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Derivation of Matrix Soil Standards for Salt under the British Columbia Contaminated Sites Regulation

Addendum D:

Prediction of Salt Ion Composition of Produced Water Releases in Northern British Columbia

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Ministry of Water, Land and Air Protection,
Ministry of Transportation and Highways,
British Columbia Buildings Corporation, and the
Canadian Association of Petroleum Producers**

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Introduction

The major causes of salt contamination of soils, groundwater and surface water in British Columbia are likely to be environmental inputs of road salt, especially at storage and handling facilities, and the release of produced water in association with oil and gas exploration and recovery.

Various major salt ions may potentially pose risks to terrestrial and/or aquatic life, including the cations sodium, potassium, calcium and magnesium and the anions chloride, carbonate, and sulfate. Draft soil remediation standards for salt ions were derived primarily in consideration of environmental protection against the risks from environmental releases of sodium and chloride. This was done in consideration of the fact that road salt formulations presently and previously used in British Columbia have been predominantly NaCl. Very few alternative de-icers such as $MgCl_2$ have been used in large quantities or across larger spatial scales. The need for separate soil remediation standards for sodium ferricyanide, often added to road salt as an anti-caking agent, was discussed and ruled out based on-

- (i) very limited use in BC,
- (ii) limited environmental persistence of cyanide in either surficial soils or water bodies, or during rail and marine transport from source areas where it is added,
- (iii) pre-existence of water quality standards in BC for cyanide – which will allow risks to be addressed, and
- (iv) evidence that ferricyanide amended road salt from a South American supplier exhibited virtually identical toxicity to soil invertebrates as pure NaCl in the absence of NaFeCN.

Unlike the situation for road salt, there was a concern that produced water releases would likely contain a broader range of salt ions than road salt releases, implying a need for the future development of soil standards for ions other than sodium and chloride – for example, potassium, calcium, magnesium, carbonate, and sulfate.

The purpose of this brief analysis is to summarize known salt ion composition of produced water from northern British Columbia, based on pre-existing information in databases held by the BC Oil and Gas Commission.

Methodology

A database search was undertaken based on records collated by the BC Oil and Gas Commission as part of routine reporting requirements for oil and gas exploration and recovery. Data were provided in spreadsheet format for 4,907 individual aqueous samples, collected and analyzed between 1941 and 1991. The variables included in the database query included the formation and sample identification number, sampling date, upper and lower depth of sampled water, salinity, calculated total dissolved solids,

relative density, resistivity, concentrations of Na^+ , K^+ , Ca^{2+} , Mg^{2+} , Ba, Sr, Fe, Cl⁻, Br⁻, I⁻, HCO_3^- , and SO_4^{2-} and sulfide odors and concentration.

No description of methods or associated QA/QC data were included with the results. Furthermore it is likely that the analytical methodology has varied across reporting entities as well as over time. The analytical detection limits apparently used for salinity, Ba, Sr, Fe, Br, and I appear to have been sufficiently high that the majority of sample results are reported as zero ('0').

Along with the sample results was a brief annotation of sample type, appearance, and possible dilution or cross-contamination with other source materials such as drilling mud. Rather than omit these results, the potentially cross-contaminated sample results were retained in this compositional analysis, since they would comprise a portion of the overall produced water that might be released to the environment as a result of operational activities.

Given the large amount of data available, all data collected prior to 1980 were omitted from analysis. In addition, data collected from 1980 to 1989 were evaluated separately from the data available for 1990 and 1991. This provided an internal check of the overall consistency of the compositional data over time, and across subsets of the reported data.

Results and Discussion

A summary of the results for major salt ions is provided in Table 1 (next page). The median values for either 1980-1989 or 1990-1991 data for total cations and total anions expressed as milliequivalents per litre (meq/L) showed within reasonable limits the expected cation – anion balance based on the major salt ions present. While other inorganic and organic ions are undoubtedly present in produced water, therefore, the major salt ions are highly dominant.

The results also show that sodium and chloride, across a variety of sample types and formations, exhibit far higher relative and absolute concentrations than the other salt ions. Across the entire data set for 1980-1989, 75% of all samples (those above the 25th %ile) had sodium concentrations that comprised 78.4% or more of the salt cation strength and chloride that accounted for 81.7% or more of the salt anion strength, when expressed on a meq/L basis.

Conversely, 10% or fewer samples (upper 90th %ile) exhibited potassium, calcium or magnesium greater than 14%, 27% or 9% of the total salt cation strength, respectively. Also, 10% or fewer samples (upper 90th %ile) exhibited carbonate or sulfate greater than 22% or 34% of the total salt anion strength, respectively.

The salt ion compositional distribution for the 1990-1991 samples was similar to the 1980-1989 samples. Figures 1 and 2 illustrate the compositional distribution of sample results reported from 1980 to 1991.

Table 1: Summary of the Salt Ion Composition of Produced Water Samples From Northern British Columbia, 1980-1991.

	Samples Analyzed in 1980s (n = 1,353)							Samples Analyzed in 1990 and 1991 (n = 394)						
	min.	10% ile	25% ile	median	75% ile	90% ile	max.	min.	10% ile	25% ile	median	75% ile	90% ile	max.
TDS (g/L) min	0			27			274	0			8			223
Na ⁺ (mg/L)	0			8,460			92,173	0			3,778			74,483
K ⁺ (mg/L)	0			155			41,000	0			89			13,477
Ca ²⁺ (mg/L)	0			499			131,300	0			244			41,800
Mg ²⁺ (mg/L)	0			146			40,300	0			49			21,100
Cl ⁻ (mg/L)	0			17,500			285,000	21			4,150			150,000
HCO ₃ ⁻ (mg/L)	0			781			22,010	0			703			6,686
SO ₄ ²⁻ (mg/L)	0			430			87,750	0			453			30,820
Total salt cations (meq/L)	0			492			4,458	0			234			3,432
Total salt anions (meq/L)	0			549			8,041	2.5			205			4,238
Percent of total cation														
Na ⁺	0.0%	30.9%	78.4%	93.0%	96.2%	98.2%	99.8%	2.5%	56.7%	81.9%	93.8%	97.5%	98.5%	99.7%
K ⁺	0.0%	0.3%	0.5%	1.0%	2.7%	13.9%	100.0%	0.1%	0.4%	0.6%	1.1%	4.1%	11.2%	88.4%
Ca ²⁺	0.0%	0.4%	1.3%	3.1%	9.6%	27.1%	91.3%	0.0%	0.5%	1.2%	3.0%	8.5%	19.6%	80.0%
Mg ²⁺	0.0%	0.1%	0.6%	1.4%	3.2%	9.0%	84.6%	0.0%	0.2%	0.4%	1.2%	3.1%	8.8%	46.4%
Percent of total anion														
Cl ⁻	0.5%	33.9%	81.7%	96.6%	99.1%	100.0%	100.0%	2.7%	21.1%	57.2%	89.6%	98.7%	100.0%	100.0%
HCO ₃ ⁻	0.0%	0.0%	0.3%	1.9%	8.5%	21.6%	95.3%	0.0%	0.0%	0.6%	3.9%	15.5%	32.2%	82.6%
SO ₄ ²⁻	0.0%	0.0%	0.1%	0.8%	4.9%	33.6%	95.9%	0.0%	0.0%	0.1%	1.7%	16.4%	57.3%	91.7%

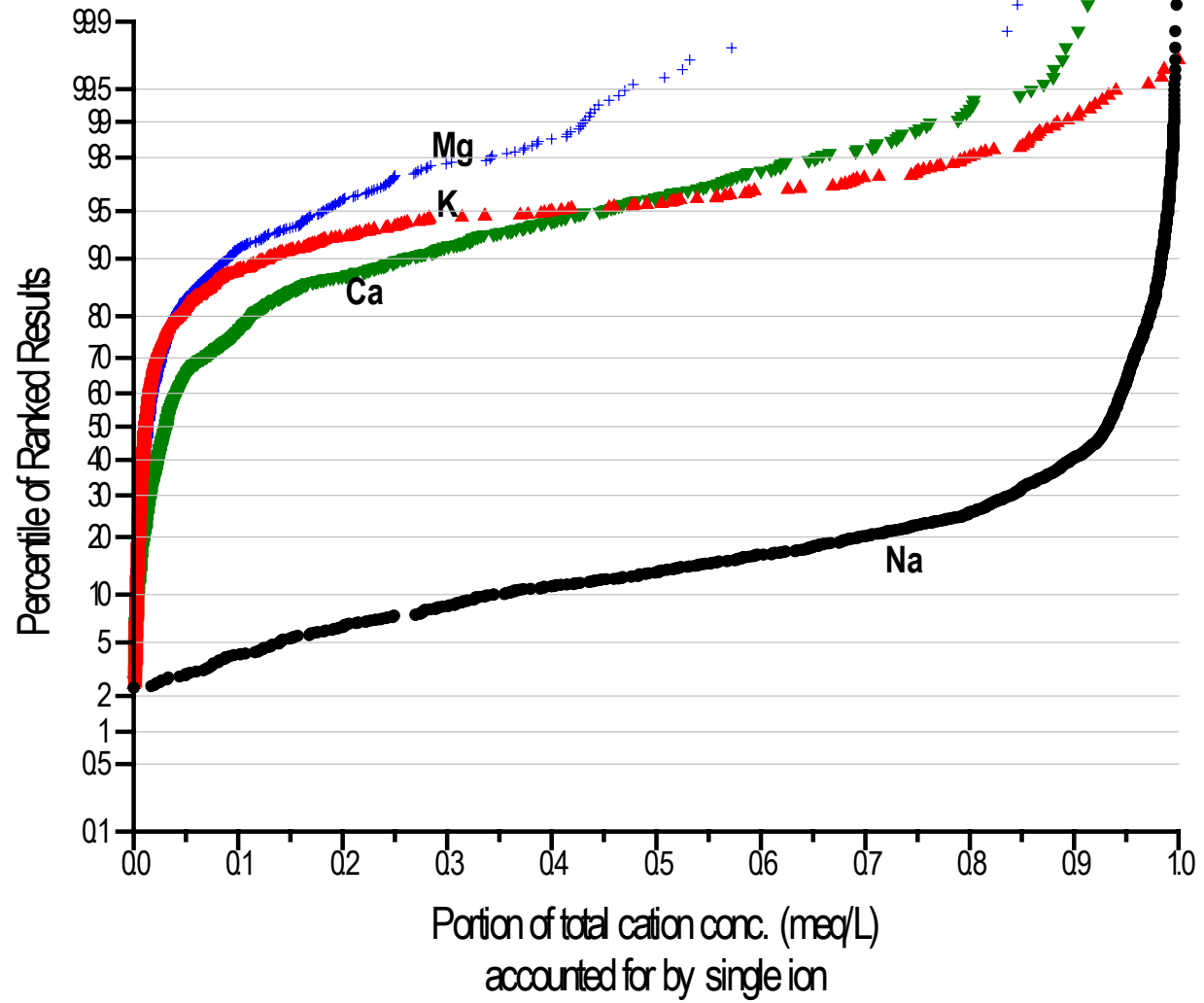
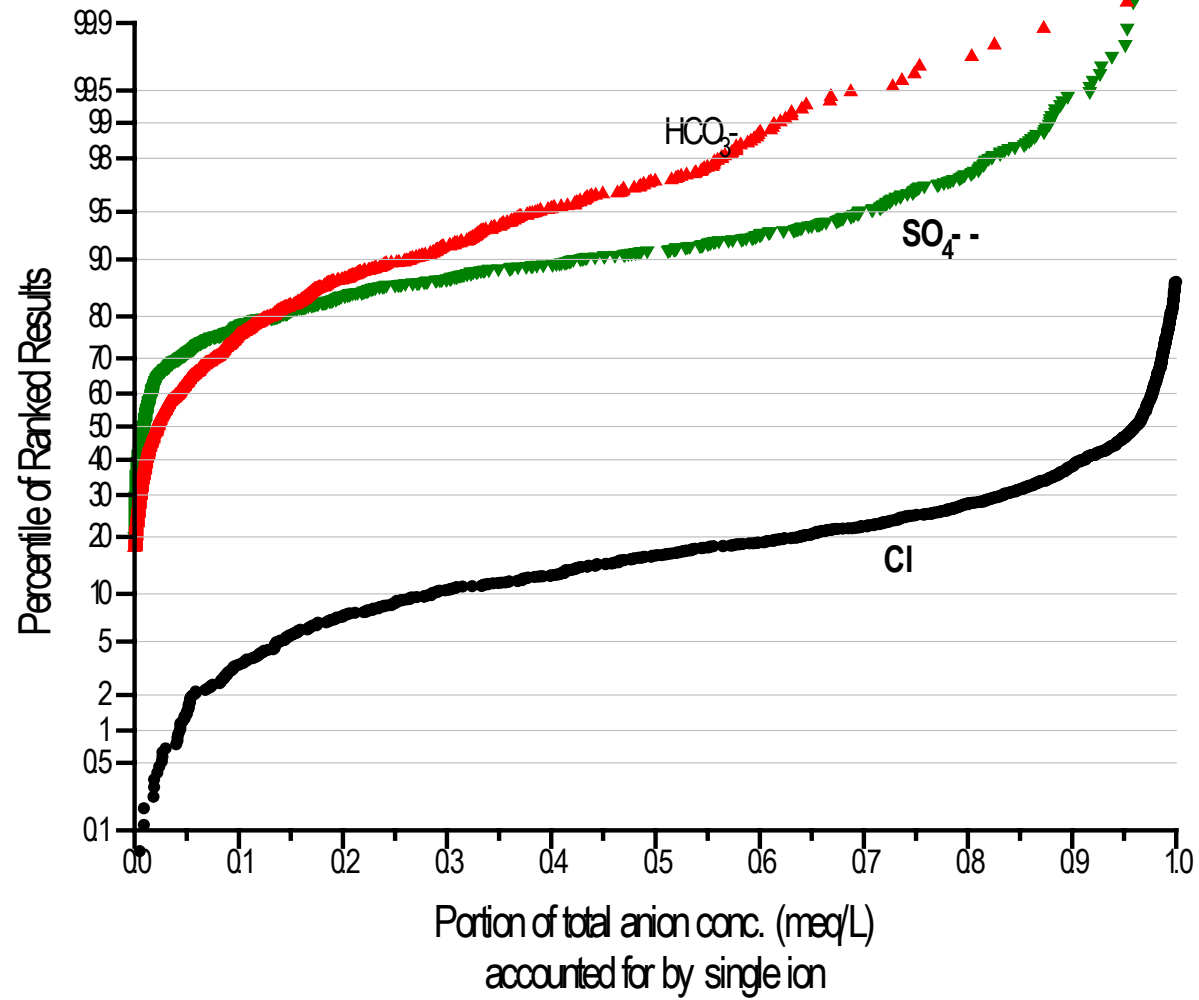


Figure 1: Compositional Distribution of Major Cations in Produced Water Samples, 1980-1991.

Figure 2: Compositional Distribution of Major Anions in Produced Water Samples, 1980-1991.



On a site-specific and sample-specific basis, there is undoubtedly the potential for releases with a composition dominated by salt ions other than sodium or chloride of produced water and/or water which has been cross-contaminated by other operation practices.

On the other hand, at least 90% of source releases encountered should be predominantly composed of NaCl, provided that the data analyzed herein are indicative of environmental releases and subsequently contaminated soil, surface water or groundwater.

It is concluded, therefore, that the further development of salt standards for ions other than sodium and chloride is a relatively low priority issue from the perspective of minimizing environmental risks of produced water release.