HMCS CHAUDIERE
MONITORING SURVEY RESULTS

FEBRUARY 1994

Waste Management Section
Pollution Abatement Division
Environmental Protection Branch
Pacific & Yukon Region

Kay Kim

Regional Data Report DR 94-01

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1. INTRODUCTION

On December 5, 1992 the HMCS CHAUDIERE, a decommissioned destroyer escort, was sunk in Sechelt Inlet (Figure 1) by the Artificial Reef Society of British Columbia to create a scuba diving attraction.

A baseline study consisting of water column analysis for trace metals, oil & grease, fibre analysis, and biological colonization of the vessel, was conducted on February 9, 1993 by Environment Canada (Ellis, 1993). Samples were taken with the co-operation of the Royal Canadian Mounted Police (RCMP) Vancouver Sub-Division Dive Unit.

A follow-up monitoring study was conducted on September 1 and 2, 1993 by Environment Canada. Due to concerns expressed by First Nations Band Council members in Sechelt regarding the perceived potential for shellfish contamination, a baseline sanitary water quality investigation was also conducted by Environment Canada between September 14 - 17, 1993. This report presents the results of the September studies.

2. METHODOLOGY

2.1 SAMPLING LOCATIONS

The locations sampled were identical to the baseline study (Ellis, 1993) except with the addition of location GR-1 (Burma Road) and the deletion of location PO-1 (Petty Officers Mess).

Table 1. HMCS Chaudiere Sample Locations

Sample locations are shown on Figure 2 and Figure 3.

LOCATION	DESCRIPTION
BR-1	Burma Road - At the generator room ahead of the mortar well on Deck 3.
GR-1	Burma Road - After the funnel uptake on Deck 3 (approx. 50 feet away from BR-1).
BW-1	Bow - At opening cut in the deck ahead of the forward gun turret.
BG-1	Bridge - Inside the Command Position.
ER-1	Engine Room - Through holes in vessel bottom.
SL-1	Shoreline - Northeast of the vessel.
REF1	Reference Station - Approximately 300 metres southwest of the vessel at a depth of 30 metres.

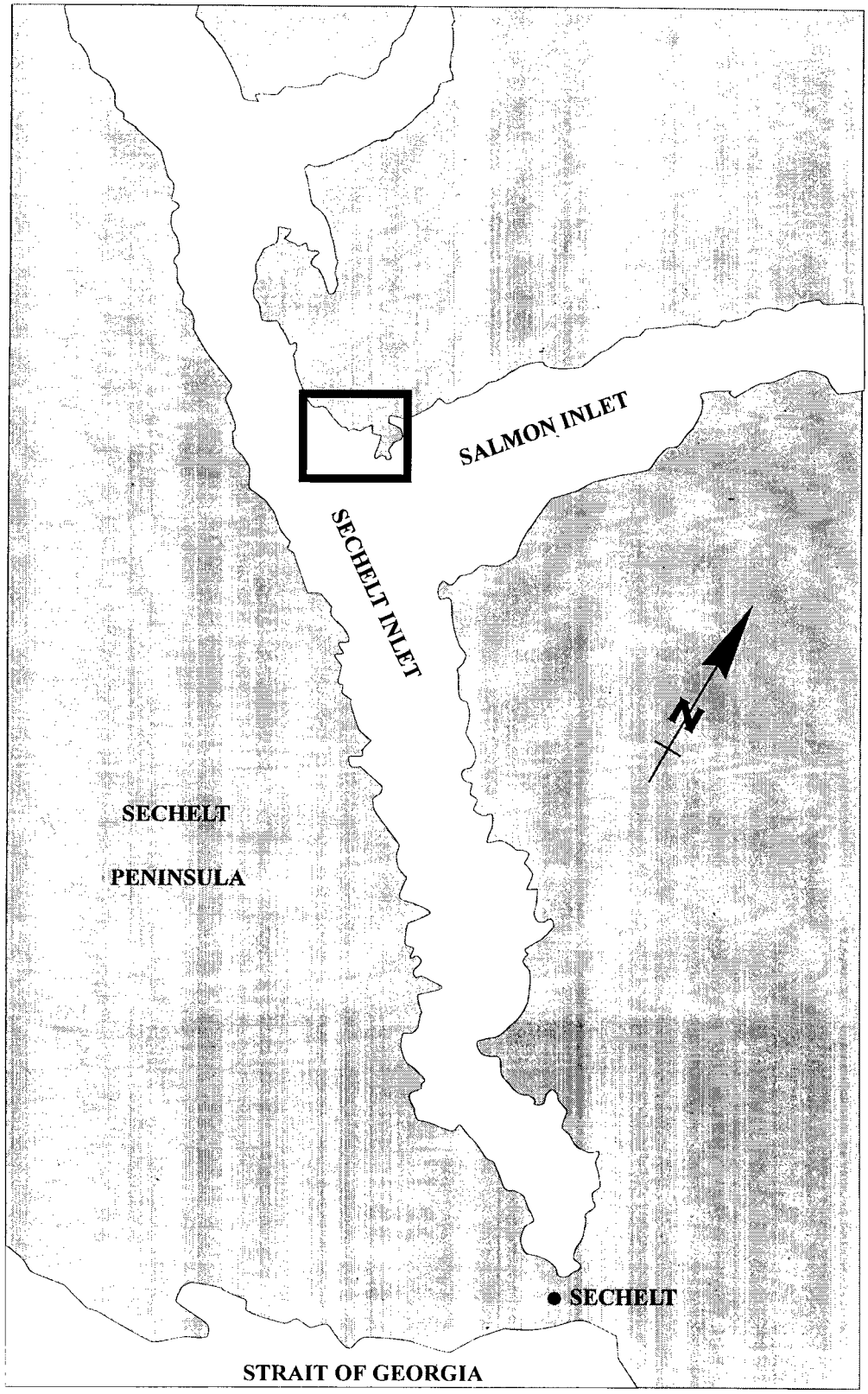


Figure 1

LOCATION MAP

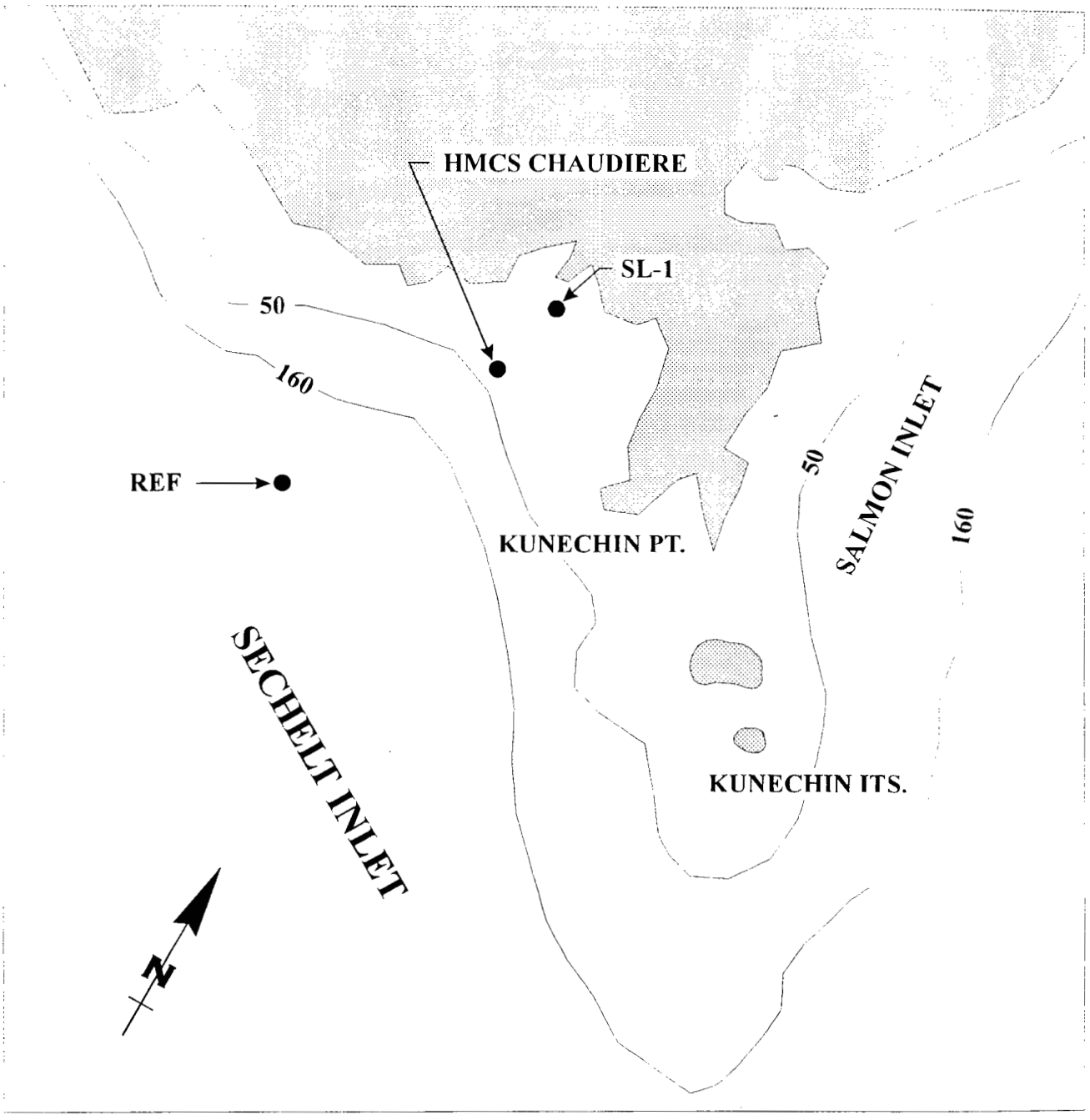


Figure 2

STATION LOCATION MAP

(indicating Reference and
shoreline sampling locations)

HMCS CHAUDIERE

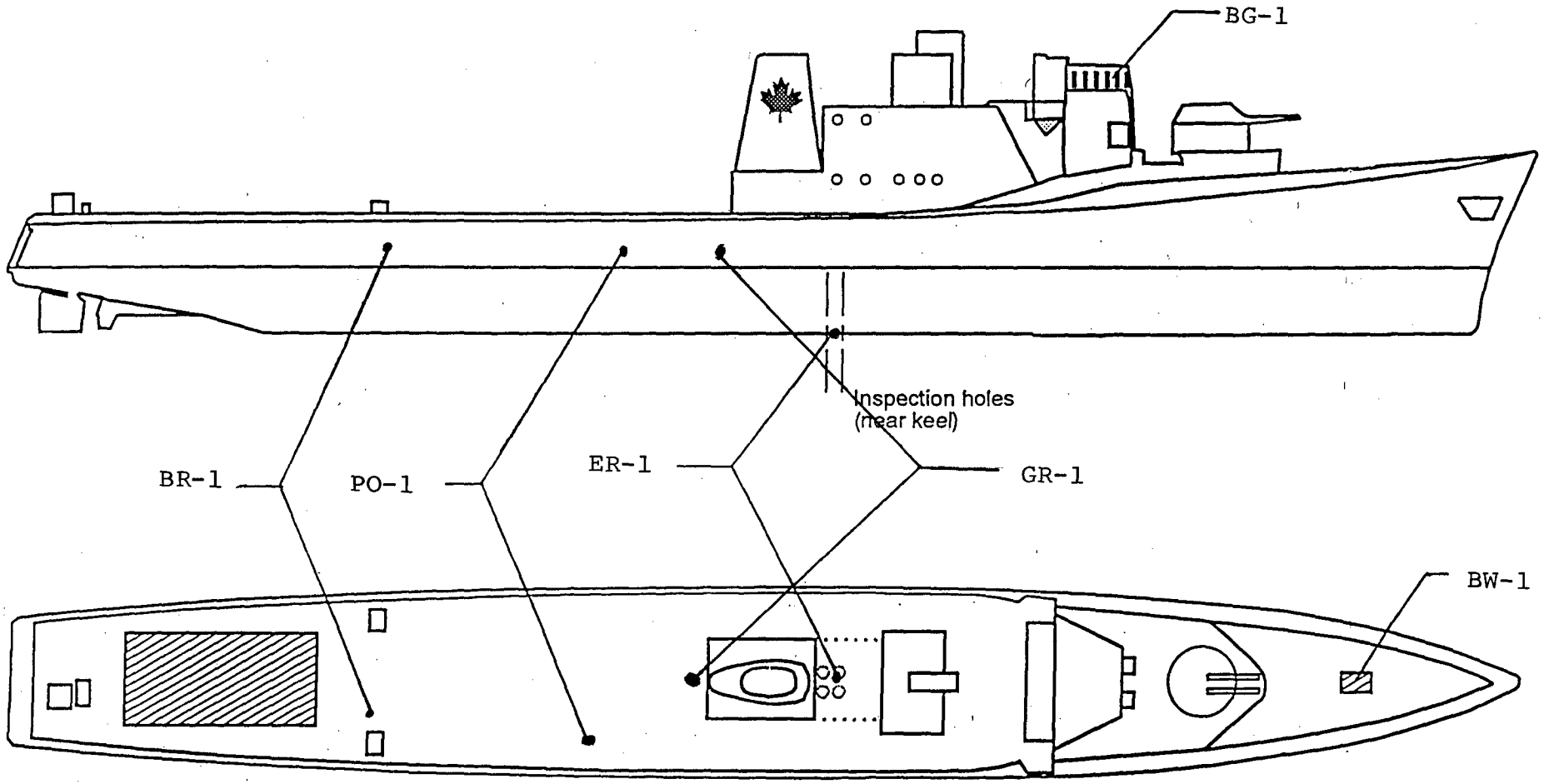


Figure 3. Vessel Schematic indicating Sample Locations

HMCS CHAUDIERE

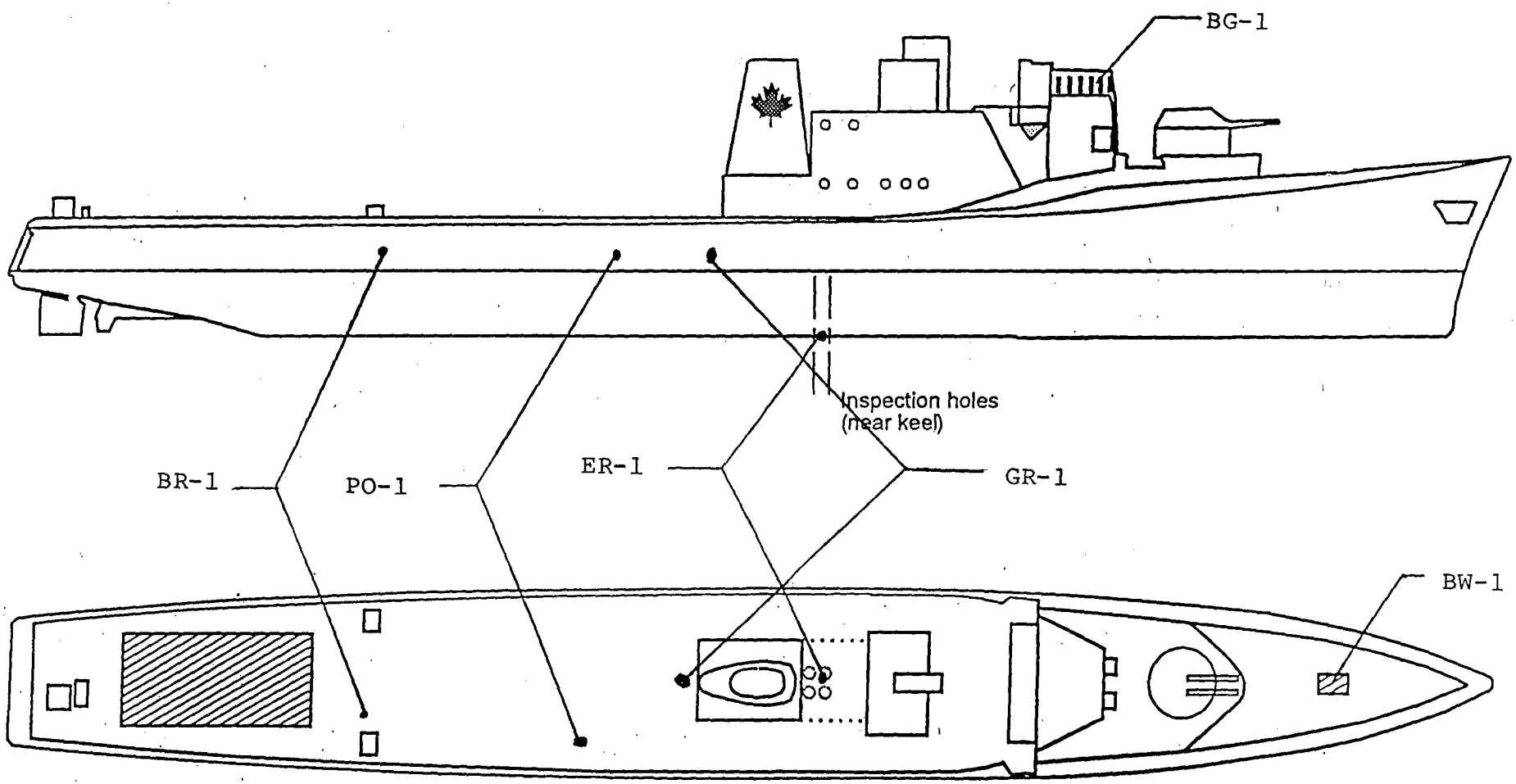


Figure 3. Vessel Schematic indicating Sample Locations

2.2 WATER SAMPLING METHODS

Water samples were collected on September 1 and 2, 1993 by RCMP divers at seven locations at depths ranging from 20 to 30 metres. The variable sampling depths reflect the sloping position of the vessel on the bottom.

Water samples were collected in Van Dorne bottles for analyses of fibre content, oil & grease, and trace metal content. All samples were stored on ice in coolers during transport to analytical laboratories.

Fibre content analysis was carried out on samples from four locations: REF-1, ER-1, BR-1, and BW-1. Sampling and analytical methods for fibres were based on discussions with Dr. H. Schreier, University of British Columbia, and Bacon Donaldson Consulting Engineers, the analytical laboratory.

2.3 COLONIZATION EVALUATION

A qualitative evaluation of biota and colonization activity on the ship's hull was undertaken on September 1 and 2, 1993. Video recording and still pictures were taken by the Royal Canadian Mounted Police (RCMP) Vancouver Sub-Division Dive Unit.

Observations of colonization of the hull were made along the exterior and within the vessel.

2.4 ANALYTICAL METHODS

2.4.1 Oil & Grease and ICP Metal Analysis

Analyses for oil & grease and trace metals from all seven locations were carried out at the Environment Canada West Vancouver Laboratory. Oil & grease were analyzed using standard infrared detection method. Trace metals were determined using an inductively coupled plasma system (ICP).

2.4.2 Fibre Content Analysis

The fibre content analysis was completed by Bacon Donaldson Consulting Engineers. The method followed was that used for analysis of asbestos in drinking water and included the measurement of pH. Details are given in Appendix C. It should be noted that, although reference is made to asbestos, the results are presented as fibres per litre. As stated in Ellis (1993), it could not be determined if the fibres measured actually were asbestos due to their small size.

Details of QA/QC and examples of mineral fibres which occur in nature can be found in Appendix D. With reference to the precision and accuracy of the analytical method, at 1 million fibres per litre (1 MFL) it is estimated that the results should be within a factor of 10 of the actual fibre content.

2.4.3 Fecal Coliform Analysis

Water samples were collected from surface waters in sterile 250 ml Nalgene bottles. Samples were stored at less than 10°C and transported to Environment Canada's Shellfish and Aquaculture Mobile Microbiology laboratory located in Pender Harbour. Three water samples were collected from each of three stations.

The laboratory reports for the fecal coliform analysis are presented in Appendix E.

Samples were analyzed using the 5-tube Most Probable Number (MPN) technique in A-1 media (Page 9-52, Standard Methods for the Examination of Water and Wastewater, 18th ed., American Public Health Assoc. 1992). The MPN method is a multiple tube fermentation technique which estimates bacterial density in a sample by the pattern of bacterial growth and gas formation in test tubes inoculated with serial dilutions of the sample. The MPN is calculated based on probability formulas, and as such is a statistical estimation.

3. RESULTS AND DISCUSSION

3.1 WATER SAMPLING RESULTS

3.1.1 Fibre Content Analysis

Data are shown in Table 2 along with the results from the February, 1993 monitoring study. Fibre content analysis at the four locations exhibited low fibre counts (0.25 - 0.50 MFL).

Table 2. Fibre Content Analysis

	No. of Fibres in 20 Grid Squares		Fibre Concentration MFL		pH of Water	
Sample	Feb/93	Sept/93	Feb/93	Sept/93	Feb/93	Sept/93
REF	16	9	0.80	0.45	7.40	7.66
BR-1	41	5	2.00	0.25	7.40	7.73
BW-1	18	10	0.90	0.50	7.50	7.74
ER-1	14	7	0.70	0.35	7.60	7.69

Natural background asbestos fibre levels in the Fraser River are 10^6 to 10^9 fibres/liter. Concentrations of fibres between stations, and between surveys, were the same. None of the fibres observed was sufficiently large enough to provide an electron diffraction pattern that could have been used to identify any specific asbestos type (Figure 4, 5 and 6).

SCANNING ELECTRON MICROGRAPHS

FIGURE 4

2.5 µm fibre in Sample BR-1.
20,000X.

FIGURE 6

1.5 µm fibre in Sample BW-1.
20,000X.

Diatom fragments in Sample BR-2.
9,000X.

SCANNING ELECTRON MICROGRAPHS

FIGURE 4

2.5 µm fibre in Sample BR-1.
20,000X.

FIGURE 5

1.5 µm fibre in Sample BW-1.
20,000X.

FIGURE 6

Diatom fragments in Sample BR-2.
9,000X.

3.1.2 Oil & Grease

Oil & grease concentrations were determined to be 0.2 mg/L or less in samples from BR-1, BR-2 and BW-1. Concentrations in samples from ER-1 and BG-1 were 0.5 mg/L and 0.6 mg/L respectively. The concentration in each of the remaining samples, SL-1 and REF, was 0.4 mg/L. Given the sensitivity of the test procedure, the results are considered to be similar among all samples.

Table 3. Oil & Grease Analysis (mg/L)

Date	BR-1	GR-1	BW-1	BG-1	ER-1	SL-1	PO-1	REF
Feb/93	0.2	-	<0.2	<0.2	0.2	<0.2	<0.2	<0.2
Sep/93	<0.2	<0.2	<0.2	0.5	0.6	0.4	-	0.4

3.1.3 Trace Metals

Similar values were determined between the vessel sites and the reference site, and are considered indicative of the background levels for Sechelt Inlet. No apparent differences were noted between the baseline study and the September 1993 monitoring study. Selected trace metal concentrations are shown in Table 4. The complete ICP trace metal data are presented in Appendix A.

Table 4. Trace Metal Concentrations (mg/L), September 1993

Parameter	BR-1	GR-1	BW-1	BG-1	ER-1	SL-1	REF
Cadmium	<0.5	<0.5	<0.5	<0.5	1.4	<0.5	<0.5
Copper	<0.5	<0.5	<0.5	<0.5	3	<0.5	<0.5
Lead	<5	<5	<5	<5	11	<5	<5
Zinc	0.3	1.1	<0.2	<0.2	0.6	<0.2	<0.2

3.1.4 Fecal Coliform Study

Canadian bivalve molluscan shellfish growing areas are classified as approved or prohibited on the following bacteriological criteria:

> In order that an area can be considered bacteriologically safe for the harvesting of shellfish, the fecal coliform median or geometric mean must not exceed 14 per 100 ml, and not more than 10% of the samples can exceed a fecal coliform level of 43 per 100 ml (i.e. the 90th percentile does not exceed 43 per 100 ml), when sampled under adverse pollution conditions. Coliform levels are determined by

the multiple tube fermentation, or Most Probable Number technique.

Based on above criteria, all marine stations sampled met the shellfish growing water quality standards. The Shellfish Growing Area Survey and Classification Program File Report is presented in Appendix E.

3.2 VIDEO OBSERVATIONS

A considerable portion of the exterior of the vessel has been colonized by *Ciona intestinalis* (crystal vase tunicates), barnacles and mussels since the baseline study (Figures 7, 8, and 9). Jelly fish, pelagic fish, a wolf eel, anemones, starfish and ling cod were found in the vicinity of the vessel. *Ciona intestinalis* were also observed in the interior of the vessel. Copies of the videotape are available through Environment Canada.

4. CONCLUSIONS

Data collected on the water quality of Sechelt Inlet in the vicinity of the HMCS Chaudiere during the February 1993 and September 1993 surveys indicate that the vessel has had no apparent impact on the marine environment. There has been no elevation in the concentration of any of the water quality parameters measured.

Future monitoring surveys may include observation and analyses of the sediments at the disposal site. Video imagery will continue to be used to record the colonization of the hull.

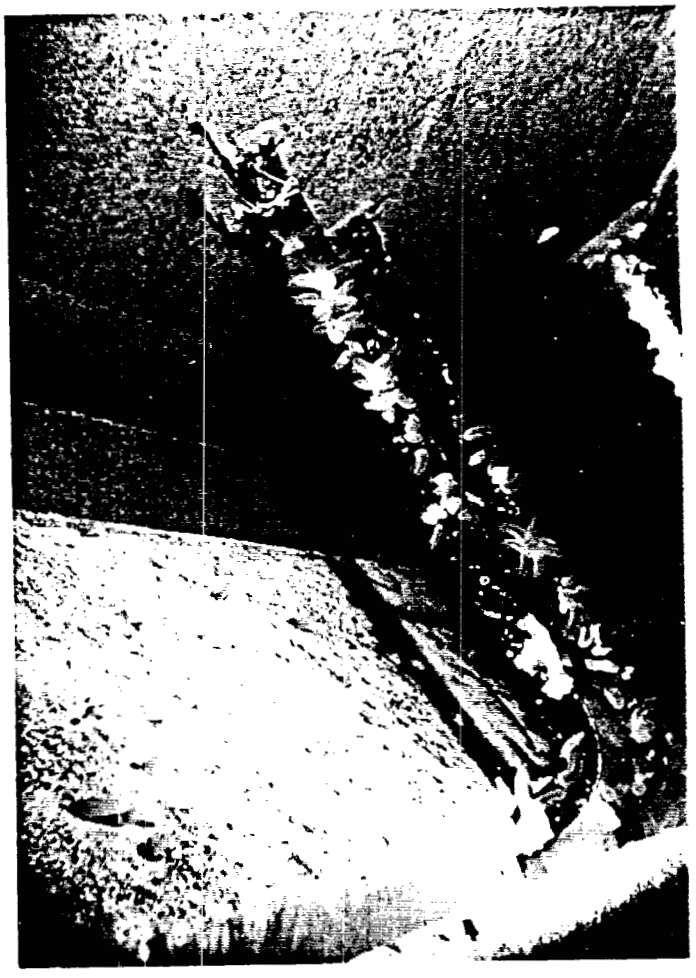


Fig. 7 Tunicate Colonies (*Ciona intestinalis)*

Fig. 8 Tunicate Colonies (*Ciona intestinalis)*

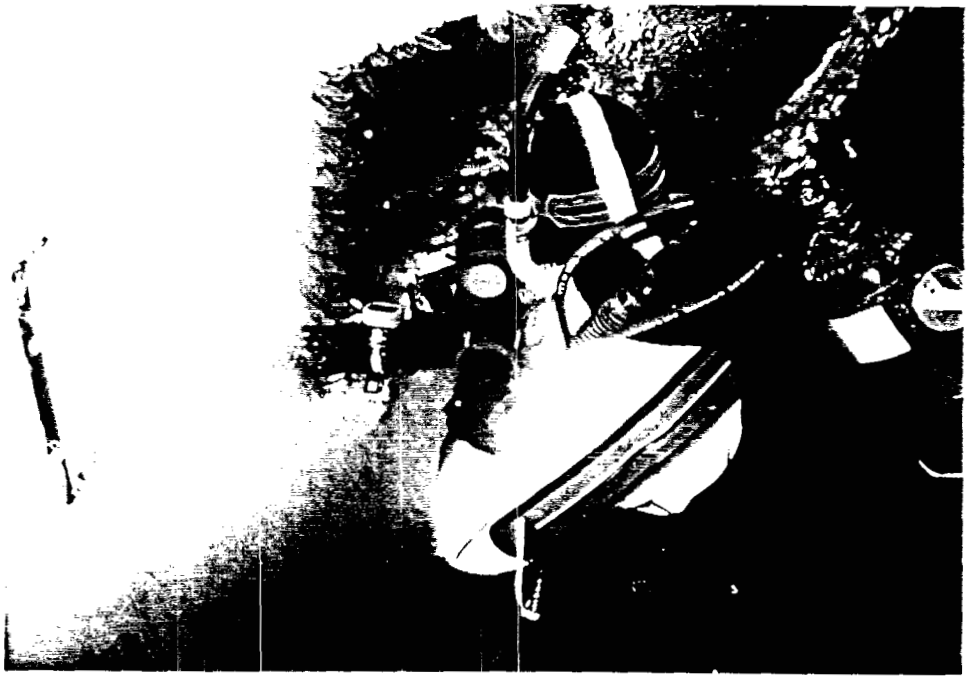


Fig. 9 Tunicate Colonies (*Ciona intestinalis)*

REFERENCES

Ellis, D. 1993. HMCS Chaudiere Monitoring Survey Results, April 1993. Environment Canada Regional Data Report 93-01.

Shreier, H., 1989. Asbestos in the Natural Environment, Studies in Environmental Science 37. Elsevier, Amsterdam.

APPENDIX A

ICP TRACE METAL RESULTS

RESULTS FOR KUNETCHIN PT SAMPLES

Parameter Analyzed		Units	GR-1 931779-001	BR-1 931779-002	BW-1 931779-003	BG-1 931779-004	ER-1 931779-005
ETALS/EXT.(WATER-ICP SCAN)	AG	mg/l	<1	<1	<1	<1	<1
	AL	mg/l	<5	<5	<5	<5	<5
	AS	mg/l	<5	<5	<5	<5	<5
	B	mg/l	3	4	4	3	6
	BA	mg/l	<.1	<.1	<.1	<.1	.9
	BE	mg/l	.1	<.1	.1	.1	<.1
	CA	mg/l	280	290	270	280	290
	CD	mg/l	<.5	<.5	<.5	<.5	1.4
	CO	mg/l	<.5	<.5	<.5	<.5	2.5
	CR	mg/l	<.5	<.5	<.5	<.5	2.7
	CU	mg/l	<.5	<.5	<.5	<.5	3
	FE	mg/l	<.5	<.5	<.5	<.5	<.5
	K	mg/l	240	260	250	240	310
	MG	mg/l	790	840	790	790	830
	MN	mg/l	<.1	<.1	<.1	<.1	.2
	MO	mg/l	<1	<1	<1	<1	2
	NA	mg/l	6720	7070	6710	6870	6610
	NI	mg/l	<2	<2	<2	<2	5
	P	mg/l	<10	<10	<10	<10	<10
	PB	mg/l	<5	<5	<5	<5	11
	SB	mg/l	<5	<5	<5	<5	<5
	SE	mg/l	<5	<5	<5	<5	18
	SI	mg/l	<5	<5	<5	<5	6
	SN	mg/l	<5	<5	<5	<5	<5
	SR	mg/l	4.7	4.9	4.7	4.7	5.1
	TI	mg/l	<.2	<.2	<.2	<.2	3.2
	V	mg/l	<1	<1	<1	<1	1
	ZN	mg/l	1.1	.3	<.2	<.2	.6
.HARDNESS/CA+MG	HC	mg/l	3940	4160	3940	3960	4120
/TOTAL	HT	mg/l	3920	4130	3900	3930	4110

RESULTS FOR KUNETCHIN PT SAMPLES

Parameter Analyzed		Units	SL-1 931779-006	REF 931779-007
METALS/EXT.(WATER-ICP SCAN)	AG	mg/l	<1	<1
	AL	mg/l	<5	<5
	AS	mg/l	<5	<5
	B	mg/l	4	7
	BA	mg/l	<.1	<.1
	BE	mg/l	<.1	.1
	CA	mg/l	260	280
	CD	mg/l	<.5	<.5
	CO	mg/l	<.5	<.5
	CR	mg/l	<.5	<.5
	CU	mg/l	<.5	<.5
	FE	mg/l	<.5	<.5
	K	mg/l	230	240
	MG	mg/l	740	780
	MN	mg/l	<.1	<.1
	MO	mg/l	<1	<1
	NA	mg/l	6350	6810
	NI	mg/l	<2	<2
	P	mg/l	<10	<10
	PB	mg/l	<5	<5
	SB	mg/l	<5	<5
	SE	mg/l	<5	<5
	SI	mg/l	<5	<5
	SN	mg/l	<5	<5
	SR	mg/l	4.3	4.6
	TI	mg/l	<.2	<.2
	V	mg/l	<1	1
	ZN	mg/l	<.2	<.2
.HARDNESS/CA+MG	HC	mg/l	3680	3910
/TOTAL	HT	mg/l	3620	3890

APPENDIX B

BACON DONALDSON WATER SAMPLE REPORT

1.0 INTRODUCTION

Seven one-litre water samples were delivered to Bacon Donaldson by Duane Brothers of Environment Canada. Four of the samples were to be analyzed for asbestos fibre content, the other three were to be preserved for possible future work.

The four samples to be analyzed were identified as follows:

REF
BR-1
BW-1
ER-4

Bacon Donaldson was to perform fibre counts by Transmission Electron Microscopy (TEM) on the four samples and determine if any differences in fibre content existed among the samples. The pH of the water samples was also to be determined.

2.0 TESTING PROCEDURES

Test procedures were identical to those described in our report to Environment Canada, Waste Management Division, dated March 11, 1993, and were as follows:

100 ml of each samples was filtered using 47 mm Nuclepore membrane filters with .4 µm hole size. The filtration was performed within 8 hours of the sample delivery. A "laboratory blank" filter was processed along with the test filters in order to eliminate any errors from contamination.

Segments of each filter were carbon coated in a vacuum evaporator, 3 mm square were cut from each filter segment and placed on carbon coated 100 mesh TEM sample grids.

The "Modified Jaffe Wick" method was used to dissolve the carbon coated nuclepore filter squares, leaving any particulate enclosed by the remaining carbon films. The samples were examined in a Hitachi HU-11E TEM.

Initial examination was carried out at lower magnifications in order to determine the overall fibre loading and the quality of the carbon films. Since the fibre loading was found to be very low, the so-called Grid Square Method was used to perform the fibre counts. This method consists of counting all the fibres found in twenty grid squares (ten on each of two sample grids). The criteria used to identify a feature as a fibre were: parallel sides and aspect ratio greater than 3:1. The actual fibre counting was performed at 20,000X magnification.

3.0 RESULTS AND DISCUSSION

The fibre counts in all four water samples was quite low. Small irregular particles, possibly organic material, and diatom fragments were observed in all four samples. Most of the fibres were less than 1 μm in length and no fibre bundles or fibres over 3 μm were seen.

The number of fibres found in 20 grid squares, the fibre concentration in MFL (millions of fibres per litre), and the pH for each sample are presented in the following table.

Sample	No. of Fibres in 20 Squares	Fibre Concentration MFL	pH of Water
REF	9	0.45	7.66
BR-1	5	0.25	7.73
BW-1	10	0.5	7.74
ER-1	7	0.35	7.69

The fibre content in all four samples is very low and the differences between the four samples are not significant.

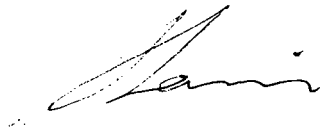
None of the fibres observed was sufficiently large to provide an electron diffraction pattern that could have been used to identify any specific asbestos type.

Electron micrographs of typical features observed in some of the samples are appended.

We trust that these results will satisfy your requirements. Should any questions arise, do not hesitate to call.

Yours truly,

BACON DONALDSON



Arvid Lacis
Electron Microscopist

AL/mg

APPENDIX C

BACON DONALDSON INFORMATION ON METHOD, FIBRE TYPES AND QUALITY ASSURANCE/QUALITY CONTROL

APPENDIX I. EXAMPLES OF MINERALS WHICH MAY OCCUR IN FIBROUS HABIT

Mineral Name(s)	Formula	Detectable Elements By Energy Dispersive X-Ray Analysis	a) Occurrence b) Associated Minerals c) Similar Minerals
Serpentine (Chrysotile) (Antigorite)	$Mg_6(OH)_8Si_4O_{10}$	Mg-Si	a) hydrothermally decomposed olivine; pyroxene, amphibole b) olivine, tremolite, talc, opal, pyrope garnierite c) ----------
Talc (Steatite)	$Mg_3(OH)_2Si_4O_{10}$	Mg-Si	a) alteration of serpentine; anthophyllite b) chlorite, serpentine, magnecite, pyrite, dolomite c) pyrophyllite; kaolinite
Amosite (Cummingtonite) (Grunerite)	$(MgFe)_7[OHSi_4O_{11}]_2$	Mg-Si-Fe	a) variety of cummingtonite b) ---------- c) chrysotile asbestos
Riebeckite (Crocidolite)	$Na_2Fe_3Fe_2$ $[(OH,F)Si_4O_{11}]_2$	Na-Si-Fe	a) in crystalline schists, yellow tiger eye b) ---------- c) ----------
Tremolite	$Ca_2Mg_5(OH,F)_2$ $[Si_4O_{11}]_2$	Mg-Si-Ca	a) in metamorphic limestone & dolomite, in talc schists b) ---------- c) chrysotile, pectolite, wollastonite
Actinolite	$Ca_2(MgFe)_5Si_8O_{22}(OH)_2$	Mg-Si-Ca-Fe	a) in impure limestone or dolomite b) ---------- c) pyroxenes
Byssolite	$Ca_2Mg_5(OH,F)_2$ $[Si_4O_{11}]_2$	Mg-Si-Ca	a) in metamorphic limestone and dolomites, in alpine cracks b) ---------- c) ----------
Anthophyllite	$(MgFe)_7[OHSi_4O_{11}]_2$	Mg-Si ± Fe	a) in crystalline schists, mica schists, in metamorphic rock b) ---------- c) chrysotile
Hornblende	$CaNa(MgFe)(AlFeTi)_3$ $Si_6O_{22}(O,OH)_2$	Na-Mg-Al-Si-Ca-Ti-Fe	a) in metamorphic & igneous rocks, in crystalline schists b) biotite, garnet, epidote, magnetite c) augite, tourmaline
Epsomite (Bitter Salt)	$Mg[SO_4]7H_2O$	Mg-S	a) weathering product in ore deposits, efflorescent crusts, alteration product of kieserite b) ---------- c) kieserite
Wollastonite (Table Spar)	$Ca_3[Si_3O_9]$	Si-Ca	a) in contact metamorphic limestone, in crystalline schists b) quartz, garnet, vesuvianite, pyroxene c) pektolite, tremolite
Pectolite	$Ca_2NaH[Si_3O_9]$	Na-Si-Ca	a) in fissures in igneous rocks b) zeolite, calcite c) tremolite, wollastonite
Zeolite (Natrolite)	$Na_2Al_2Si_3O_{10}\cdot 2H_2O$	Na-Al-Si	a) in cavities in igneous rocks, in fissures in granites & crystalline schists b) other zeolites, calcite, apophyllite c) aragonite scolecite, thomsonite, mesolite, gavellite
Pyrophyllite	$Al_2[(OH)_2Si_4O_{10}]$	Al-Si	a) in quartz veins & ore veins, in slate clays b) ---------- c) talc, kaolinite

Appendix I. Examples of Minerals Which May Occur in Fibrous Habit

Mineral Name(s)	Formula	Detectable Elements By Energy Dispersive X-Ray Analysis	a) Occurrence b) Associated Minerals c) Similar Minerals
Ilpnomelan	$(K,H_2O)(Fe,Mg,Al)_3[(OH)_2Si_4O_{10}](H_2O)_2$	Mg-Al-Si-K-Fe	a) in ore veins b) pyrite, siderite, limonite sphalerite, quartz c) ----------
Anhydrite	$Ca[SO_4]$	Ca-S	a) in ore veins, in salt deposits b) halite, gypsum, dolomite c) cryolite, gypsum, barytes, calcite
Sillimanite (Fibrolite)	$Al_2[OSiO_4]$	Al-Si	a) in crystalline schists, granulites eclogites, in contact-metamorphic rocks b) ---------- c) cyanite
Zoisite & Clino-zoisite	$Ca_2Al_2[OOHSiO_4Si_2O_7]$	Al-Si-Ca	a) in crystalline schists & metamorphic rocks b) amphibole, garnet, vesuvianite epidote, quartz c) tremolite
Epidote & Pistacite	$Ca_2(FeAl)Al_2[OHSiO_4Si_2O_7]$	Al-Si-Ca-Fe	a) in fissures & vesicles of basic igneous rocks & crystalline schists b) zeolite, calcite, axinite garnet, copper, vesuvianite c) hemimorphite, aragonite, staffelite; tourmaline, actinolite,
Zeolite (Thomsonite)	$NaCa_2[Al]_2(AlSi)Si_2O_{10}]_2 \cdot 6H_2O$	Na-Al-Si-Ca	a) in vesicles in basic igneous rocks, in vesuvianite lavas b) other zeolites, analcite, calcite c) natrolite, prehnite
Palygorskite (Attapulgite)	$(MgAl)_2[OHSi_4O_{10}] \cdot 4H_2O$	Mg-Al-Si	a) weathering product of serpentine b) chalcedony, opal, chlorite, magnesite c) ----------
Sepiolite (Meerschaum)	$Mg_4[(OH)_2Si_6O_{15}] \cdot 2H_2O + 4H_2O$	Mg-Si	a) weathering product of serpentine b) opal, chalcedony, magnesite, chlorite c) ----------
Halloysite	$Al_2Si_2O_5(OH)_4$	Al-Si	a) weathering product of kaolinite b) feldspars, other clays c) ----------
Brucite (Nemolite)	$Mg(OH)_2$	Mg	a) low temperature in serpentine or dolomite metamorphic rocks b) periclase c) ----------
Magnesite	$MgCO_3$	Mg	a) metasomatic deposits replacing limestone & dolomite, in serpentine in calc schists b) ---------- c) ankerite, calcite, dolomite
Zeolite (Laumontite)	$Ca[AlSi_2O_6]_2 \cdot 4H_2O$	Al-Si-Ca	a) in ore veins, in cavities & fissures in eruptive rocks b) other zeolites, calcite, chlorite c) feldspars
Aragonite & Calcite	$CaCO_3$	Ca	a) in rock-fissures, in ore deposits embedded in sulfur as sinter formation b) ---------- c) calcite, barytes, coelestine, strontianite, natrolite, topaz, dolomite
Apjohnite	$MnAl_2[SO_4]_4 \cdot 22H_2O$	Mn-Al-S	a) in rock as weathering product of sulphides b) ---------- c) alunogen

Appendix I. Examples of Minerals Which May Occur in Fibrous Habit

Mineral Name(s)	Formula	Detectable Elements By Energy Dispersive X-Ray Analysis	a) Occurrence b) Associated Minerals c) Similar Minerals
Gypsum & Selenite	$CaSo_6 \cdot 2H_2O$	S-Ca	a) rocks in salt deposits, weathering product of sulphides in sedimentary rocks, in ore deposits b) anhydrite, aragonite, sulphur c) mica, talc, kaolinite
Valentinite (Antimony Bloom)	Sb_2O_3	Sb	a) weathering product of antimony ores b) antimonite, galena c) cerussite
Arsenopyrite	FeAsS	S-Fe-As	a) in ore veins b) galena, silver c) lollingite, chloanthite, skutterudite
Lollingite (Leucopyrite)	$FeAs_2$	Fe-As	a) in ore veins b) arsenopyrite c) ----------
Cedrite	$(MgFe)_6Al_2$ $[OH(AlSi)Si_3O_{11}]_2$	Mg-Al-Si-Fe	a) in metamorphic rocks, in crystalline schists, in granites, in ore veins b) ---------- c) bronzite
Pyroxene Family			
1) Diopside	$CaMg[Si_2O_6]$	Mg-Si-Ca	a) in magnetite lodes, in fissures in metamorphic rocks b) chlorite, hematite, magnetite, apatite, biotite c) clinochlore, augite
2) Violane	$CaMg[Si_2O_6] \pm Mn, Fe$	Mg-Si-Ca $\pm$ Mn, Fe	a) ---------- b) ---------- c) ----------
3) Enstatite	$Mg_2[Si_2O_6]$	Mg-Si	a) rock constituent in serpentine, in pegmatic apatite veins b) apatite, phlogopite, olivine, bronzite c) hypersthene
4) Augite	(Ca,Mg,Fe_2,Fe_3,Ti,Al) $[(SiAl)_2O_6]$	Mg-Si-Ca,Ti-Fe	a) rock constituent in basic rocks, in tuffs, lavas & volcanic ejecta b) ---------- c) amphibole
5) Hedenbergite	$CaFe[Si_2O_6]$	Si-Ca-Fe	a) in metamorphic & metasomatic rocks b) magnetite, pyrite c) ----------
6) Acmite-Aegirite	$NaFeSi_2O_6$	Na-Si-Fe	a) common in high-soda, low-silica rocks b) ---------- c) nepheline, leucite
Alunogen	$Al_2(SO_4)_3 \cdot 16H_2O$	Al-S	a) in ore veins, in coal piles, in clays b) pyrite melanterite c) alunite
Halotrichite	$FeAl_2[SO_4]_4 \cdot 22H_2O$	Al-S-Fe	a) weathering product of pyrites in ore deposits, in lignites b) ---------- c) ajohnite
Celestite	$SrSO_4$	S-Sr	a) in sedimentary rocks, in sandstone or limestone b) fluorite, calcite, gypsum, dolomite, galena, sphalerite c) ----------

reagents for carrying out asbestos analyses. Analytical determinations of asbestos can be carried out only after an acceptably low level of contamination has been established.

9. Calculations

9.1 Fiber Concentrations

Grid Square Counting Method - If the Grid Square Method of counting is employed, use the following formula to calculate the total asbestos fiber concentration in MFL.

$$C = (\bar{F} \times A_f)/(A_g \times V_o \times 1000) \qquad (1)$$

where: C = Fiber concentration (MFL)

$\bar{F}$ = Average number of fibers per grid opening

A_f = Effective filtration area of filter paper (mm^2) used in grid preparation for fiber counting

A_g = Average area of one grid square (mm^2)

V_o = Original volume of sample filtered (ml)

If ashing is involved, use the same formula but substitute the effective filtration area of the 25-mm diameter filter for A_f instead of that for the 47-mm diameter filter. If one-half the filter is ashed, multiple C by two.

Field-of-View Counting Method - If the Field-of-View Method of counting is employed, use the following formula to calculate the total asbestos fiber concentrations (MFL).

$$C = (\bar{F} \times A_f \times 1000)/(A_v \times V_o) \qquad (2)$$

where: C = Fiber concentration

$\bar{F}$ = Average number of fibers per field of view

A_f = Effective filtration area of filter paper (mm^2) used in grid preparation for fiber counting

A_v = Area of one field of view (μm^2)

V_o = Original volume of sample filtered (ml)

If ashing is involved, use the same formula but substitute the effective filtration area of the 25-mm diameter filter for A_f instead of that for the 47-mm diameter filter.

9.2 Estimated Mass Concentration

Calculate the mass (µg) of each fiber counted using the following formula.

$$M = L \times W^2 \times D \times 10^{-6}$$

If the fiber content is predominantly chrysotile, the following formula may be used.

$$M = \frac{\pi}{4} \times L \times W^2 \times D \times 10^{-6} \quad (3)$$

where: M = Mass (µg)

L = Length (µm)

W = Width (µm)

D = Density of fibers (g/cm^3)

Then calculate the mass concentration (µg/l) employing the following formula.

$$M_c = C \times \bar{M}_f \times 10^6$$

where: M_c = mass concentration (µg/l)

C = fiber concentration (MFL)

$\bar{M}_f$ = mean mass per fiber (µg)

To calculate $\bar{M}_f$ use the following formula.

$$\bar{M}_f = \sum_{i=1}^{n} M_{i/n} \quad (4)$$

where: M_i = mass of each fiber, respectively

n = number of fibers counted

NOTE 1: Because many of the amphibole fibers are lath shaped rather than square in cross section the computed mass will tend to be high because laths will, in general, tend to lie flat rather than on edge.

NOTE 2: Assume the following densities: chrysotile 2.5, amphibole 3.25.

9.3 Aspect Ratio

The aspect ratio for each fiber is calculated by dividing the length by the width.

10. Reporting

10.1 Report the following concentration as MFL for sample and blank using 95% confidence intervals.

a. Chrysotile

b. Amphibole

c. Total asbestos fibers

10.2 Use two significant figures for concentrations greater than 1 MFL, and one significant figure for concentrations less than 1 MFL.

10.3 Tabulate the size distribution, length and width.

10.4 Tabulate the aspect ratio distribution.

10.5 Report the calculated mass as µg/l.

10.6 Indicate the detection limit in MFL.

10.7 Indicate if less than five fibers were counted.

10.8 Include remarks concerning pertinent observations, (clumping, amount of organic matter, debris) amount of suspected though not identifiable as asbestos fibers (ambiguous).

11. Precision

11.1 Intra-Laboratory

The precision that is obtained within an individual laboratory is dependent upon the number of fibers counted. If 100 fibers are counted and the loading

is at least 3.5 fibers/grid square, computer modeling of the counting procedure shows that a relative standard deviation of about 10% can be expected.

In actual practice some degradation from this precision will be observed but should not exceed ± 15% if several grids are prepared from the same filtered sample. The relative standard deviation of analyses of the same water sample in the same laboratory will increase as a result of sample preparation errors and a relative standard deviation of about about ± 25 to 35% will occur. As the number of fibers counted decreases, the precision will also decrease approximately proportional to $\sqrt{N}$ where N is the number of fibers counted. The precision for mass concentration is generally poorer than that for fiber concentration.

Based upon the analysis of one laboratory utilizing a different analyst for each of three water samples, intra-laboratory precision data are presented in Table 1.

11.2 Inter-Laboratory

Based upon the analysis by various government and private industry laboratories of filters prepared from nine water samples, inter-laboratory precision data of the method are presented in Table 2.

12. Accuracy

12.1 Fiber Concentrations

As no standard reference materials are available, only approximate estimates of the accuracy of the procedure can be made. At 1 MFL, it is estimated that the results should be within a factor of 10 of the actual asbestos fiber content.

This method requires the positive identification of a fiber to be asbestos as a means for its quantitative determination. As the state-of-the-art precludes the positive identification of all of the asbestos fibers present, the results of this method, as expressed as MFL, will be biased on the low side and, assuming no fiber loss, represent 0.4 to 0.8 of the total asbestos fibers present.

Fig. 8 Tunicate Colonies (*Ciona intestinalis)*

Fig. 9 Tunicate Colonies (*Ciona intestinalis)*

Fig. 7 Tunicate Colonies (*Ciona intestinalis)*

Marine Stations Daily Results

Shellfish Area : 28 Sechelt Inlet (ST)
Shellfish Sector : 03 Sechelt Inlet
Sampling Period : August 1990 - September 1993
Includes Depth Samples : No
Key Station Only : No
Sample Type * : Water

Stn	Date	Time	Depth (m)	Tide State	Fecal Coliform	Salinity (ppt)	TOTAL PRECIPITATION (mm) Curr. 24h	Prev. 24h	Prev. 48h	Prev. 5d
70	14-AUG-90	0905		Flood	<2	25	-	-	-	-
	15-AUG-90	1505		Flood	<2	24	.3	-	-	-
	16-AUG-90	0840		Ebb	<2	24	.4	.3	.3	.3
	17-AUG-90	1300		Flood	<2	23	-	.4	.7	.7
	18-AUG-90	1305		Flood	<2	23	.3	-	.4	.7
	05-MAY-91	1055		High Slack	<2	25	10.2	7.4	7.4	7.4
	06-MAY-91	0915		High Slack	2	24	4.0	10.2	17.6	17.6
	07-MAY-91	1040		Low Slack	<2	24	3.4	4.0	14.2	21.6
	08-MAY-91	1045		Low Slack	<2	24	.2	3.4	7.4	25.0
	09-MAY-91	1135		Low Slack	<2	22	-	.2	3.6	25.2
	14-SEP-93	1125		Ebb	<2	27				
	16-SEP-93	1045		Ebb	<2	28				
	17-SEP-93	1100		Ebb	<2	25				

* Units are per 100ml for water samples and per 100g for sediment or biota samples.

Marine Stations Summary Report

Shellfish Area : 28 Sechelt Inlet (ST)
Shellfish Sector : 03 Sechelt Inlet
Sampling Period : August 1990 - September 1993
Includes Depth Samples : No
Key Station Only : No
Sample Type * : Water

FECAL COLIFORM

Stn	Samples	Min.	Max.	Median	Geo. Mean	90 Percentile	% > 43
70	13	<2	2	<2.0	.3	<2.0	.0

* Units are per 100ml for water samples and per 100g for sediment or biota samples.

Marine Stations Listing

Shellfish Area : 28 Sechelt Inlet (ST)
Shellfish Sector : 03 Sechelt Inlet
Survey ID : 939
Survey Period : September 14, 1993 - September 17, 1993

Stn	Stn ID	Station Description	Latitude	Longitude	DFO Sub-Area
70	2607	THIRD SMALL BAY INSIDE KUNECHIN POINT	49° 38.50'	123° 48.83'	16-07
83	4722	SOUTHEAST BAY NORTH OF KUNECHIN POINT	49° 37.76'	123° 48.32'	-
84	4723	MIDDLE BUOY OFF KUNECHIN PT AT CHAUDIERE SITE	49° 37.70'	123° 48.51'	-

Marine Stations Daily Results

Shellfish Area : 28 Sechelt Inlet (ST)
Shellfish Sector : 03 Sechelt Inlet
Survey ID : 939
Survey Period : September 14, 1993 - September 17, 1993
Includes Depth Samples : No
Key Station Only : No
Sample Type * : Water

Stn	Date	Time	Depth (m)	Tide State	Fecal Coliform	Salinity (ppt)	TOTAL PRECIPITATION (mm) Curr. 24h	Prev. 24h	Prev. 48h	Prev. 5d
70	14-SEP-93	1125		Ebb	<2	27				
	16-SEP-93	1045		Ebb	<2	28				
	17-SEP-93	1100		Ebb	<2	25				
83	14-SEP-93	1130		Ebb	<2	28				
	16-SEP-93	1050		Ebb	<2	26				
	17-SEP-93	1105		Ebb	2	26				
84	14-SEP-93	1125		Ebb	<2	28				
	16-SEP-93	1055		Ebb	<2	26				
	17-SEP-93	1100		Ebb	<2	25				

* Units are per 100ml for water samples and per 100g for sediment or biota samples.

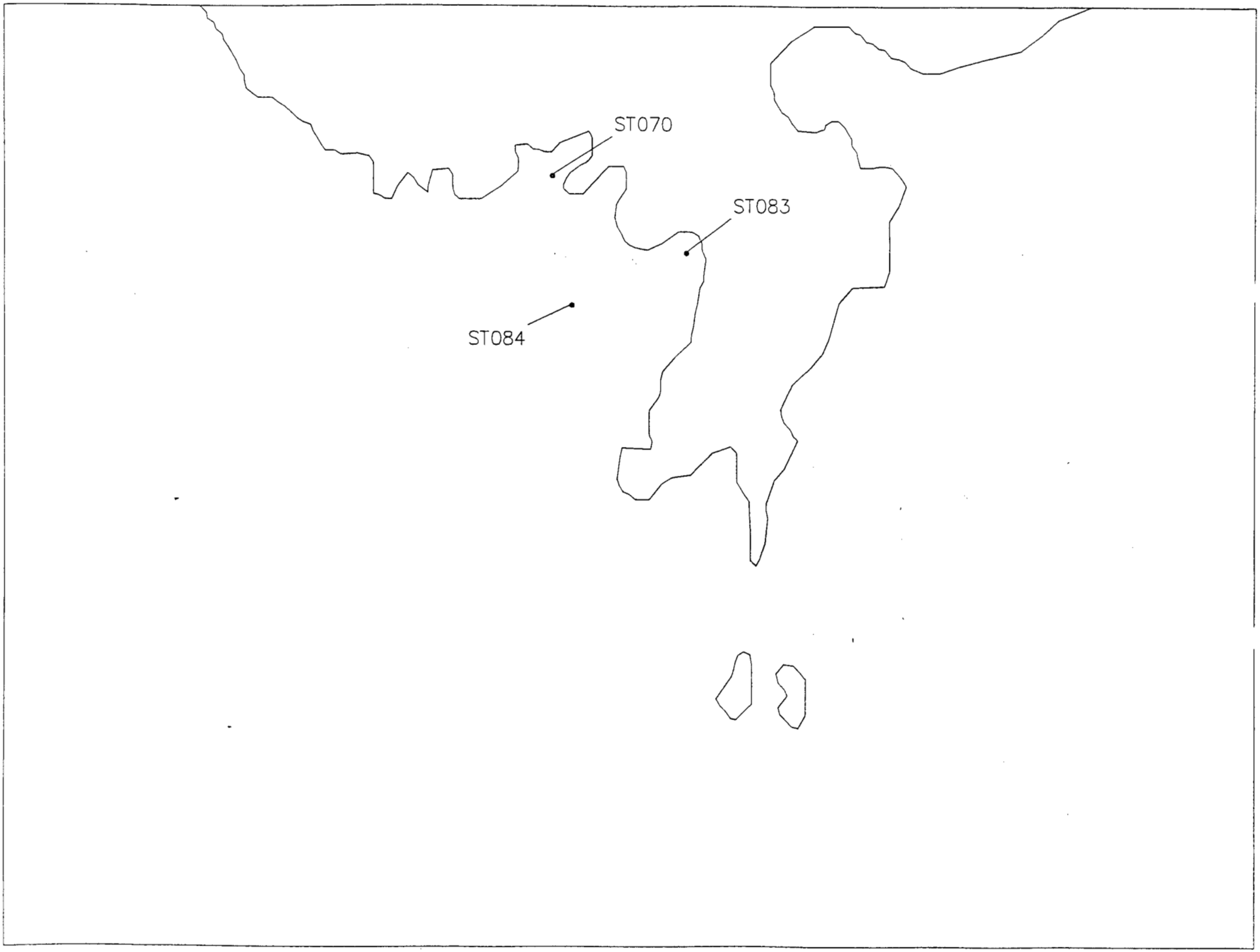
Marine Stations Summary Report

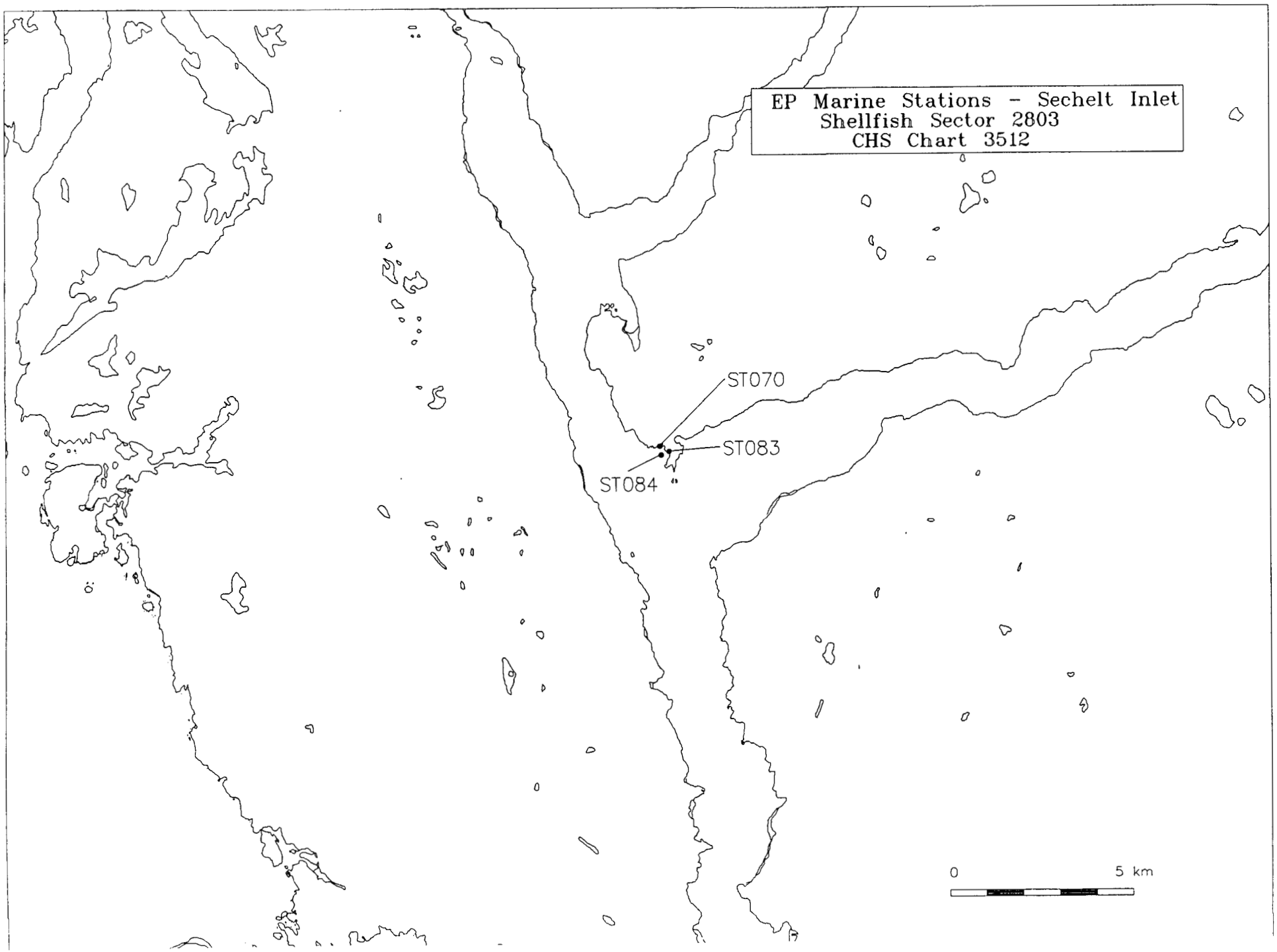
Shellfish Area : 28 Sechelt Inlet (ST)
Shellfish Sector : 03 Sechelt Inlet
Survey ID : 939
Survey Period : September 14, 1993 - September 17, 1993
Includes Depth Samples : No
Key Station Only : No
Sample Type * : Water

FECAL COLIFORM

Stn	Samples	Min.	Max.	Median	Geo. Mean	90 Percentile	% > 43
70	3	<2	<2	<2.0	.3	<2.0	.0
83	3	<2	2	<2.0	.3	2.0	.0
84	3	<2	<2	<2.0	.3	<2.0	.0

* Units are per 100ml for water samples and per 100g for sediment or biota samples.


ST070
ST083
ST084


EP Marine Stations - Sechelt Inlet
Shellfish Sector 2803
CHS Chart 3512
ST070
ST083
ST084
0
5 km

VIII. Recommendations:

1. The area will be re-surveyed in 1995. Enquiries should be made of the local dive boat charter operators regarding the presence of heads or holding tanks in their boats.

On Sept. 17, 1993, a dive boat with approximately 6 divers on board was anchored off sample station ST084. Local knowledge indicates that dive charters operate off the ship almost daily. Scuba divers in the water could be a cause of direct fecal coliform contamination, but loading would likely be at a minimal level. Loading could increase to a higher level if the dive boats have heads and no holding tanks.

IV. Hydrographic and Meteorlogic Characteristics:

Marine sampling was conducted during the ebb period of the tidal cycle.

There was no rainfall during the survey.

V. Water Quality Studies:

This file report presents marine water quality survey data for a very restricted re-evaluation survey conducted off Kunechin Point in Sechelt Inlet during September 1993. This survey off the site of the HMCS Chaudiere was conducted at the request of the Ocean Disposal Control Program and was part of a larger monitoring survey which included water quality analyses for trace metals, fibre, oil and grease (off the ship itself), a colonization evaluation using video, and trace metals analyses of resident shellfish species.

Generally, re-evaluation surveys are conducted triannually as outlined in the Canadian Shellfish Sanitation Program. Surveys are usually conducted during adverse pollution conditions to determine the impact on shellfish growing water quality. Due to the extensive survey requirements of the program, this is not always possible.

VI. Methodology:

Water samples were collected from surface waters in sterile 250ml Nalgene bottles. Samples were stored at <10 C and transported to the Shellfish and Aquaculture Mobile Microbiology Laboratory located in Pender Harbour in under 6 hours. Three water samples were collected from each of three stations over a four day period.

Samples were analyzed using the 5-tube Most Probable Number technique in A-1 media (Page 9-52, Standard Methods for the Examination of Water and Wastewater, 18th ed., American Public Health Assoc. 1992). The MPN method is a multiple tube fermentation technique which estimates bacterial density in a sample by the pattern of bacterial growth and gas formation in test tubes inoculated with serial dilutions of the sample. The MPN is calculated based on probability formulas, and as such is a statistical estimation.

VII. Conclusions:

1. All marine stations met the shellfish growing water quality standard.

Growing Area: Sechelt Inlet
Sector: 2803 (Sechelt Inlet)
Survey Date: September 14 - 17, 1993
Survey Type: Re-evaluation (939)

I. Executive Summary:

All marine stations sampled met the shellfish growing water quality standard.

This survey was conducted at the request of the Ocean Disposal Control Program of Environmental Protection, as part of a larger monitoring survey of the HMCS Chaudiere underwater dive site..

II. Description of Growing Area:

Location: Sechelt Inlet is a large mainland inlet north of Sechelt. Kunechin Point is located about halfway up the inlet, at its junction with Salmon Inlet. On December 5, 1992, the Artificial Reef Society of B.C. sunk the HMCS Chaudiere, a former Canadian naval vessel, in approximately 30m of water off Kunechin Point. The site is marked by three yellow buoys and is now attracting scuba divers as an artificial reef.

Population Centers: The closest population centers are Sechelt to the south and Egmont to the north. Both are too distant to have any effect on bacteriological water quality.

Previous survey dates: Keystation - May 1991
Keystation - August 1990

Marine station ST070 was sampled during the May 1991 and August 1990 survey. All 10 samples collected had a fecal coliform level of either <2 or 2 FC/100ml MPN, well under the standard of 14 FC/100ml MPN.

Closures: There are no shellfish prohibition order closures in the Kunechin Point area.

Marine sampling stations: ST070,083,084
Total - 3

Freshwater sampling stations: none

III. Pollution Sources:

There are no homes in the immediate area of Kunechin Point, and no sea mammals or birds were observed during the 3 days of sampling.

SHELLFISH GROWING AREA SURVEY AND CLASSIFICATION PROGRAM

FILE REPORT

Commercial bivalve molluscan shellfish growing areas require frequent sanitary surveys to ensure that water quality meets approved federal standards for direct harvesting. Environment Canada regularly assesses both water quality and pollution sources in shellfish growing areas, and publishes reports to evaluate trends in data. Interim File Reports, such as this one, are also prepared and include printouts from the regional shellfish database which describe data from specific surveys.

Canadian bivalve molluscan shellfish growing areas are classified as approved or prohibited based on the following bacteriological criteria:

> In order that an area can be considered bacteriologically safe for the harvesting of shellfish, the fecal coliform median or geometric mean must not exceed 14 per 100 ml, and not more than 10% of the samples exceed a fecal coliform level of 43 per 100 ml (i.e. the 90th percentile does not exceed 43 per 100 ml), when sampled under adverse pollution conditions. Coliform levels are determined by the multiple tube fermentation, or Most Probable Number (MPN) technique.

Shellfish growing areas can also be closed on the basis of known or potential pollution sources which may or may not be reflected in the bacteriological water quality results. These sources are evaluated during shoreline sanitary surveys.

Further information on the shellfish program in general, or this report in particular, can be obtained from:

Shellfish and Aquaculture Programs
Conservation and Protection
Environment Canada
1801 Welch Street
North Vancouver, B.C.
V7P 1B7

Ms. Jady Tyers
Program Biologist
tel. (604) 666-7148

Mr. Blair Holmes
Program Microbiologist
tel. (604) 666-6047

Shellfish water quality protection program

Programme de salubrité des eaux coquillières

ENVIRONMENT CANADA
CONSERVATION AND PROTECTION

SHELLFISH GROWING AREA SURVEY AND CLASSIFICATION PROGRAM

FILE REPORT

GROWING AREA 28: SECHELT INLET
SECTOR 03: SECHELT INLET

SURVEY DATE: September 14-17, 1993

Environment Canada
Conservation and Protection

Environnement Canada
Conservation et Protection

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APPENDIX D

FECAL COLIFORM STUDY REPORT BY SHELLFISH SECTION OF ENVIRONMENT CANADA

where: X_u = Upper value of 95% confidence interval for chrysotile

X_L = Lower value of 95% confidence interval for chrysotile

$\bar{X}$ = Average number of fibers per grid opening

t = Value listed in t-distribution tables at the 95% confidence level for a two tailed distribution with N-1 degree of freedom

S_c = Standard deviation of the fiber counts for chrysotile

N = Number of grid openings examined for the sample

The values of X_u and X_L can be converted to concentrations in millions of fibers per liter using the formula in section 9 and substituting either X_u or X_L for the term F.

Obtain the upper and lower values of the 95% confidence interval for amphibole asbestos fibers and total asbestos fibers by substituting the corresponding values of $\bar{X}$ and S into equations (7) and (8).

Report the precision of the analysis, in terms of the upper and lower limits of the 95% confidence interval, for chrysotile, amphibole, and total asbestos fiber content. If a lower limit is found to be negative, report the value of the limit as zero.

NOTE: If an average area for the grid squares has been measured as outlined in 8.4.5, the term np_i represents the mean fiber count per grid square.

If the value for X^2 exceeds the value listed in statistical tables for the 0.1% significance level with N-1 degrees of freedom, the fibers are not considered to be uniformly and randomly distributed among the grid openings. In this case, it is advisable to try to improve the uniformity of fiber deposition by filtering another aliquot of the sample and repeating the analysis.

13.3 If uniformity and randomness of fiber deposition on the microscope grids has been demonstrated as in 13.2, and the fiber concentration is assumed to be normally distributed about the mean value, the 95% confidence interval about the mean fiber concentrations for chrysotile, amphibole, and total asbestos fibers may be determined using the following formulae.

$$S_c = \left[\frac{N \sum_{i=1}^{N} X_i^2 - \left(\sum_{i=1}^{N} X_i \right)^2}{N(N-1)} \right]^{1/2} \quad (6)$$

where: S_c = Standard deviation of the chrysotile fiber count

N = Number of grid openings examined for the sample

X_i = Number of chrysotile fibers in each grid opening, respectively

Obtain the standard deviations of the fiber counts for amphibole asbestos fibers and for total asbestos fibers by substituting the corresponding value of X_i into equation (6).

$$X_u = \bar{X} + \frac{tS_c}{\sqrt{N}} \quad (7)$$

$$X_L = \bar{X} - \frac{tS_c}{\sqrt{N}} \quad (8)$$

12.2 Mass Concentrations

As in the case of the fiber concentrations, no standard samples of the size distribution found in water are available. The estimated mass concentration is often very inaccurate because of poor counting statistics associated with large fibers that are few in number but represent most of the actual mass concentration.

13. Suggested Statistical Evaluation of Grid Fiber Counts

13.1 Because the fiber distribution on the sample filter, resulting from the method of filtration, has not been fully characterized, the fiber distribution obtained on the electron microscope grids for each sample should be tested statistically against an assumed distribution and a measure of the precision of the analysis should be provided.

13.2 Assume that the fibers are uniformly and randomly distributed on the sample filter and grids. One method for confirming this assumption is given below.

Using the chi-square test, determine whether the total number of fibers found in individual grid openings are randomly and uniformly distributed among the openings using the following formula.

$$X^2 = \sum_{i=1}^{N} \frac{(n_i - np_i)^2}{np_i} \qquad (5)$$

where: X^2 = Chi-square statistic

N = Number of grid openings examined for the sample

n_i = Total number of fibers found in each respective grid opening

n = Total number of fibers found in N grid openings

p_i = Ratio of the area of each respective grid opening to the sum of the areas of all grid openings examined

TABLE 1. INTRA-LABORATORY PRECISION

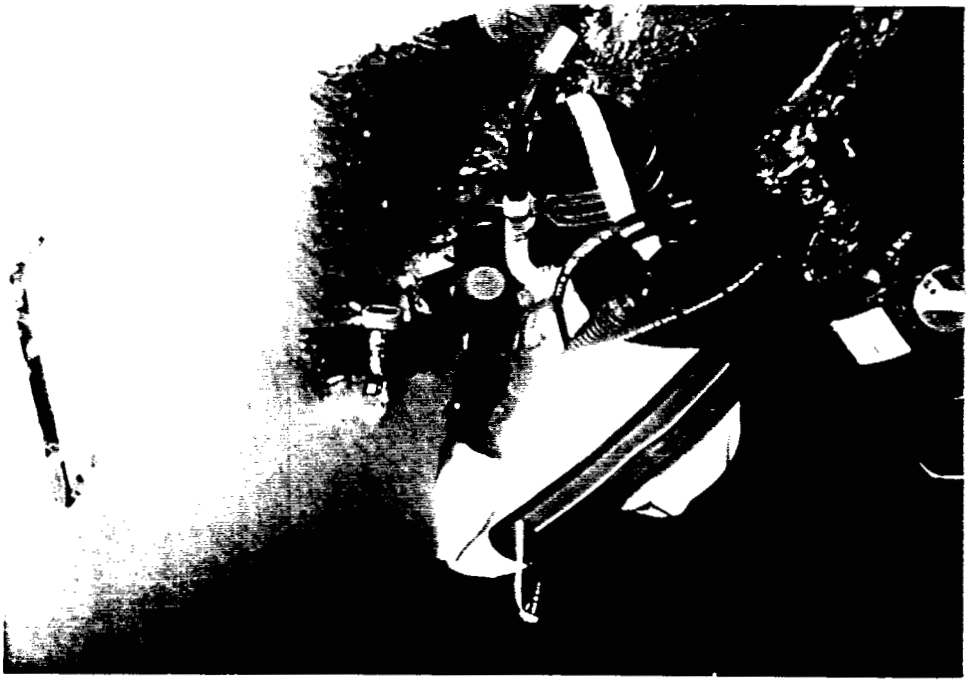
Sample Type	Number of Sample Aliquots Analyzed	Mean Fiber Concentration MFL (millions of asbestos fibers/l)	Precision, Relative Standard Deviation	Mass Concentration (µg/l)	Precision, Relative Standard Deviation
Chrysotile (UICC)	26	23	37%	0.32	71%
Crocidolite (UICC)	20	8	36%	1.5	48%
Taconite (raw water)	20	16	24%	10.5	65%

TABLE 2. INTER-LABORATORY PRECISION

Sample Type	Number of Labs Reporting	Mean Fiber Concentration, MFL (millions of asbestos fibers/l)	Precision, Relative Standard Deviation
Chrysotile	10	877	35%
	9	119	43%
	11	59	41%
	9	31	65%
	9	28	32%
	3	25	35%
Amphibole	11	139	50%
	4	95	52%
	14	36	66%

Fig. 7 Tunicate Colonies (*Ciona intestinalis)*

Fig. 8 Tunicate Colonies (*Ciona intestinalis*)



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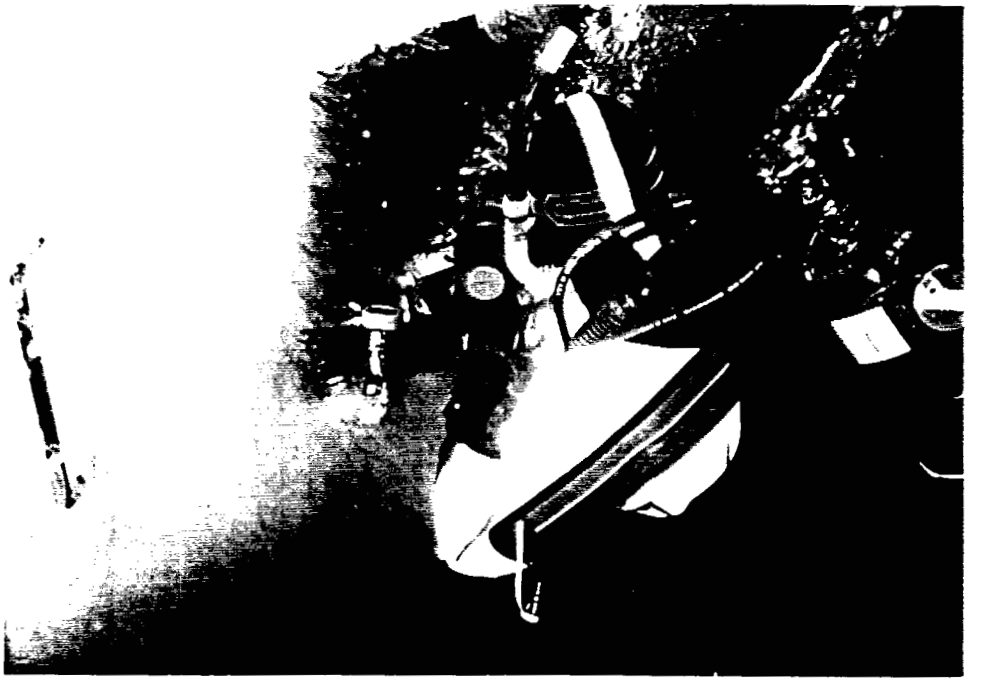

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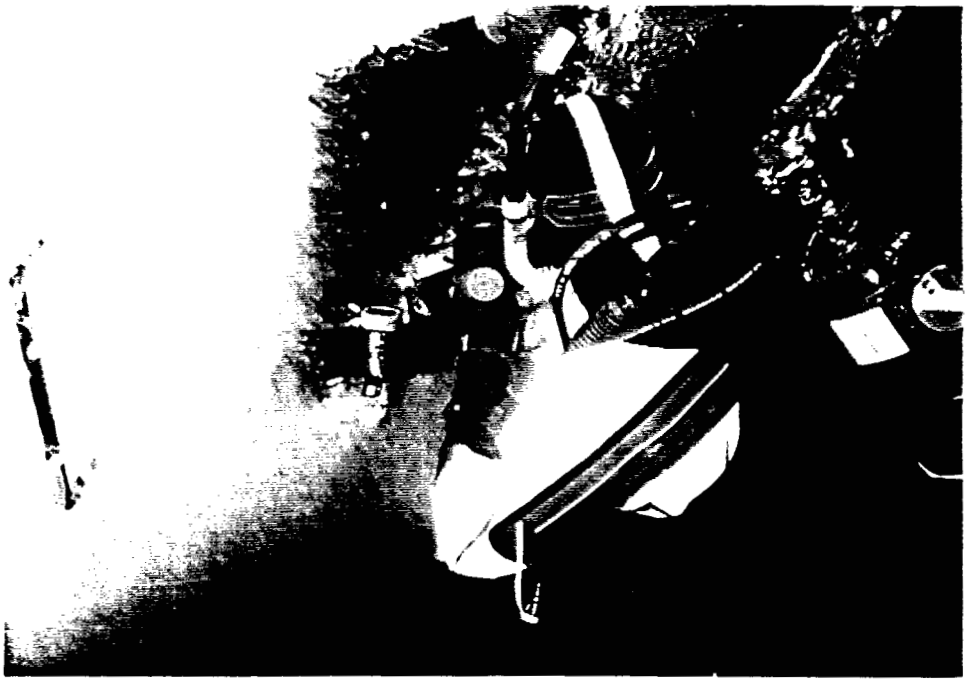

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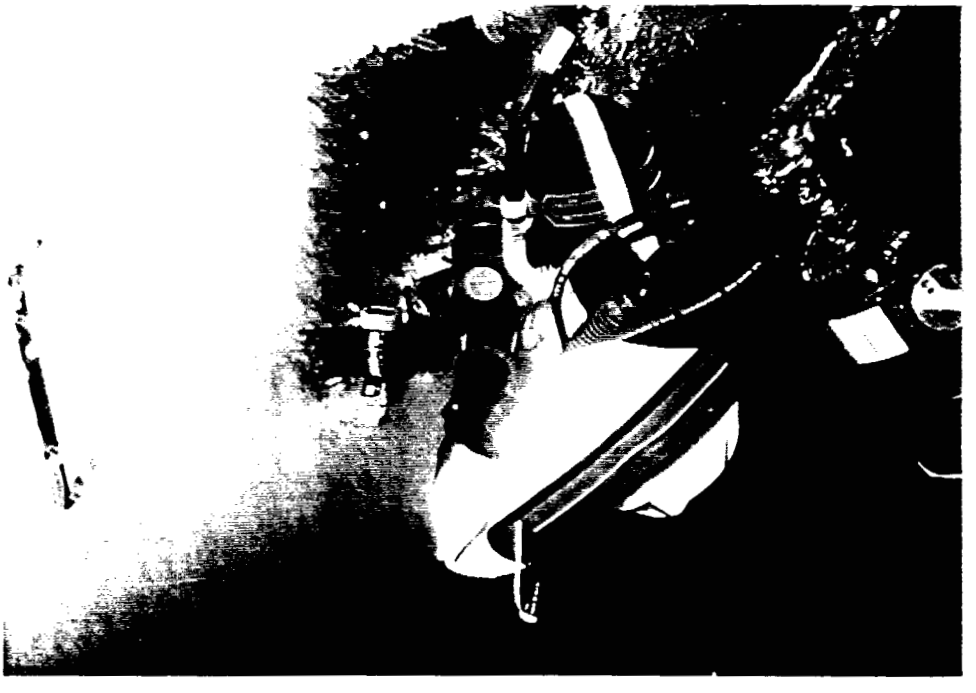

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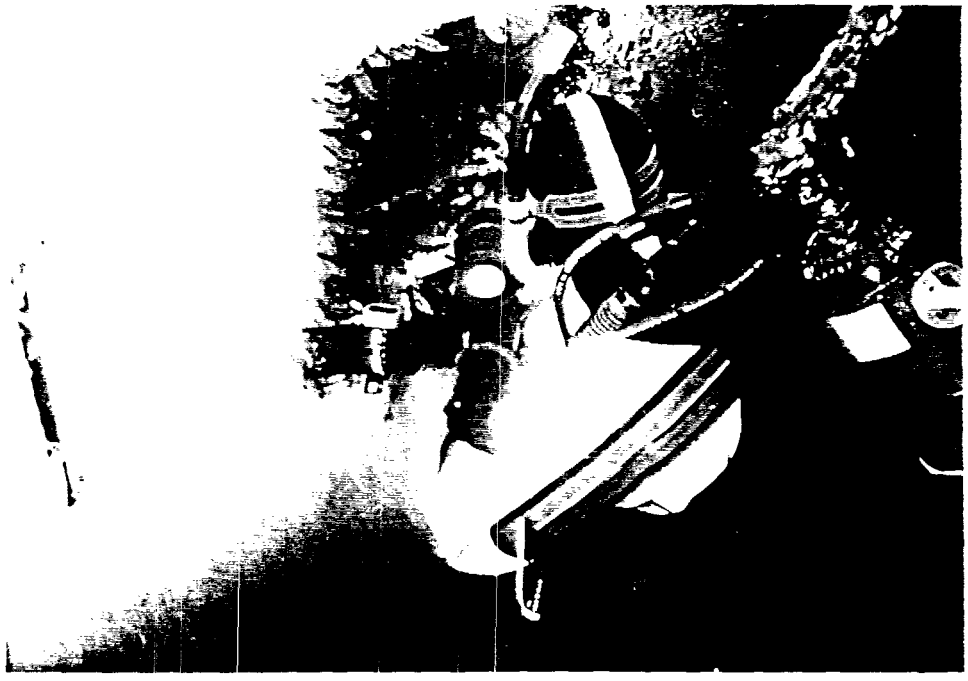

Fig. 9 Tunicate Colonies (*Ciona intestinalis*)