

**Well Water Survey for Arsenic in the Powell River and Sunshine Coast Communities of  
British Columbia - March to June 1994**

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## **Abstract**

The discovery of elevated concentrations of arsenic in well water in Powell River initiated a large scale well water survey in the Powell River and Sunshine Coast communities of British Columbia in March 1994. A total of 458 well owners submitted well water samples for analysis of arsenic (117 of these wells were also analysed for boron and fluoride). In the Powell River communities the arsenic concentrations ranged from not detected to 1.3100 mg/L, with a mean concentration of 0.0483 mg/L. In the Sunshine Coast communities, the arsenic concentrations ranged from not detected to 2.4400 mg/L, with a mean concentration of 0.0593 mg/L (the Guideline for Canadian Drinking Water Quality (GCDWQ) for arsenic is 0.025 mg/L). High arsenic concentrations were identified on a community basis as well as at a local district lot level.

Arsenic is ubiquitous in the granite rocks in the study area and, in general, the deepest wells sampled were the wells with the highest arsenic concentrations. However, in both the Powell River and Sunshine Coast Regions, well depth and arsenic levels were weakly correlated ( $r = 0.30$ ).

## **Introduction**

In 1993, a family in Powell River, British Columbia, failed to recover from an extended period of sickness. The family initially tested their well in April 1993 and it was discovered the water contained elevated levels of arsenic. In fact, the arsenic concentration was 13 times the Guideline for Canadian Drinking Water Quality (GCDWQ) for arsenic (0.025 mg/L)<sup>1</sup>. The identification of high arsenic levels in this well and other wells in the Powell River area and on

the Sunshine Coast initiated a large scale well water survey in these two coastal communities of British Columbia in March 1994.

The identification of high arsenic concentrations generated anxiety and concern among residents in the communities of Powell River and the Sunshine Coast. Public meetings were held to inform residents of the detections of arsenic found to date in samples from local wells, and to address the public health concerns. Physicians in the Powell River and Sunshine Coast areas were briefed on the health effects of arsenic exposure and a question and answer sheet on arsenic was prepared and distributed to medical clinics and the local Health Unit offices.

The objectives of the survey were to give residents with wells considered to be at risk the opportunity to have samples analysed as quickly as possible to address health concerns, to assess the extent of arsenic concentrations in wells in communities in the Powell River and Sunshine Coast areas, and to identify specific geographic locations with high arsenic levels. The survey was initiated in March 1994, funded by the B.C. Ministry of Health, and consisted of well owners/tenants submitting samples of their well water to their local Health Unit offices for analysis.

### **Physical Setting**

The Powell River and Sunshine Coast regions are located on the southwest coast of British Columbia, north of the city of Vancouver (see Figure 1). The geological setting of the Powell River and Sunshine Coast is fairly complex. The area is essentially bedrock, covered by a thin

veener of unconsolidated sediments. The bedrock is mainly intrusive igneous rock, which is highly variable in type and nature. The region has been subjected to intense deformation forces as evidenced by the extensive system of joints, fractures and faults<sup>2</sup>. Arsenic is ubiquitous throughout the rock types found in the study area<sup>3</sup>. In addition, accessory minerals such as pyrite, chalcopyrite and others indicate the presence of hydrothermal activity, and may serve as arsenic sources. Deformation forces have created joints, fractures, faults and crevices providing a pathway for groundwater movement in the bedrock. Dissolution of arsenic occurs from both the accessory minerals, and the fabric of the rock itself.

## **Methodology**

Samples were collected for analysis from March 16th to June 15th, 1994 by either the property owners or tenants. A sampling protocol, a 250 mL acid washed sample container specific for metals and a well survey form were provided to either the property owner or tenant. Samples and completed well survey forms were returned to the Gibsons, Sechelt and Powell River Health Unit offices where the samples were packaged and shipped for analysis.

At the onset of the study, it was decided to test well water not only for dissolved arsenic but for fluoride and boron as well, as these three constituents are often associated. However, the public response to the sampling program was overwhelming and, due to a limited budget, not all wells were tested for boron and fluoride. Methods used by the laboratory for analysis were based on those found in "Standard Methods for the Examination of Water and Wastewater", 18th Edition. Field duplicates, blanks and reference samples were submitted for analysis to check for

contamination problems and the laboratory's accuracy and precision in analysis.

## **Results and Discussion**

A total of 199 wells in Powell River and 259 wells in the Sunshine Coast area were sampled and analyzed for dissolved arsenic. Both of these areas will be discussed separately. Some of these wells (117 wells) were also sampled for fluoride and boron. In all calculations, a non-detect value (ND) was assigned the value of the detection limit in the statistical calculations: arsenic 0.0005 mg/L, fluoride 0.100 mg/L and boron 0.008 mg/L.

**Powell River Region.** Reported well depths for the 199 wells sampled in the Powell River Region ranged from 1.8 to 137 metres. The relationship between the reported depth of the well sampled and the corresponding arsenic value is shown in Figure 2. The arsenic values are plotted on a logarithmic scale. The distribution of results on the left hand side of the graph indicates those wells with arsenic values at or below the analytical level of detection. There does not appear to be a strong relationship between the reported well depth and arsenic value ( $r=0.30$ ). This same relationship holds true when different well depths are categorized.

Although the intent of the study was to sample wells completed into bedrock, public concerns over recent water quality problems in this area relating to detections of coliform bacteria and nitrates prompted a large number of shallow well (arbitrarily defined as wells  $\leq 20$  metres in depth) owners to submit samples for arsenic analysis. In the Powell River

area, 45% of the samples (90 wells) submitted were from shallow wells. Figure 3 shows the difference in arsenic values for the shallow and deep wells in the Powell River Region. Most of the arsenic values for the shallow wells were at or slightly higher than the analytical detection limit (0.0005 mg/L). None of the arsenic results from the shallow wells exceeded 0.025 mg/L, the Canadian guideline for arsenic. The deeper wells may be more representative of the groundwater affected by the host materials, i.e., bedrock, in the area.

This study identified areas of high arsenic concentrations at a community level as well as within smaller areas such as District Lots. Table 1 shows the summary results for the Powell River region.

In the Lang Bay to Saltery Bay and the Black Point/Kelly Creek areas elevated arsenic levels were evident. High arsenic levels in these areas are most likely related to natural variations in the bedrock chemistry. In the Lang Bay to Saltery Bay area, most of the wells sampled were shallow wells ( $\leq 20$  metres in depth) and all had non detectable or low arsenic values. However, 3 of the 4 deep wells sampled had arsenic values  $>0.025$  mg/L. Most of the wells with high arsenic concentrations were located in the Kelly Creek area. Although there does not appear to be a problem with elevated arsenic values in the shallow wells sampled in this study, bacteriological and nitrate contamination are other water quality concerns.

The arsenic and fluoride results for the Powell River Region are shown in Figure 4. The

mean and median fluoride values for the 58 wells sampled in the Powell River Region were 0.677 mg/L and not detected, respectively and the range was not detected to 8.59 mg/L. Thirty wells or 52% of the wells sampled had no detection of fluoride. There were 7 wells (12% of wells sampled in Powell River area) with fluoride values that exceeded 1.5 mg/L. All of these wells, located in the Black Point/Kelly Creek area, also had elevated levels of arsenic ranging from 0.4630 to 1.0700 mg/L. There was a strong relationship between fluoride and arsenic when the reported well depth was >20 metres ( $r=0.89$ ) but the same relationship does not apply when the reported well depth was  $\leq 20$  metres ( $r=0.12$ ).

The arsenic and boron results for the Powell River Region are shown in Figure 5. The average and median boron values for the 53 wells sampled in the Powell River Region were 0.874 and 0.026 mg/L, respectively. Boron ranged in value from not detected to 9.190 mg/L. There were 9 wells or 15% of the wells sampled with no detection of boron. Four wells (7% of the wells sampled for boron) had boron levels above the Guideline value of 5.0 mg/L. All of these wells had elevated values for both arsenic and fluoride and are located in the Black Point/Kelly Creek area. Boron and arsenic are highly correlated ( $r=0.95$ ). Wells deeper than 20 metres have a strong boron/arsenic relationship ( $r=0.94$ ), whereas wells  $\leq 20$  metres do not have this same relationship ( $r=0.03$ ).

**Sunshine Coast Region.** Reported well depths for the 259 wells sampled in the Sunshine Coast Region ranged from 1.8 to 198 metres in depth. As with the Powell River Region wells, there does not appear to be a strong relationship between the depths

of the wells sampled and the arsenic values ( $r = 0.30$ ). Box plots for the arsenic results from the Sunshine Coast Region are shown in Figure 6.

Figure 6 shows the wide variability of arsenic results for the Sunshine Coast Region as well as each of the community areas. As in the Powell River Region, the arsenic values range over 4 orders of magnitude. In some areas, there was a large difference between the average or mean and median arsenic value. In these cases, the mean does not necessarily represent the arsenic values and is influenced by a few high arsenic values.

In the Sunshine Coast area, there were several community areas where over 20% of the wells sampled had arsenic values  $>0.025$  mg/L - Halfmoon Bay, Secret Cove, Middlepoint, Madeira Park and Kleindale. Two areas where both the mean and median arsenic values were  $>0.025$  mg/L were Secret Cove and Middlepoint. The highest arsenic concentrations detected in this study were from wells located in the Middlepoint area.

There were some high arsenic concentrations detected in Kleindale, but the median arsenic value for this area was very low. In the other community areas (Gambier/Keats, Gibsons Area, Roberts Creek, Sechelt and Area, Garden Bay and Egmont/Ruby Lake) at least 75% of the wells sampled had arsenic values  $<0.025$  mg/L (see Figure 6).

In the Sunshine Coast area there were not as many shallow wells ( $\leq 20$  metres) sampled - 13% of the wells sampled were shallow. None of these shallow wells had arsenic values exceeding 0.025 mg/L. The same trend as seen in Powell River results was seen with the Sunshine Coast area results. Wells with reported depths  $\leq 20$  metres have very low levels of arsenic and a small range of values (1.5 orders of magnitude) compared to those wells



with reported depths >20 metres (4 orders of magnitude).

The mean and median fluoride values for the 59 wells sampled in the Sunshine Coast Region were 0.281 mg/L and not detected, respectively. Fluoride values ranged from not detected to 1.700 mg/L. Almost half the wells sampled in the Sunshine Coast region did not have detectable fluoride values. Fluoride and arsenic values in the Sunshine Coast region were not as highly correlated ( $r=0.47$ ) as those in the Powell River Region (see Figure 4). There are 6 wells that have high fluoride values but low arsenic values that are affecting this regression analysis. There does not appear to be a clear explanation why this is occurring, i.e., there is not a commonality among location or reported depth of the well.

The mean and median boron values for the Sunshine Coast region were 0.347 and 0.072 mg/L, respectively. There were no wells with boron values exceeding the GCDWQ for boron of 5.0 mg/L. Arsenic and boron concentrations were strongly correlated ( $r=0.92$ ).

**Quality Assurance/Quality Control.** The blind blank samples submitted did not have any detections of arsenic. There were insufficient field duplicates collected to determine natural and sample collection variation, i.e., only two blind duplicates were collected for analysis. For the blind duplicates submitted, the percent deviation for one sample was acceptable, however, there was a large deviation (28%) between the results from the other duplicate sampled collected. This could possibly be due to a laboratory dilution error as the concentration of the sample was very high or it could be a result of a variation of

arsenic concentrations in the groundwater. The blind reference sample results on the whole showed good recoveries ranging from 71-124% recovery.

**Speciation.** Arsenic can exist in many oxidation states in the natural environment including the +V (arsenates), +III (arsenites), +I (arsonium metals) and -III (arsine) valences, and rarely in the elemental form (arsenic). A speciation test was done on one of the samples. The results were 0.524 mg/L for arsenic (+V) and not detected for arsenic (+III). This indicates that the arsenic found was predominantly in the arsenate (+V) oxidation state.

## **Conclusions**

This water quality survey identified areas of high arsenic concentrations at a community level as well as within smaller areas, such as District Lots. There were however certain limitations in this study which restrict the interpretation of the arsenic results, i.e., no direct control over sample collection, samples were not filtered at collection, sampling sites were not pre-selected, and well logs were not available for all the wells sampled. Despite these resource and methodology limitations however, the health concerns of the communities were satisfactorily addressed. Timely and effective public communication of issues such as toxicology, exposure risks, sampling protocol, and results, together with public meetings, were instrumental in reducing anxiety and concern among the populations at risk.

In general, the wells with the highest arsenic values tended to be the deepest wells. The deeper

wells access bedrock which is likely to have a higher arsenic content. In addition, the qualities of deeper groundwater, i.e., reducing environment, are more conducive for liberating arsenic from bedrock. However, there were several deep wells with low arsenic concentrations. For instance, in the Halfmoon Bay area, the deepest well sampled had a low value of arsenic detected (0.0101 mg/L) compared to 2 deep wells in close proximity with high levels of arsenic detected. Wells completed into unconsolidated sediments had very low arsenic levels detected, regardless of the depth of the well. This lends weight to the source of arsenic being bedrock or accessory minerals in cracks and fissures.

In order to fully interpret the results from this survey, the source of arsenic needs to be identified and substantiated. Although arsenic may be ubiquitous in the granite rocks in the study area, local geologic conditions must be influencing the anomalies identified in this study.

This study raised the awareness of the public in the study area with respect to potentially high arsenic concentrations in the groundwater and homeowners are now closely monitoring their well water quality. After the study, those well owners who had arsenic results exceeding the GCDWQ in many cases installed a point of use treatment device, such as reverse osmosis and prefiltration, following the selection criteria developed by the Health Unit and engineering consultants. Two notable exceptions to the use of point of use treatment devices were two schools, one in the Powell River area and the other on the Sunshine Coast. These schools are currently using bottled water sources for drinking water. Another result of this study is that land subdivision in the study area is being restricted unless groundwater quality complies with the current CDWQG or is serviced by a community water system. The success of this well water

survey was demonstrated by the reduction of the public's concerns and was due in part to the "team" effort of all involved.

## **Acknowledgements**

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## References

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**Table 1. Summary results for the Powell River region.**

	Number of wells sampled	Wells with Non Detects (ND)	Average (mg/L)	Median (mg/L)	Maximum (mg/L)	Wells with values >GCDWQ
Powell River Region (all wells ≤20 metres in depth) - arsenic	90	61	0.0008	ND	0.0066	0
Powell River Region (all wells >20 metres in depth) - arsenic	105	32	0.0953	0.0021	1.3100	22 (21%)
<b>Lang Bay to Saltery Bay</b>						
Arsenic	16	9	0.0345	ND	0.3100	3 (19%)
Fluoride	4	3	0.392	ND	1.610	0
Boron	5	2	0.259	0.024	1.210	0
<b>Black Point/Kelly Creek</b>						
Arsenic	91	38	0.1044	0.0008	1.3100	18 (20%)
Fluoride	33	14	1.078	ND	8.590	7 (21%)
Boron	24	2	1.157	0.059	5.590	4 (17%)
<b>Powell River Region; South of Municipal Boundary to Victory Road</b>						
Arsenic	65	37	0.0028	ND	0.0920	1 (2%)
Fluoride	17	12	0.118	ND	0.260	0
Boron	18	5	0.025	0.011	0.128	0
<b>Powell River Region; North of Municipal Boundary</b>						
Arsenic	27	8	0.0039	0.0012	0.0201	0
Fluoride	4	1	0.102	0.120	0.150	0
Boron	6	1	0.553	0.052	3.000	0

ND = Not detected

	Number of wells sampled	Wells with Non Detects (ND)	Average (mg/L)	Median (mg/L)	Maximum Value (mg/L)	Well with Values > GCDWQ
<b>Sunshine Coast Region (all wells sampled)</b>						
Arsenic	258	44	0.0593	0.0040	2.4400	59(23%)
Fluoride	59	29	0.281	ND	1.700	3
Boron	59	4	0.347	0.072	3.570	0
<b>Gambier/Keats Island</b>						
Arsenic	15	2	0.0202	0.0110	0.0990	2(13%)
Fluoride	4	1	0.538	0.175	1.700	1
Boron	4	0	0.094	0.031	0.299	0
<b>Gibsons Area</b>						
Arsenic	10	1	0.0032	0.0013	0.0203	0
Fluoride	4	1	0.265	0.155	0.740	0
Boron	4	1	0.166	0.015	0.627	0
<b>Roberts Creek</b>						
Arsenic	51	6	0.0063	0.0033	0.0284	4(8%)
Fluoride	17	9	0.322	0.100	1.530	1
Boron	17	2	0.065	0.018	0.375	0
<b>Sechelt and Area</b>						
Arsenic	30	7	0.0198	0.0037	0.3110	4(13%)
Fluoride	4	0	0.523	0.155	1.68	1
Boron	4	0	0.839	0.037	3.26	0
<b>Halfmoon Bay</b>						
Arsenic	23	2	0.0864	0.0117	0.5600	7(27%)
Fluoride	11	9	0.225	ND	1.050	0
Boron	11	0	0.589	0.045	3.570	0
<b>Secret Cove</b>						
Arsenic	12	0	0.1330	0.0439	0.4090	8(67%)
Fluoride	2	0	0.130	0.130	0.160	1
Boron	2	0	0.295	0.295	0.420	0
<b>Middlepoint</b>						
Arsenic	41	6	0.1775	0.0333	2.4400	21(51%)
Fluoride	10	4	0.249	0.11	1.36	0
Boron	10	0	0.613	0.351	3.32	0
<b>Madeira Park</b>						
Arsenic	3	0	0.0400	0.0084	0.1110	1(33%)
Note: only 1 well was sampled for both fluoride and boron						
<b>Kleindale</b>						
Arsenic	27	11	0.0816	0.0009	1.2400	7(26%)
Fluoride	3	1	0.120	0.110	0.150	0



Boron	3	1	0.302	0.098	0.799	0
<b>Garden Bay</b>						
Arsenic	25	2	0.0126	0.0034	0.1000	4(16%)
Note: No fluoride or boron analysis was done in this area.						
<b>Egmont/Ruby Lake</b>						
Arsenic	21	7	0.0093	0.0020	0.1190	1(5%)
Fluoride	3	2	0.107	ND	0.120	0
Boron	3	0	0.254	0.279	0.390	