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Vanadium Contamination Monitored by an Arctic Bivalve, *Cyrtodaria kurriana*

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The trace element Vanadium enters the ocean principally through natural weathering processes, atmospheric fallout and man's activity (Bertine and Goldberg, 1971). Although recent studies failed to detect any significant input of atmospheric Vanadium in the Arctic environment (Herron *et al.*, 1977, Vermette and Bingham, 1986), local contamination is always possible. Tuktoyaktuk is a small Inuvialuit community situated on the eastern edge of the Mackenzie River Delta along the shore of Kugmallit Bay (Fig 1). It has one of the few good natural harbours in the Western Arctic, and serves as the principle support base for oil and gas industry operations. Residual oil, high in Vanadium content (Zoller *et al.*, 1973), powers the electric generators and is periodically sprayed over the dirt road surfaces to keep dust levels down. This, along with heavy ship traffic, may contribute to local Vanadium contamination in the marine system.

Unsal (1982) has shown that this metal can effectively be transferred within the food chain. The Arctic Propeller clam, *Cyrtodaria kurriana* (Dunker), is the most common filter feeding bivalve in Tuktoyaktuk Harbour and is a major component in the trophic chain (Thomas *et al.*, 1981). This study investigates the utility of this bivalve as a monitor for Vanadium contamination in the Arctic environment.

MATERIALS AND METHODS

In July 1985, sediment and *Cyrtodaria kurriana* samples were collected at 8 stations in Tuktoyaktuk Harbour and 1 control station (60 km Northeast) in M^{c}Kinley Bay, on

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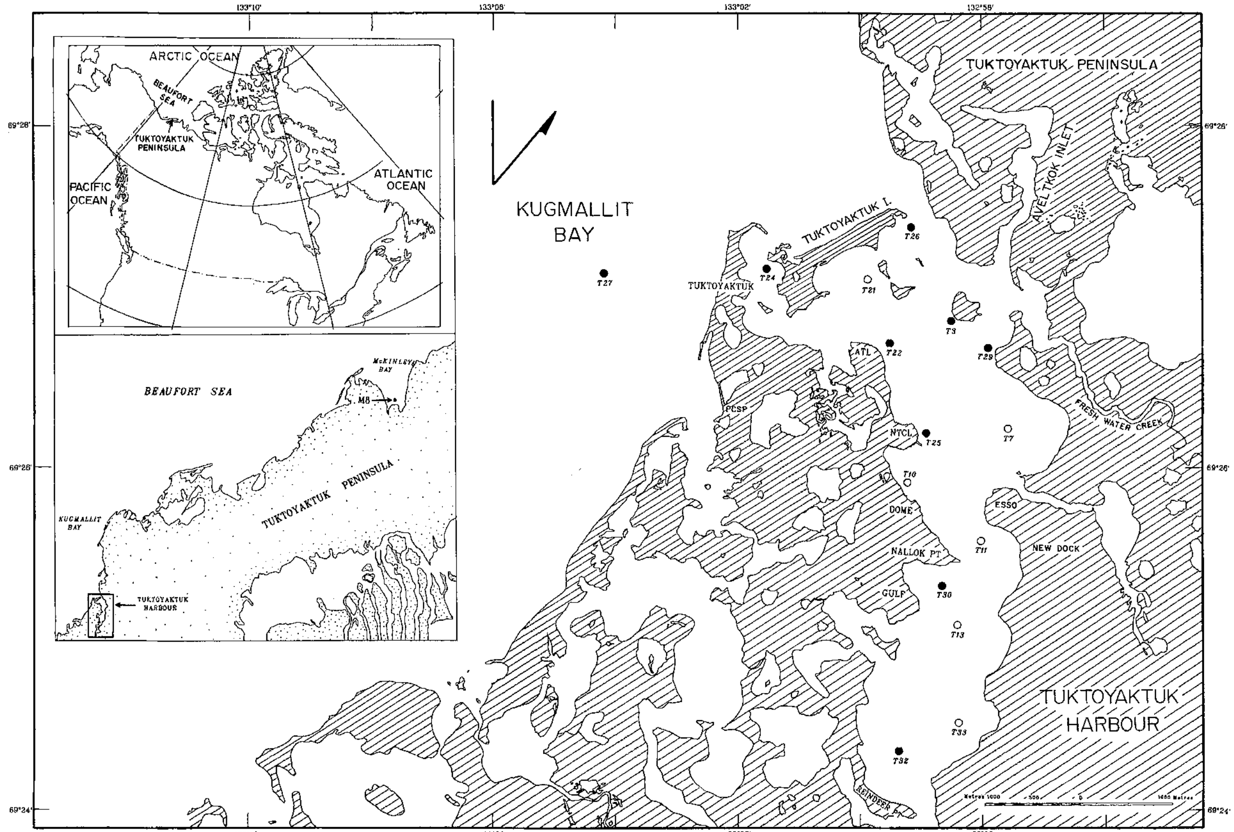

Figure 1. Location of sampling stations. (●) where bivalve and sediment samples were collected; (0) where only sediment samples were collected.

the Tuktoyaktuk Peninsula (Fig 1). Additional sediment samples were collected at 7 other stations in Tuktoyaktuk Harbour. The bivalves were obtained with a Ponar grab and the sediments were retrieved by diver (SCUBA) using an acrylic box core.

Sediments from the oxidized surface layer (1 cm deep) were sampled and kept frozen until further processing (≈ 40 days). In the laboratory, thawed sediments were sieved through 100µm polyethylene mesh and dried at 60°C. The total Vanadium content was determined on a sediment subsample by X-ray fluorescence spectrometry. A second subsample was extracted for 2h with 10 ml of 1N HCl. Extractions were carried out in 20 ml polyethylene scintillation-counting vials, shaken continuously. The extract was separated from the sediment by filtration under pressure through 0.45µm membrane filters. The Vanadium content of the extracts was determined using an atomic absorption spectrometer (Perkin-Elmer 603) equipped with a graphite furnace (HGA-2100) and a background corrector.

Cyrtodaria kurriana specimens ranging in length in between 11 and 13 mm were allowed to depurate for 24h and then frozen. The soft tissues were removed from the shell, dried at 60°C for 48h, and ground in an agate mortar. The Vanadium content was determined by short-decay instrumental neutron activation analysis using a 5 megawatt pool type nuclear reactor (McMaster University). Pre-weighed ground tissue samples were placed in acid cleaned 5 ml polyethylene vials and irradiated in a thermal neutron flux of $5x10^{12}$ n cm^2 sec^{-1} for 10s. The irradiated sample was transferred to an inert vial and analyzed on a high-resolution Ge(Li) γ-ray detector (APTEC/NRD) coupled to a multichannel analyzer (Canberra Series 85). An average delay time of 120s and a count time of 3 min gave optimum precision.

RESULTS AND DISCUSSION

The low salinities measured at the sampling stations illustrate how the Mackenzie fluvial system dominates the Kugmallit Bay area (Table 1). The river's considerable sediment load, 203 mg/L dissolved solids content (Reeder *et al.*, 1972), gives the brackish surface water layer (≈ 15 m) a muddy appearance. This material is mainly derived from the weathering of Marine Cretaceous rocks and is composed of 50% kaolinite, 45% illite and varying ratios of montmorillonite-chlorite (Dewis *et al.*, 1972). The total Vanadium content in the sediments fell within background levels (Landergren, 1978) ranging from 114 to 180 µg/g (Table 1). The McKinley Bay control sample contained 153 µg/g Vanadium, in the range recorded by Tuktoyaktuk sediments. A superficial view of sediment analyses would, therefore, suggest that no appreciable Vanadium contamination occurred in Tuktoyaktuk Harbour.

Table 1. Physical parameters and total Vanadium content in sediment samples (X-ray Fluorescence).

STATIONS	DEPTH (m)	SALINITY (°/₀₀)	TEMP (°C)	SEDIMENT [V] (µg/g)
T3	4.0	0.5	9.0	155
T7	6.0	2.0	4.0	163
T10	3.5	0.5	8.0	122
T11	19.5	27.5	1.0	142
T13	23.0	27.5	1.0	135
T21	3.5	0.5	9.0	164
T22	5.0	1.5	5.0	159
T24	4.5	1.0	9.0	150
T25	5.0	1.0	6.5	156
T26	4.5	1.0	7.5	114
T27	3.0	0.0	12.0	147
T29	5.0	1.5	5.5	164
T30	6.0	2.5	4.0	158
T32	5.0	1.0	9.0	180
T33	3.0	0.5	9.0	159
M8	4.0	25.5	2.0	153
				$\bar{x}$: 151
				s: 17

The tissue analyses, however, revealed that *Cyrtodaria kurriana* specimens collected from Tuktoyaktuk Harbour contained about 5 times more Vanadium ($\bar{x}$: 20.1 µg/g) than those obtained from McKinley Bay ($\bar{x}$: 4.3µg/g; Fig 2). The acid extraction further showed that 10 times as much Vanadium was extracted from the Tuktoyaktuk Harbour sediments ($\bar{x}$: 11.2µg/g) than the McKinley Bay sediments (1.2 µg/g). These differences are significant at the 95% confidence level (Student's t-test).

This conforms with Hoffman (1971), who observed that the major fraction of anthropogenically derived Vanadium was soluble in dilute acid solutions. Other studies (Luoma and Bryan, 1982; Tessier *et al.*, 1984) have demonstrated that the degree of bioavailability of sediment-bound metals is best estimated by mild acid extractions. Miramand *et al.*, (1980) noticed that the Vanadium uptake in mussels varied inversely with salinity. It is therefore possible that the higher

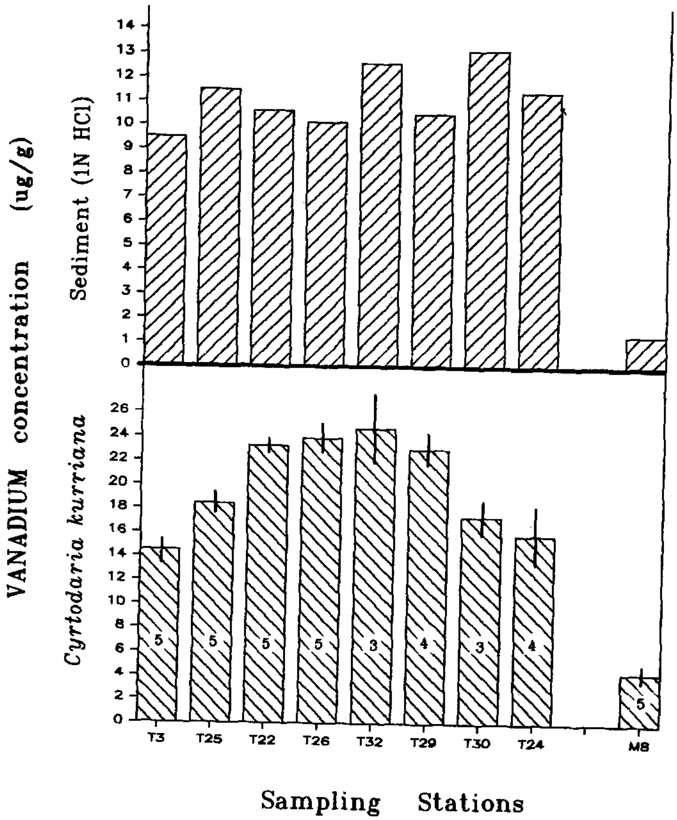

Figure 2. Vanadium concentration in 1N HCl sediment extracts (converted to µg V/g of sediment) and *Cyrtodaria kurriana* tissues, determined by Neutron Activation Analysis. Vertical lines represent confidence intervals calculated using the expression: $\pm ts/\sqrt{n}$; s: standard deviation; t: value at the 95% confidence level and n-1 degrees of freedom; n: number of analyses. The numbers within the bars represent the number of analyses/sample.

salinities encountered at McKinley Bay (Table 1) may also have contributed to lowering the Vanadium tissue concentration in these bivalves.

This study suggests that *Cyrtodaria kurriana* can serve as a useful environmental monitor for Vanadium contamination and also illustrates the importance in evaluating the speciation of particulate trace metals.

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REFERENCES

Bertine KK and Goldberg ED (1977) Fossil fuel combustion and the major sedimentary cycle. Science. 173: 233-235.
Dewis FJ, Levinson AA, Bayliss P (1972) Hydrogeochemistry of the Mackenzie River drainage basin, Canada-IV. Boron-salinity-clay mineralogy relationships in modern deltas. Geochim Cosmochim Acta, 36: 1359-1375.
Herron MM, Langway CL Jr., Weiss HV, Cragin JH (1977) Atmospheric trace metals and sulfate in the Greenland Ice Sheet. Geochim Cosmochim Acta, 41: 915-920.
Hoffman GL (1971) Particulate trace metals in the Hawaiian marine atmosphere, Ph.D. thesis, University of Hawaii, Honolulu, Hawaii, USA.
Landergren S (1978) Vanadium abundance in common sediments and sedimentary rocks. In: Wedepohl KH (ed) Handbook of Geochemistry, Vol II/2 Elements Si(14) to V (23). Springer-Verlag, New York, 23-K-1 - 23-K-5.
Luoma SN and Bryan GW (1982) A statistical study of environmental factors controlling concentrations of heavy metals in the burrowing bivalve *Scrobicularia plana* and the polychaete *Nereis diversicolor*. Estuar Coastal & Shelf Sci., 15: 95-108.
Miramand P, Guary JC, Fowler SW (1980) Vanadium transfer in the mussel *Mytilus galloprovincialis*. Mar Biol, 56: 281-293.
Reeder SW, Hitchon B, Levinson AA (1972) Hydrogeochemistry of the surface waters of the Mackenzie River drainage basin, Canada-I. Factors controlling inorganic composition. Geochim. Cosmochim. Acta, 36: 825-865.
Tessier A, Campbell PGC, Auclair JC, Bisson, M (1984) Relationships between the partitioning of trace metals in sediments and their accumulation in the tissues of the freshwater mollusc *Elliptio complanata* in a mining area. Can J Fish Aquat Sci, 41: 1463-1472.
Thomas DJ, Heath WA, Thompson KA, Koleba JM (1981) An oceanographic study of Tuktoyaktuk Harbour, Northwest Territories, report prepared for Dome Petroleum Limited, 244 pp.
Unsal M (1982) The accumulation and transfer of vanadium within the food chain. Mar Pollut Bull, 13 (4): 139-141.
Vermette SJ and Bingham VG (1986) Trace elements in Frobisher Bay rainwater. Arctic 39 (2): 177-179.
Zoller WH, Gordon GE, Gladney ES, Jones AG (1973) The sources and distribution of vanadium in the atmosphere, In: Trace Elements in the Environment, Kothny EL (ed.), Advances in Chemistry Series No. 123, American Chemical Society, Washington, DC, 31-47.

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