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WATER AND WASTE MANAGEMENT ISSUES IN THE CANADIAN ARCTIC: IQALUIT, BAFFIN ISLAND

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Abstract
Water and waste management issues for the town of Iqaluit, a rapidly growing coastal community soon to be the capital of Nunavut, are examined in this study. The expanding population of Iqaluit has resulted in increased pressure on the coastal environment, and waste management issues have become increasingly complicated. Analysis of the freshwater entering the coastal waters identifies the sewage lagoon as a source of disturbance. Dissolved oxygen readings indicate heavy pollution. TAB/BART tests, used for the first time in the Canadian Arctic, indicate a highly aggressive to aggressive bacteria population. Results from previous studies indicate that the dumpsites are also sources of disturbance. It is evident that the activities of the community of Iqaluit are impacting the coastal environment. In order to reduce these impacts, improvements to existing facilities are required, and careful planning tailored to the Arctic environment is necessary in order to accommodate future growth in Iqaluit.

Résumé
La présente étude examine les problèmes de gestion des déchets et des eaux résiduaires relatifs à la ville d'Iqaluit, une communauté en pleine expansion de la région côtière, en voie de devenir la capitale du Territoire Nunavut. La croissance de la population d'Iqaluit a intensifié l'impact sur le milieu naturel côtier et les problèmes de gestion des déchets n'ont pas cessé d'accroître en complexité. Des analyses portant sur les origines des eaux fraîches convergeant vers la région côtière, identifient la lagune de déversement des égouts, comme étant la source des problèmes. Les relevés d'oxygène dissout indiquent une lourde pollution et les test TAB/BART utilisés pour la première fois dans la région arctique canadienne, ont montré la présence d'une population bactérielle allant du degré agressif à extrêmement agressif. Les résultats d'études antérieures ont indiqué que les sites-dépotoirs représentent également des sources de problèmes. Il est évident que les activitiés de la communauté d'Iqaluit ont un impact sur la milieu naturel côtier. Dous le but de reduire cet impact, il est nécessaire de modifier et d'améliorer les aménagements existants. Un plan d'action judicieux adapté au milieu naturel arctique est indispensable pour faveriser de futurs développements à Iqaluit.

Introduction

Water and waste management issues are examined for the town of Iqaluit (formerly Frobisher Bay), Koojesse Inlet, on the southeast corner of Baffin Island, Northwest Territories (Figure 1). Iqaluit, a rapidly growing coastal community, has been chosen as

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the capital of the new eastern Arctic territory, Nunavut, to be implemented on April 1, 1999. The coastline and the wide expanses of the tidal flats of Koojesse Inlet are subject to a variety of activities by the residents of Iqaluit. The expanding population of Iqaluit has resulted in increased impacts to the freshwater and coastal environment, and waste management issues have become increasingly complicated. Iqaluit is typical of a long-term Inuit settlement, replacing more transient settlements such as military bases and mining towns.

The Canadian Arctic contains unique physical environments and biological communities worthy of investigation (McCann *et al.*, 1981; Thomson *et al.*, 1986; Martini, 1991). Population, urbanization and industrialization are rapidly growing in the region. An increase in human activity in an area that is not well understood calls for environmental monitoring studies to assess these activities (Environmental Sciences Group (ESG), 1995; Fournier, 1996). Monitoring and maintaining a balance between Arctic ecosystems and urbanization of the Arctic require such studies. The present study addresses some of the potential water and waste management issues with respect to the coastal environment of Koojesse Inlet and the community of Iqaluit.

The freshwater streams of Koojesse Inlet, including the sewage lagoon, were analyzed as part of a larger study which examined the biological communities of the inlet (Samuelson, 1997). The main areas of concern in the present study include the sewage lagoon, dumpsites, the decommissioned military base, boating and snowmobiling activities, all of which impact Koojesse Inlet.

Study Area

The Physical Environment

The town of Iqaluit is situated on a fluvial plain, surrounded by undulating rocky hills, at the head of Koojesse Inlet. The inlet is characterized by expansive boulder-strewn tidal flats nearly 1 kilometre in width (Figure 2), the result of a tidal range in excess of 11 metres (Department of Fisheries and Oceans, 1994). Sea ice dominates the inlet for eight to nine months of the year, reaching a maximum

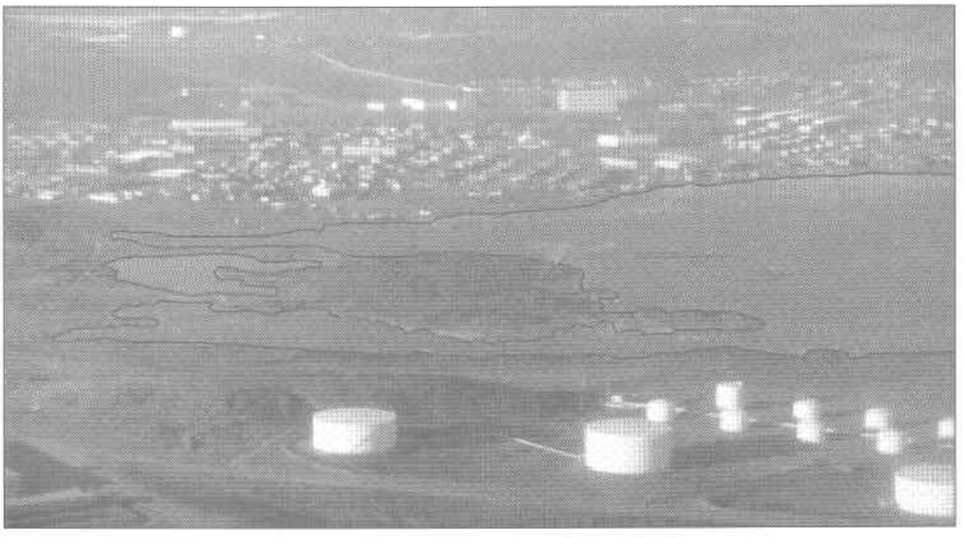

Figure 1: Aerial View of the Townsite of Iqaluit, Looking Northeast Across Koojesse Inlet

thickness of 2 metres (McCann *et al.*, 1981; Nunavut Implementation Commission (NIC), 1995). The hydrologic system of the area is poorly developed and poorly integrated, composed of numerous small drainage basins (Miller *et al.*, 1980).

History of Iqaluit

Iqaluit ('place of fish' in Inuktitut) has been a traditional hunting and fishing area of the Inuit for more than 4000 years (McConkey, 1991; Rigby, 1991). Recorded history of the area began in 1576 with the voyages of Martin Frobisher in search of the Northwest Passage (Forbes, 1953; McConkey, 1991), followed by whaling ships and the fur trade in the eighteenth and nineteenth centuries (McConkey, 1991; Rigby, 1991; Watt, 1996).

In 1941, the Iqaluit area was chosen as the site for an United States Air Force base. American military presence continued periodically until 1963 and during this time, a Pole Vault radar station was constructed at Upper Base (Figure 2) (NWT Data Book, 1990; Department of National Defence (DND), 1995; Watt, 1996). The Inuit began to settle in the area, and by 1955 the community numbered 100 people (McConkey, 1991; Watt, 1996).

During the following 40 years, Iqaluit developed into the eastern Arctic's largest community with a present population of 4,220 including 300 in the suburb of Apex (Figure 2) (Allerston, 1996; Statistics Canada, 1997). The areal extent of Iqaluit has also increased substantially with new residential subdivisions in the southeast. Between 1994 and 1995 residential dwellings increased from 1000 to 1060, a rate of 6 percent (Brown, pers. comm., 1997). Iqaluit remains a Forward Operating Location for the Canadian Armed Forces and an occasional base for the Unites States Air Force (Rigby, 1991; NIC, 1995).

Human Activity on the Coastline

The proximity of the town to the coastal environment results in a considerable amount of activity on the tidal flats of Koojesse Inlet. The town of Iqaluit is situated at the head

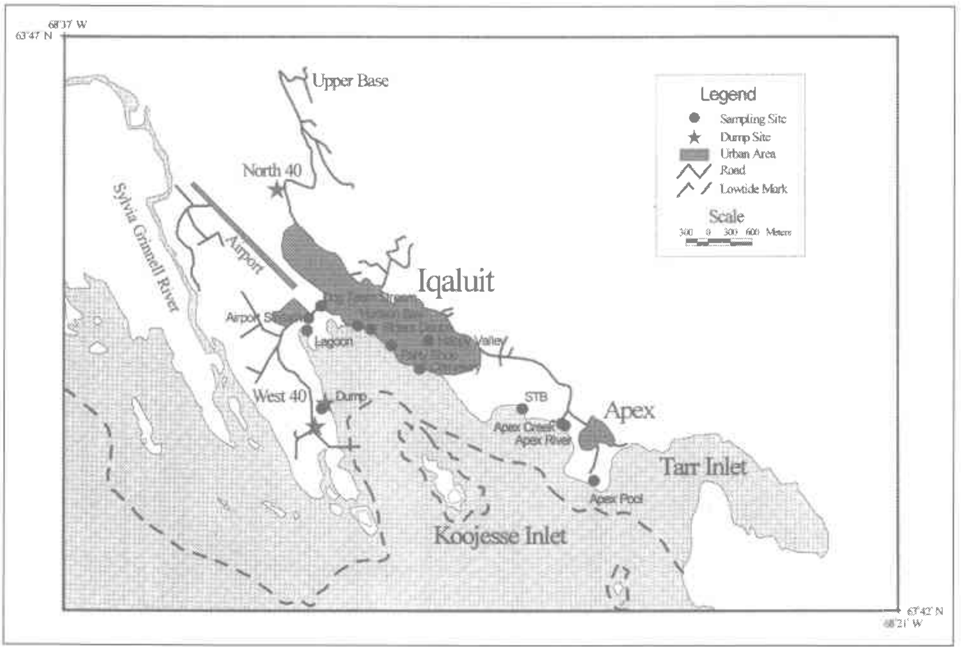

Figure 2: Location of Freshwater Sampling Sites, Iqaluit, Koojesse Inlet

and along the northeast side of the inlet, while Apex is located near the mouth of the northeast side of the inlet. The southwest side, referred to as West 40, contains industrial activities and dumpsites, as well as a local summer camping area. North 40, located northwest of Iqaluit, also contains industrial activities and a dumpsite (Figure 2).

Boats are a common form of transportation for the residents of Iqaluit in summer resulting in the construction of numerous boat houses and a large volume of traffic, fuel spillage and litter along the coastline. To combat the large tidal range of the area, five small breakwaters have been constructed in recent years along the northeast side of the inlet for the mooring of boats. The breakwaters are constructed of boulders and sediment bulldozed from the tidal flats and from an extraction site in North 40 (Eno, pers. comm., 1997).

An area of the tidal flats at the head of the inlet, referred to as Sealift Beach, is cleared of coarse sediment every spring. This permits vehicular traffic on the tidal flats during low tide. A municipal water truck makes repeated daily trips during the summer months for seawater to apply to the gravel roads of the town. Sealift ships make several trips to Iqaluit every summer, and this cleared area is used to land the barges to unload the ships. In addition, a channel, presently in need of repair, was dredged at the head of the inlet to accommodate boating traffic (Reid Crowther and Partners, 1990; NIC, 1995).

The summer camp area on the southwest side of the inlet is also a centre of activity for boating and snowmobiling. Residents fish and harvest clams in this area, as well as on the opposite side of the inlet near Apex. The tidal flats also serve a recreation purpose for walks by residents and field trips by students.

Potential Contaminant Sources

The community produces a variety of potential contaminants to Koojesse Inlet from the sewage lagoon, three dumpsites and the decommissioned military base at Upper Base (Figure 2). The sewage lagoon is located directly on the coastline at the head of Koojesse Inlet. The old municipal dumpsite, approximately 1.2 hectares (ha) in size, is located directly on the coastline adjacent to the sewage lagoon. The new municipal dumpsite, covering approximately 1.5 ha, is located just inland of the old dump. The North 40 area contains a dumpsite approximately 30 ha in size. Located in the hills above North 40 is Upper Base, which occupies 220 ha (ESG, 1995). A fourth dumpsite in Apex was closed in 1979 (ESG, 1995).

Iqaluit's sewage lagoon is a settling pond providing primary sewage treatment with a ten-day retention period (Brown, pers. comm., 1997). Sewage is transported to the lagoon by piped utilidor and truck service, and bagged sewage is deposited in the new municipal dumpsite. Due to the absence of a meter on the lagoon, estimates of sewage input are based on the town's water consumption, little of which is for commercial or industrial use. Water usage estimates are; 1994, 457,000 m^3; 1995, 401,000 m^3; 1996, 464,000 m^3; or approximately 0.30 m^3 per person per day (NWT Data Book, 1990; Municipality of Iqaluit, 1995; Smith, pers. comm., 1997).

The sewage lagoon drains from a culvert directly onto the tidal flats at the head of the inlet at an estimated flow rate of 15–20 L/s. A study of the effluent's dispersion rate indicates poor circulation and diffusion (Webb, 1992). The lagoon discharge remains confined at the head of the inlet for several days and moves up and down the tidal flats with the tidal cycle. Thus a large area of the tidal flats, primarily at the head and the southwest side of the inlet, is exposed to high concentrations of sewage effluent (Webb, 1992). In addition, Iqaluit's lagoon has suffered numerous breaches and seepage over the past decade, the most significant of which took place in 1991, when approximately 56,000 m^3 of effluent escaped from the lagoon onto the tidal flats (Municipality of Iqaluit, 1995; Eno, pers. comm., 1997; Smith, pers. comm., 1997).

Some Measures of Contaminants

Approximately 620 metres from the lagoon, faecal coliform measurements (<1000 cfu/dL) and effluent concentrations (10 ppb) were found to be within recommended guidelines for waste water (Stanley Associates Engineering Ltd., 1987; Webb, 1992). However, survival rates for coliform bacteria increase in Arctic waters because of low temperatures, low reaction rates and ice cover, thus expanding the area of potential impact from the lagoon (Associated Engineering Services Ltd., 1980; Heroux and Rowney, 1987; Stanley Associates Engineering Ltd., 1987). It is difficult to quantify the effects of the lagoon on the coastal environment as there has been little research regarding the impacts of waste water discharge to Arctic waters, and little development of applicable standards for monitoring waste water in the Arctic (Heroux and Rowney, 1987).

Soil from the dumpsites and Upper Base have been analyzed for several contaminants by the Department of National Defence (1995) and the Environmental Sciences Group (1995). Standards for these contaminants are derived from the DEW Line Clean-up Criteria, Canadian Environmental Protection Act and Canadian Council of Ministers of the Environment. However, further research is required to determine accurate background concentrations of contaminants in the Arctic and to develop suitable standards for these contaminants (DND, 1995).

Soil samples from the old and new municipal dumpsites have the following mean concentrations: arsenic (3.7 ppm), cadmium (1.4 ppm), copper (81 ppm), lead (176 ppm), nickel (17 ppm) and zinc (353 ppm) elevated above background levels. Some samples contained concentrations of cadmium (5.2 ppm), copper (145 ppm), lead (840 ppm) and zinc (1080 ppm) above standards. Pesticides were detected, and PAHs and PCBs (0.74 ppm) were elevated above background concentrations. Water located within the new dumpsite contained PCBs (0.0086 ppm) and cooper (0.012 ppm) in excess of standards (DND, 1995; ESG, 1995). The Iqaluit Leachate Monitoring Program detected levels of ammonia nitrogen (5.8 mg/L), suspended solids (997 mg/L), PAHs (4.7 mg/L) and TPHs (0.042 mg/L) above standards in the leachate from the new dumpsite (Department of Indian Affairs and Northern Development (DIAND), 1994).

Analysis of the North 40 dumpsite revealed concentrations of copper (119 ppm) and lead (249 ppm) above standards. Mean concentrations of arsenic (1.5 ppm), copper (28 ppm), lead (42 ppm), nickel (9.5 ppm) and zinc (112 ppm) were above background concentrations. Pesticides and PAHs were detected and PCBs (0.29 ppm) were elevated above background concentrations. In addition, over 250 metal barrels contained concentrations of inorganic contaminants, requiring the barrels to be shipped south for disposal (DND, 1995; ESG, 1995). The stream referred to as Dog Team Stream in this study (Figure 2) flowing from Upper Base through this dumpsite, past the airport and onto the tidal flats had concentrations of iron (715 μg/L), PAHs (1.1 mg/L) and TPHs (0.002 mg/L) above standards as detected by the Iqaluit Leachate Monitoring Program. In addition, the pH of 9.5 was above recommended levels (DIAND, 1994).

Clean-up of Upper Base, contaminated with PCBs and other contaminants, was completed in the fall of 1996. A total of 230 m^3 of PCB contaminated soil (60 m^3 > 50 ppm; 170 m^3 > 5 ppm) required removal to treatment facilities in the south. Soil with lower concentrations of PCBs was placed in a dumpsite constructed at Upper Base. Concentrations of arsenic (49 ppm), cadmium (10.4 ppm), copper (2500 ppm), lead (9860 ppm) and zinc (2640 ppm) were above standards. There were elevated levels of dioxins (1.2 ppb), pesticides (9.3 ppm) and PAHs. In addition, asbestos was found in several buildings (DND, 1995; ESG, 1995).

Sediment samples taken from the bottom of Koojesse Inlet were analyzed for a variety of contaminants by the Department of National Defence. Elevated levels of lead (20 ppm) and PCBs (123 ppb) were detected at Sealift Beach. Dioxin/furan (613.9/132 ppt) levels were also high in this area and their signature was similar to those found at the base. Within the inlet, arsenic (6.1 ppm), pesticides (1.5 ppb) and PAHs (60 ppb) were detected at levels elevated above background concentrations (DND, 1995).

Biological samples collected within Koojesse Inlet revealed further PCB contamination. Clams (14 ppb), Arctic char (54 ppb), sculpins (40 ppb) and isopod tissues (104 ppb) collected from the southwest side of the inlet had levels of PCBs that were elevated above background levels (DND, 1995).

The Iqaluit Shellfish Monitoring Program analyzed the clam, *Mya truncata*, near the old municipal dump in 1983–1985, 1990–1993, 1995 and 1996. Results of this program have been mixed. Samples from 1983 (2,700 MPN/100g) and 1984 (330 MPN/100g) contained faecal coliform levels above the guidelines for human consumption (Coleman and Nesbitt, 1989). In 1985, 1990 and 1992, the samples were within guidelines. In 1991 and 1993, samples contained faecal coliform (1991 – 330; 1993 – 490 MPN/100g) and *Escherichia coli* (1991 – 230; 1993 – 490 MPN/100g) in excess of human consumption guidelines. The 1991 results may be due to the breech of the sewage lagoon that year. In 1995 and 1996 the samples were within guidelines (Stephenson, 1991; Keast and Stephenson, 1997).

Finally, with respect to potential impacts, the townsite of Iqaluit may contribute contaminants through urban runoff and litter. Several seasonal streams run directly through the town onto the tidal flats; however, with the exception of the Dog Team Stream, they have not been previously analyzed. The number of streams and the magnitude of flow increases during the spring melt. These streams, including the sewage lagoon, were analyzed in this study.

Analysis of freshwater streams of Koojesse Inlet

A variety of freshwater measurements and standards are recommended for environmental monitoring studies, but there is a lack of knowledge, in particular the measurement of oxygen content, of their applicability to Arctic environments. Specific measurements and standards for freshwater characteristics which take into account low temperatures and ice cover are lacking for the Arctic (Heroux and Rowney, 1987; Rump and Krist, 1988). In addition, the influence of freshwater streams on the biological communities of coastal environments is poorly understood, especially when the freshwater streams have been influenced by human activity (Reise, 1985; Nybakken, 1988).

In this study water samples were collected from all freshwater sources draining onto the tidal flats (Figure 2). Ten sites were sampled in July, 1995 and thirteen sites during peak spring discharge in June, 1996. The three new sites in 1996 were the Airport Stream, Elders Centre and Happy Valley sites. Duplicate water samples were collected in polyethylene bottles, half of which were acidified with nitric acid to a pH of 2 to prepare the sample for trace metal analysis (Golterman *et al.*, 1978; Inland Waters Directorate, 1981; Franson, 1985; Rump and Krist, 1988). Water temperature, pH, dissolved oxygen, salinity and conductivity were measured, and the samples shipped to the University of Regina, Chemistry Department for trace metal analysis by atomic absorption spectrometry, which provides accurate and precise measurements (Golterman *et al.*, 1978; Inland Waters Directorate, 1981; Franson, 1985).

In the field, the water samples were subjected to a Total Aerobic Bacteria/Biological Activity Reaction Test (TAB-BART), used for the first time in the Canadian Arctic, according to the guidelines of Droycon Bioconcepts Inc. (DBI) (1994). The TAB-BART provides an estimate of the bacteria population in a water sample. The time required for a positive reaction is proportional to the bacteria population. The more quickly a positive result is obtained, the larger the bacteria population (DBI, 1994).

Description of Freshwater Sampling Sites

All water samples were taken from locations proximal to the coastline. Four sample sites were in the vicinity of Iqaluit's waste facilities and industrial activities. The Dump site is located seaward of the new municipal dump on the southwest side of the inlet. A small stream drains from the hills near the dump into a pool and onto the tidal flats. Water samples were taken from the pool. The Lagoon samples were taken from a culvert which drains the sewage lagoon. Organic enrichment of this area is evident by the lush vegetation. The water was murky and green in 1995, but less so during the 1996 spring runoff. The Airport creek samples are from a small seasonal stream which flows from the airport and industrial area of Iqaluit. This stream joins the lagoon runoff and flows over the tidal flats. Water samples were taken from a culvert located close to the lagoon culvert. The Dog Team stream flows from the hills near Upper Base, through the North 40 dump area, the airport and the town. The large stream enters the head of the inlet and flows over the tidal flats in tandem with the sewage runoff. The stream flow is relatively rapid and contains a considerable amount of household litter. Water samples were taken from a bridge culvert located close to Sealift Beach.

Five streams flow through the town, across the narrow beach and onto the tidal flats. The Hudson Bay and Elder's Centre samples were taken from culverts of small seasonal streams. The Party Shop site, similar to the Dog Team Stream, is from a large, relatively rapid stream flowing from the surrounding hills. Water samples were taken from a culvert near the coastline. The three previous streams are in a high traffic area with significant amounts of household litter. The Cemetery and Happy Valley sites are located in small seasonal streams.

The Slow Tide Bay (STB) samples were taken from a small stream which flows from the hills along the coastline and onto the tidal flats. This area is subjected to relatively little human activity.

Three samples were taken in the vicinity of the community of Apex. The Apex creek site is in a small stream, located close to the Apex River, a relatively large, rapidly-flowing river. Both flow from the surrounding hills onto the tidal flats. There is a moderate amount of household litter and traffic in this area. Water samples were taken from the Apex pool site, which is formed by a small stream draining from the surrounding hills, through a collection of empty fuel barrels and household litter, onto the tidal flats.

Results of Freshwater Analysis

The results of freshwater analysis revealed one potential source of impact to the coastal environment, the sewage lagoon (Table 1). Measurements for the other 12 sites were all within recommended guidelines for freshwater (Franson, 1985; Rump and Krist, 1988), with temperature readings below 25°C, pH between 6 and 9, D.O. above 4 mg/L, salinity close to 0 ppt, and conductivity below 150 mS/m. In addition, the reaction time of the TAB/BART test was greater than three days indicating a background population of bacteria (1.8 $^{+}/_{-}$ 1.2 Log cfu/mL) (DBI, 1994). However, there are concerns over the adoption of standards derived outside the Arctic.

Analysis of trace metals, lead, nickel and zinc, revealed no significant contamination at any of the 13 sites. All samples had values <1 ppm, which is the detection limit for the analytical method. Standard addition tests were negative, indicating that there was no background interference affecting the results of the trace metal analysis (Inland Waters Directorate, 1981; Franson, 1985; Rump and Krist, 1988).

Water analysis from the sewage lagoon runoff indicates this site has characteristics which may impact the coastal environment. A brown scum and strong odour are evident

Table 1: Results of Freshwater Analysis, Koojesse Inlet

Sample	Temperature (°C)	pH	D.O. (mg/L)	TAB-BART (days)	Salinity (ppt)	Conductivity (mS/m)	Trace Metal Analysis
July, 1995							
Dump	15.0	7.81	9.70	4.5	0.00	0.69	<1 ppm
Lagoon	14.0	7.01	0.14	1.5	0.20	4.61	<1 ppm
Dog Team	12.0	7.96	9.60	4.0	0.00	1.18	<1 ppm
Hudson Bay	13.5	7.90	9.10	3.5	0.10	4.57	<1 ppm
Party Shop	12.0	8.05	9.65	4.0	0.00	1.22	<1 ppm
Cemetery	13.5	7.99	9.15	4.0	0.20	4.82	<1 ppm
STB	10.0	8.00	9.50	5.0	0.00	0.51	<1 ppm
Apex Creek	13.5	8.12	9.55	4.5	0.00	1.61	<1 ppm
Apex River	13.5	7.79	9.50	4.0	0.00	1.04	<1 ppm
Apex Pool	11.0	8.31	8.90	5.0	0.00	1.28	<1 ppm
June, 1996							
Dump	8.5	7.11	6.55	8.5	0.00	2.31	<1 ppm
Lagoon	6.0	6.84	3.25	1.5	0.20	3.99	<1 ppm
Airport	7.0	7.24	6.75	6.5	0.00	0.57	<1 ppm
Dog Team	5.0	7.49	6.45	4.5	0.00	0.55	<1 ppm
Hudson Bay	10.0	7.32	6.60	5.5	0.00	2.27	<1 ppm
Elders Centre	12.0	7.47	6.95	7.5	0.00	1.27	<1 ppm
Party Shop	5.0	7.32	6.45	5.5	0.00	0.45	<1 ppm
Cemetery	11.0	7.33	6.35	5.5	0.10	3.09	<1 ppm
Happy Valley	6.0	7.19	6.80	6.5	0.00	0.76	<1 ppm
STB	4.0	7.66	7.10	10.0	0.00	0.38	<1 ppm
Apex Creek	1.0	8.08	7.10	9.5	0.00	1.33	<1 ppm
Apex River	1.0	7.24	6.90	6.5	0.00	0.33	<1 ppm
Apex Pool	5.0	7.51	7.15	10.0	0.00	0.36	<1 ppm

along the surface of the 800 m wide tidal flat, and are particularly pronounced within the first 400 m of the lagoon. pH values were within guidelines, however the 1996 reading was the only slightly acidic value (6.84) obtained in this study. The D.O. readings, 0.14 mg/L in 1995 and 3.25 mg/L in 1996, are below the recommended guideline of 4 mg/L (Rump and Krist, 1988). The 1995 reading is well below 2 mg/L, indicating heavy pollution (Rump and Krist, 1988). In addition, the results of the TAB-BART test in both years, at 1.5 days, indicates a highly aggressive (5.0 $^{+}/_{-}$ 1.5 Log cfu/mL) to aggressive bacteria population (4.0 $^{+}/_{-}$ 1.0 Log cfu/mL) suggesting the need for more detailed analysis (DBI, 1994). Long-term monitoring of the 13 freshwater streams would provide a more detailed picture of the water quality of these streams.

Conclusions About The Future

The community of Iqaluit has changed substantially in the last 50 years, experiencing rapid increases in population and urbanization. In 1999 when it will become the capital of Nunavut, new employment opportunities will result in further growth in population and infrastructure (Fournier, 1996; Sackett, 1996). Management concerns inevitably result from such rapid growth rates, including the areas of water and waste management.

Water analysis of the 13 freshwater sources in Koojesse Inlet reveal the sewage lagoon as a source of disturbance. Dissolved oxygen readings indicate heavy pollution and TAB/BART tests, indicate a highly aggressive to aggressive bacteria population. Results from other studies indicate that runoff from Upper Base and the North 40 dump, through the Dog Team stream, as well as runoff from the old and new municipal dumpsites, are also potential sources of disturbance. Previous studies found various contaminants to be above recommended levels in all three dumpsites, as well as in sediment and biota from within Koojesse Inlet (DIAND, 1994; DND, 1995; ESG, 1995).

Biological samples of polychaete worms were taken from two zones in the inlet (Samuelson, 1997). Zone 1 comprises samples proximal to the townsite and Zone 2 samples distal from the townsite (Table 2). Differences in these zones provide evidence of the impacts of freshwater runoff in Koojesse Inlet. Zone 1, located proximal to runoff from the sewage lagoon, dumpsites and the Dog Team stream, as well as boating and snowmobiling activity, is characterized by fewer species, lower densities and lower biological diversity, as measured by the Shannon-Weiner Index. In addition, Zone 1 has a higher percentage of species identified as pollution tolerant. The clam species, *Mya truncata*, was found in lower densities (<25/m^2) and with a smaller average weight (35.8 g) in Zone 1 than in Zone 2 (>75/m^2; 42.2 g). Residents have reported a decrease in the number and size of fish and clams in Koojesse Inlet in recent years.

It is evident that the activities of the community are affecting the coastal environment of Koojesse Inlet, and future growth may increase the magnitude of this impact. In order to reduce these disturbances, improvements to existing facilities are required and careful planning tailored to the Arctic environment is necessary in order to accommodate future growth.

Improvements to the sewage lagoon should include secondary treatment of the sewage, as well as increased dispersion and dilution of the effluent. Improvements to the sewage lagoon have become a condition of Iqaluit's water license agreement (Municipality of Iqaluit, 1995). However, solutions have yet to be found. Regular monitoring of the effluent and maintenance of the lagoon are needed. A lack of understanding of water measurements, especially oxygen content and impacts of waste water in the low temperatures of the Arctic, necessitates further research in order to accomplish and monitor improvements to lagoon systems. The eight to nine months of ice cover must also be taken into consideration for water and waste management plans.

Existing contaminants and leachate in the municipal dumpsites may be compounded by the addition of new waste material including solid sewage from the community. Leachate, sediment and biota in this area were found to have levels of suspended solids, trace metals, PAHs, TPHs and PCBs above standards (DND, 1995; ESG, 1995). The new municipal dumpsite, opened in 1994, was designed as a temporary facility,

Table 2: Biological Statistics, Polychaete Worm Species, Koojesse Inlet

	Number of Polychaete Species	Percentage of Pollution Tolerant Species	Average Density (Individuals per 100 cm^2)	Shannon-Weiner Index (H')
Zone 1 Proximal to Iqaluit	7	57	19.7	0.87
Zone 2 Distal from Iqaluit	16	25	40.0	1.15

however plans have not been initiated for a permanent dumpsite (Brown, pers. comm., 1997). Iqaluit needs to make advances in the clean-up of existing dumpsites and in the development of a permanent dumpsite. Solid waste management is complicated by exposed bedrock which makes the construction of sanitary landfills difficult. Standards and monitoring protocol for Arctic dumpsites are also required in order to reduce potential impacts to the coastal environment. Research is required to give insight into background concentrations of contaminants in the Arctic and the impacts of these contaminants on the physical and biological environment.

Water and waste management issues in Iqaluit include health concerns of the residents who make use of the inlet and tidal flats for recreation purposes, such as walking and student field trips. The harvesting of fish and clams, such as *Mya truncata*, within the inlet is a potential health risk. These activities should be curtailed until adequate monitoring protocol is available and improvements have been made to existing waste facilities.

Increasing population has resulted in the need to expand or improve most of Iqaluit's infrastructure. Demands on the drinking water supply made it necessary to raise the level of the water reservoir by 1.5 m during the summer of 1996 (Brown, pers. comm., 1997). Community members are concerned that continued population growth may exceed the capacity of the water reservoir, as well as the existing waste management facilities.

In order to meet the needs of residential boating traffic, in 1966 construction began on a permanent breakwater and dock along the northeast side of the inlet. Construction of the breakwater included dredging of the tidal flats, with additional material brought in from the North 40 extraction site (Eno, pers. comm., 1997). It is possible that this structure may further reduce dispersion and dilution of runoff from the sewage lagoon, and material brought in from North 40 may introduce new contaminants to the coastal environment. Leachate and soils from the nearby North 40 dumpsite had trace metals, PAHs, TPHs and PCBs above standards (DIAND, 1994; ESG, 1995).

The community has several water and waste management issues and concerns: the clean-up of Upper Base; a recycling program, which may make use of empty sealift ships returning south every summer; the ongoing search for secondary sewage treatment methods; and concerns over the clean-up of dumpsites and expansion of existing facilities. Most proposals are costly. Iqaluit has the opportunity to become a model for water and waste management in Arctic communities. It is necessary to move beyond using standards and protocols developed in temperate climates and implement techniques more suitable to the Arctic environment. Urban planning efforts may assist if Iqaluit can grow in stages and develop an approach that integrates future growth with the location and improvement of water and waste treatment facilities. Difficulties remain with the uncertainty of how much growth Iqaluit can expect and how quickly it will happen. Permanent long-term settlements in the Arctic are likely to increase in number and size, making standards and monitoring protocol for water and waste management a research priority in the Canadian Arctic.

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References

Allerston, R. 1996. "Insider's Guide to Iqaluit." *Uphere: Life in Canada's North*, 12(2): 26–27.

Associated Engineering Services Ltd. 1980. *Environmental Effects of Domestic Waste Discharges to Marine Arctic Waters*. Government of the NWT, Yellowknife.

Brown, Sara. 1997. Town Engineer, Municipality of Iqaluit, Iqaluit. Personal communication.

Coleman, T.S. and T. Nesbitt 1989. *An Investigation of Contaminants in Locally Harvested Bivalves in the Eastern Arctic: 1983–1985*. Canadian Department of Fisheries and Oceans, Iqaluit.

Department of Fisheries and Oceans. 1994. *Canadian Tide and Current Tables, 1995, Volume 4, Arctic and Hudson Bay*. Fisheries and Oceans, Ottawa.

Department of Indian Affairs and Northern Development (DIAND). 1994. *Assessment of Leachate Quality and License Requirements at Selected Communities in the Northwest Territories*. DIAND, Yellowknife.

Department of National Defence (DND). 1995. *Baffin Region Ocean Disposal Investigation: Seabed Debris and Contaminant Inputs Near Iqaluit, Resolution Island, Cape Dyer and Kivitoo*. Department of National Defence, Ottawa.

Droycon Bioconcepts Inc. (DBI). 1994. *TAB-BART*. Droycon Bioconcepts Inc., Regina.

Eno, R. 1997. Environmental Protection Officer, Department of Resources, Wildlife and Economic Development, Iqaluit. Personal communication.

Environmental Sciences Group (ESG). 1995. *Environmental Study of a Military Installation and Six Waste Disposal Sites at Iqaluit, Northwest Territories*. Department of Indian and Northern Affairs and Environment Canada, Ottawa.

Forbes, A. 1953. *Quest for a Northern Air Route*. Harvard University Press, Cambridge.

Fournier, C. 1996. "Getting Ready for the Next Century." *Uphere: Life in Canada's North*, 12(2): 16–19.

Franson, M.A.H. 1985. *Standard Methods for the Examination of Water and Wastewater: Sixteenth Edition*. American Public Health Association, Washington.

Golterman, H.L., R.S. Clymo and M.A.M. Ohnstad. 1978. *Methods for Physical and Chemical Analysis of Fresh Water: Second Edition*. Blackwell Scientific Publications, Oxford.

Heroux, J. and A.C. Rowney. 1987. "Biodegradation Kinetics in Arctic Waters." *Cold Regions Environmental Engineering: proceedings of the second conference*, D.W. Smith and T. Tilsworth, (eds.). 198–209.

Inland Waters Directorate 1981. *Analytical Methods Manual*. Environment Canada, Ottawa.

Keast M. and T. Stephenson. 1997. *Iqaluit Shellfish Monitoring Program*. Canadian Department of Fisheries and Oceans, Iqaluit.

Martini, I.P. 1991. "Sedimentology of Aubarctic Tidal Flats of Western James Bay and Hudson Bay, Ontario, Canada." *Clastic Tidal Sedimentology*, D.G. Smith, G.E. Reinson, B.A. Zaitlin and R.A. Rahmani (eds.). 301–312.

McCann, S., J. Dale and P. Hale. 1981. "Subarctic Tidal Flats in Areas of Large Tidal Range, Southern Baffin Island, Eastern Canada." *Geographie physique et Quaternaire*, 35(2): 183–204.

McConkey, B. 1991. *A Brief History of Iqaluit*. Department of Culture and Communications, Iqaluit.

Miller, G.H., W.W. Locke and G.W. Locke. 1980. "Physical Characteristics of the Southeastern Baffin Island Coastal Zone." *The Coastline of Canada*, S.B. McCann (ed.). 251–265.

Municipality of Iqaluit. 1995. *Northwest Territories Water Board Public Hearing*. Municipality of Iqaluit.

Nunavut Implementation Commission (NIC). 1995. *Choosing a Capital: a Supplementary Report of the Nunavut Implementation Commission*. NIC, Iqaluit.

NWT Data Book 1990/91. 1990. Outcrop Ltd., Yellowknife.

Nybakken, J. 1988. *Marine Biology: an Ecological Approach*. Harper & Row Pub., New York.

Reid Crowther and Partners. 1990. *Eastern Arctic/Baffin Region Port Facilities Study*. Government of the NWT, Yellowknife.

Reise, K. 1985. *Tidal Flat Ecology: An Experimental Approach to Species Interactions*. Springer-Verlag, Berlin.

Rigby, C. (ed.). 1991. *1991 Iqaluit Visitors Guide*. Nortext, Iqaluit.

Rump, H.H. and H. Krist. 1988. *Laboratory Manual for the Examination of Water, Wastewater and Soil*. VCH Publishers, New York.

Sackett, S. 1996. "Iqaluit; the New Capital of Nunavut." *Above and Beyond*, 8(2): 11–16.

Samuelson, G. 1997. *Benthic Organisms as Indicators of Environmental Change on Subarctic Tidal Flats, Iqaluit, Baffin Island, N.W.T.* M.Sc. Thesis, University of Regina, Regina.

Smith, P. 1997. Water Resources Officer, Department of Indian Affairs and Northern Development, Iqaluit. Personal communication.

Stanley Associates Engineering Ltd. 1987. *Sewage Waste Discharge to the Arctic Marine Environment*. Department of Indian Affairs and Northern Development, Ottawa.

Statistics Canada. 1997. *1996 Census: A National Overview, Population and Dwelling Counts, 93–357*. Statistics Canada, Ottawa.

Stephenson, T. 1991. *Shellfish Contaminants Monitoring, Iqaluit, NWT, 1991*. Department of Fisheries and Oceans, Iqaluit.

Thomson, D.H., C.M. Martin and W.E. Cross. 1986. *Identification and Characterization of Arctic Nearshore Benthic Habitats*. Fisheries and Oceans, Winnipeg.

Watt, E. 1996. "The Town That Was." *Uphere: Life in Canada's North*, 12(2): 22–25.

Webb, A.J. 1992. *Dye Dispersion Study of the Marine Wastewater Discharge Near the Town of Iqaluit, NWT*. Seaconsult Marine Research Ltd., Vancouver.