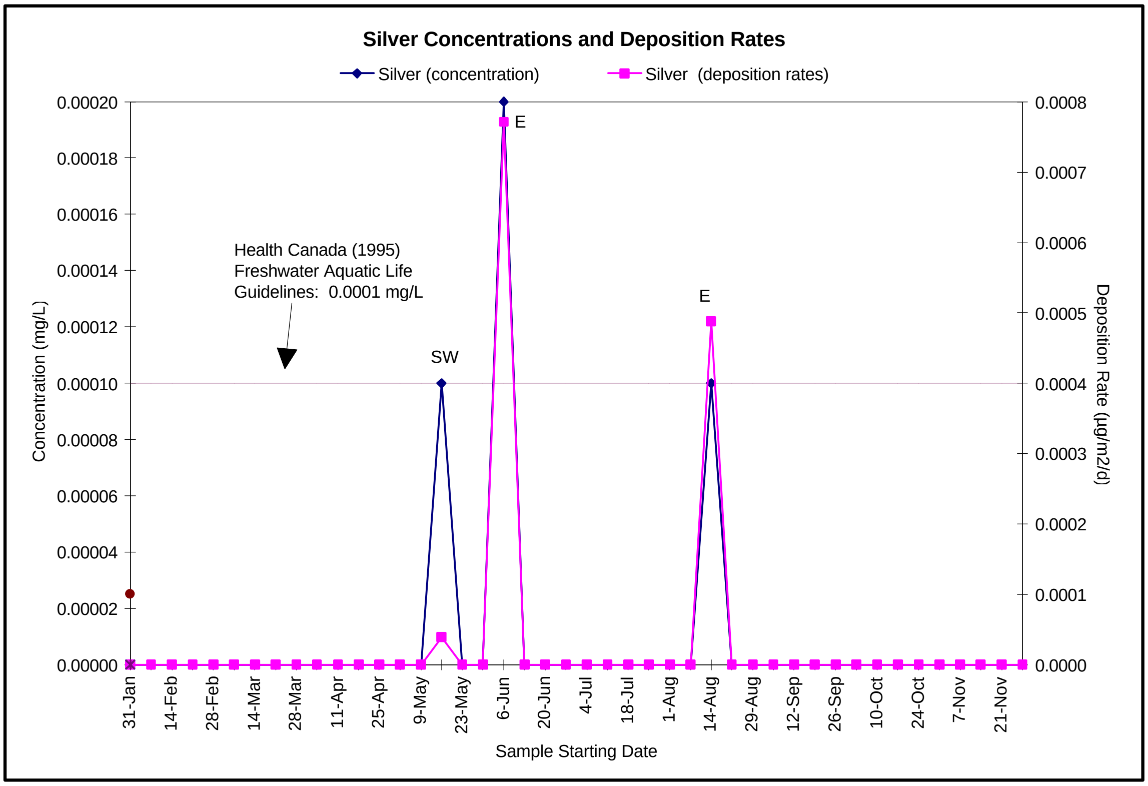


Figure 7: Aluminum in rainfall

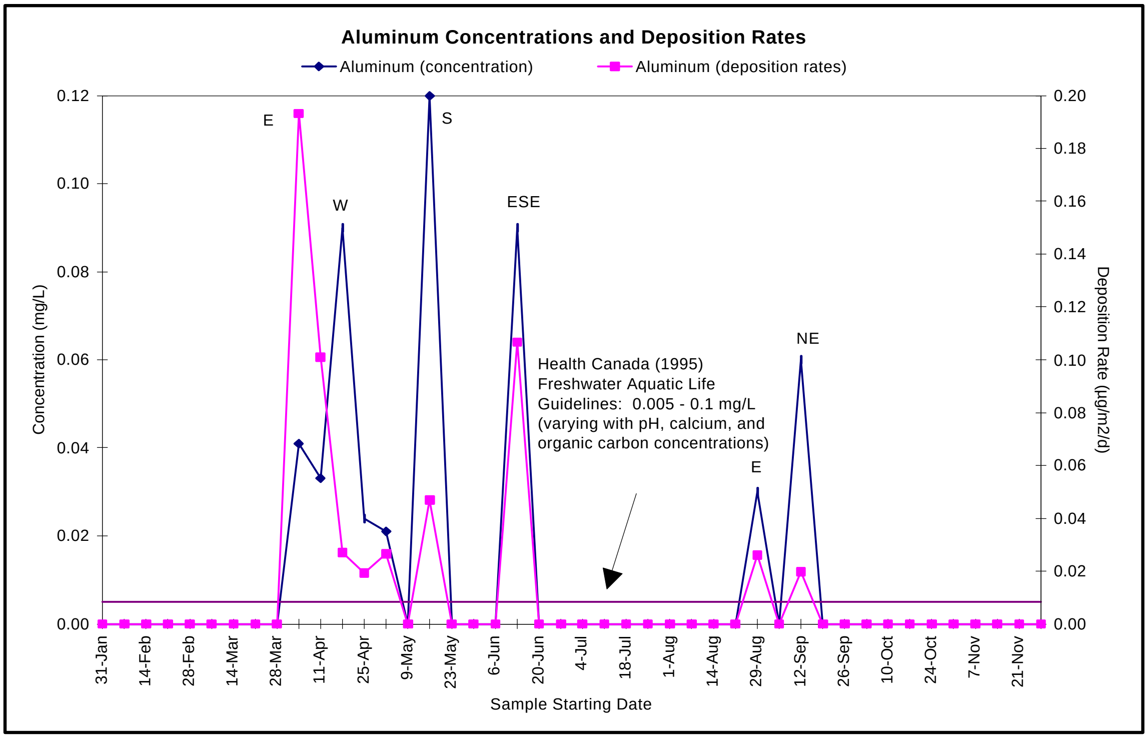


Figure 8: Arsenic in rainfall

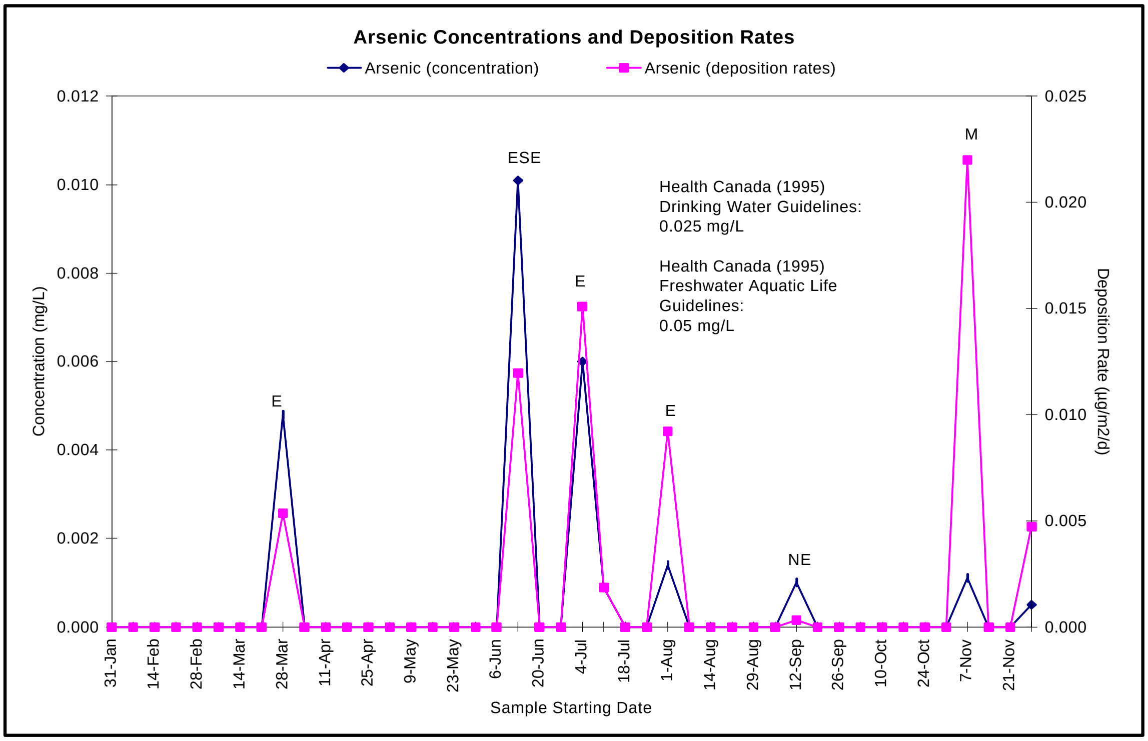


Figure 9: Boron in rainfall

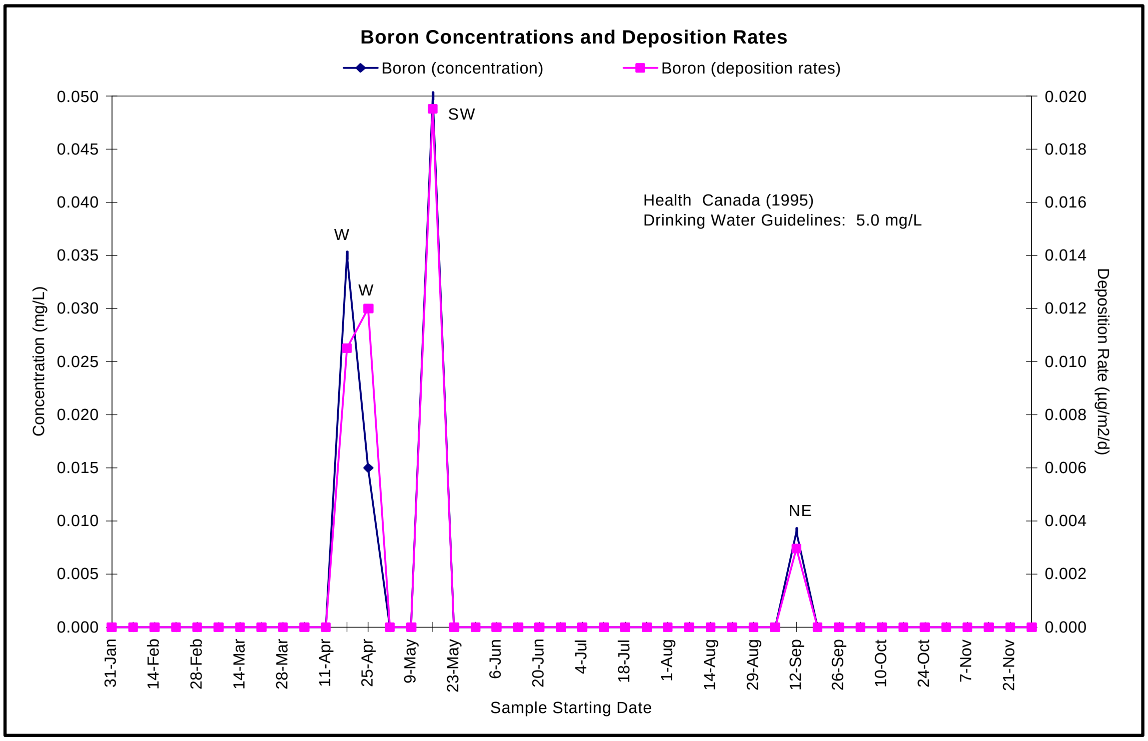


Figure 10: Barium in rainfall

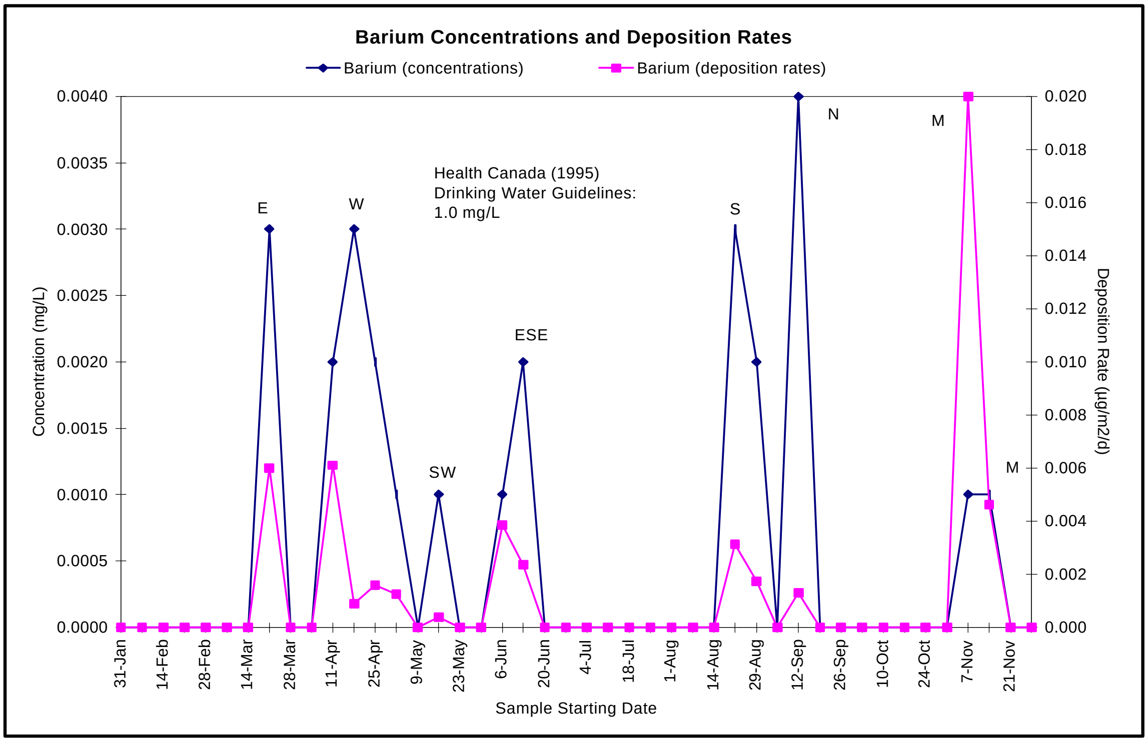


Figure 11: Calcium in rainfall

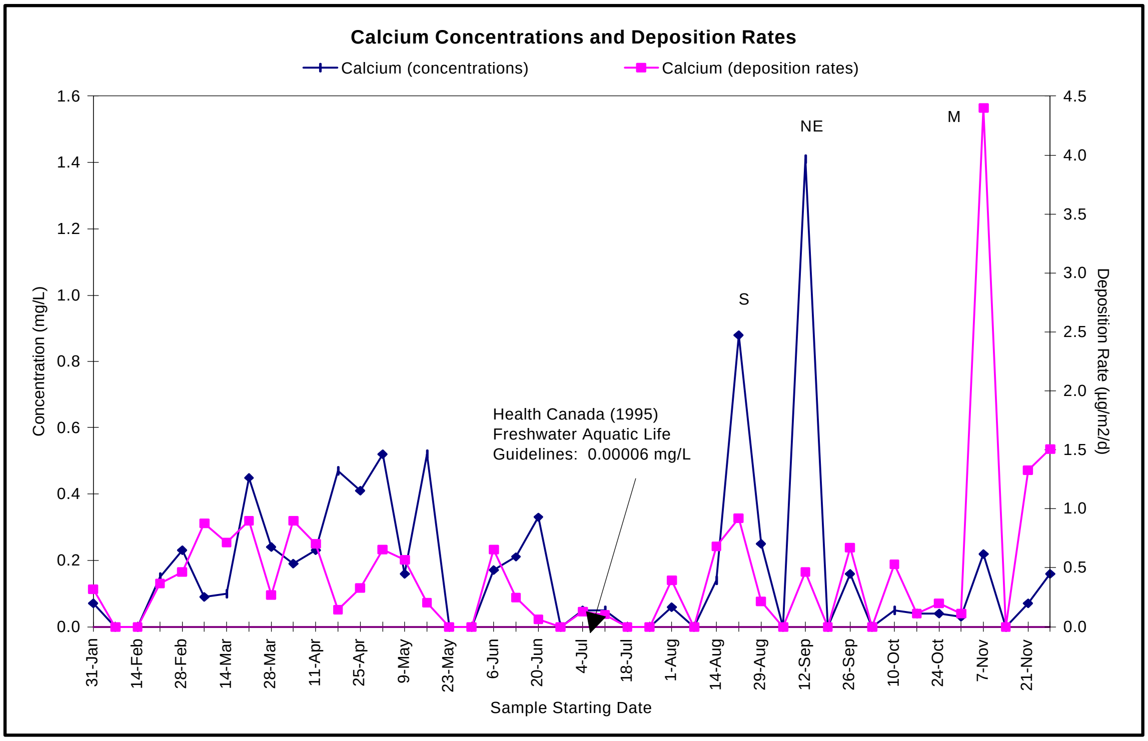


Figure 12: Cadmium in rainfall

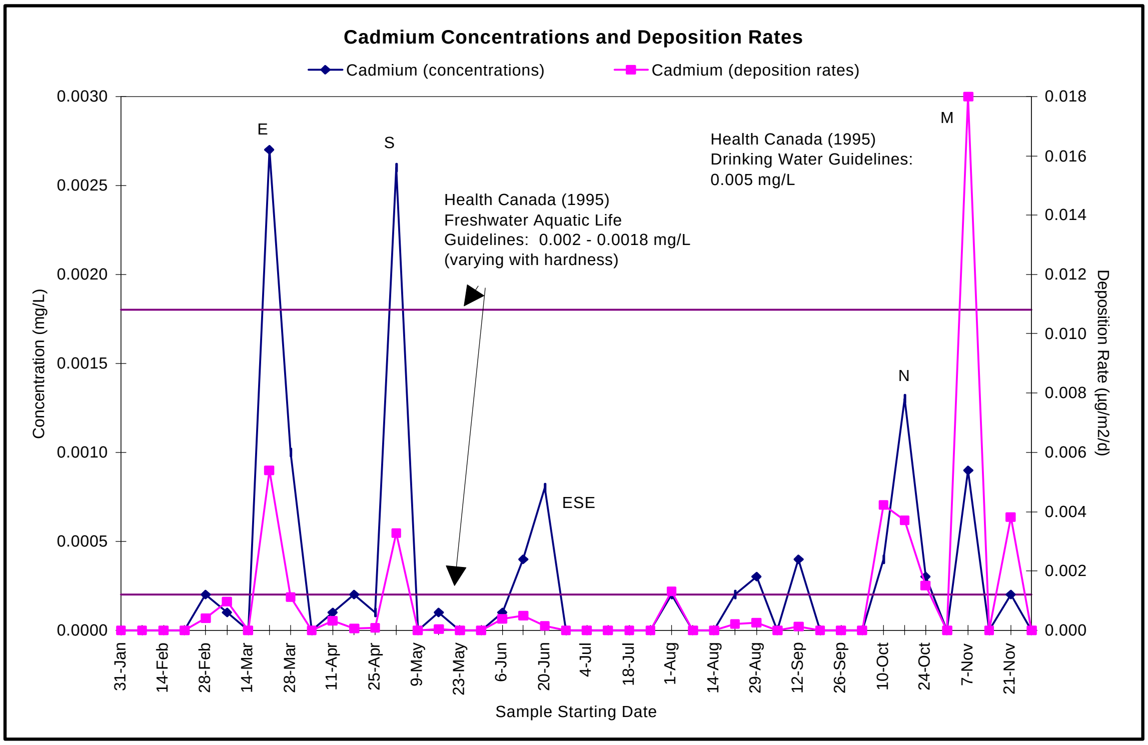


Figure 13: Chromium in rainfall

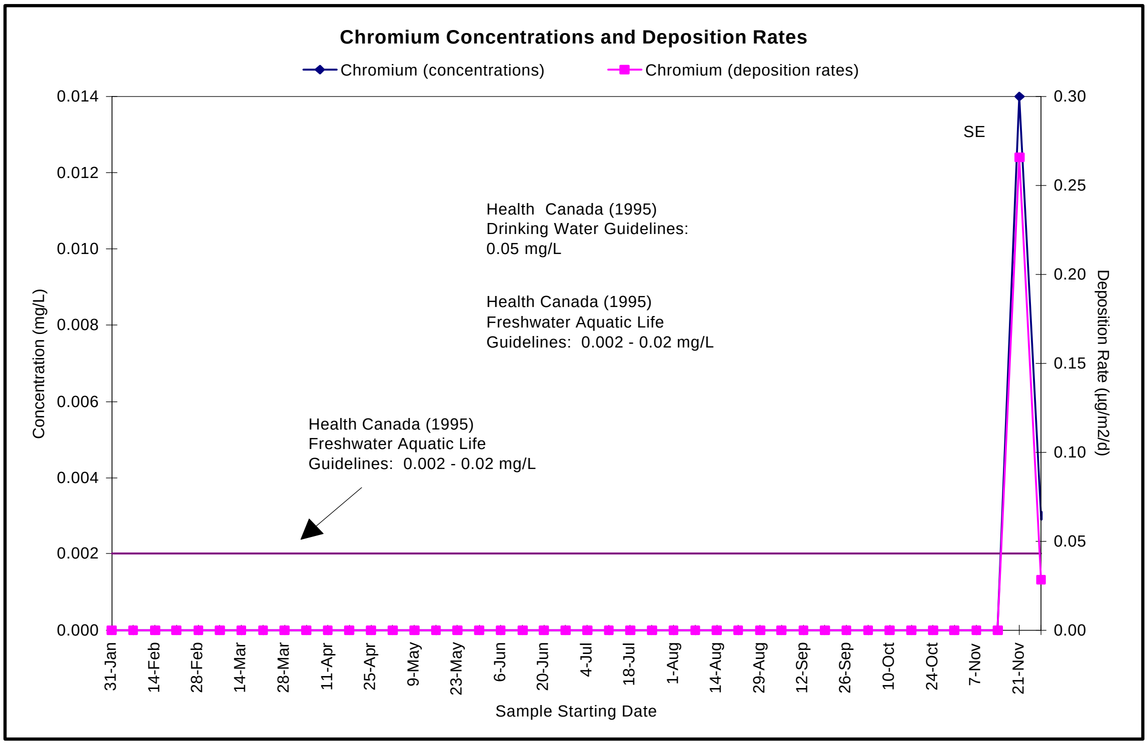


Figure 14: Copper in rainfall

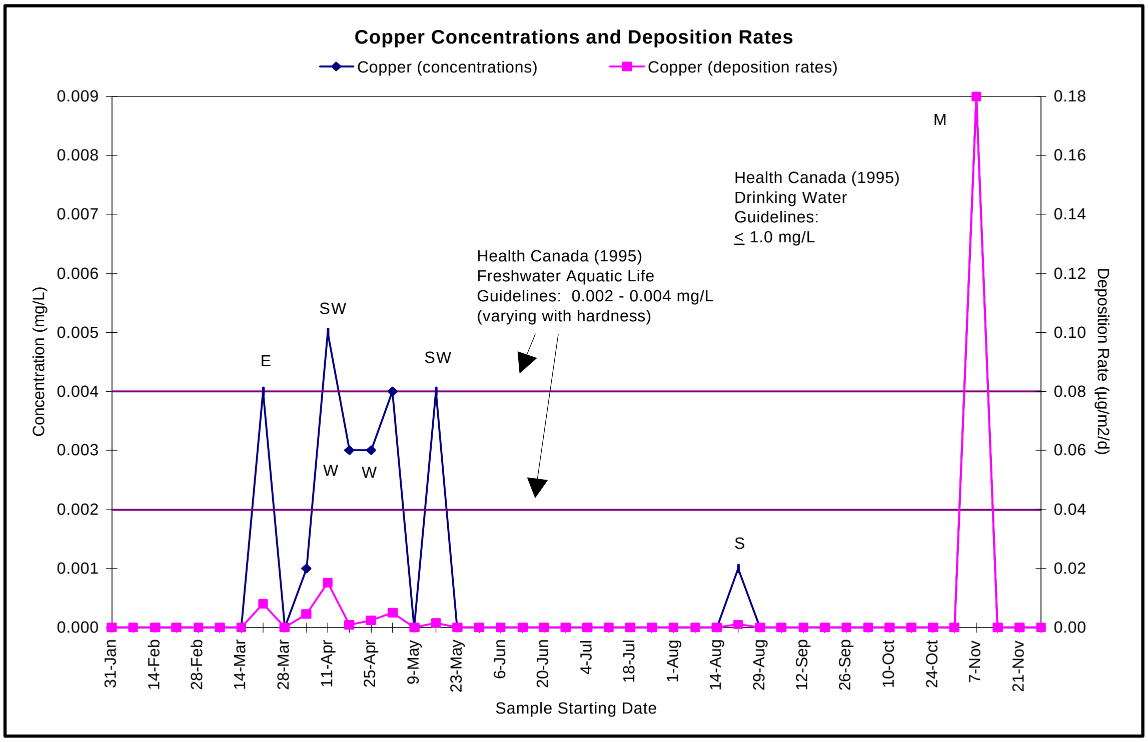


Figure 15: Iron in rainfall

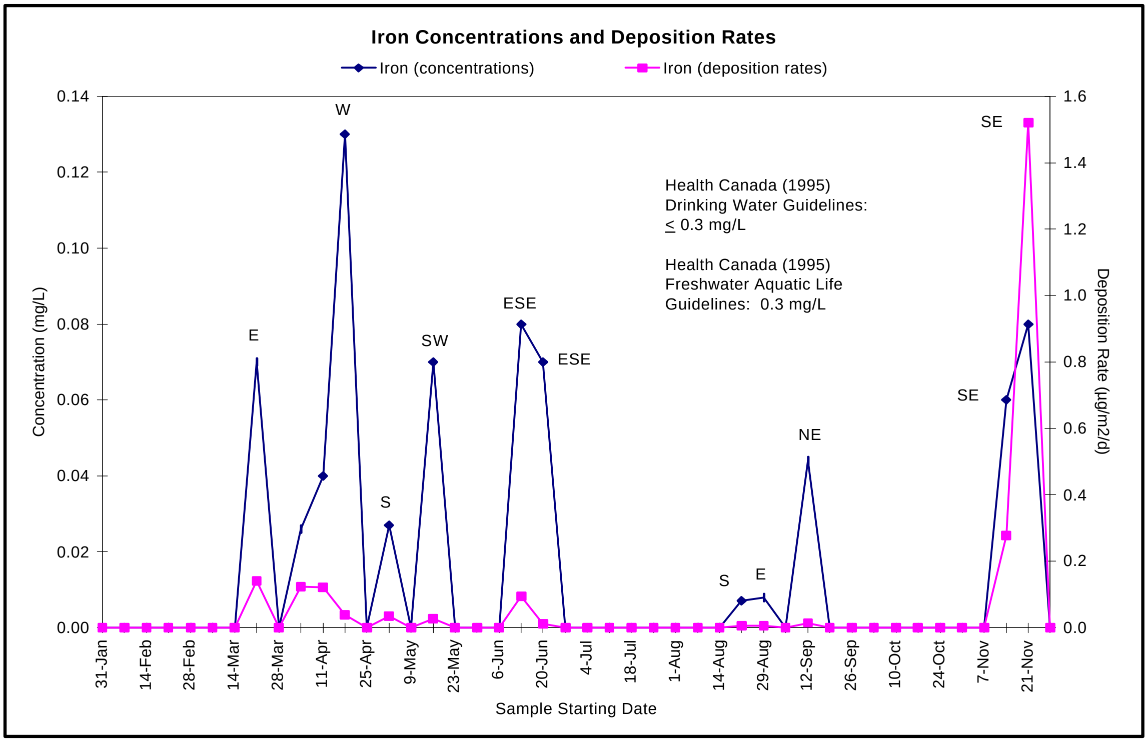


Figure 16: Mercury in rainfall

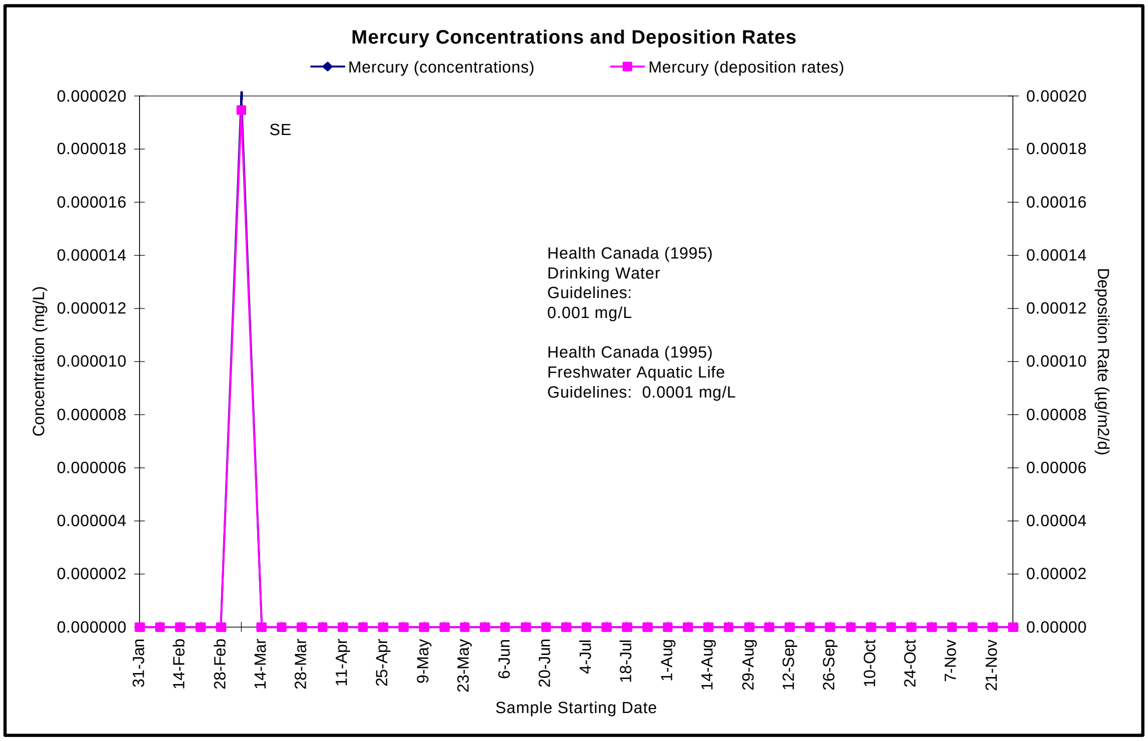


Figure 17: Magnesium in rainfall

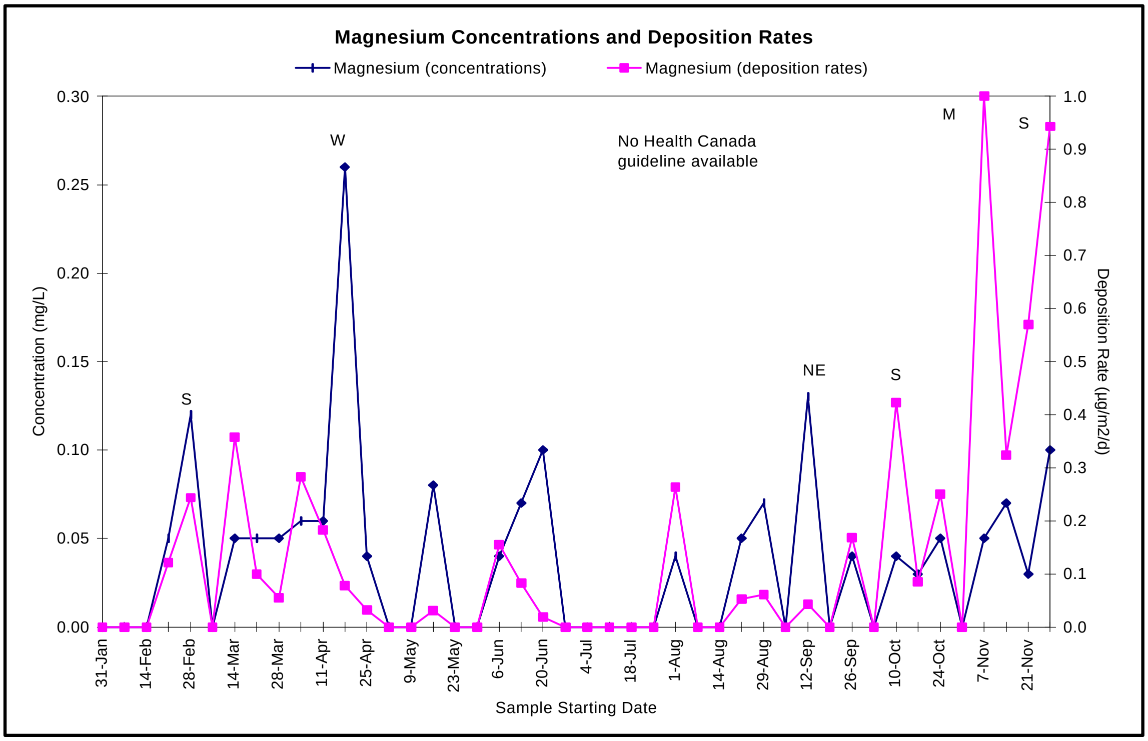


Figure 18: Manganese in rainfall

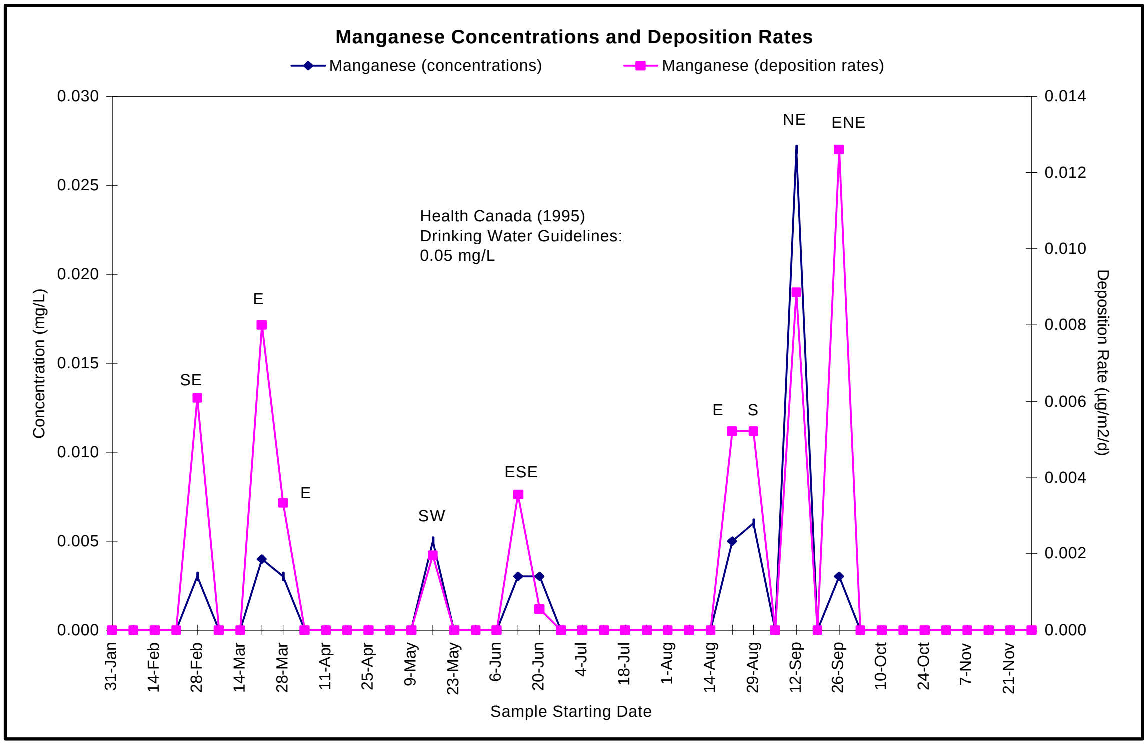


Figure 19: Sodium in rainfall

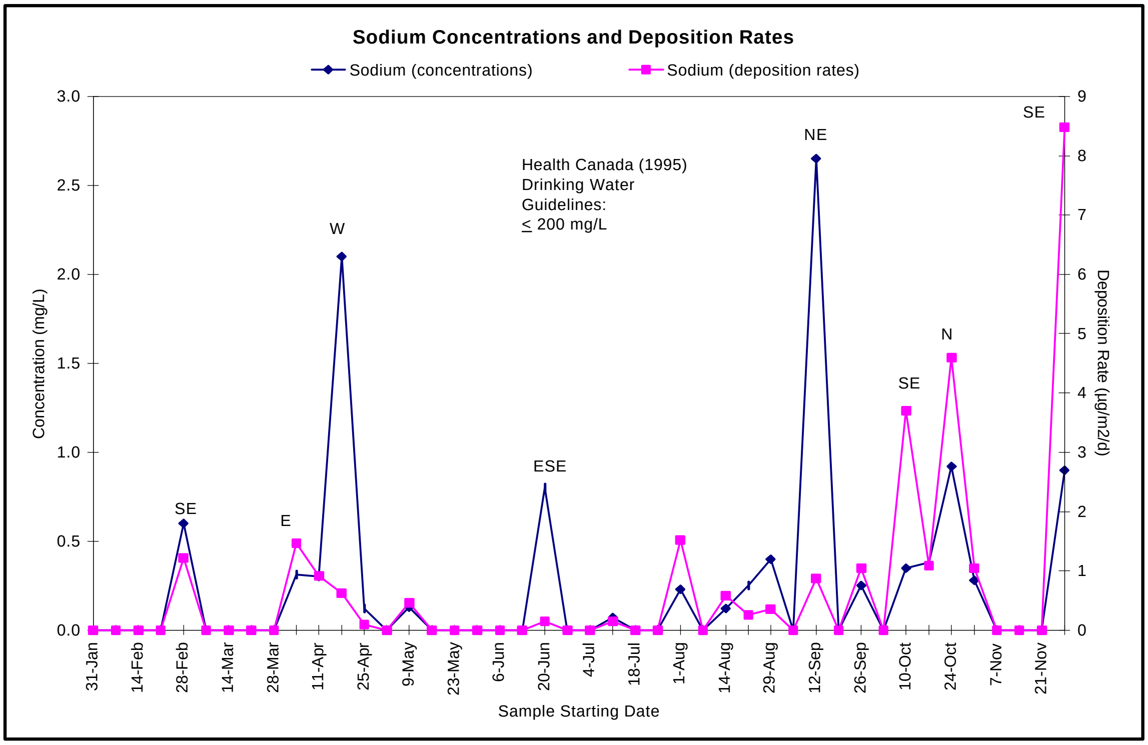


Figure 20: Nickel in rainfall

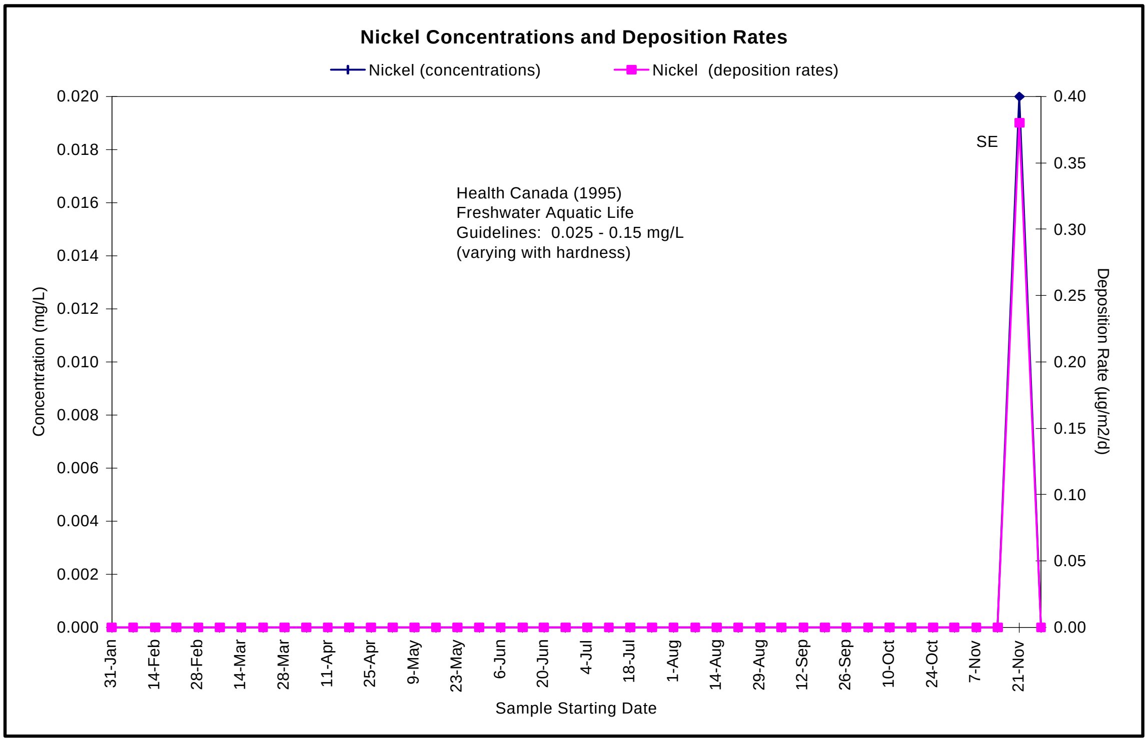


Figure 21: Lead in rainfall

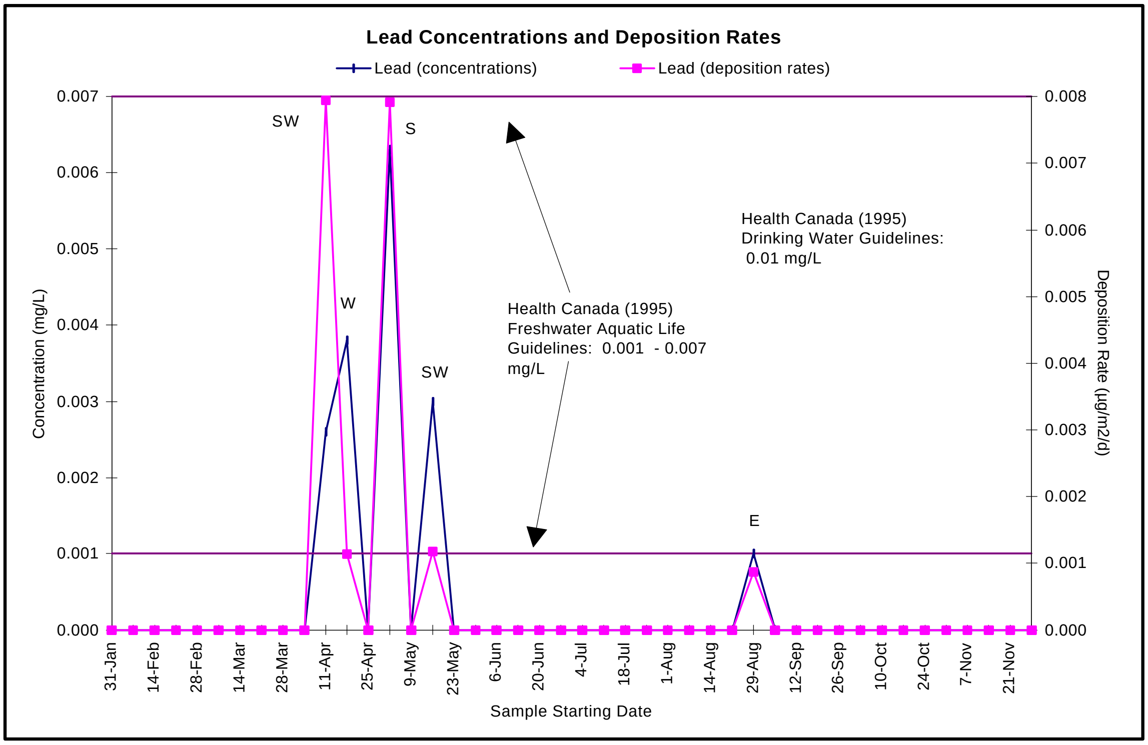
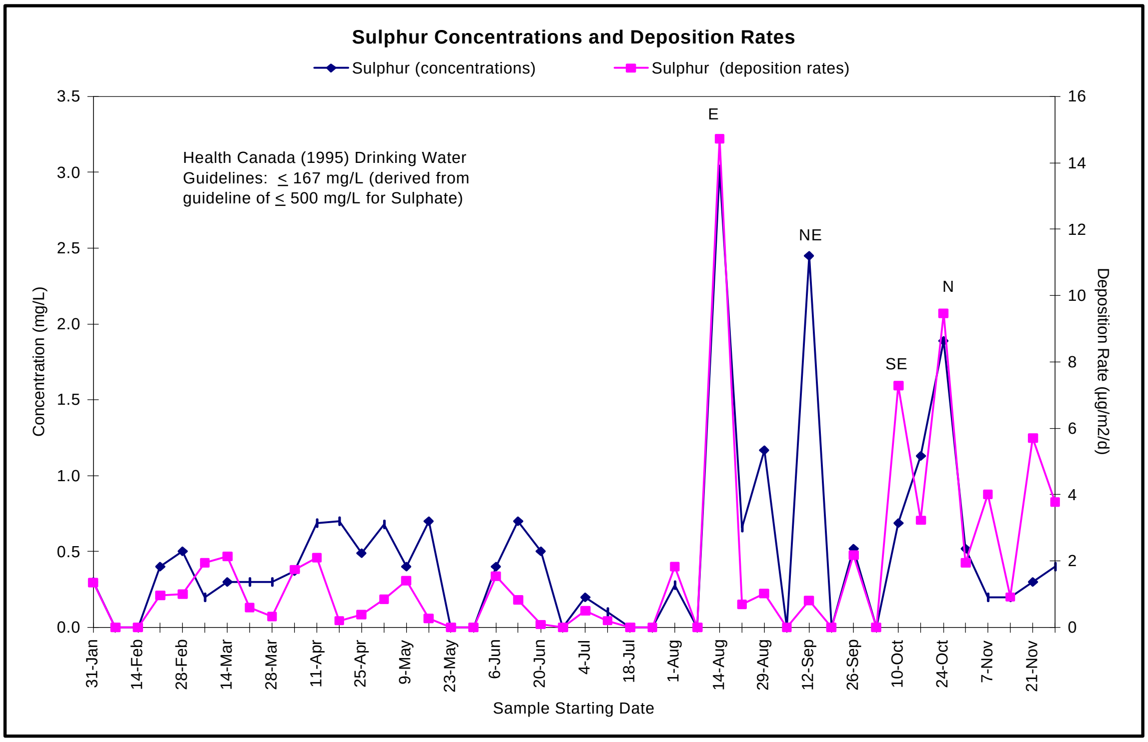
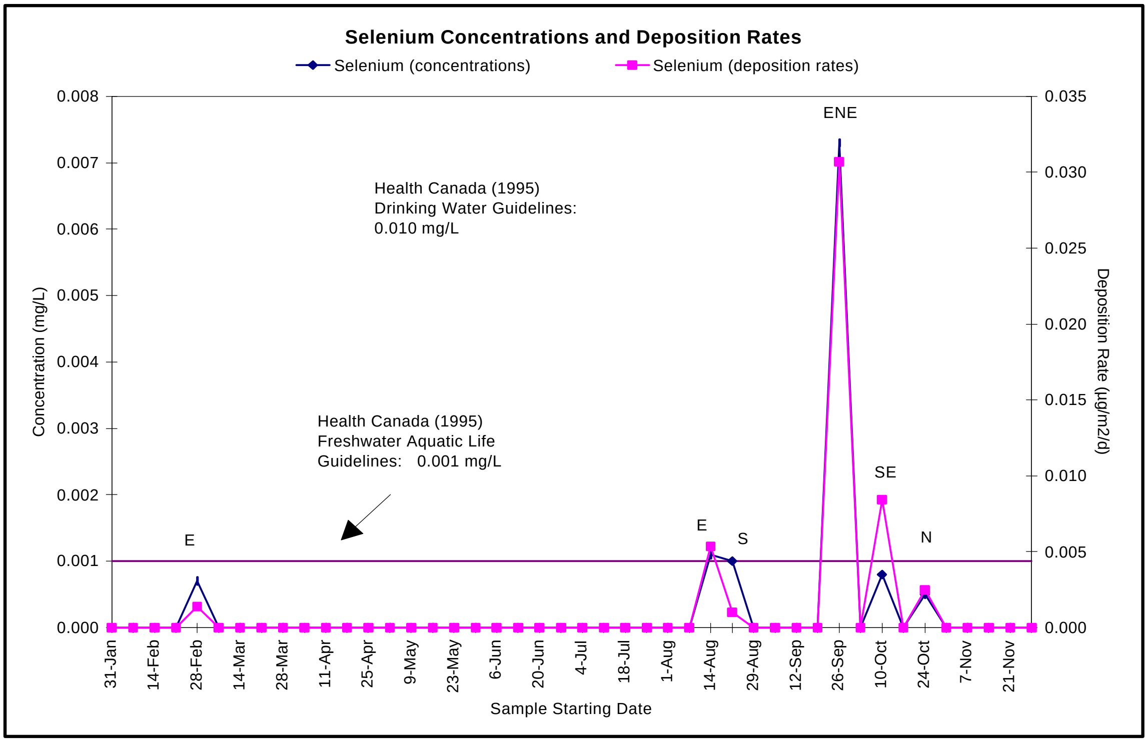


Figure 22: Sulfur in rainfall


Sulphur Concentrations and Deposition Rates

Health Canada (1995) Drinking Water Guidelines: ≤ 167 mg/L (derived from guideline of ≤ 500 mg/L for Sulphate)

Figure 23: Selenium in rainfall


Selenium Concentrations and Deposition Rates

Health Canada (1995) Drinking Water Guidelines: 0.010 mg/L

Health Canada (1995) Freshwater Aquatic Life Guidelines: 0.001 mg/L

Figure 24: Silicon in rainfall

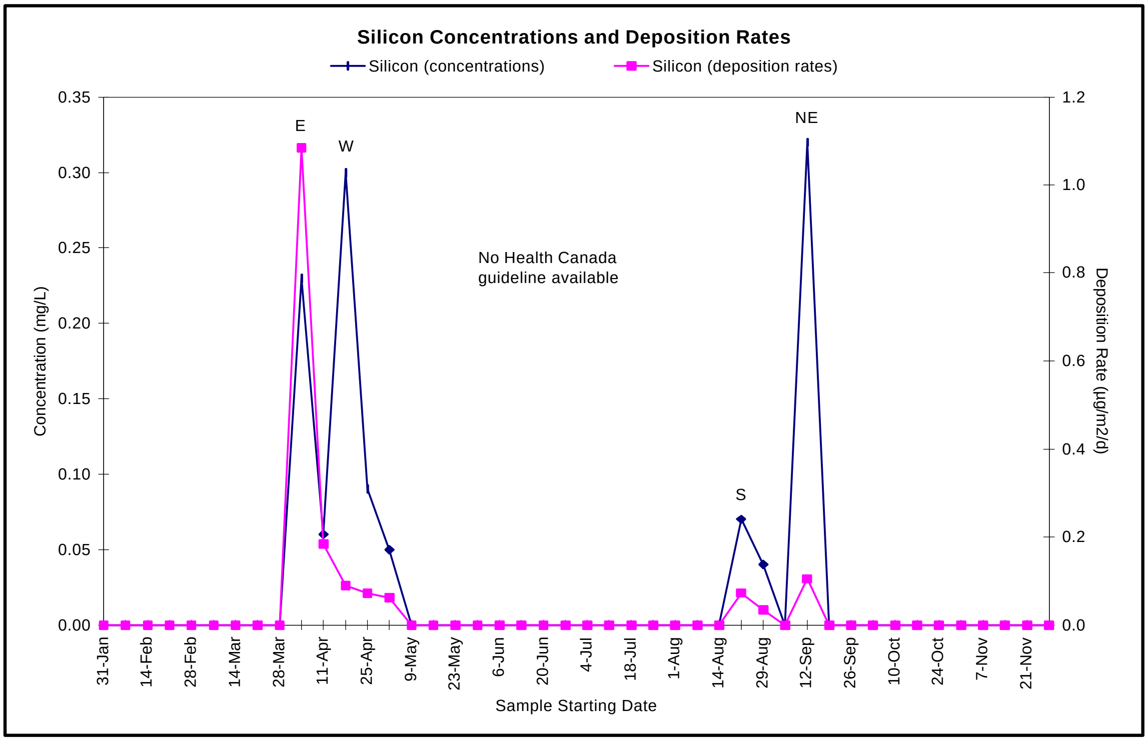


Figure 25: Strontium in rainfall

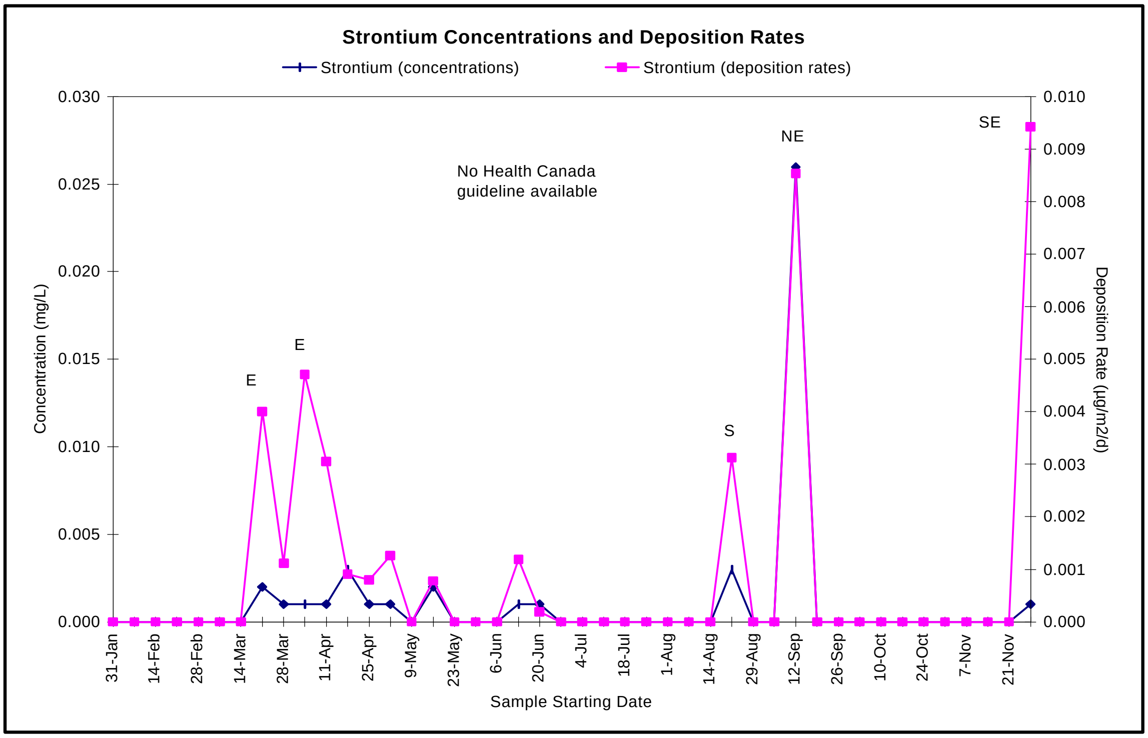


Figure 26: Titanium in rainfall

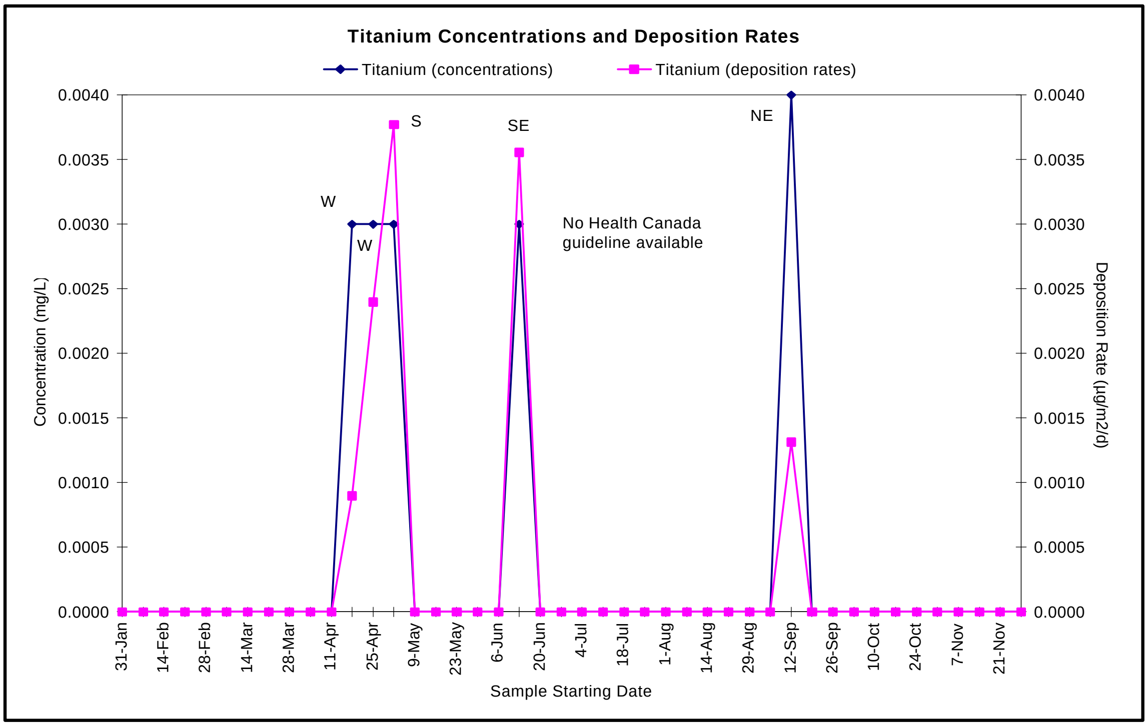


Figure 27: Zinc in rainfall

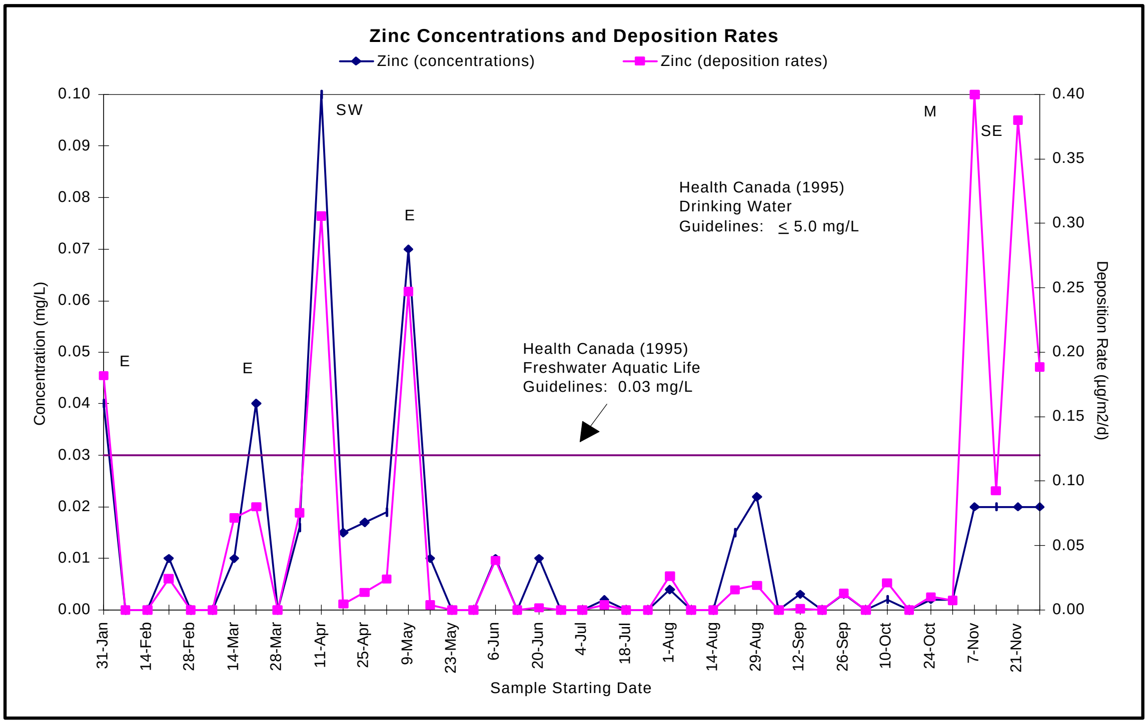


Figure 28: Temperature comparison

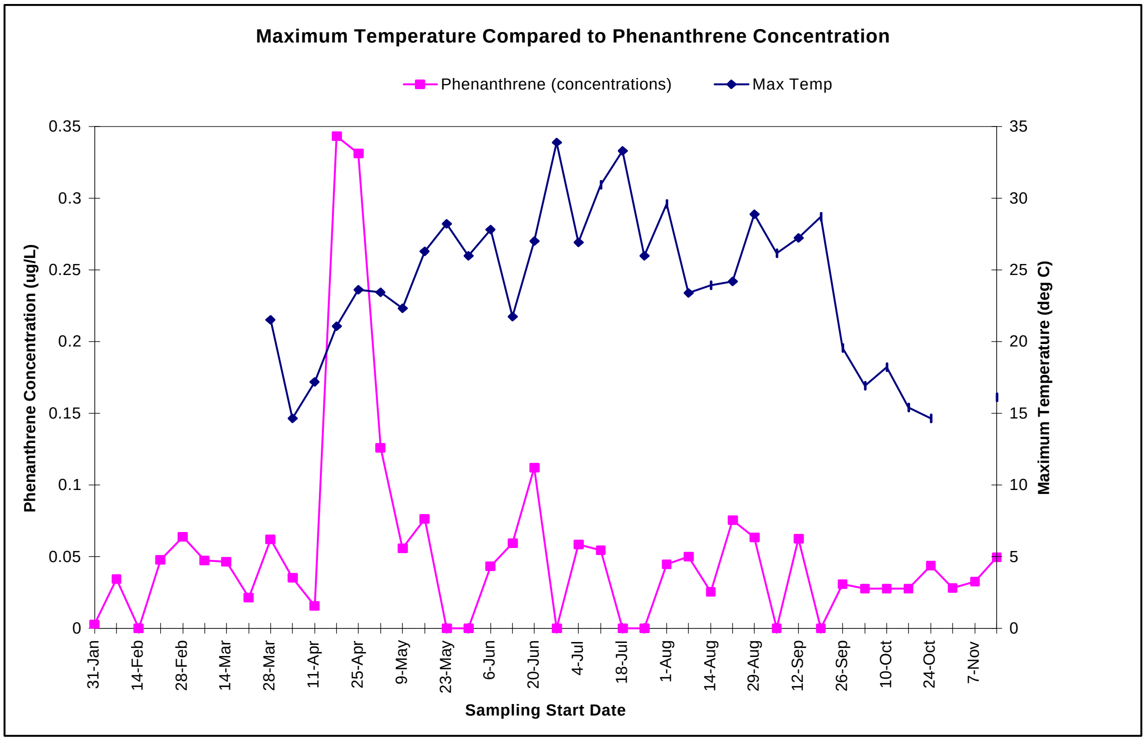


Figure 29: Naphthalene in rainfall

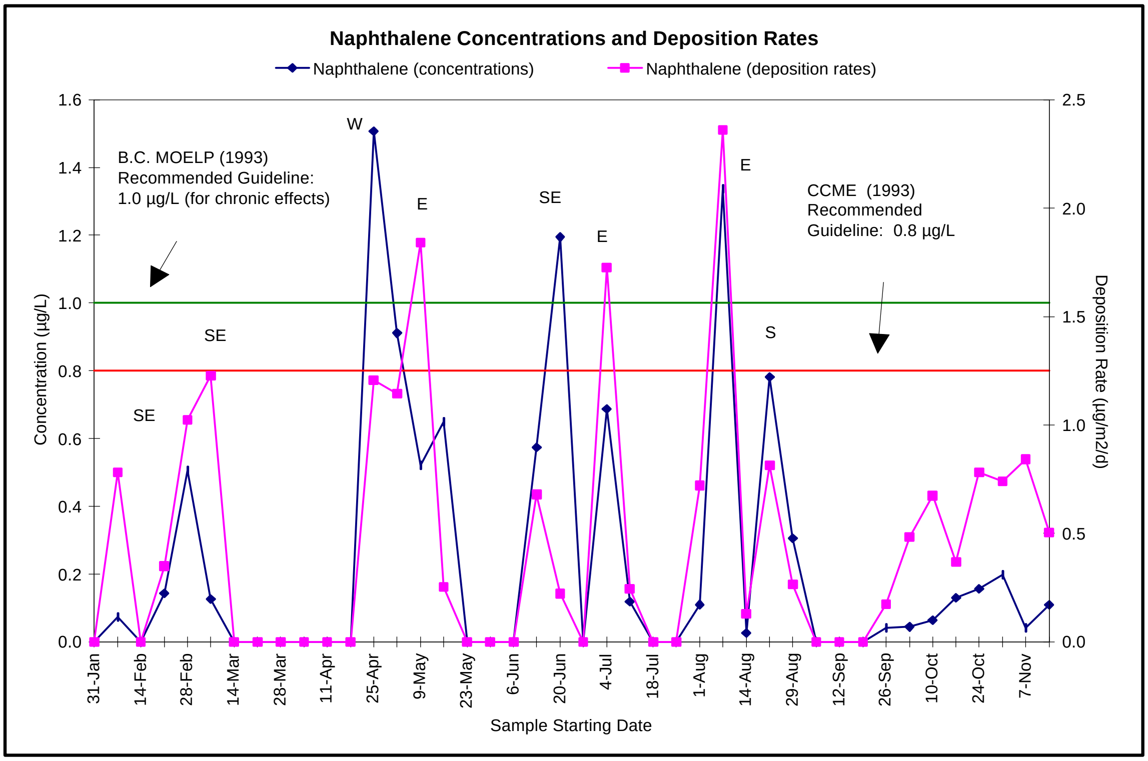


Figure 30: Acenaphthylene in rainfall

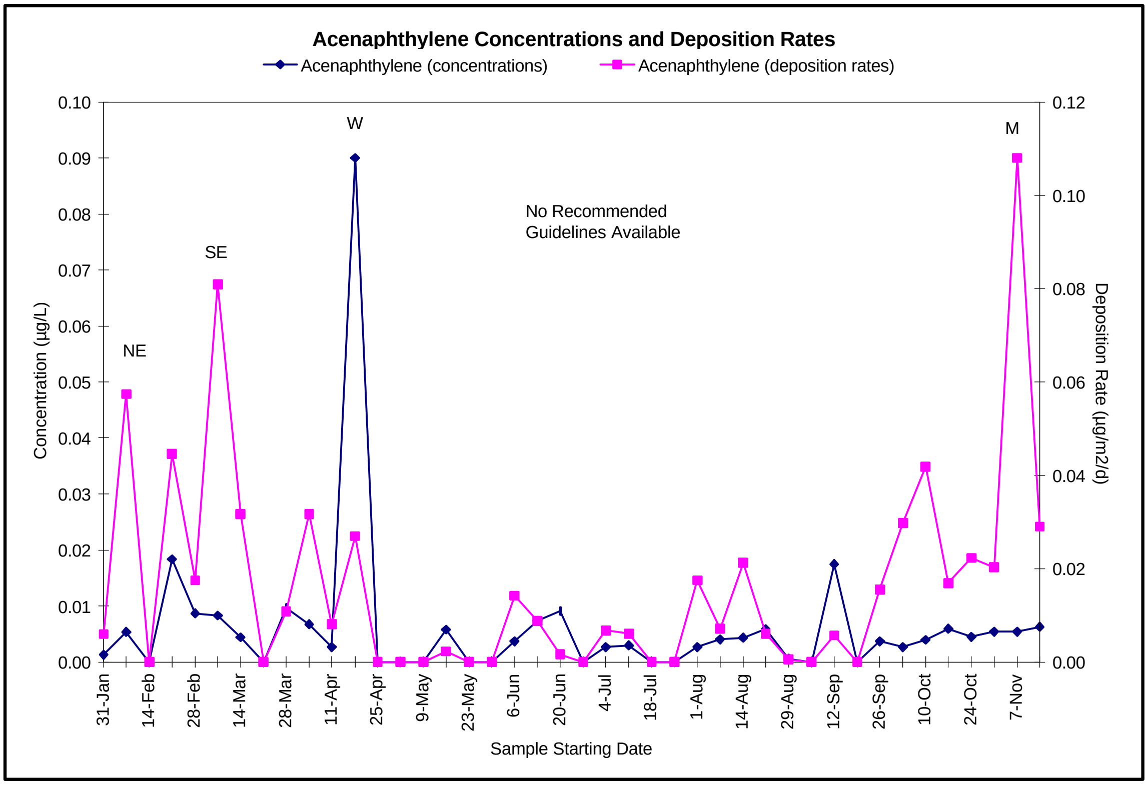


Figure 31: Acenaphthene in rainfall

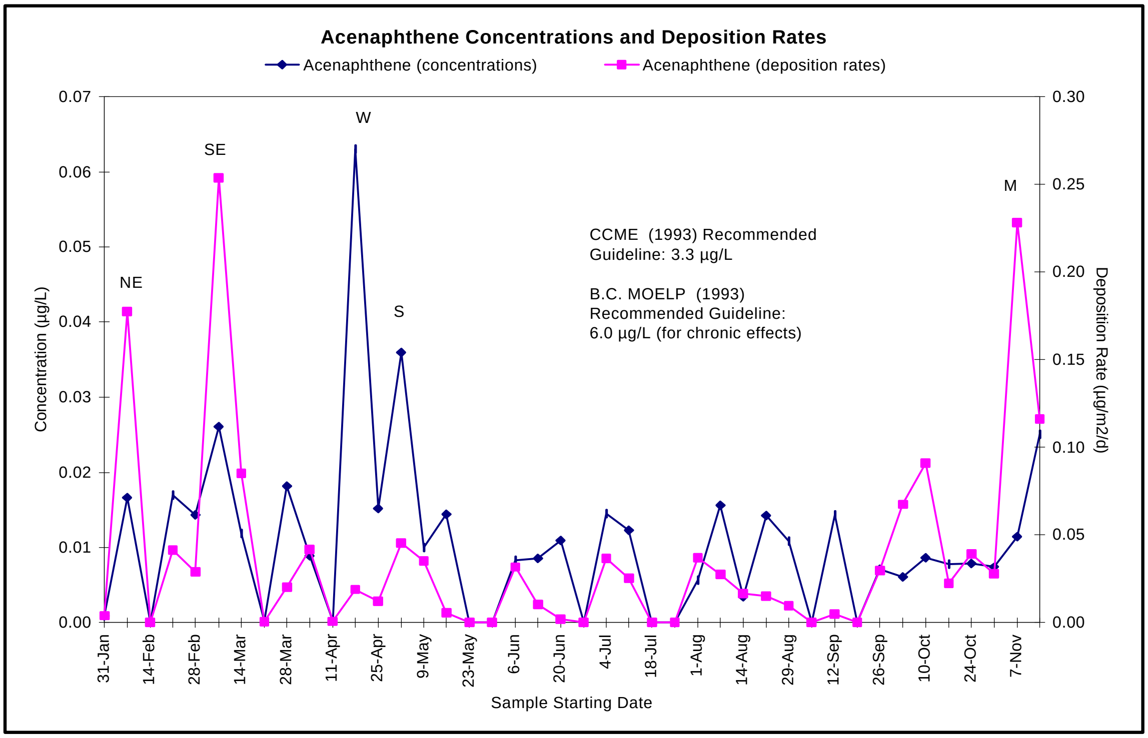


Figure 32: Fluorene in rainfall

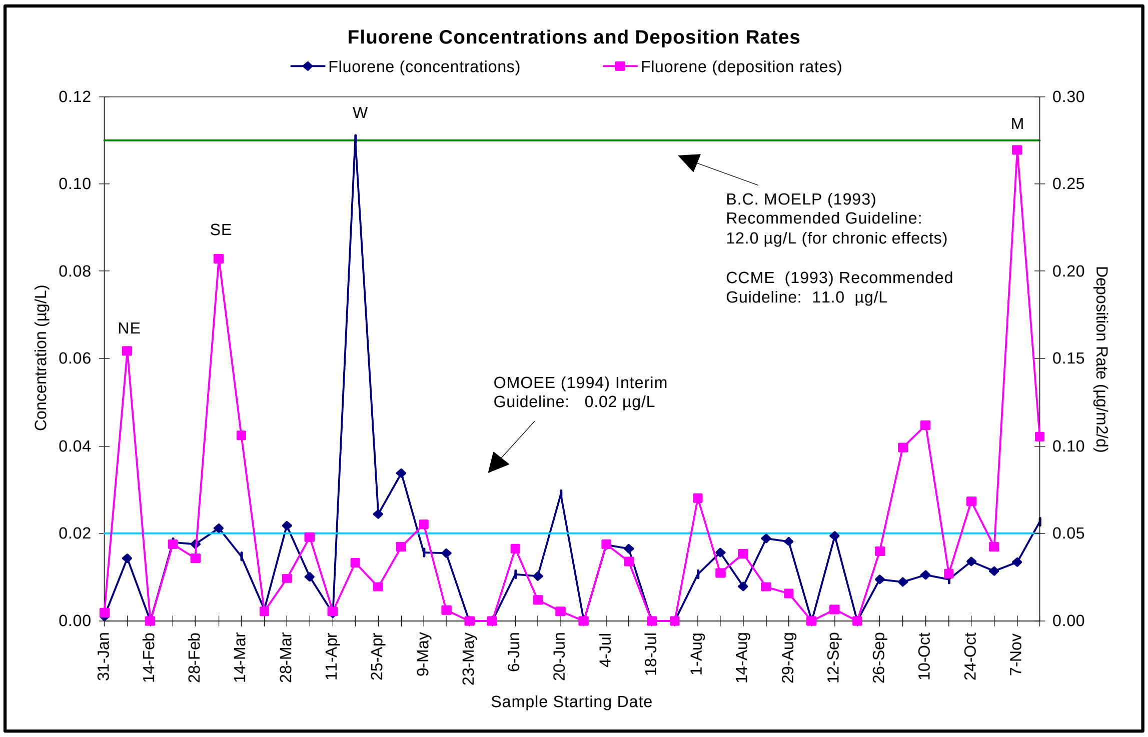


Figure 33:Phenanthrene in rainfall

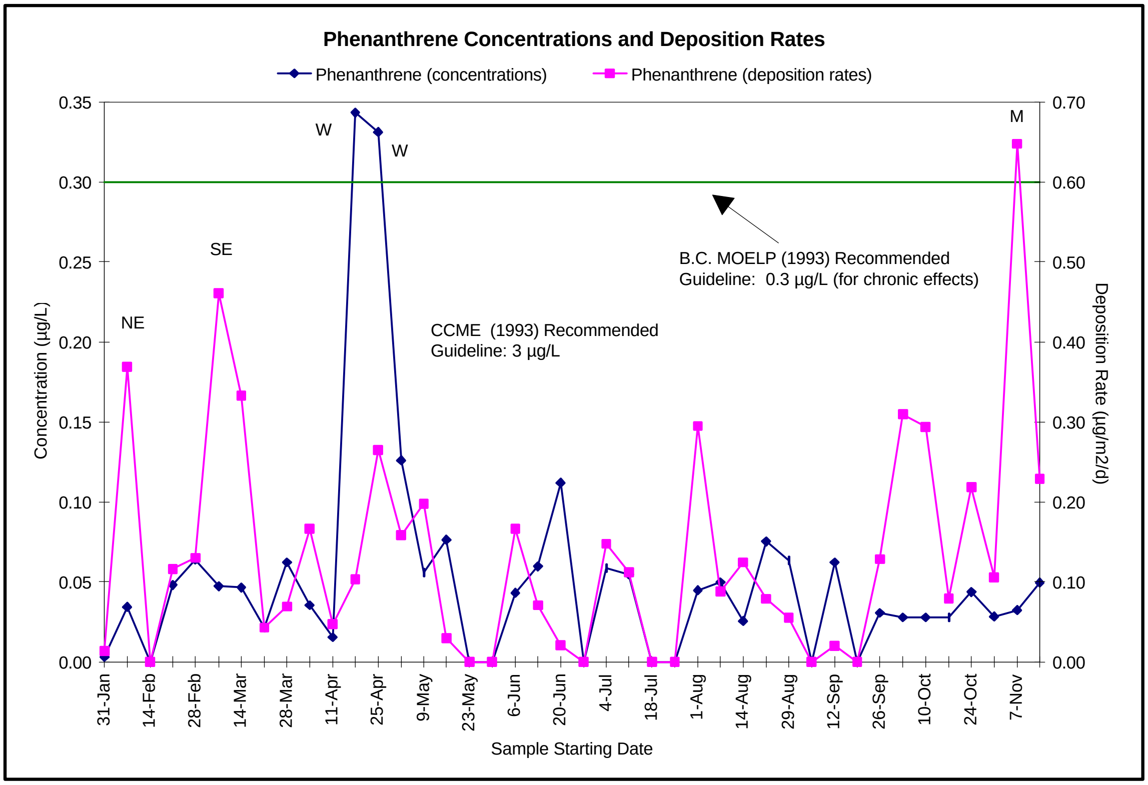


Figure 34: Anthracene in rainfall

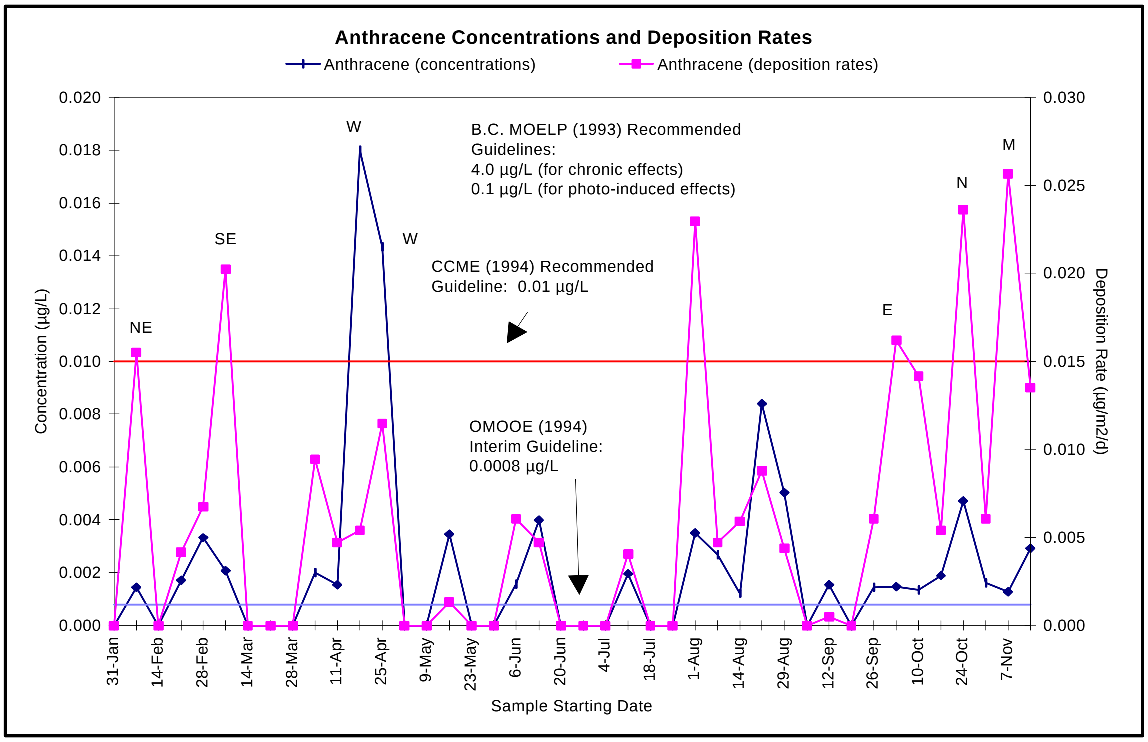


Figure 35: Benzo(g,h,i)perylene in rainfall

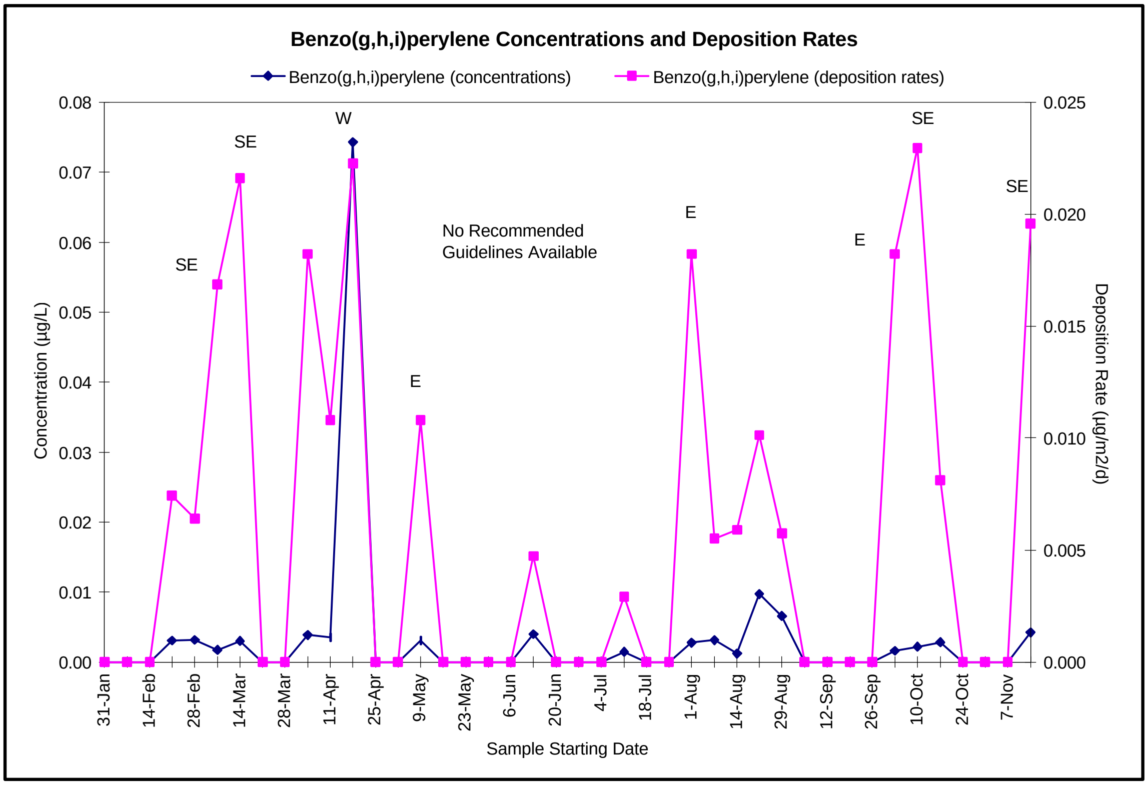


Figure 36: Fluoranthene in rainfall

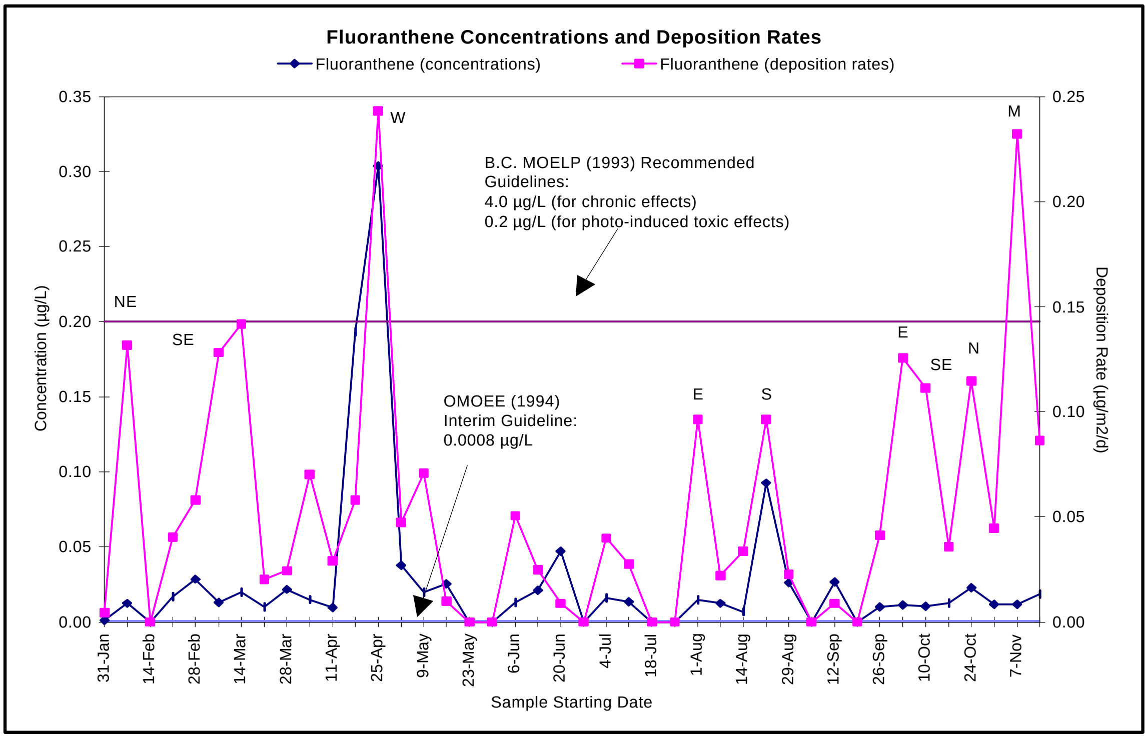


Figure 37: Pyrene in rainfall

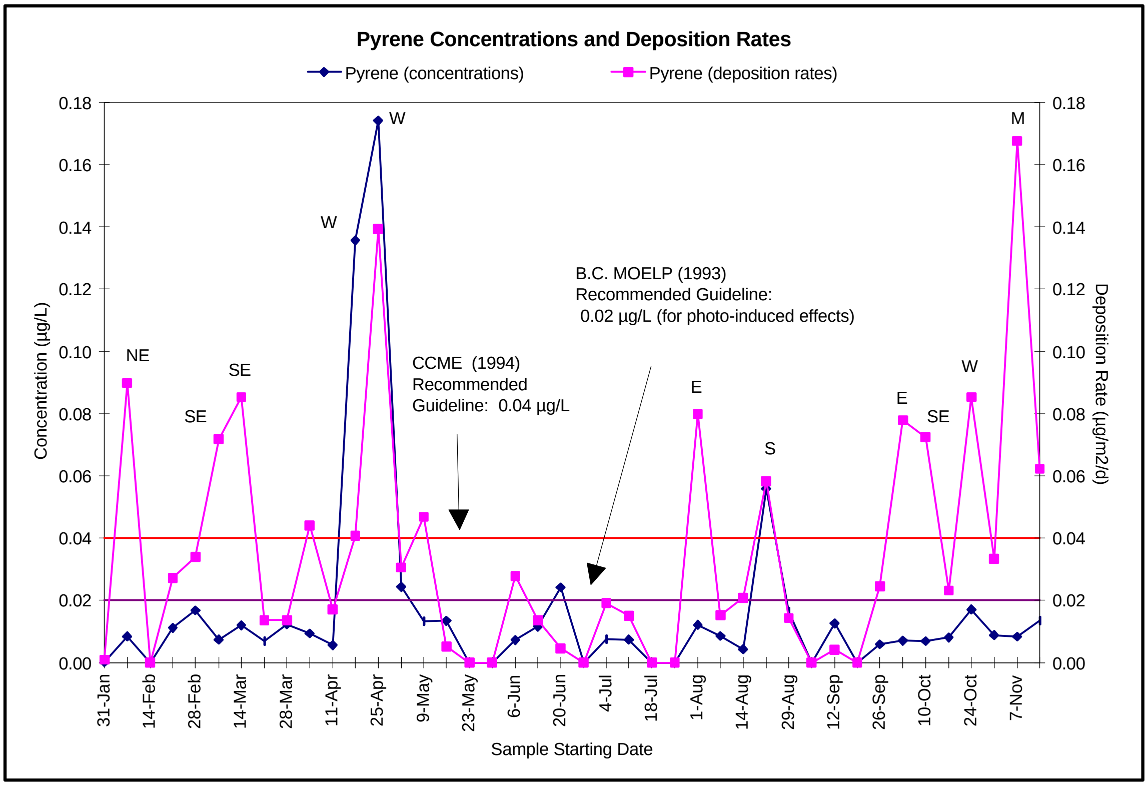
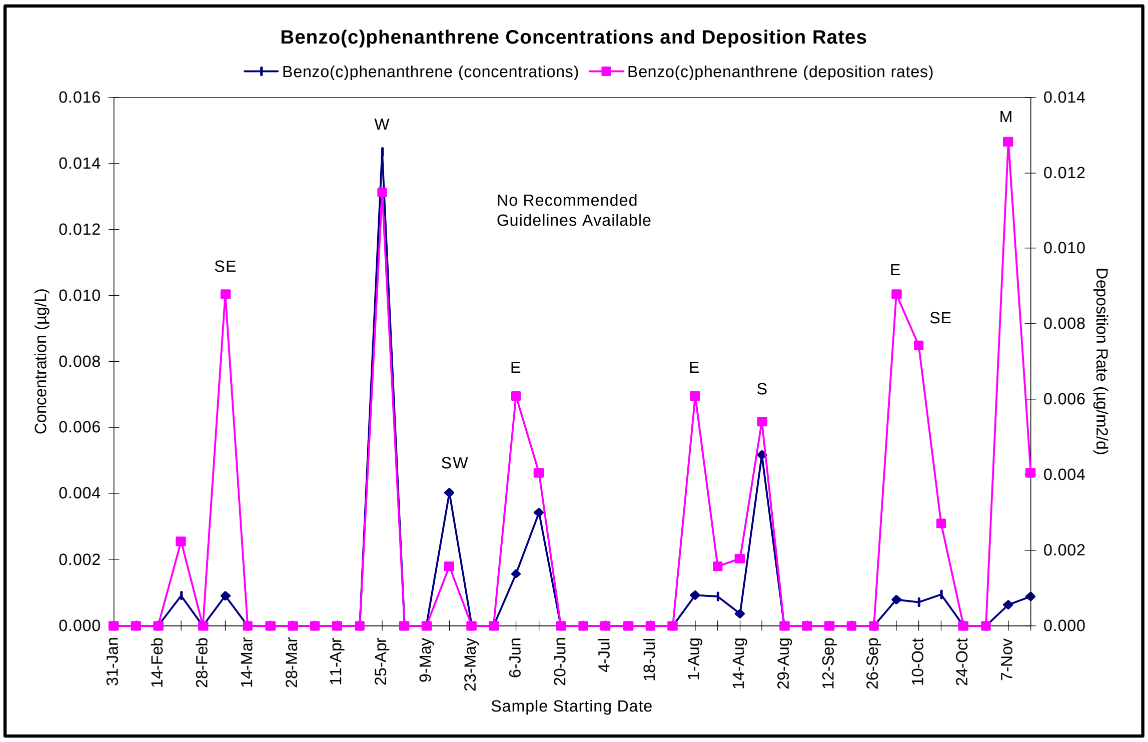
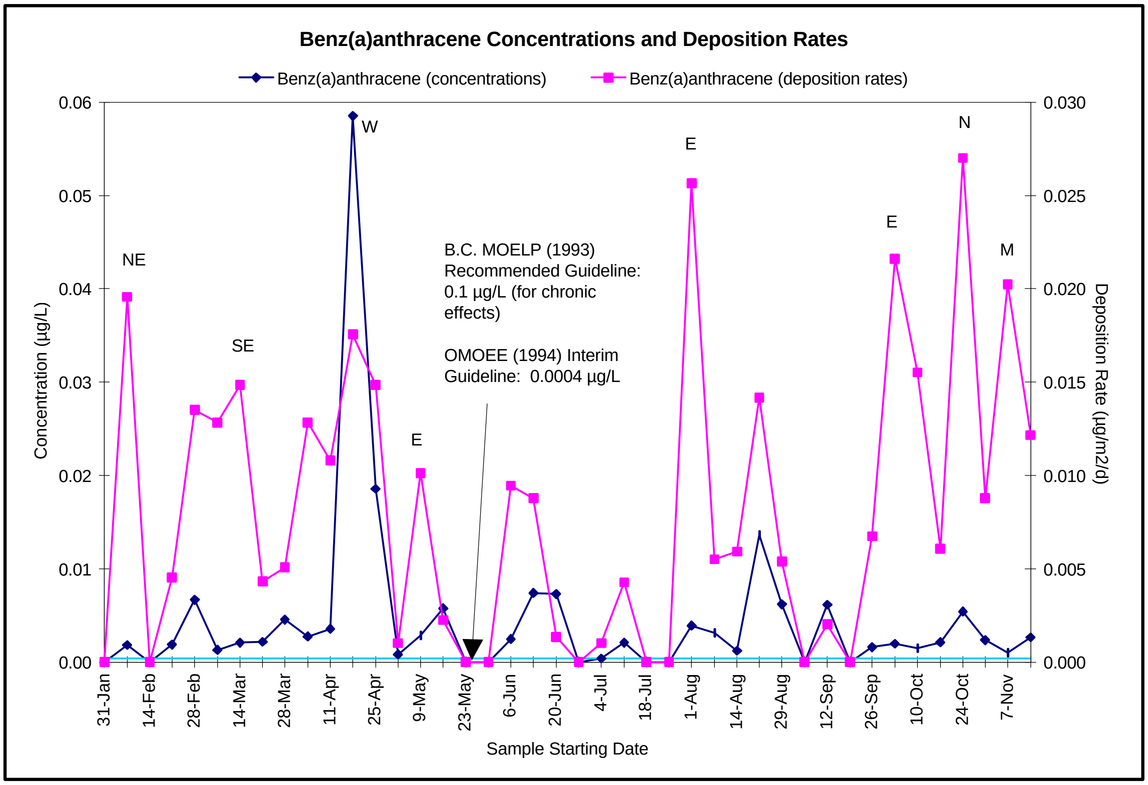


Figure 38: Benzo(c)phenanthrene



No Recommended
Guidelines Available

Figure 39: Benz(a)anthracene



B.C. MOELP (1993)
Recommended Guideline:
0.1 µg/L (for chronic
effects)

OMOEE (1994) Interim
Guideline: 0.0004 µg/L

Figure 40: Chrysene in rainfall

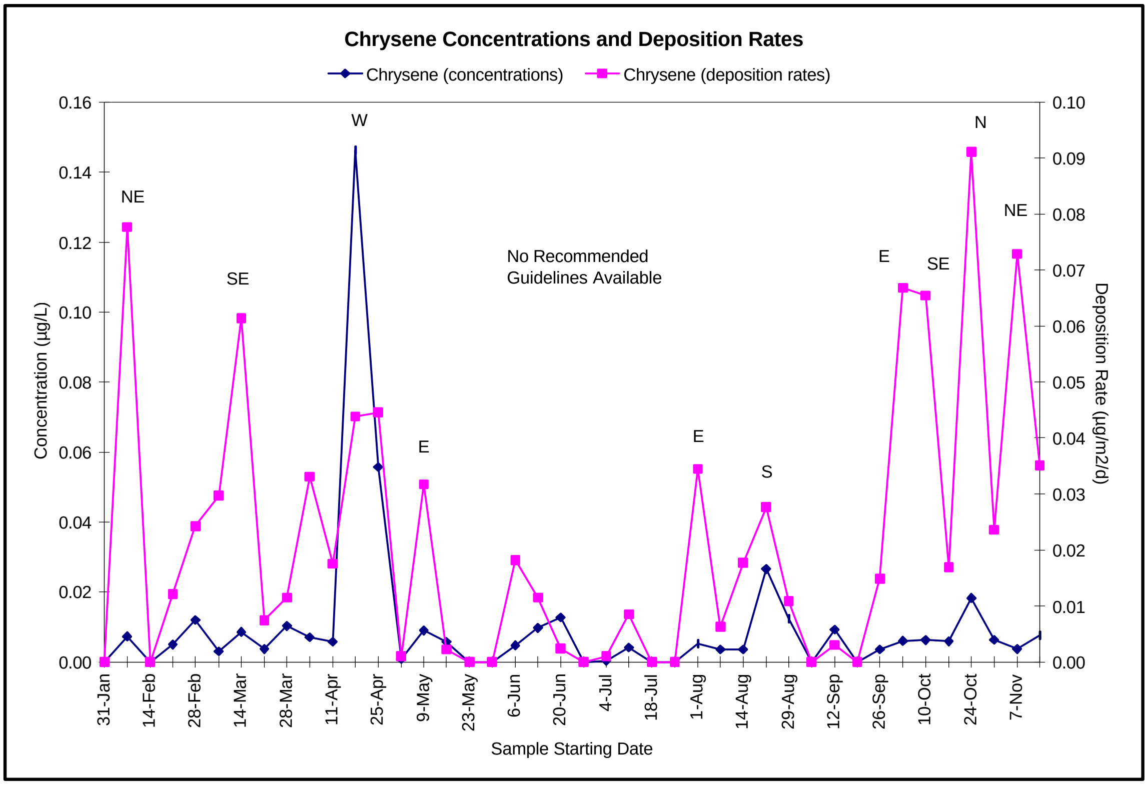


Figure 41: Benzo(b)fluoranthene in rainfall

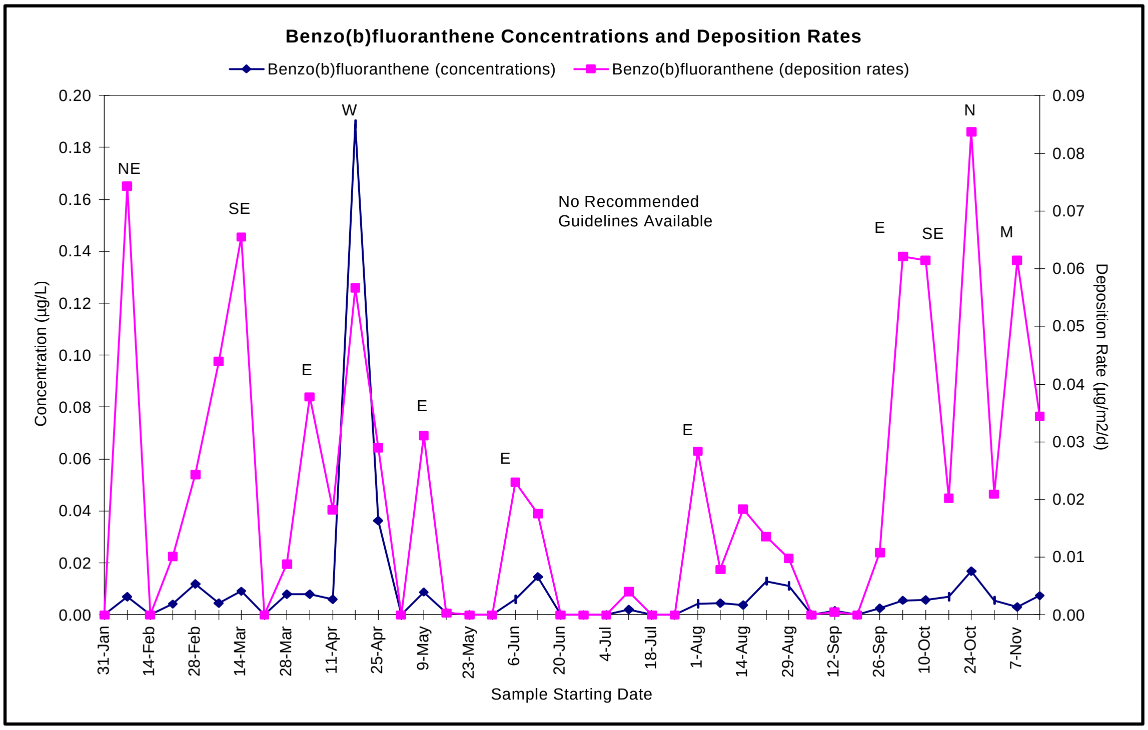


Figure 42: Benzo(k)fluoranthene in rainfall

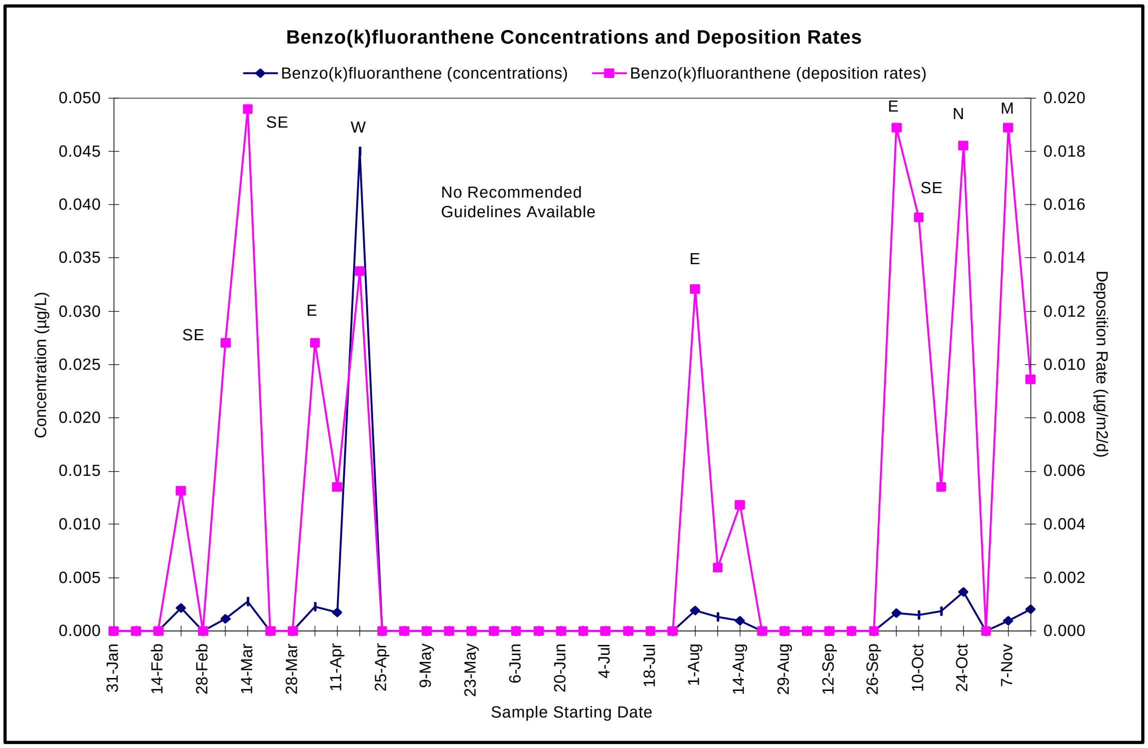


Figure 43: Benzo(j)fluoranthene in rainfall

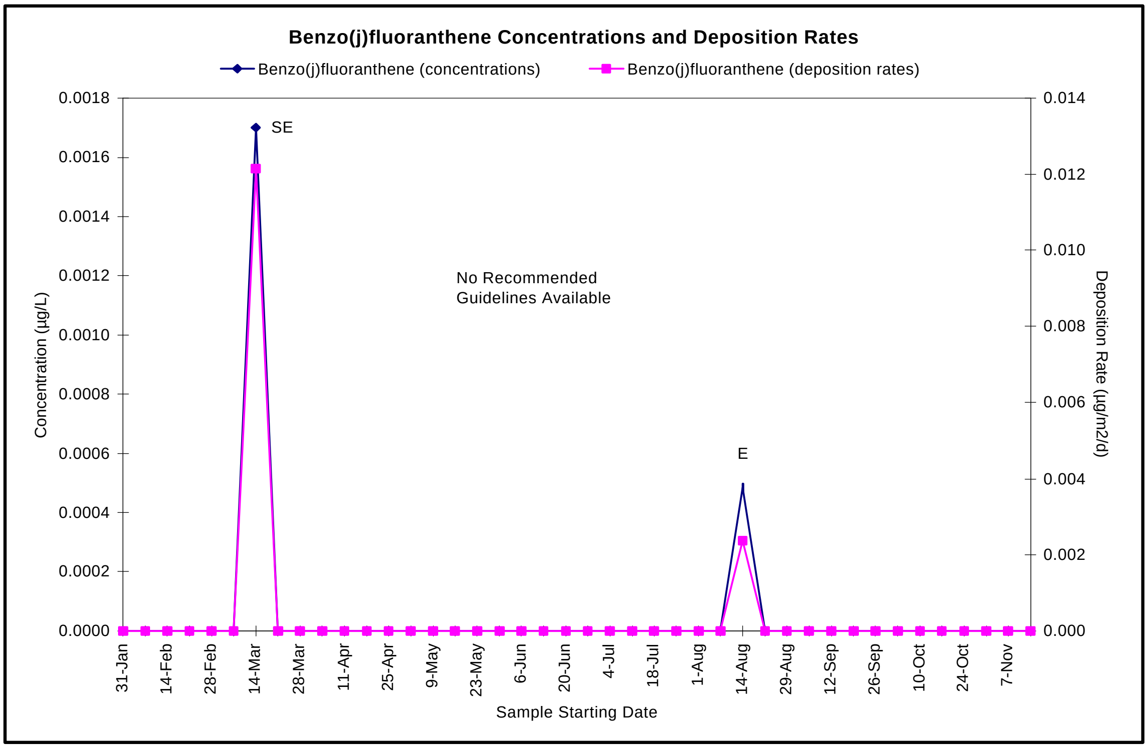


Figure 44: Benzo(a)pyrene in rainfall

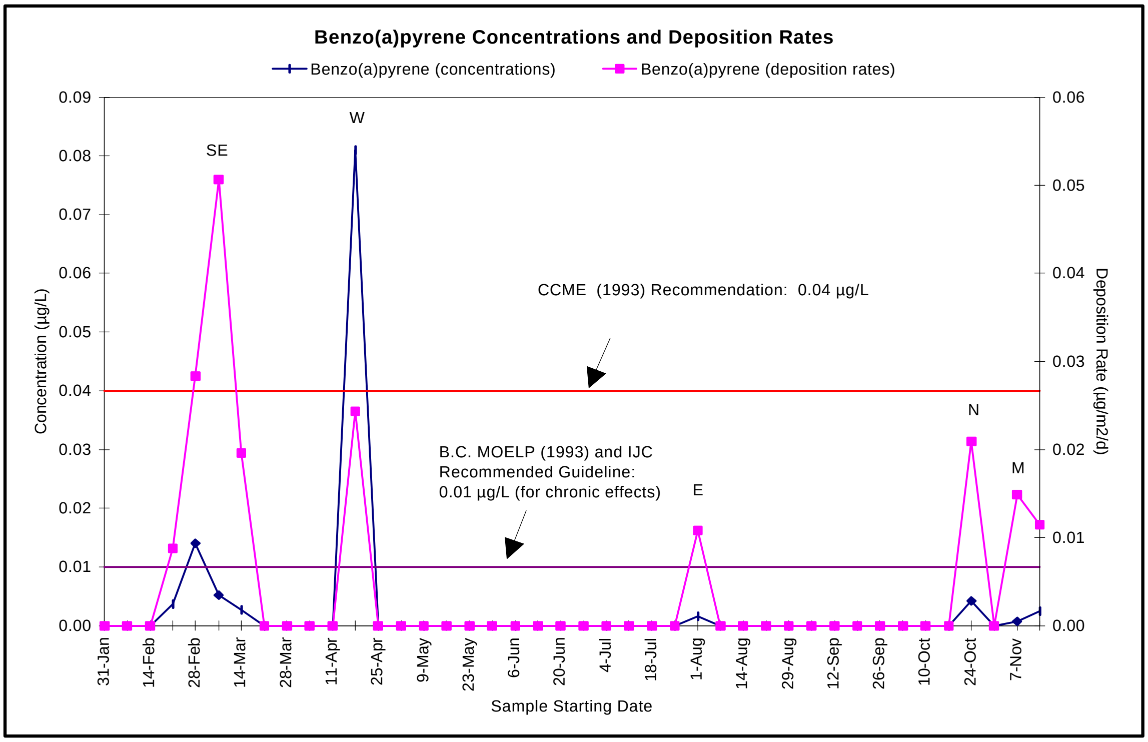


Figure 45: Dibenz(a,h)anthracene in rainfall

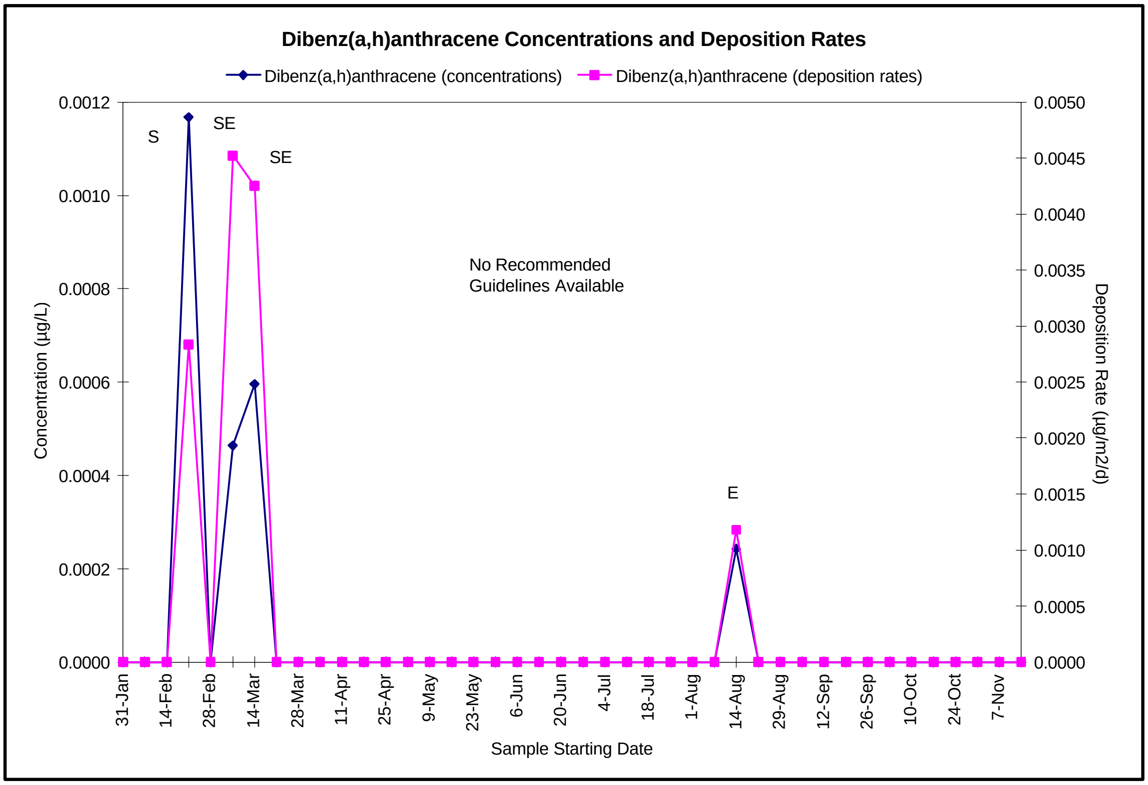


Figure 46: Indeno(1,2,3-c,d)pyrene in rainfall

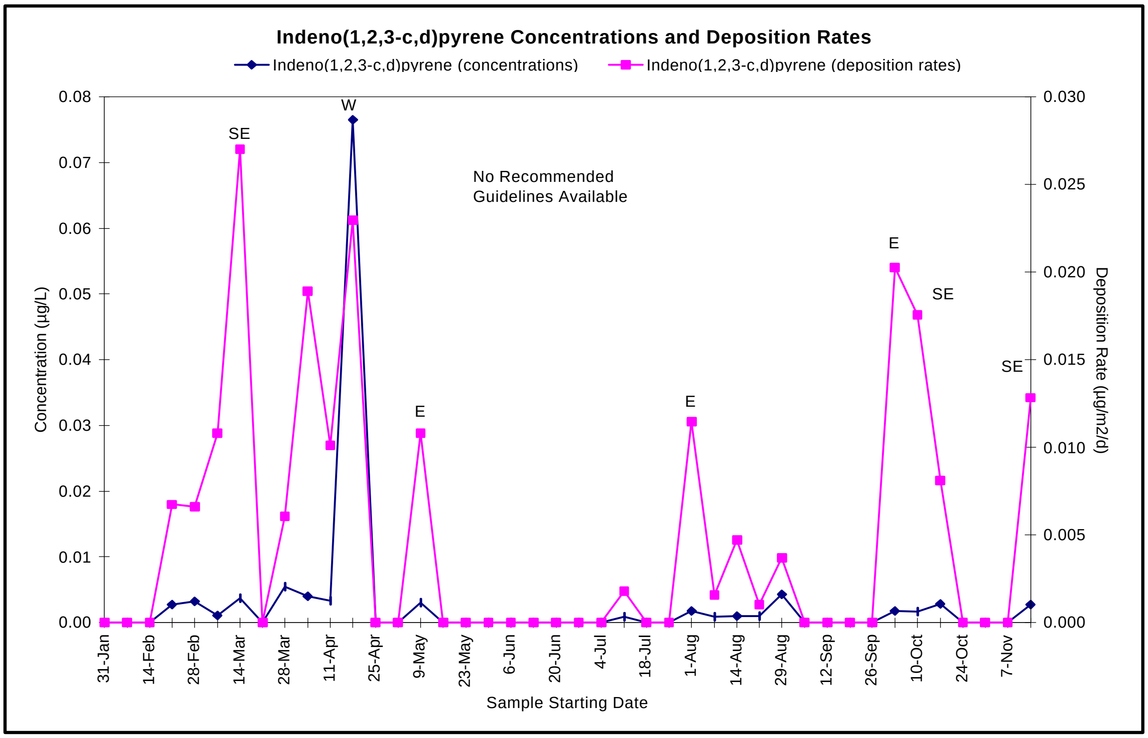


Table 1: Weekly Mean Meteorological Data for Burnaby Lake Study

SAMPLE DATE					AVERAGE			TOTAL
START	STOP	WD DIR	WD SPD (kts)	TEMP (C)	PRESSURE (mb)	RH (%)	PRECIP (mm)	RAIN GA (mm)
Jan-31-95	Feb-06-95	E	3.2	8.0	1021	86.8	N/A	31.8
Feb-07-95	Feb-13-95	NE	5.2	4.7	1019	70.4	N/A	10.0
Feb-14-95	Feb-20-95	SE	3.7	5.5	1012	98.8	24.2	140.0
Feb-21-95	Feb-27-95	S	2.0	5.1	1023	91.4	2.7	17.0
Feb-28-95	Mar-06-95	SE	2.8	2.7	1017	75.4	2.3	14.2
Mar-07-95	Mar-13-95	SE	4.4	7.9	1002	90.3	11.5	68.2
Mar-14-95	Mar-20-95	SE	5.2	9.2	1012	82.8	8.3	50
Mar-21-95	Mar-27-95	E	3.6	5.6	1021	80.5	0.2	14.0
Mar-28-95	Apr-03-95	E	2.6	10.7	1018	74.9	9.6	7.8
Apr-04-95	Apr-10-95	E	4.0	8.4	1011	84.2	37.8	33.0
Apr-11-95	Apr-17-95	SW	3.3	7.9	1013	78.1	24.0	21.4
Apr-18-95	Apr-24-95	W	2.7	10.4	1018	77.4	0.0	2.1
Apr-25-95	Apr-28-95	W	3.0	15.1	1009	64.6	0.0	5.6
May-02-95	May-08-95	S	2.8	13.8	1011	81.0	9.2	8.8
May-09-95	May-15-95	E	3.4	13.8	1010	83.2	28.0	24.7
May-16-95	May-22-95	SW	3.2	14.4	1016	69.3	0.4	0.4
May-23-95	May-29-95	SE	3.0	18.5	1015	66.9	0.0	0.0
May-30-95	Jun-05-95	SE and S	3.2	16.8	1013	73.9	8.8	7.8
Jun-06-95	Jun-12-95	E	3.1	15.9	1014	81.5	30.4	27.0
Jun-13-95	Jun-19-95	SE and E	3.3	14.9	1010	83.3	9.2	8.3
Jun-20-95	Jun-26-95	SE, S and E	3.0	17.7	1019	76.9	0.0	0.0
Jun-27-95	Jul-03-95	E and SW	3.7	21.2	1013	67.0	3.2	2.6
Jul-04-95	Jul-10-95	E	2.9	17.9	1014	78.9	19.6	17.6
Jul-11-95	Jul-17-95	W	3.6	19.8	1018	73.1	0.0	0.0
Jul-18-95	Jul-24-95	E	3.8	20.8	1013	76.2	0.2	0.15
Jul-25-95	Jul-31-95	SW, S and SE	3.7	17.4	1015	75.9	51.0	43.0
Aug-01-95	Aug-07-95	E	3.3	17.5	1011	86.0	51.6	46.0
Aug-08-95	Aug-13-95	E	3.6	15.6	1014	85.6	11.2	10.6
Aug-14-95	Aug-21-95	E	2.9	15.2	1013	85.9	45.4	39.0
Aug-22-95	Aug-28-95	S	2.8	15.8	1014	80.1	7.2	7.3
Aug-29-95	Sep-04-95	E	Anemometer	17.0	1014	80.5	9.4	0.0
Sep-05-95	Sep-11-95	E	Problems	16.8	1016	85.7	3.8	12.2
Sep-12-95	Sep-18-95	NE	"	18.2	1015	82.6	1.6	0.8
Sep-19-95	Sep-25-95	NE	"	15.7	1015	76.0	4.4	3.8
Sep-26-95	Oct-02-95	E and NE	"	13.2	1012	90.0	33.6	29.4
Oct-03-95	Oct-09-95	E	3.3	11.5	1015	90.9	89.8	78.0
Oct-10-95	Oct-16-95	SE	2.6	11.3	1016	92.5	76.6	74.0
Oct-17-95	Oct-23-95	N	2.5	8.9	1022	90.5	9.2	20.0
Oct-24-95	Oct-30-95	N	4.4	5.8	1017	86.0	30.2	35.0
Oct-31-95	Nov-06-95	M	M	M	M	M	M	26.2
Nov-07-95	Nov-13-95	M	M	M	M	M	M	140.0
Nov-14-95	Nov-20-95	SE	3.3	9.4	1016	78.6	36.4	32.4
Nov-21-95	Nov-27-95	SE	3.3	9.1	1013	81.8	131.4	133.0
Nov-28-95	Dec-05-95	SE and S	4.6	6.5	1006	77.6	71.0	66.0
suspect data shaded								

Table 2: Results from Rainfall Metal Blanks for Burnaby Lake Study (mg/L)

Start Sampling Date:			7-Mar-95	6-Jun-95
Parameter	**MDC**	**Unit**		
Silver	0.0001	mg/L	<	<
Aluminum	0.02	mg/L	<	<
Arsenic	0.0005	mg/L	<	<
Boron	0.008	mg/L	<	<
Barium	0.001	mg/L	<	<
Beryllium	0.001	mg/L	<	<
Bismuth	0.02	mg/L	<	<
Calcium	0.01	mg/L	<	<
Cadmium	0.0001	mg/L	<	<
Cobalt	0.003	mg/L	<	<
Chromium	0.002	mg/L	<	<
Copper	0.001	mg/L	<	<
Iron	0.003	mg/L	<	<
Mercury	0.00005	mg/L	0.00007	<
Potassium	0.4	mg/L	<	<
Magnesium	0.02	mg/L	<	<
Manganese	0.002	mg/L	<	<
Molybdenum	0.004	mg/L	<	<
Sodium	0.01	mg/L	<	<
Nickel	0.008	mg/L	<	<
Phosphorus	0.04	mg/L	<	<
Lead	0.001	mg/L	<	<
Sulphur	0.03	mg/L	<	<
Antimony	0.015	mg/L	<	<
Selenium	0.0005	mg/L	<	<
Silicon	0.03	mg/L	<	<
Tin	0.02	mg/L	<	<
Strontium	0.001	mg/L	<	<
Tellurium	0.02	mg/L	<	<
Titanium	0.003	mg/L	<	<
Thallium	0.02	mg/L	<	<
Vanadium	0.003	mg/L	<	<
Zinc	0.002	mg/L	<	<
Zirconium	0.003	mg/L	<	<

Table 3: Results from Rainfall PAH Blanks for Burnaby Lake Study (µg)

	Sample Date			**7-Feb**		**28-Mar**		**16-May**
PAH	**MDC**	**Unit**						
Naphthalene	0.003	µg		0.66		1.2		2.29
Acenaphthylene	0.003	"	<	0.0015	<	0.0015	<	0.0015
Acenaphthene	0.003	"	<	0.0015	<	0.0015		0.004
Fluorene	0.003	"	<	0.0015	<	0.0015		0.003
Phenanthrene	0.003	"	<	0.0015		0.0078		0.007
Anthracene	0.003	"	<	0.0015	<	0.0015	<	0.0015
Total low MW PAH's	**0.003**	**"**		**0.66**		**1.2078**		**2.304**
Benzo(g,h,i)perylene	0.003	"	<	0.0015	<	0.0015	<	0.0015
Fluoranthene	0.003	"	<	0.0015		0.0029	<	0.0015
Pyrene	0.003	"	<	0.0015		0.0037	<	0.0015
Benzo(c)phenanthrene	0.003	"		NR	<	0.0015	<	0.0015
Benz(a)anthracene	0.003	"	<	0.0015	<	0.0015	<	0.0015
Chrysene	0.003	"	<	0.0015	<	0.0015	<	0.0015
Benzo(b)fluoranthene	0.003	"	<	0.0015	<	0.0015	<	0.0015
Benzo(k)fluoranthene	0.003	"	<	0.0015	<	0.0015	<	0.0015
Benzo(j)fluoranthene	0.003	"		NR	<	0.0015	<	0.0015
7,12-Dimethylb(a)anthrene	0.010	"		NR	<	0.005	<	0.005
Benzo(a)pyrene	0.003	"	<	0.0015	<	0.0015	<	0.0015
3-Methylcholanthrene	0.010	"		NR	<	0.005	<	0.005
Dibenz(a,h)anthracene	0.003	"	<	0.0015	<	0.0015	<	0.0015
Dibenzo(a,l)pyrene	0.010	"		NR	<	0.005	<	0.005
Dibenzo(a,i)pyrene	0.010	"		NR	<	0.005	<	0.005
Dibenzo(a,h)pyrene	0.010	"		NR	<	0.005	<	0.005
Indeno(1,2,3-c,d)pyrene	0.003	"	<	0.0015	<	0.0015	<	0.0015
Total high MW PAH's	**0.003**	**"**		**0**		**0.0066**		**0**
Total PAH's	**0.003**	**"**		**0.66**		**1.2144**		**2.304**
Notes:								
"< " = Less than MDC								
MDC = Minimum Detectable Conc.								
"NR" = Not reported								

Table 4: Raw Lab Data for Metals Rainfall Samples (mg/L)

Sample type			Rain	Rain	Rain	Rain	Rain Blk	Rain	Rain	Rain	Rain	Rain	Rain	Rain
Sample Starting Date			**31-Jan**	**21-Feb**	**28-Feb**	**7-Mar**	**7-Mar**	**14-Mar**	**21-Mar**	**28-Mar**	**4-Apr**	**11-Apr**	**18-Apr**	**25-Apr**
Parameter	MDC	Unit												
Silver	0.0001	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Aluminum	0.02	mg/L	<	<	<	<	<	<	<	<	0.041	0.033	0.090	0.024
Arsenic	0.0005	mg/L	<	<	<	<	<	<	<	0.0048	<	<	<	<
Boron	0.008	mg/L	<	<	<	<	<	<	<	<	<	<	0.035	0.015
Barium	0.001	mg/L	<	<	<	<	<	<	0.003	<	<	0.002	0.003	0.002
Beryllium	0.001	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Bismuth	0.02	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Calcium	0.01	mg/L	0.07	0.15	0.23	0.09	<	0.10	0.45	0.24	0.19	0.23	0.47	0.41
Cadmium	0.0001	mg/L	<	<	0.0002	0.0001	<	<	0.0027	0.0010	<	0.0001	0.0002	0.0001
Cobalt	0.003	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Chromium	0.002	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Copper	0.001	mg/L	<	<	<	<	<	<	0.004	<	0.001	0.005	0.003	0.003
Iron	0.003	mg/L	<	<	<	<	<	<	0.070	<	0.026	0.040	0.130	<
Mercury	0.00005	mg/L	<	<	<	0.00009	0.00007	<	<	<	<	<	<	<
Potassium	0.4	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Magnesium	0.02	mg/L	<	0.05	0.12	<	<	0.05	0.05	0.05	0.06	0.06	0.26	0.04
Manganese	0.002	mg/L	<	<	0.003	<	<	<	0.004	0.003	<	<	<	<
Molybdenum	0.004	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Sodium	0.01	mg/L	<	<	0.6	<	<	<	<	<	0.31	0.30	2.10	0.12
Nickel	0.008	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Phosphorus	0.04	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Lead	0.001	mg/L	<	<	<	<	<	<	<	<	<	0.0026	0.0038	<
Sulphur	0.03	mg/L	0.30	0.40	0.50	0.20	<	0.30	0.30	0.30	0.37	0.69	0.70	0.49
Antimony	0.015	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Selenium	0.0005	mg/L	<	<	0.0007	<	<	<	<	<	<	<	<	<
Silicon	0.03	mg/L	<	<	<	<	<	<	<	<	0.23	0.06	0.30	0.09
Tin	0.02	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Strontium	0.001	mg/L	<	<	<	<	<	<	0.002	0.001	0.001	0.001	0.003	0.001
Tellurium	0.02	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Titanium	0.003	mg/L	<	<	<	<	<	<	<	<	<	<	0.003	0.003
Thallium	0.02	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Vanadium	0.003	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Zinc	0.002	mg/L	0.040	0.010	<	<	<	0.010	0.040	<	0.016	0.100	0.015	0.017
Zirconium	0.003	mg/L	<	<	<	<	<	<	<	<	<	<	<	<

Table 4: Raw Lab Data for Metals Rainfall Samples (mg/L) (Con't))

Sample type			Rain	Rain	Rain	Rain	Rain Blk	Rain	Rain	Rain	Rain	Rain	Rain	Rain
Sample Starting Date			**2-May**	**9-May**	**16-May**	**6-Jun**	**6-Jun**	**13-Jun**	**20-Jun**	**4-Jul**	**11-Jul**	**1-Aug**	**14-Aug**	**22-Aug**
Parameter	MDC	Unit												
Silver	0.0001	mg/L	<	<	0.0001	0.0002	<	<	<	<	<	<	0.0001	<
Aluminum	0.02	mg/L	0.021	<	0.120	<	<	0.090	<	<	<	<	<	<
Arsenic	0.0005	mg/L	<	<	<	<	<	0.0101	<	0.0060	0.0009	0.0014	<	<
Boron	0.008	mg/L	<	<	0.05	<	<	<	<	<	<	<	<	<
Barium	0.001	mg/L	0.001	<	0.001	0.001	<	0.002	<	<	<	<	<	0.003
Beryllium	0.001	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Bismuth	0.02	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Calcium	0.01	mg/L	0.52	0.16	0.52	0.17	<	0.21	0.33	0.05	0.05	0.06	0.14	0.88
Cadmium	0.0001	mg/L	0.0026	<	0.0001	0.0001	<	0.0004	0.0008	<	<	0.0002	<	0.0002
Cobalt	0.003	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Chromium	0.002	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Copper	0.001	mg/L	0.004	<	0.004	<	<	<	<	<	<	<	<	0.001
Iron	0.003	mg/L	0.027	<	0.070	<	<	0.080	0.070	<	<	<	<	0.007
Mercury	0.00005	mg/L	<	<	<	<	<	<	<	<	0.00005	<	<	<
Potassium	0.4	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Magnesium	0.02	mg/L	<	<	0.08	0.04	<	0.07	0.10	<	<	0.04	<	0.05
Manganese	0.002	mg/L	<	<	0.005	<	<	0.003	0.003	<	<	<	<	0.005
Molybdenum	0.004	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Sodium	0.01	mg/L	<	0.13	<	<	<	<	0.80	<	0.07	0.23	0.12	0.25
Nickel	0.008	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Phosphorus	0.04	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Lead	0.001	mg/L	0.0063	<	0.0030	<	<	<	<	<	<	<	<	<
Sulphur	0.03	mg/L	0.68	0.40	0.70	0.40	<	0.70	0.50	0.20	0.10	0.28	3.02	0.66
Antimony	0.015	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Selenium	0.0005	mg/L	<	<	<	<	<	<	<	<	<	<	0.0011	0.0010
Silicon	0.03	mg/L	0.05	<	<	<	<	<	<	<	<	<	<	0.07
Tin	0.02	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Strontium	0.001	mg/L	0.001	<	0.002	<	<	0.001	0.001	<	<	<	<	0.003
Tellurium	0.02	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Titanium	0.003	mg/L	0.003	<	<	<	<	0.003	<	<	<	<	<	<
Thallium	0.02	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Vanadium	0.003	mg/L	<	<	<	<	<	<	<	<	<	<	<	<
Zinc	0.002	mg/L	0.019	0.070	0.010	0.010	<	<	0.010	<	0.002	0.004	<	0.015
Zirconium	0.003	mg/L	<	<	<	<	<	<	<	<	<	<	<	<

Table 4: Raw Lab Data for Metals Rainfall Samples (mg/L) (Con't))

Sample type			Rain	Rain	Rain	Rain	Rain	Rain	Rain	Rain	Rain	Rain	Rain
Sample Starting Date			**29-Aug**	**12-Sep**	**26-Sep**	**10-Oct**	**17-Oct**	**24-Oct**	**31-Oct**	**7-Nov**	**14-Nov**	**21-Nov**	**28-Nov**
Parameter	MDC	Unit											
Silver	0.0001	mg/L	<	<	<	<	<	<	<	<	<	<	<
Aluminum	0.02	mg/L	0.03	0.06	<	<	<	<	<	<	<	<	<
Arsenic	0.0005	mg/L	<	0.0010	<	<	<	<	<	0.0011	<	<	0.0005
Boron	0.008	mg/L	<	0.009	<	<	<	<	<	<	<	<	<
Barium	0.001	mg/L	0.002	0.004	<	<	<	<	<	0.001	0.001	<	<
Beryllium	0.001	mg/L	<	<	<	<	<	<	<	<	<	<	<
Bismuth	0.02	mg/L	<	<	<	<	<	<	<	<	<	<	<
Calcium	0.01	mg/L	0.25	1.41	0.16	0.05	0.04	0.04	0.03	0.22	<	0.07	0.16
Cadmium	0.0001	mg/L	0.0003	0.0004	<	0.0004	0.0013	0.0003	<	0.0009	<	0.0002	<
Cobalt	0.003	mg/L	<	<	<	<	<	<	<	<	<	<	<
Chromium	0.002	mg/L	<	<	<	<	<	<	<	<	<	0.014	0.003
Copper	0.001	mg/L	<	<	<	<	<	<	<	0.009	<	<	<
Iron	0.003	mg/L	0.008	0.044	<	<	<	<	<	<	0.06	0.08	<
Mercury	0.00005	mg/L	<	<	<	<	<	<	<	<	<	<	<
Potassium	0.4	mg/L	<	<	<	<	<	<	<	<	<	<	<
Magnesium	0.02	mg/L	0.07	0.13	0.04	0.04	0.03	0.05	<	0.05	0.07	0.03	0.10
Manganese	0.002	mg/L	0.006	0.027	0.003	<	<	<	<	<	<	<	<
Molybdenum	0.004	mg/L	<	<	<	<	<	<	<	<	<	<	<
Sodium	0.01	mg/L	0.40	2.65	0.25	0.35	0.38	0.92	0.28	<	<	<	0.90
Nickel	0.008	mg/L	<	<	<	<	<	<	<	<	<	0.02	<
Phosphorus	0.04	mg/L	<	<	<	<	<	<	<	<	<	<	<
Lead	0.001	mg/L	0.001	<	<	<	<	<	<	<	<	<	<
Sulphur	0.03	mg/L	1.17	2.45	0.52	0.69	1.13	1.89	0.52	0.20	0.20	0.30	0.40
Antimony	0.015	mg/L	<	<	<	<	<	<	<	<	<	<	<
Selenium	0.0005	mg/L	<	<	0.0073	0.0008	<	0.0005	<	<	<	<	<
Silicon	0.03	mg/L	0.04	0.32	<	<	<	<	<	<	<	<	<
Tin	0.02	mg/L	<	<	<	<	<	<	<	<	<	<	<
Strontium	0.001	mg/L	<	0.026	<	<	<	<	<	<	<	<	0.001
Tellurium	0.02	mg/L	<	<	<	<	<	<	<	<	<	<	<
Titanium	0.003	mg/L	<	0.004	<	<	<	<	<	<	<	<	<
Thallium	0.02	mg/L	<	<	<	<	<	<	<	<	<	<	<
Vanadium	0.003	mg/L	<	<	<	<	<	<	<	<	<	<	<
Zinc	0.002	mg/L	0.022	0.003	0.003	0.002	<	0.002	0.002	0.020	0.020	0.020	0.020
Zirconium	0.003	mg/L	<	<	<	<	<	<	<	<	<	<	<

Table 5: Blank Corrected Metals Rainfall Concentration Data

Metals - Rain Concentrations (mg/L)

Start Sampling Date:	**31-Jan**	**21-Feb**	**28-Feb**	**7-Mar**	**14-Mar**	**21-Mar**	**28-Mar**	**4-Apr**	**11-Apr**	**18-Apr**	**25-Apr**	**2-May**	**9-May**	**16-May**	**6-Jun**	**13-Jun**	**20-Jun**
Silver	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0001	0.0002	-	-
Aluminum	-	-	-	-	-	-	-	0.041	0.033	0.090	0.024	0.021	-	0.120	-	0.090	-
Arsenic	-	-	-	-	-	-	0.0048	-	-	-	-	-	-	-	-	0.0101	-
Boron	-	-	-	-	-	-	-	-	-	0.035	0.015	-	-	0.050	-	-	-
Barium	-	-	-	-	-	0.003	-	-	0.002	0.003	0.002	0.001	-	0.001	0.001	0.002	-
Calcium	0.07	0.15	0.23	0.09	0.10	0.45	0.24	0.19	0.23	0.47	0.41	0.52	0.16	0.52	0.17	0.21	0.33
Cadmium	-	-	0.0002	0.0001	-	0.0027	0.001	-	0.0001	0.0002	0.0001	0.0026	-	0.0001	0.0001	0.0004	0.0008
Chromium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Copper	-	-	-	-	-	0.004	-	0.001	0.005	0.003	0.003	0.004	-	0.004	-	-	-
Iron	-	-	-	-	-	0.070	-	0.026	0.040	0.130	0.000	0.027	-	0.070	-	0.080	0.070
Mercury	-	-	-	0.00002	-	-	-	-	-	-	-	-	-	-	-	-	-
Magnesium	-	0.05	0.12	-	0.05	0.05	0.05	0.06	0.06	0.26	0.04	-	-	0.08	0.04	0.07	0.1
Manganese	-	-	0.003	-	-	0.004	0.003	-	-	-	-	-	-	0.005	-	0.003	0.003
Sodium	-	-	0.60	-	-	-	-	0.31	0.30	2.10	0.12	-	0.13	-	-	-	0.80
Nickel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lead	-	-	-	-	-	-	-	-	0.0026	0.0038	0	0.0063	-	0.003	-	-	-
Sulphur	0.30	0.40	0.50	0.20	0.30	0.30	0.30	0.37	0.69	0.70	0.49	0.68	0.40	0.70	0.40	0.70	0.50
Selenium	-	-	0.0007	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silicon	-	-	-	-	-	-	-	0.23	0.06	0.30	0.09	0.05	-	-	-	-	-
Strontium	-	-	-	-	-	0.002	0.001	0.001	0.001	0.003	0.001	0.001	-	0.002	-	0.001	0.001
Titanium	-	-	-	-	-	-	-	-	-	0.003	0.003	0.003	-	-	-	0.003	-
Zinc	0.04	0.01	-	-	0.01	0.04	-	0.02	0.10	0.02	0.02	0.02	0.07	0.01	0.01	-	0.01

'-' denotes a value below the limit of detection

Table 5: Blank Corrected Metals Rainfall Concentration Data (Con't)

Metals - Rain Concentrations (mg/L)																
Start Sampling Date:	**4-Jul**	**11-Jul**	**1-Aug**	**14-Aug**	**22-Aug**	**29-Aug**	**12-Sep**	**26-Sep**	**10-Oct**	**17-Oct**	**24-Oct**	**31-Oct**	**7-Nov**	**14-Nov**	**21-Nov**	**28-Nov**
Silver	-	-	-	0.0001	-	-	-	-	-	-	-	-	-	-	-	-
Aluminum	-	-	-	-	-	0.030	0.060	-	-	-	-	-	-	-	-	-
Arsenic	0.0060	0.0009	0.0014	-	-	-	0.0010	-	-	-	-	-	0.0011	-	-	0.0005
Boron	-	-	-	-	-	-	0.009	-	-	-	-	-	-	-	-	-
Barium	-	-	-	-	0.003	0.002	0.004	-	-	-	-	-	0.001	0.001	-	-
Calcium	0.05	0.05	0.06	0.14	0.88	0.25	1.41	0.16	0.05	0.04	0.04	0.03	0.22	-	0.07	0.16
Cadmium	-	-	0.0002	-	0.0002	0.0003	0.0004	-	0.0004	0.0013	0.0003	-	0.0009	-	0.0002	-
Chromium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.014	0.003
Copper	-	-	-	-	0.001	-	-	-	-	-	-	-	0.009	-	-	-
Iron	-	-	-	-	0.007	0.008	0.044	-	-	-	-	-	-	0.060	0.080	-
Mercury	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Magnesium	-	-	0.04	-	0.05	0.07	0.13	0.04	0.04	0.03	0.05	-	0.05	0.07	0.03	0.1
Manganese	-	-	-	-	0.005	0.006	0.027	0.003	-	-	-	-	-	-	-	-
Sodium	-	0.07	0.23	0.12	0.25	0.40	2.65	0.25	0.35	0.38	0.92	0.28	-	-	-	0.90
Nickel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	-
Lead	-	-	-	-	-	0.001	-	-	-	-	-	-	-	-	-	-
Sulphur	0.20	0.10	0.28	3.02	0.66	1.17	2.45	0.52	0.69	1.13	1.89	0.52	0.20	0.20	0.30	0.40
Selenium	-	-	-	0.0011	0.0010	-	-	0.0073	0.0008	-	0.0005	-	-	-	-	-
Silicon	-	-	-	-	0.07	0.04	0.32	-	-	-	-	-	-	-	-	-
Strontium	-	-	-	-	0.003	-	0.026	-	-	-	-	-	-	-	-	0.001
Titanium	-	-	-	-	-	-	0.004	-	-	-	-	-	-	-	-	-
Zinc	-	0.00	0.00	-	0.02	0.02	0.00	0.00	0.00	-	0.00	0.00	0.02	0.02	0.02	0.02

'-' denotes a value below the limit of detection

Table 6: Calculated Metals Rainfall Deposition Rates for Burnaby Lake Study (mg/m^2/d)

	METALS-RAIN DEPOSITION RATES																
(mg / m² / d)																	
Duration of sample periods (days):	*7*	*7*	*7*	*7*	*7*	*7*	*7*	*7*	*7*	*7*	*7*	*7*	*7*	*21*	*7*	*7*	*14*
Sample Starting Date	**31-Jan**	**21-Feb**	**28-Feb**	**7-Mar**	**14-Mar**	**21-Mar**	**28-Mar**	**4-Apr**	**11-Apr**	**18-Apr**	**25-Apr**	**2-May**	**9-May**	**16-May**	**6-Jun**	**13-Jun**	**20-Jun**
Silver	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00004	0.0008	-	-
Aluminum	-	-	-	-	-	-	-	0.193	0.101	0.0270	0.0192	0.0264	-	0.0469	-	0.107	-
Arsenic	-	-	-	-	-	-	0.0053	-	-	-	-	-	-	-	-	0.0120	-
Boron	-	-	-	-	-	-	-	-	-	0.0105	0.0120	-	-	0.0195	-	-	-
Barium	-	-	-	-	-	0.0060	-	-	0.0061	0.0009	0.0016	0.0013	-	0.0004	0.0039	0.0024	-
Calcium	0.318	0.364	0.467	0.877	0.714	0.900	0.267	0.896	0.703	0.141	0.328	0.654	0.565	0.203	0.656	0.249	0.0613
Cadmium	-	-	0.0004	0.0010	-	0.0054	0.0011	-	0.0003	0.0001	0.0001	0.0033	-	0.00004	0.0004	0.0005	0.0001
Chromium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Copper	-	-	-	-	-	0.0080	-	0.0047	0.0153	0.0009	0.0024	0.0050	-	0.0016	-	-	-
Iron	-	-	-	-	-	0.140	-	0.123	0.122	0.0390	-	0.0339	-	0.0273	-	0.0949	0.0130
Mercury	-	-	-	0.0002	-	-	-	-	-	-	-	-	-	-	-	-	-
Magnesium	-	0.121	0.243	-	0.357	0.100	0.0557	0.283	0.183	0.0780	0.0320	-	-	0.0312	0.154	0.0830	0.0186
Manganese	-	-	0.0061	-	-	0.0080	0.0033	-	-	-	-	-	-	0.0020	-	0.0036	0.0006
Sodium	-	-	1.22	-	-	-	-	1.46	0.917	0.630	0.0960	-	0.4587	-	-	-	0.1486
Nickel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lead	-	-	-	-	-	-	-	-	0.0079	0.0011	-	0.0079	-	0.0012	-	-	-
Sulphur	1.36	0.971	1.01	1.95	2.14	0.600	0.334	1.74	2.11	0.210	0.392	0.855	1.41	0.273	1.54	0.830	0.0929
Selenium	-	-	0.0014	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silicon	-	-	-	-	-	-	-	1.08	0.183	0.0900	0.0720	0.0629	-	-	-	-	-
Strontium	-	-	-	-	-	0.0040	0.0011	0.0047	0.0031	0.0009	0.0008	0.0013	-	0.0008	-	0.0012	0.0002
Titanium	-	-	-	-	-	-	-	-	-	0.0009	0.0024	0.0038	-	-	-	0.0036	-
Zinc	0.182	0.0243	-	-	0.0714	0.0800	-	0.0754	0.306	0.0045	0.0136	0.0239	0.247	0.0039	0.0386	-	0.0019

'-' denotes a value below the limit of detection

Table 6: Calculated Metals Rainfall Deposition Rates for Burnaby Lake Study (mg/m2/d) (Con't)

	METALS-RAIN DEPOSITION RATES															
(mg / m^2 / d)																
Duration of sample periods (days):	*7*	*21*	*7*	*8*	*7*	*14*	*14*	*7*	*7*	*7*	*7*	*7*	*7*	*7*	*7*	*7*
Sample Starting Date	**4-Jul**	**11-Jul**	**1-Aug**	**14-Aug**	**22-Aug**	**29-Aug**	**12-Sep**	**26-Sep**	**10-Oct**	**17-Oct**	**24-Oct**	**31-Oct**	**7-Nov**	**14-Nov**	**21-Nov**	**28-Nov**
Silver	-	-	-	0.0005	-	-	-	-	-	-	-	-	-	-	-	-
Aluminum	-	-	-	-	-	0.0261	0.0197	-	-	-	-	-	-	-	-	-
Arsenic	0.0151	0.0018	0.0092	-	-	-	0.0003	-	-	-	-	-	0.0220	-	-	0.0047
Boron	-	-	-	-	-	-	0.0030	-	-	-	-	-	-	-	-	-
Barium	-	-	-	-	0.0031	0.0017	0.0013	-	-	-	-	-	0.0200	0.0046	-	-
Calcium	0.126	0.103	0.394	0.683	0.918	0.218	0.463	0.672	0.529	0.114	0.200	0.112	4.40	-	1.33	1.51
Cadmium	-	-	0.0013	-	0.0002	0.0003	0.0001	-	0.0042	0.0037	0.0015	-	0.0180	-	0.0038	-
Chromium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.266	0.0283
Copper	-	-	-	-	0.0010	-	-	-	-	-	-	-	0.180	-	-	-
Iron	-	-	-	-	0.0073	0.0070	0.0145	-	-	-	-	-	-	0.278	1.52	-
Mercury	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Magnesium	-	-	0.263	-	0.0521	0.0610	0.0427	0.168	0.423	0.0857	0.250	-	1.00	0.324	0.570	0.943
Manganese	-	-	-	-	0.0052	0.0052	0.0089	0.0126	-	-	-	-	-	-	-	-
Sodium	-	0.144	1.51	0.585	0.261	0.349	0.871	1.05	3.70	1.09	4.60	1.05	-	-	-	8.49
Nickel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.380	-
Lead	-	-	-	-	-	0.0009	-	-	-	-	-	-	-	-	-	-
Sulphur	0.503	0.205	1.84	14.7	0.688	1.0196	0.805	2.18	7.29	3.23	9.45	1.95	4.00	0.926	5.70	3.77
Selenium	-	-	-	0.0054	0.0010	-	-	0.0307	0.0085	-	0.0025	-	-	-	-	-
Silicon	-	-	-	-	0.0730	0.0349	0.105	-	-	-	-	-	-	-	-	-
Strontium	-	-	-	-	0.0031	-	0.0085	-	-	-	-	-	-	-	-	0.0094
Titanium	-	-	-	-	-	-	0.0013	-	-	-	-	-	-	-	-	-
Zinc	-	0.0041	0.0263	-	0.0156	0.0192	0.0010	0.0126	0.0211	-	0.0100	0.0075	0.400	0.0926	0.380	0.189
'-' denotes a value below the limit of detection																

Table 7: Molecular Weights and Boiling Points of PAHs in the Burnaby Lake Study

Chemicals	MW (amu)	BP ºC
Naphthalene	128.16	217.9
Acenaphthylene	152.20	270
Acenaphthene	154.21	279
Fluorene	166.22	294
Phenanthrene	178.24	339
Anthracene	178.24	339.9
Benzo(g,h,i)perylene	276.34	sublimes @ 350
Fluoranthene	202.26	367
Pyrene	202.24	404
Benzo(c)phenanthrene	228.29	-
Benz(a)anthracene	228.30	400
Chrysene	228.30	448
Benzo(b)fluoranthene	252.32	-
Benzo(k)fluoranthene	252.32	480
Benzo(j)fluoranthene	252.32	-
7,12-Dimethylb(a)anthrene	256.36	-
Benzo(a)pyrene	252.32	312 @ 10mm
3-Methylcholanthrene	268.37	280 @ 80mm
Dibenz(a,h)anthracene	278.36	-
Dibenzo(a,l)pyrene	302.38	-
Dibenzo(a,i)pyrene	302.38	-
Dibenzo(a,h)pyrene	302.38	-
Indeno(1,2,3-c,d)pyrene	276.34	-
'-' means not found		

Table 8: Raw Lab Data for Burnaby Lake PAHs Rainfall Samples

					Rain Blank							Rain Blank				
Sample Starting Date			**31-Jan**	**7-Feb**	**7-Feb**	**21-Feb**	**28-Feb**	**7-Mar**	**14-Mar**	**21-Mar**	**28-Mar**	**28-Mar**	**4-Apr**	**11-Apr**	**18-Apr**	**25-Apr**
PAH	**MDC**	**Unit**														
Naphthalene	0.003	µg	0.058	3.7	0.66	1.9	2.9	3.2	0.95	1	1.3	1.2	1.15	0.66	0.71	3.17
Acenaphthylene	0.003	"	0.0088	0.17	< 0.0015	0.066	0.026	0.12	0.047	< 0.0015	0.016	< 0.0015	0.047	0.012	0.04	< 0.0015
Acenaphthene	0.003	"	0.0099	0.53	< 0.0015	0.065	0.047	0.38	0.13	0.0046	0.034	< 0.0015	0.066	0.005	0.032	0.022
Fluorene	0.003	"	0.01	0.46	< 0.0015	0.068	0.056	0.31	0.16	0.011	0.039	< 0.0015	0.074	0.011	0.052	0.032
Phenanthrene	0.003	"	0.028	1.1	< 0.0015	0.18	0.2	0.69	0.5	0.071	0.11	0.0078	0.254	0.077	0.16	0.4
Anthracene	0.003	"	< 0.0015	0.046	< 0.0015	0.0062	0.01	0.03	< 0.0015	< 0.0015	< 0.0015	< 0.0015	0.014	0.007	0.008	0.017
Total low MW PAH's	**0.003**	**"**	**0.1147**	**6.006**	**0.66**	**2.2852**	**3.239**	**4.73**	**1.787**	**1.0866**	**1.499**	**1.2078**	**1.61**	**0.772**	**1.002**	**3.641**
Benzo(g,h,i)perylene	0.003	"	< 0.0015	< 0.0015	< 0.0015	0.011	0.0095	0.025	0.032	< 0.0015	< 0.0015	< 0.0015	0.027	0.016	0.033	< 0.0015
Fluoranthene	0.003	"	0.0066	0.39	< 0.0015	0.06	0.086	0.19	0.21	0.03	0.036	0.0029	0.104	0.043	0.086	0.36
Pyrene	0.003	"	0.005	0.27	< 0.0015	0.044	0.054	0.11	0.13	0.024	0.024	0.0037	0.069	0.029	0.064	0.21
Benzo(c)phenanthrene	0.003	"	< 0.0015	NR	NR	0.0033	< 0.0015	0.013	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	0.017
Benz(a)anthracene	0.003	"	< 0.0015	0.058	< 0.0015	0.0067	0.02	0.019	0.022	0.0064	0.0075	< 0.0015	0.019	0.016	0.026	0.022
Chrysene	0.003	"	< 0.0015	0.23	< 0.0015	0.018	0.036	0.044	0.091	0.011	0.017	< 0.0015	0.049	0.026	0.065	0.066
Benzo(b)fluoranthene	0.003	"	< 0.0015	0.22	< 0.0015	0.015	0.036	0.065	0.097	< 0.0015	0.013	< 0.0015	0.056	0.027	0.084	0.043
Benzo(k)fluoranthene	0.003	"	< 0.0015	< 0.0015	< 0.0015	0.0078	< 0.0015	0.016	0.029	< 0.0015	< 0.0015	< 0.0015	0.016	0.008	0.02	< 0.0015
Benzo(j)fluoranthene	0.003	"	< 0.0015	NR	NR	< 0.0015	< 0.0015	< 0.0015	0.018	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015
7,12-Dimethylb(a)anthrene	0.010	"	< 0.005	NR	NR	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Benzo(a)pyrene	0.003	"	< 0.0015	< 0.0015	< 0.0015	0.013	0.042	0.075	0.029	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	0.036	< 0.0015
3-Methylcholanthrene	0.010	"	< 0.005	NR	NR	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Dibenz(a,h)anthracene	0.003	"	< 0.0015	< 0.0015	< 0.0015	0.0042	< 0.0015	0.0067	0.0063	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015
Dibenzo(a,l)pyrene	0.010	"	< 0.005	NR	NR	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Dibenzo(a,i)pyrene	0.010	"	< 0.005	NR	NR	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Dibenzo(a,h)pyrene	0.010	"	< 0.005	NR	NR	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Indeno(1,2,3-c,d)pyrene	0.003	"	< 0.0015	< 0.0015	< 0.0015	0.01	0.0098	0.016	0.04	< 0.0015	0.009	< 0.0015	0.028	0.015	0.034	< 0.0015
Total high MW PAH's	**0.003**	**"**	**0.0116**	**1.168**	**0**	**0.19**	**0.2933**	**0.5797**	**0.7043**	**0.0714**	**0.1065**	**0.0066**	**0.37**	**0.18**	**0.448**	**0.72**
Total PAH's	**0.003**	**"**	**0.1263**	**7.174**	**0.66**	**2.4782**	**3.5323**	**5.3097**	**2.4913**	**1.158**	**1.6055**	**1.2144**	**1.97**	**0.952**	**1.45**	**4.359**
Surrogate Recovery																
Naphthlene d10		%	75	NR	NR	F	89	92	86	81	NR	NR	64	60	62	92
Acenaphthene d10		"	87	84	71	F	117	106	98	89	97	99	77	68	71	96
Phenanthrene d10		"	84	77	78	F	126	130	97	100	102	91	78	74	77	98
Chrysene d12		"	120	121	102	F	123	105	102	89	105	88	84	83	85	99
Perylene d12		"	126	90	90	F	102	89	92	92	97	106	88	88	86	82
Field Surrogate Recovery																
Benzo(ghi)perylene d12		%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene d12		"	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 8: Raw Lab Data for Burnaby Lake PAHs Rainfall Samples (Con’t)

Sampling Starting Date:			2-May	9-May	16-May	16-May	6-Jun	13-Jun	20-Jun	4-Jul	11-Jul	1-Aug	8-Aug	14-Aug	22-Aug	29-Aug
PAH	**MDC**	**Unit**														
Naphthalene	0.003	µg	3.08	4.11	2.51	2.29	1.3	2.39	2.04	3.94	2.47	2.45	4.38	1.6	2.59	2.17
Acenaphthylene	0.003	"	< 0.0015	< 0.0015	0.01	< 0.0015	0.021	0.013	0.005	0.01	0.027	0.026	0.009	0.036	0.009	< 0.0015
Acenaphthene	0.003	"	0.071	0.056	0.029	0.004	0.051	0.019	0.01	0.058	0.116	0.059	0.039	0.032	0.026	0.032
Fluorene	0.003	"	0.066	0.085	0.03	0.003	0.064	0.021	0.019	0.068	0.154	0.107	0.038	0.068	0.032	0.05
Phenanthrene	0.003	"	0.242	0.3	0.14	0.007	0.254	0.112	0.069	0.226	0.506	0.444	0.119	0.218	0.124	0.171
Anthracene	0.003	"	< 0.0015	< 0.0015	0.006	< 0.0015	0.009	0.007	< 0.0015	< 0.0015	0.018	0.034	0.006	0.01	0.013	0.013
Total low MW PAH's	**0.003**	**"**	**3.459**	**4.551**	**2.725**	**2.304**	**1.699**	**2.562**	**2.143**	**4.302**	**3.291**	**3.12**	**4.591**	**1.964**	**2.794**	**2.436**
Benzo(g,h,i)perylene	0.003	"	< 0.0015	0.016	< 0.0015	< 0.0015	< 0.0015	0.007	< 0.0015	< 0.0015	0.013	0.027	0.007	0.01	0.015	0.017
Fluoranthene	0.003	"	0.07	0.105	0.044	< 0.0015	0.075	0.037	0.026	0.059	0.123	0.143	0.028	0.057	0.143	0.067
Pyrene	0.003	"	0.049	0.073	0.027	< 0.0015	0.045	0.024	0.017	0.032	0.071	0.122	0.023	0.039	0.09	0.046
Benzo(c)phenanthrene	0.003	"	< 0.0015	< 0.0015	0.007	< 0.0015	0.009	0.006	< 0.0015	< 0.0015	< 0.0015	0.009	0.002	0.003	0.008	< 0.0015
Benz(a)anthracene	0.003	"	< 0.0015	0.015	0.01	< 0.0015	0.014	0.013	0.004	< 0.0015	0.019	0.038	0.007	0.01	0.021	0.016
Chrysene	0.003	"	< 0.0015	0.047	0.01	< 0.0015	0.027	0.017	0.007	< 0.0015	0.038	0.051	0.008	0.03	0.041	0.032
Benzo(b)fluoranthene	0.003	"	< 0.0015	0.046	< 0.0015	< 0.0015	0.034	0.026	< 0.0015	< 0.0015	0.018	0.042	0.01	0.031	0.02	0.029
Benzo(k)fluoranthene	0.003	"	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	0.019	0.003	0.008	< 0.0015	< 0.0015
Benzo(j)fluoranthene	0.003	"	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	0.004	< 0.0015	< 0.0015
7,12-Dimethylb(a)anthrene	0.010	"	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Benzo(a)pyrene	0.003	"	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	0.016	< 0.0015	< 0.0015	< 0.0015	< 0.0015
3-Methylcholanthrene	0.010	"	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Dibenz(a,h)anthracene	0.003	"	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	0.002	< 0.0015	< 0.0015
Dibenzo(a,l)pyrene	0.010	"	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Dibenzo(a,i)pyrene	0.010	"	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Dibenzo(a,h)pyrene	0.010	"	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Indeno(1,2,3-c,d)pyrene	0.003	"	< 0.0015	0.016	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	< 0.0015	0.008	0.017	0.002	0.008	< 0.0015	0.011
Total high MW PAH's	**0.003**	**"**	**0.119**	**0.318**	**0.098**	**0**	**0.204**	**0.13**	**0.054**	**0.091**	**0.29**	**0.484**	**0.09**	**0.202**	**0.338**	**0.218**
Total PAH's	**0.003**	**"**	**3.578**	**4.869**	**2.823**	**2.304**	**1.903**	**2.692**	**2.197**	**4.393**	**3.581**	**3.604**	**4.681**	**2.166**	**3.132**	**2.654**
Surrogate Recovery																
Naphthlene d10		%	99	115	61	56	62	60	59	96	63	71	76	63	92	91
Acenaphthene d10		"	101	103	66	62	67	66	77	97	88	90	78	78	99	89
Phenanthrene d10		"	102	105	69	64	71	71	89	94	96	95	85	88	99	92
Chrysene d12		"	106	107	65	79	76	75	90	102	109	110	100	105	100	108
Perylene d12		"	89	86	70	75	76	77	86	76	88	82	85	82	90	81
Field Surrogate Recovery																
Benzo(ghi)perylene d12		%	NA	NA	NA	NA	NA	NA	NA	NA	113	112	122	50	110	40
Fluoranthene d12		"	NA	NA	NA	NA	NA	NA	NA	NA	70	76	77	34	87	45

Table 8: Raw Lab Data for Burnaby Lake PAHs Rainfall Samples (Con't)

Sampling Starting Date:				**12-Sep**		**26-Sep**		**3-Oct**		**10-Oct**		**17-Oct**		**24-Oct**		**31-Oct**		**7-Nov**		**14-Nov**
PAH	**MDC**	**Unit**																		
Naphthalene	0.003	µg		1.26		1.64		2.1		2.38		1.93		2.54		2.48		2.63		2.13
Acenaphthylene	0.003	"		0.017		0.023		0.044		0.062		0.025		0.033		0.03		0.16		0.043
Acenaphthene	0.003	"		0.018		0.048		0.104		0.139		0.037		0.062		0.045		0.342		0.176
Fluorene	0.003	"		0.022		0.062		0.15		0.169		0.043		0.104		0.066		0.402		0.159
Phenanthrene	0.003	"		0.068		0.198		0.466		0.443		0.125		0.331		0.164		0.967		0.347
Anthracene	0.003	"	<	0.0015		0.009		0.024		0.021		0.008		0.035		0.009		0.038		0.02
Total low MW PAH's	**0.003**	**"**		**1.385**		**1.98**		**2.888**		**3.214**		**2.168**		**3.105**		**2.794**		**4.539**		**2.875**
Benzo(g,h,i)perylene	0.003	"	<	0.0015	<	0.0015		0.027		0.034		0.012	<	0.0015	<	0.0015	<	0.0015		0.029
Fluoranthene	0.003	"		0.026		0.061		0.186		0.165		0.053		0.17		0.066		0.344		0.128
Pyrene	0.003	"		0.016		0.04		0.119		0.111		0.038		0.13		0.053		0.252		0.096
Benzo(c)phenanthrene	0.003	"	<	0.0015	<	0.0015		0.013		0.011		0.004	<	0.0015	<	0.0015		0.019		0.006
Benz(a)anthracene	0.003	"		0.006		0.01		0.032		0.023		0.009		0.04		0.013		0.03		0.018
Chrysene	0.003	"		0.009		0.022		0.099		0.097		0.025		0.135		0.035		0.108		0.052
Benzo(b)fluoranthene	0.003	"	<	0.0015		0.016		0.092		0.091		0.03		0.124		0.031		0.091		0.051
Benzo(k)fluoranthene	0.003	"	<	0.0015	<	0.0015		0.028		0.023		0.008		0.027	<	0.0015		0.028		0.014
Benzo(j)fluoranthene	0.003	"	<	0.0015	<	0.0015	<	0.0015	<	0.0015	<	0.0015	<	0.0015	<	0.0015	<	0.0015	<	0.0015
7,12-Dimethylb(a)anthrene	0.010	"	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005
Benzo(a)pyrene	0.003	"	<	0.0015	<	0.0015	<	0.0015	<	0.0015	<	0.0015		0.031	<	0.0015		0.022		0.017
3-Methylcholanthrene	0.010	"	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005
Dibenz(a,h)anthracene	0.003	"	<	0.0015	<	0.0015	<	0.0015	<	0.0015	<	0.0015	<	0.0015	<	0.0015	<	0.0015	<	0.0015
Dibenzo(a,l)pyrene	0.010	"	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005
Dibenzo(a,i)pyrene	0.010	"	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005
Dibenzo(a,h)pyrene	0.010	"	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005	<	0.005
Indeno(1,2,3-c,d)pyrene	0.003	"	<	0.0015	<	0.0015		0.03		0.026		0.012	<	0.0015	<	0.0015	<	0.0015		0.019
Total high MW PAH's	**0.003**	**"**		**0.057**		**0.149**		**0.626**		**0.581**		**0.191**		**0.657**		**0.198**		**0.894**		**0.43**
Total PAH's	**0.003**	**"**		**1.442**		**2.129**		**3.514**		**3.795**		**2.359**		**3.762**		**2.992**		**5.433**		**3.305**
Surrogate Recovery																				
Naphthlene d10		%		71		71		78		82		67		78		72		82		81
Acenaphthene d10		"		79		72		78		81		75		94		92		90		94
Phenanthrene d10		"		89		78		90		92		88		102		100		101		104
Chrysene d12		"		106		95		114		118		111		130		130		125		100
Perylene d12		"		86		72		81		80		79		80		80		78		93
Field Surrogate Recovery																				
Benzo(ghi)perylene d12		%		49		60		54		59		67		53		44		66		81
Fluoranthene d12		"		71		78		74		82		90		96		93		93		82

Table 9: Rainfall and Calculated Volume of Rain Passed through Organic Sampler for Period of January 31, 1995 to November 21, 1995

Area of organic sampler(m2)=		0.2116				
START DATE	**RAIN GA (mm)**	**Volume Spl (L)**		**START DATE**	**RAIN GA (mm)**	**Volume Spl (L)**
31-Jan	31.8	6.73		11-Jul	43.2	9.13
7-Feb	10.0	2.12		1-Aug	46.0	9.73
14-Feb	140.0	29.62		8-Aug	10.6	2.24
21-Feb	17.0	3.60		14-Aug	39.0	8.25
28-Feb	14.2	3.00		22-Aug	7.3	1.54
7-Mar	68.2	14.43		29-Aug	12.2	2.58
14-Mar	50	10.58		12-Sep	4.6	0.97
21-Mar	14.0	2.96		26-Sep	29.4	6.22
28-Mar	7.8	1.65		3-Oct	78.0	16.50
4-Apr	33.0	6.98		10-Oct	74.0	15.66
11-Apr	21.4	4.53		17-Oct	20.0	4.23
18-Apr	2.1	0.44		24-Oct	35.0	7.41
25-Apr	5.6	1.18		31-Oct	26.2	5.54
2-May	8.8	1.86		7-Nov	140.0	29.62
9-May	24.7	5.23		14-Nov	32.4	6.86
16-May	0.4	0.08				
30-May	7.8	1.65				
6-Jun	27.0	5.71				
13-Jun	8.3	1.76				
20-Jun	2.6	0.55				
4-Jul	17.6	3.72				

Table 10: Calculated PAH Rainfall Concentrations for Burnaby Lake Study (µg/L)

PAH Rain Concentrations
(µg / L)

Sample Starting Date	**31-Jan**	**7-Feb**	**21-Feb**	**28-Feb**	**7-Mar**	**14-Mar**	**21-Mar**	**28-Mar**	**4-Apr**	**11-Apr**	**18-Apr**	**25-Apr**
Naphthalene	-	0.0730	0.1436	0.5048	0.1259	-	-	-	-	-	-	1.5078
Acenaphthylene	0.0013	0.0054	0.0183	0.0087	0.0083	0.0044	-	0.0097	0.0067	0.0027	0.0900	-
Acenaphthene	0.0009	0.0166	0.0170	0.0143	0.0261	0.0119	0.0002	0.0182	0.0089	0.0002	0.0630	0.0152
Fluorene	0.0010	0.0144	0.0181	0.0176	0.0213	0.0148	0.0027	0.0218	0.0102	0.0018	0.1103	0.0245
Phenanthrene	0.0031	0.0344	0.0480	0.0641	0.0473	0.0466	0.0215	0.0622	0.0353	0.0154	0.3434	0.3313
Anthracene	-	0.0014	0.0017	0.0033	0.0021	-	-	-	0.0020	0.0015	0.0180	0.0143
Total low MW PAH's	**0.0170**	**0.1892**	**0.6353**	**1.0780**	**0.3278**	**0.1689**	**0.3668**	**0.9082**	**0.2299**	**0.1705**	**2.2549**	**3.0727**
Benzo(g,h,i)perylene	-	-	0.0031	0.0032	0.0017	0.0030	-	-	0.0039	0.0035	0.0743	-
Fluoranthene	0.0010	0.0123	0.0167	0.0286	0.0132	0.0198	0.0101	0.0218	0.0149	0.0095	0.1935	0.3038
Pyrene	0.0002	0.0084	0.0112	0.0167	0.0074	0.0119	0.0069	0.0123	0.0094	0.0056	0.1357	0.1741
Benzo(c)phenanthrene	-	-	0.0009	-	0.0009	-	-	-	-	-	-	0.0143
Benz(a)anthracene	-	0.0018	0.0019	0.0067	0.0013	0.0021	0.0022	0.0045	0.0027	0.0035	0.0585	0.0186
Chrysene	-	0.0072	0.0050	0.0120	0.0030	0.0086	0.0037	0.0103	0.0070	0.0057	0.1463	0.0557
Benzo(b)fluoranthene	-	0.0069	0.0042	0.0120	0.0045	0.0092	-	0.0079	0.0080	0.0060	0.1890	0.0363
Benzo(k)fluoranthene	-	-	0.0022	-	0.0011	0.0027	-	-	0.0023	0.0018	0.0450	-
Benzo(j)fluoranthene	-	-	-	-	-	0.0017	-	-	-	-	-	-
Benzo(a)pyrene	-	-	0.0036	0.0140	0.0052	0.0027	-	-	-	-	0.0810	-
Dibenz(a,h)anthracene	-	-	0.0012	-	0.0005	0.0006	-	-	-	-	-	-
Indeno(1,2,3-c,d)pyrene	-	-	0.0028	0.0033	0.0011	0.0038	-	0.0055	0.0040	0.0033	0.0765	-
Total high MW PAH's	**0.0017**	**0.0368**	**0.0537**	**0.0976**	**0.0402**	**0.0666**	**0.0241**	**0.0645**	**0.0527**	**0.0398**	**1.0082**	**0.6059**
Total PAH's	**0.0188**	**0.2260**	**0.6889**	**1.1756**	**0.3679**	**0.2355**	**0.3909**	**0.9727**	**0.2826**	**0.2102**	**3.2631**	**3.6786**

'-' denotes a value below the limit of detection

Table 10: Calculated PAH Rainfall Concentrations for Burnaby Lake Study (µg/L) (Con't)

(µg / L)

Sample Starting Date	**2-May**	**9-May**	**16-May**	**6-Jun**	**13-Jun**	**20-Jun**	**4-Jul**	**11-Jul**	**1-Aug**	**8-Aug**	**14-Aug**	**22-Aug**
Naphthalene	0.9112	0.5217	0.6493	-	0.5732	1.1937	0.6865	0.1190	0.1096	1.3360	0.0263	0.7812
Acenaphthylene	-	-	0.0058	0.0037	0.0074	0.0091	0.0027	0.0030	0.0027	0.0040	0.0044	0.0058
Acenaphthene	0.0360	0.0099	0.0144	0.0082	0.0085	0.0109	0.0145	0.0123	0.0057	0.0156	0.0034	0.0142
Fluorene	0.0338	0.0157	0.0156	0.0107	0.0102	0.0291	0.0175	0.0165	0.0107	0.0156	0.0079	0.0188
Phenanthrene	0.1260	0.0560	0.0764	0.0432	0.0596	0.1120	0.0587	0.0546	0.0449	0.0498	0.0255	0.0755
Anthracene	-	-	0.0035	0.0016	0.0040	-	-	0.0020	0.0035	0.0027	0.0012	0.0084
Total low MW PAH's	**1.8576**	**0.8708**	**1.5705**	**0.2974**	**1.4588**	**3.8952**	**1.1552**	**0.3604**	**0.3205**	**2.0468**	**0.2380**	**1.8088**
Benzo(g,h,i)perylene	-	0.0031	-	-	0.0040	-	-	0.0014	0.0028	0.0031	0.0012	0.0097
Fluoranthene	0.0376	0.0201	0.0254	0.0131	0.0211	0.0473	0.0158	0.0135	0.0147	0.0125	0.0069	0.0926
Pyrene	0.0243	0.0133	0.0134	0.0072	0.0116	0.0242	0.0076	0.0074	0.0122	0.0086	0.0043	0.0559
Benzo(c)phenanthrene	-	-	0.0040	0.0016	0.0034	-	-	-	0.0009	0.0009	0.0004	0.0052
Benz(a)anthracene	0.0008	0.0029	0.0058	0.0025	0.0074	0.0073	0.0004	0.0021	0.0039	0.0031	0.0012	0.0136
Chrysene	0.0008	0.0090	0.0058	0.0047	0.0097	0.0127	0.0004	0.0042	0.0052	0.0036	0.0036	0.0265
Benzo(b)fluoranthene	-	0.0088	0.0009	0.0060	0.0148	-	-	0.0020	0.0043	0.0045	0.0038	0.0129
Benzo(k)fluoranthene	-	-	-	-	-	-	-	-	0.0020	0.0013	0.0010	-
Benzo(j)fluoranthene	-	-	-	-	-	-	-	-	-	-	0.0005	-
Benzo(a)pyrene	-	-	-	-	-	-	-	-	0.0016	-	-	-
Dibenz(a,h)anthracene	-	-	-	-	-	-	-	-	-	-	0.0002	-
Indeno(1,2,3-c,d)pyrene	-	0.0031	-	-	-	-	-	0.0009	0.0017	0.0009	0.0010	0.0010
Total high MW PAH's	**0.0655**	**0.0608**	**0.0573**	**0.0357**	**0.0740**	**0.0982**	**0.0252**	**0.0318**	**0.0497**	**0.0401**	**0.0245**	**0.2198**
Total PAH's	**1.9231**	**0.9316**	**1.6278**	**0.3331**	**1.5328**	**3.9934**	**1.1804**	**0.3922**	**0.3703**	**2.0870**	**0.2625**	**2.0286**

'-' denotes a value below the limit of detection

PAHRAIN CONCENTRATIONS

Table 10: Calculated PAH Rainfall Concentrations for Burnaby Lake Study (µg/L) (Con't)

Sample Starting Date	**29-Aug**	**12-Sep**	**26-Sep**	**3-Oct**	**10-Oct**	**17-Oct**	**24-Oct**	**31-Oct**	**7-Nov**	**14-Nov**
Naphthalene	0.3047	-	0.0413	0.0434	0.0637	0.1292	0.1562	0.1978	0.0421	0.1089
Acenaphthylene	0.0006	0.0175	0.0037	0.0027	0.0040	0.0059	0.0045	0.0054	0.0054	0.0063
Acenaphthene	0.0108	0.0144	0.0071	0.0061	0.0086	0.0078	0.0078	0.0074	0.0114	0.0251
Fluorene	0.0182	0.0195	0.0095	0.0089	0.0106	0.0095	0.0136	0.0114	0.0135	0.0228
Phenanthrene	0.0634	0.0623	0.0306	0.0278	0.0278	0.0278	0.0437	0.0282	0.0324	0.0495
Anthracene	0.0050	0.0015	0.0014	0.0015	0.0013	0.0019	0.0047	0.0016	0.0013	0.0029
Total low MW PAH's	**0.9442**	**1.4244**	**0.3183**	**0.1750**	**0.2053**	**0.5123**	**0.4193**	**0.5040**	**0.1532**	**0.4194**
Benzo(g,h,i)perylene	0.0066	-	-	0.0016	0.0022	0.0028	-	-	-	0.0042
Fluoranthene	0.0260	0.0267	0.0098	0.0113	0.0105	0.0125	0.0230	0.0119	0.0116	0.0187
Pyrene	0.0164	0.0126	0.0058	0.0070	0.0069	0.0081	0.0171	0.0089	0.0084	0.0135
Benzo(c)phenanthrene	-	-	-	0.0008	0.0007	0.0009	-	-	0.0006	0.0009
Benz(a)anthracene	0.0062	0.0062	0.0016	0.0019	0.0015	0.0021	0.0054	0.0023	0.0010	0.0026
Chrysene	0.0124	0.0092	0.0035	0.0060	0.0062	0.0059	0.0182	0.0063	0.0036	0.0076
Benzo(b)fluoranthene	0.0112	0.0015	0.0026	0.0056	0.0058	0.0071	0.0167	0.0056	0.0031	0.0074
Benzo(k)fluoranthene	-	-	-	0.0017	0.0015	0.0019	0.0036	-	0.0009	0.0020
Benzo(j)fluoranthene	-	-	-	-	-	-	-	-	-	-
Benzo(a)pyrene	-	-	-	-	-	-	0.0042	-	0.0007	0.0025
Dibenz(a,h)anthracene	-	-	-	-	-	-	-	-	-	-
Indeno(1,2,3-c,d)pyrene	0.0043	-	-	0.0018	0.0017	0.0028	-	-	-	0.0028
Total high MW PAH's	**0.0844**	**0.0601**	**0.0240**	**0.0379**	**0.0371**	**0.0451**	**0.0887**	**0.0357**	**0.0302**	**0.0627**
Total PAH's	**1.0287**	**1.4845**	**0.3422**	**0.2129**	**0.2424**	**0.5574**	**0.5080**	**0.5397**	**0.1834**	**0.4821**

'-' denotes a value below the limit of detection

Table 11: Calculated PAH Rainfall Deposition Rates for Burnaby Lake Study (µg/m^2/d)

PAH Rain Deposition Rates																	
µg/m2/d																	
Start Sampling Date:	**31-Jan**	**7-Feb**	**21-Feb**	**28-Feb**	**7-Mar**	**14-Mar**	**21-Mar**	**28-Mar**	**4-Apr**	**11-Apr**	**18-Apr**	**25-Apr**	**2-May**	**9-May**	**16-May**	**6-Jun**	**13-Jun**
Naphthalene	-	0.782	0.349	1.02	1.23	-	-	-	-	-	-	1.21	1.15	1.84	0.254	-	0.680
Acenaphthylene	0.0059	0.0574	0.0446	0.0176	0.0810	0.0317	-	0.0108	0.0317	0.0081	0.0270	-	-	-	0.0023	0.0142	0.0088
Acenaphthene	0.0040	0.1776	0.0412	0.0290	0.254	0.0851	0.0004	0.0203	0.0419	0.0007	0.0189	0.0122	0.0452	0.0351	0.0056	0.0317	0.0101
Fluorene	0.0047	0.154	0.0439	0.0358	0.207	0.106	0.0054	0.0243	0.0479	0.0054	0.0331	0.0196	0.0425	0.0554	0.0061	0.0412	0.0122
Phenanthrene	0.0139	0.369	0.117	0.130	0.461	0.333	0.0429	0.0693	0.166	0.0470	0.103	0.265	0.158	0.198	0.0298	0.166	0.0706
Anthracene	-	0.0155	0.0042	0.0068	0.0203	-	-	-	0.0095	0.0047	0.0054	0.0115	-	-	0.0014	0.0061	0.0047
Total low MW PAH's	**0.0286**	**1.56**	**0.599**	**1.24**	**2.25**	**0.555**	**0.0487**	**0.125**	**0.297**	**0.0659**	**0.187**	**1.51**	**1.39**	**2.13**	**0.299**	**0.260**	**0.786**
Benzo(g,h,i)perylene	-	-	0.0074	0.0064	0.0169	0.0216	-	-	0.0182	0.0108	0.0223	-	-	0.0108	-	-	0.0047
Fluoranthene	0.0045	0.132	0.0405	0.0581	0.128	0.142	0.0203	0.0243	0.0702	0.0290	0.0581	0.243	0.0473	0.0709	0.0099	0.0506	0.0250
Pyrene	0.0009	0.0899	0.0272	0.0340	0.0718	0.0853	0.0137	0.0137	0.0441	0.0171	0.0407	0.139	0.0306	0.0468	0.0052	0.0279	0.0137
Benzo(c)phenanthrene	-	-	0.0022	-	0.0088	-	-	-	-	-	-	0.0115	-	-	0.0016	0.0061	0.0041
Benz(a)anthracene	-	0.0196	0.0045	0.0135	0.0128	0.0149	0.0043	0.0051	0.0128	0.0108	0.0176	0.0149	0.0010	0.0101	0.0023	0.0095	0.0088
Chrysene	-	0.0776	0.0122	0.0243	0.0297	0.0614	0.0074	0.0115	0.0331	0.0176	0.0439	0.0446	0.0010	0.0317	0.0023	0.0182	0.0115
Benzo(b)fluoranthene	-	0.0743	0.0101	0.0243	0.0439	0.0655	-	0.0088	0.0378	0.0182	0.0567	0.0290	-	0.0311	0.0003	0.0230	0.0176
Benzo(k)fluoranthene	-	-	0.0053	-	0.0108	0.0196	-	-	0.0108	0.0054	0.0135	-	-	-	-	-	-
Benzo(j)fluoranthene	-	-	-	-	-	0.0122	-	-	-	-	-	-	-	-	-	-	-
Benzo(a)pyrene	-	-	0.0088	0.0284	0.0506	0.0196	-	-	-	-	0.0243	-	-	-	-	-	-
Dibenz(a,h)anthracene	-	-	0.0028	-	0.0045	0.0043	-	-	-	-	-	-	-	-	-	-	-
Indeno(1,2,3-c,d)pyrene	-	-	0.0068	0.0066	0.0108	0.0270	-	0.0061	0.0189	0.0101	0.0230	-	-	0.0108	-	-	-
Total high MW PAH's	**0.0053**	**0.393**	**0.128**	**0.196**	**0.389**	**0.473**	**0.0457**	**0.0694**	**0.246**	**0.119**	**0.300**	**0.482**	**0.0799**	**0.2122**	**0.0216**	**0.135**	**0.0853**
Total PAH's	**0.0339**	**1.95**	**0.727**	**1.44**	**2.64**	**1.03**	**0.0945**	**0.194**	**0.543**	**0.185**	**0.487**	**2.00**	**1.47**	**2.34**	**0.320**	**0.395**	**0.871**
'-' denotes a value below the limit of detection																	

Table 11: Calculated PAH Rainfall Concentrations for Burnaby Lake Study (µg/L) (Con't)

Start Sampling Date:	**20-Jun**	**4-Jul**	**11-Jul**	**1-Aug**	**8-Aug**	**14-Aug**	**22-Aug**	**29-Aug**	**12-Sep**	**26-Sep**	**3-Oct**	**10-Oct**	**17-Oct**	**24-Oct**	**31-Oct**	**7-Nov**	**14-Nov**
Naphthalene	0.222	1.73	0.245	0.720	2.360	0.128	0.815	0.266	-	0.173	0.484	0.673	0.369	0.781	0.740	0.842	0.504
Acenaphthylene	0.0017	0.0068	0.0061	0.0176	0.0071	0.0213	0.0061	0.0005	0.0057	0.0155	0.0297	0.0419	0.0169	0.0223	0.0203	0.1080	0.0290
Acenaphthene	0.0020	0.0365	0.0252	0.0371	0.0276	0.0165	0.0149	0.0095	0.0047	0.0297	0.0675	0.0911	0.0223	0.0392	0.0277	0.228	0.116
Fluorene	0.0054	0.0439	0.0340	0.0702	0.0276	0.0384	0.0196	0.0159	0.0064	0.0398	0.0992	0.112	0.0270	0.0682	0.0425	0.269	0.105
Phenanthrene	0.0208	0.148	0.112	0.295	0.0879	0.124	0.0787	0.0552	0.0205	0.129	0.310	0.294	0.0794	0.218	0.106	0.648	0.229
Anthracene	-	-	0.0041	0.0230	0.0047	0.0059	0.0088	0.0044	0.0005	0.0061	0.0162	0.0142	0.0054	0.0236	0.0061	0.0257	0.0135
Total low MW PAH's	**0.252**	**1.96**	**0.426**	**1.16**	**2.52**	**0.335**	**0.943**	**0.351**	**0.0378**	**0.393**	**1.01**	**1.23**	**0.520**	**1.15**	**0.943**	**2.12**	**0.997**
Benzo(g,h,i)perylene	-	-	0.0029	0.0182	0.0055	0.0059	0.0101	0.0057	-	-	0.0182	0.0230	0.0081	-	-	-	0.0196
Fluoranthene	0.0088	0.0398	0.0277	0.0965	0.0221	0.0337	0.0965	0.0226	0.0088	0.0412	0.126	0.111	0.0358	0.115	0.0446	0.232	0.0864
Pyrene	0.0045	0.0191	0.0151	0.0799	0.0152	0.0209	0.0583	0.0143	0.0042	0.0245	0.0778	0.0724	0.0232	0.0853	0.0333	0.168	0.0623
Benzo(c)phenanthrene	-	-	-	0.0061	0.0016	0.0018	0.0054	-	-	-	0.0088	0.0074	0.0027	-	-	0.0128	0.0041
Benz(a)anthracene	0.0014	0.0010	0.0043	0.0257	0.0055	0.0059	0.0142	0.0054	0.0020	0.0068	0.0216	0.0155	0.0061	0.0270	0.0088	0.0203	0.0122
Chrysene	0.0024	0.0010	0.0086	0.0344	0.0063	0.0177	0.0277	0.0108	0.0030	0.0149	0.0668	0.0655	0.0169	0.0911	0.0236	0.0729	0.0351
Benzo(b)fluoranthene	-	-	0.0041	0.0284	0.0079	0.0183	0.0135	0.0098	0.0005	0.0108	0.0621	0.0614	0.0203	0.0837	0.0209	0.0614	0.0344
Benzo(k)fluoranthene	-	-	-	0.0128	0.0024	0.0047	-	-	-	-	0.0189	0.0155	0.0054	0.0182	-	0.0189	0.0095
Benzo(j)fluoranthene	-	-	-	-	-	0.0024	-	-	-	-	-	-	-	-	-	-	-
Benzo(a)pyrene	-	-	-	0.0108	-	-	-	-	-	-	-	-	-	0.0209	-	0.0149	0.0115
Dibenz(a,h)anthracene	-	-	-	-	-	0.0012	-	-	-	-	-	-	-	-	-	-	-
Indeno(1,2,3-c,d)pyrene	-	-	0.0018	0.0115	0.0016	0.0047	0.0010	0.0037	-	-	0.0203	0.0176	0.0081	-	-	-	0.0128
Total high MW PAH's	**0.0170**	**0.0610**	**0.0644**	**0.324**	**0.0680**	**0.117**	**0.227**	**0.0723**	**0.0185**	**0.0981**	**0.420**	**0.390**	**0.126**	**0.441**	**0.131**	**0.601**	**0.288**
Total PAH's	**0.269**	**2.02**	**0.491**	**1.49**	**2.58**	**0.452**	**1.17**	**0.423**	**0.0563**	**0.491**	**1.43**	**1.62**	**0.647**	**1.59**	**1.07**	**2.72**	**1.29**
'-' denotes a value below the limit of detection																	

Table 12: Summary of Metals found in Rainfall in the Burnaby Lake Study (mg/L)

METALS-RAIN CONCENTRATIONS

	Concentrations (mg/L)		
	Average	**Maximum**	**Minimum**
Silver	0.000012	0.0002	-
Aluminum	0.015	0.12	-
Arsenic	0.0008	0.0101	-
Boron	0.0033	0.05	-
Barium	0.000788	0.004	-
Calcium	0.247	1.41	-
Cadmium	0.000382	0.0027	-
Chromium	0.000515	0.014	-
Copper	0.00103	0.009	-
Iron	0.0216	0.13	-
Mercury	0.000001	0.00002	-
Magnesium	0.0524	0.26	-
Manganese	0.00188	0.027	-
Sodium	0.338	2.65	-
Nickel	0.000606	0.02	-
Lead	0.000506	0.0063	-
Sulphur	0.656	3.02	0.1
Selenium	0.000345	0.0073	-
Silicon	0.0352	0.32	-
Strontium	0.00133	0.026	-
Titanium	0.000485	0.004	-
Zinc	0.0152	0.10	-

'-' denotes a value below the limit of detection

Table 13: Summary of Deposition Rates of Metals found in Rainfall in the Burnaby Lake Study (mg/m^2/d)

Metals - Rain Deposition Rates

	Deposition Rates (mg/m2/d)		
	Average	**Maximum**	**Minimum**
Silver	0.00004	0.00077	-
Aluminum	0.017	0.19	-
Arsenic	0.0021	0.022	-
Boron	0.0014	0.02	-
Barium	0.0016	0.02	-
Calcium	0.61	4.4	-
Cadmium	0.00139	0.0180	-
Chromium	0.00892	0.266	-
Copper	0.00663	0.180	-
Iron	0.0733	1.52	-
Mercury	0.00001	0.00019	-
Magnesium	0.179	1.00	-
Manganese	0.00168	0.0126	-
Sodium	0.867	8.49	-
Nickel	0.012	0.38	-
Lead	0.00058	0.00795	-
Sulphur	2.31	14.7	0.093
Selenium	0.00150	0.0307	-
Silicon	0.0517	1.08	-
Strontium	0.00118	0.00943	-
Titanium	0.00036	0.00377	-
Zinc	0.0682	0.40	-

'-' denotes a value below the limit of detection

Table 14: Standards for Deposition Rates of Metals as proposed by R.M. Hoff

Sample Period - starting Jan. 31/95 - ending Dec. 5/95			
	Deposition Rates (mg/m2/yr)		
	Average	Maximum	Minimum
Silver	0.014	0.282	-
Aluminum	6.26	70.5	-
Arsenic	0.780	8.03	-
Boron	0.498	7.13	-
Barium	0.590	7.30	-
Calcium	223	1606	-
Cadmium	0.507	6.57	-
Chromium	3.25	97.1	-
Copper	2.42	65.7	-
Iron	26.8	555	-
Mercury	0.002	0.071	-
Magnesium	65.5	365	-
Manganese	0.613	4.60	-
Sodium	317	3097	-
Nickel	4.20	139	-
Lead	0.211	2.90	-
Sulphur	842	5374	33.9
Selenium	0.547	11.2	-
Silicon	18.9	396	-
Strontium	0.432	3.44	-
Titanium	0.132	1.38	-
Zinc	24.9	146	-
'-' denotes a value below the limit of detection			
Metals of Interest: those which exceed ± 100 µg/m2/yr			
Flux of interest for Mercury: ± 10 µg/m2/yr			
- R. M. Hoff, 1996			

Table 15: Summary of Deposition Rates of Metals found in Rainfall in the Burnaby Lake Study

Metals - Rain Deposition Rates			
	Deposition Rates (kg/ha/yr)		
	Average	**Maximum**	**Minimum**
Silver	0.00014	0.00282	-
Aluminum	0.0626	0.705	-
Arsenic	0.00780	0.0803	-
Boron	0.00498	0.0713	-
Barium	0.00590	0.0730	-
Calcium	2.23	16.1	-
Cadmium	0.00507	0.0657	-
Chromium	0.0325	0.971	-
Copper	0.0242	0.657	-
Iron	0.268	5.55	-
Mercury	0.00002	0.00071	-
Magnesium	0.655	3.65	-
Manganese	0.00613	0.0460	-
Sodium	3.17	31.0	-
Nickel	0.0420	1.39	-
Lead	0.00211	0.0290	-
Sulphur	8.42	53.7	0.339
Selenium	0.00547	0.112	-
Silicon	0.189	3.96	-
Strontium	0.00432	0.0344	-
Titanium	0.00132	0.0138	-
Zinc	0.249	1.46	-
'-' denotes a value below the limit of detection			

Table 16: Standards for Concentrations of Metals

Metals - concentrations (μg/L)							
				Health Canada		**B.C. Water Quality**	
		Burnaby Lake					
	max	**min**	**avg**	**Drinking Water**	**Freshwater Aquatic Life**	**Drinking Water**	**Freshwater Aquatic Life**
Silver	0.2	-	0.01	N/A	0.10	N/A	0.1
Aluminum	120	-	15.42	N/A	5.0-100	200	20-100
Arsenic	10.1	-	0.78	25	50	50	50
Boron	50	-	3.30	5000	N/A	5000	N/A
Barium	4	-	0.79	1000	N/A	1000	5000
Calcium	1410	-	246.97	N/A	0.06	N/A	4000-8000
Cadmium	2.7	-	0.38	5.0	0.2-1.8	5	2-1.8
Chromium	14	-	0.52	50	2.0-20	50	2-20
Copper	9	-	1.03	< 1000	2.0-4.0	500	eqn
Iron	130	-	21.58	< 300	300	300	300
Mercury	0.02	-	0.0006	1.0	0.1	N/A	N/A
Magnesium	260	-	52.42	N/A	N/A	100000-500000	N/A
Manganese	27	-	1.88	< 50	N/A	50	100-1000
Sodium	2650	-	338.18	< 200000	N/A	N/A	N/A
Nickel	20	-	0.61	N/A	25-150	200-250	25-150
Lead	6.3	-	0.51	10	1.0-7.0	50	3-330
Sulphur	3020	100	656.36	N/A	N/A	N/A	N/A
Selenium	7.3	-	0.35	10	1.0	10	1
Silicon	320	-	35.15	N/A	N/A	N/A	N/A
Strontium	26	-	1.33	N/A	N/A	N/A	N/A
Titanium	4	-	0.48	N/A	N/A	100	100
Zinc	100	-	15.21	< 5000	30	5000	30

'-' denotes a zero

Table 17: Comparison of Rainfall Metals Results from Burnaby Lake Study to other similar studies

Metals Concentrations (µg/L)	**Burnaby Lake**	**Villeroy ***	**Switzerland ****	**Southern Sweden annual (vol.wtd mean)**	**Northern Sweden annual (vol.wtd mean)**	**SE U.S. annual (vol.wtd mean)**	**SW Ontario annual (vol.wtd mean)**	**Sudbury Ontario annual (vol.wtd mean)**	**Dorset Ontario fall (vol.wtd mean)**	**Lewes Delaware annual (vol.wtd mean)**	**Enewetak pacific (vol.wtd mean)**	**N Pacific air (vol.wtd mean)**	**Remoteness Bermuda (mean) (vol.wtd mean)**	**Bermuda (mean) (vol.wtd mean)**	**NW Ontario (vol.wtd mean)**	**Northern Sweden (vol.wtd mean)**
Silver	0.01	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Aluminum	15.42	~	-	~	~	~	~	~	~	~	~	~	~	~	~	~
Arsenic	0.78	~	~	~	~	~	~	~	0.23	~	~	~	~	~	~	~
Boron	3.30	~	5.60	~	~	~	~	~	~	~	~	~	~	~	~	~
Barium	0.79	~	6.80	~	~	~	~	~	~	~	~	~	~	~	~	~
Calcium	246.97	188.20	810	~	~	~	~	~	~	~	~	~	~	~	~	~
Cadmium	0.38	0.28	~	0.14	0.07	0.04-0.25	0.16	0.1-0.7	<0.02	0.18	0.002	0.01	0.06	0.06	0.09	0.093
Chromium	0.52	~	0.30	~	~	~	~	0.2-0.9	<1.00	~	~	~	~	~	~	~
Copper	1.03	0.88	2.75	1.40	1.50	~	1.4	1-24	1.30	0.68	0.01	0.14	0.32	0.66	1.30	1.83
Iron	21.58	~	8.04	~	~	~	~	~	~	~	~	~	~	~	~	~
Mercury	0.0006	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Magnesium	52.42	39.20	50	~	~	~	~	~	~	~	~	~	~	~	~	~
Manganese	1.88	~	5.63	6.80	4.20	1.3-3.2	4.7	~	2.40	1.40	0.01	0.49	0.22	0.27	2.70	5.4
Sodium	338.18	~	220	~	~	~	~	~	~	~	~	~	~	~	~	~
Nickel	0.61	~	0.34	~	~	~	0.9	0.5-17	~	0.79	~	~	0.17	~	0.70	~
Lead	0.51	2.24	2.17	8.80	3.40	3.2-5.6	7.0	4-14	15.00	3.00	<0.04	0.15	0.72	0.77	2.30	2.39
Sulphur	656.36	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Selenium	0.35	0.35	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Silicon	35.15	~	360	~	~	~	~	~	~	~	~	~	~	~	~	~
Strontium	1.33	~	2.45	~	~	~	~	~	~	~	~	~	~	~	~	~
Titanium	0.48	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
Zinc	15.21	8.08	22.30	16	10	4.9-10.3	9.0	4-50	4.7	6.4	0.05	0.99	1.53	1.15	4.0	12.4

'-' denotes a zero
~ = Not sampled for

Notes:
Burnaby Data: Our study
* Poissant, Koprivnjak, and Harvey, 1992
** Atteia, 1994
The rest is taken from Barrie et al, 1986

Table 18: Toxicity Equivalent Factors of PAHs

PAH Toxicity Factors				
			Relative Potencies of PAHs ^	
PAH	**TEF ***	**RCPF****	**Carcinogenicity**	**Mutagenicity**
Benzo(a)anthracene	0.1	~	0.145	0.62
Benzo(a)pyrene	**1.0**	**1.0**	**1.0**	**1.0**
Benzo(b)fluoranthene	0.1	0.06	0.141	0.20
Benzo(j)fluoranthene	~	0.05	0.061	~
Benzo(k)fluoranthene	0.1	0.04	0.066	~
Benzo(ghi)perylene	~	~	0.022	0.08
Chrysene	~	~	0.0044	0.37
Dibenzo(a,h)anthracene	1.1	N/A	1.11	0.47
Indeno(1,2,3-c,d)pyrene	0.2	0.12	0.232	0.14
Pyrene	~	~	0.081	0.20
* TEF = Toxicity Equivalent Factors, B.C. Waste Management Act, 1992				
** RCPF = Relative Carcinogenic Potency Factors, PSL, 1994				
^ from Collins et al, 1991				
~ = not found				

Table 19: Summary of Concentrations of PAHs found in Rainfall in the Burnaby Lake Study (µg/L)

Sample period - starting Jan. 31/95 - ending Nov. 14/95			
	Concentrations (µg/L)		
PAH's	**Average**	**Maximum**	**Minimum**
Naphthalene	0.329	1.508	-
Acenaphthylene	0.00779	0.0900	-
Acenaphthene	0.0145	0.0630	0.00020
Fluorene	0.0188	0.110	0.00104
Phenanthrene	0.0731	0.343	0.00306
Anthracene	0.00292	0.01800	-
Total low MW PAH's	**0.993**	**3.90**	**0.0170**
Benzo(g,h,i)perylene	0.00401	0.0743	-
Fluoranthene	0.0348	0.304	0.00098
Pyrene	0.0207	0.174	0.00019
Benzo(c)phenanthrene	0.00108	0.0143	-
Benz(a)anthracene	0.00557	0.0585	-
Chrysene	0.0129	0.146	-
Benzo(b)fluoranthene	0.0123	0.189	-
Benzo(k)fluoranthene	0.00209	0.0450	-
Benzo(j)fluoranthene	0.00007	0.00170	-
Benzo(a)pyrene	0.00339	0.0810	-
Dibenz(a,h)anthracene	0.00004	0.00060	-
Indeno(1,2,3-c,d)pyrene	0.00362	0.0743	-
Total high MW PAH's	**0.101**	**1.01**	**0.00172**
Total PAH's	**1.00**	**3.99**	**0.0188**
'-' denotes a value below the limit of detection			

Table 20: Summary of Deposition Rates of PAHs found in Rainfall in the Burnaby Lake Study (µg/m^2/d)

Sample period - starting Jan. 31/95 - ending Nov. 14/95			
	Deposition Rate (µg/m2/d)		
PAH's	**Average**	**Maximum**	**Minimum**
Naphthalene	0.636	2.36	-
Acenaphthylene	0.0204	0.108	-
Acenaphthene	0.0504	0.254	0.0004
Fluorene	0.0555	0.269	0.0047
Phenanthrene	0.171	0.648	0.0139
Anthracene	0.0068	0.0257	-
Total low MW PAH's	**0.924**	**2.52**	**0.0286**
Benzo(g,h,i)perylene	0.0069	0.0230	-
Fluoranthene	0.0692	0.243	0.0045
Pyrene	0.0457	0.1676	0.0009
Benzo(c)phenanthrene	0.0025	0.0128	-
Benz(a)anthracene	0.0103	0.0270	-
Chrysene	0.0277	0.0911	-
Benzo(b)fluoranthene	0.0263	0.0837	-
Benzo(k)fluoranthene	0.0050	0.0196	-
Benzo(j)fluoranthene	0.0004	0.0122	-
Benzo(a)pyrene	0.0055	0.0506	-
Dibenz(a,h)anthracene	0.0003	0.0045	-
Indeno(1,2,3-c,d)pyrene	0.0059	0.0270	-
Total high MW PAH's	**0.204**	**0.601**	**0.0053**
Total PAH's	**1.08**	**2.72**	**0.0339**
'-' denotes a value below the limit of detection			

Table 21: Summary of Deposition Rates of PAHs found in Rainfall in the Burnaby Lake Study (g/ha/yr)

Sample period - starting Jan. 31/95 - ending Nov. 14/95			
	Deposition Rates (g/ha/yr)		
PAH's	**Average**	**Maximum**	**Minimum**
Naphthalene	2.32	8.62	-
Acenaphthylene	0.0744	0.394	-
Acenaphthene	0.184	0.927	0.0015
Fluorene	0.203	0.983	0.0172
Phenanthrene	0.625	2.36	0.0508
Anthracene	0.0248	0.0936	-
Total low MW PAH's	**3.37**	**9.18**	**0.1042**
Benzo(g,h,i)perylene	0.0253	0.0838	-
Fluoranthene	0.253	0.887	0.0163
Pyrene	0.167	0.612	0.0032
Benzo(c)phenanthrene	0.0091	0.0468	-
Benz(a)anthracene	0.0377	0.0986	-
Chrysene	0.101	0.333	-
Benzo(b)fluoranthene	0.0960	0.306	-
Benzo(k)fluoranthene	0.0184	0.0715	-
Benzo(j)fluoranthene	0.0016	0.0444	-
Benzo(a)pyrene	0.0200	0.185	-
Dibenz(a,h)anthracene	0.0011	0.0165	-
Indeno(1,2,3-c,d)pyrene	0.0217	0.0986	-
Total high MW PAH's	**0.743**	**2.19**	**0.0195**
Total PAH's	**3.96**	**9.93**	**0.1237**
'-' denotes a value below the limit of detection			

Table 22: Standards for Concentrations of PAHs

Sample period - starting Jan. 31/95 - ending Nov. 21/95						
Concentrations (ng/L)	**Burnaby Lake**			**CCME**	**B.C. MOELP**	**OMOEE**
	max	**min**	**avg**	**Recommended Guideline ***	**Recommended Guideline (chronic) ****	**Interim Guideline *****
Naphthalene	1507.81	-	328.83	800	1000	7000
Acenaphthylene	90.02	-	7.79	~	~	~
Acenaphthene	63.01	0.20	14.50	3300	6000	~
Fluorene	110.27	1.04	18.83	11000	12000	20
Phenanthrene	343.42	3.06	73.13	3000	300	30
Anthracene	18.00	-	2.92	10	4000	0.8
Benzo(g,h,i)perylene	74.26	-	4.01	~	~	~
Fluoranthene	303.81	0.98	34.78	~	4000	0.8
Pyrene	174.10	0.19	20.70	40	50000	~
Benzo(c)phenanthrene	14.35	-	1.08	~	~	0.4
Benz(a)anthracene	58.51	-	5.57	~	20	0.1
Chrysene	146.28	-	12.88	~	100	
Benzo(b)fluoranthene	189.04	-	12.25	~	~	~
Benzo(k)fluoranthene	45.01	-	2.09	~	~	~
Benzo(j)fluoranthrene	1.70	-	0.07	~	~	~
Benzo(a)pyrene	81.02	-	3.39	10-40	10	~
Dibenz(a,h)anthracene	0.60	-	0.04	~	~	~
Indeno(1,2,3-c,d)pyrene	76.51	-	3.62	~	~	~
'-' denotes a zero						
~ = not found						
RG: recommended guideline; NA: not applicable; R: recommendation; O: objective						
* Germain, A., 1993						
** Nagpal, N., 1993						
*** OMOEE, 1994						

Table 23: Comparison of Rainfall PAHs Results from Burnaby Lake Study to other similar studies

Sample period - starting Jan. 31/95 - ending Nov. 21/95						
Concentrations (ng/L)	**Burnaby Lake**	**Villeroy ***	**Chesapeake Bay ^**	**Chesapeake Bay ^^**	**Portland ****	**PEI *****
Naphthalene	328.83	~	~	~	~	~
Acenaphthylene	7.79	~	~	~	~	~
Acenaphthene	14.50	~	~	~	~	~
Fluorene	18.83	~	1.80	~	0.44	11.00
Phenanthrene	73.13	27.50	6.70	3.60	4.1*	~
Anthracene	2.92	19.80	1.20	~		~
Benzo(g,h,i)perylene	4.01	~	2.30	~	6.00	~
Fluoranthene	34.78	1.32	9.00	~	4.40	~
Pyrene	20.70	7.90	17.00	0.90	4.10	~
Benzo(c)phenanthrene	1.08	~	~	~	~	~
Benz(a)anthracene	5.57	~	1.30	~	1.50	~
Chrysene	12.88	~	3.40	1.90	3.60	~
Benzo(b)fluoranthene	12.25	~	5.70	1.40	9.2**	2.00
Benzo(k)fluoranthene	2.09	~	3.10	0.71		~
Benzo(j)fluoranthrene	0.07	~	~	~		~
Benzo(a)pyrene	3.39	1.47	1.90	~	2.80	1.50
Dibenz(a,h)anthracene	0.04	~	1.10	~	~	~
Indeno(1,2,3-c,d)pyrene	3.62	~	2.10	0.75	~	~
'-' denotes a zero						
~ = Not sampled for						
*=phenanthrene + anthracene						
**=Benzo(b+k+j)fluoranthene						
Notes:						
Burnaby data: our study						
* Poissant, Koprivnjak, and Harvey, 1992						

Table 24: Total Deposition of PAHs in Rain in a year in the Burnaby Lake Watershed

Sample Period - starting Jan. 31/95 - ending Dec. 5/95			
Yearly Total Deposition into Burnaby Lake Watershed (kg)			
	Average	Maximum	Minimum
Silver	1.03	20.3	-
Aluminum	451	5080	-
Arsenic	56.1	578	-
Boron	35.8	513	-
Barium	42.4	526	-
Calcium	16033	115632	-
Cadmium	36.5	473	-
Chromium	234	6990	-
Copper	174	4730	-
Iron	1927	39946	-
Mercury	0.155	5.12	-
Magnesium	4717	26280	-
Manganese	44.1	331	-
Sodium	22791	223005	-
Nickel	303	9986	-
Lead	15.2	209	-
Sulphur	60619	386907	2440
Selenium	39.4	806	-
Silicon	1358	28495	-
Strontium	31.1	248	-
Titanium	9.51	99.1	-
Zinc	1792	10512	-
'-' denotes a value below the limit of detection			

Table 25: Total Deposition of Metals in Rain in a year in the Burnaby Lake Watershed

Sample period - starting Jan. 31/95 - ending Nov. 14/95			
Yearly Total Deposition into Burnaby Lake Watershed (kg)			
PAH's	**Average**	**Maximum**	**Minimum**
Naphthalene	16.7	62.0	-
Acenaphthylene	0.536	2.84	-
Acenaphthene	1.33	6.67	0.011
Fluorene	1.46	7.08	0.124
Phenanthrene	4.50	17.0	0.365
Anthracene	0.179	0.674	-
Total low MW PAH's	24.3	66.1	0.751
Benzo(g,h,i)perylene	0.182	0.603	-
Fluoranthene	1.82	6.39	0.117
Pyrene	1.20	4.41	0.023
Benzo(c)phenanthrene	0.066	0.337	-
Benz(a)anthracene	0.272	0.710	-
Chrysene	0.728	2.40	-
Benzo(b)fluoranthene	0.691	2.20	-
Benzo(k)fluoranthene	0.133	0.515	-
Benzo(j)fluoranthene	0.012	0.319	-
Benzo(a)pyrene	0.144	1.331	-
Dibenz(a,h)anthracene	0.008	0.119	-
Indeno(1,2,3-c,d)pyrene	0.156	0.710	-
Total high MW PAH's	5.35	15.8	0.140
Total PAH's	28.5	71.5	0.891
'-' denotes a value below the limit of detection			

Table 26: Standards for Deposition Rates of PAHs as Proposed by R.M. Hoff

Sample period - starting Jan. 31/95 - ending Nov. 14/95			
	Deposition Rates (µg/m2/yr)		
PAH's	**Average**	**Maximum**	**Minimum**
Naphthalene	232.32	861.53	-
Acenaphthylene	7.44	39.43	-
Acenaphthene	18.41	92.65	0.15
Fluorene	20.26	98.32	1.72
Phenanthrene	62.47	236.47	5.08
Anthracene	2.48	9.36	-
Total low MW PAH's	**337.29**	**918.05**	**10.42**
Benzo(g,h,i)perylene	2.53	8.38	-
Fluoranthene	25.27	88.71	1.63
Pyrene	16.69	61.19	0.32
Benzo(c)phenanthrene	0.91	4.68	-
Benz(a)anthracene	3.77	9.86	-
Chrysene	10.12	33.27	-
Benzo(b)fluoranthene	9.60	30.56	-
Benzo(k)fluoranthene	1.84	7.15	-
Benzo(j)fluoranthene	0.16	4.44	-
Benzo(a)pyrene	2.00	18.48	-
Dibenz(a,h)anthracene	0.11	1.65	-
Indeno(1,2,3-c,d)pyrene	2.17	9.86	-
Total high MW PAH's	**74.29**	**219.39**	**1.95**
Total PAH's	**395.91**	**993.47**	**12.37**

'-' denotes a value below the limit of detection

PAHs of interest: those which exceed ± 1 µg/m2/yr
- R. M. Hoff, 1996