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ABSTRACT

Providing microbiological support to research and monitoring projects initiated by Environment Canada scientists and managers has long been hampered by the necessity of processing water, effluent and sediment samples within 24 hours of collection for traditional microbiological parameters. In an attempt to develop a set of microbial parameters which would be amenable to preservation and stability over a 48-72 hr transit period, the Microbiology Laboratories Section staff have investigated several techniques, one being the coliphage technique.

This report presents the first set of data collected from three Canadian rivers, on the relationship of coliphage (bacteriophage to *E. coli*) to traditional indicator enteric indicator bacteria.

RÉSUMÉ

Les gestionnaires et les chercheurs d'Environnement Canada chargés de la bonne marche des projets de recherche et de contrôle ont toujours été contraints d'analyser dans un délai de 24 heures les échantillons d'eau, d'effluents et de sédiments pour déterminer les paramètres microbiologiques traditionnels. Dans le but de mettre au point un ensemble de paramètres microbiologiques qui seraient moins susceptibles de se détériorer et qui pourraient être analysés entre 48 et 72 heures après le prélevement des échantillons, le personnel de la Section des laboratoires de microbiologie a examiné plusieurs techniques dont celle des coliphages.

Le présent rapport renferme le premier ensemble de données pour les échantillons provenant de trois cours d'eau du Canada et permettant d'établir le lien entre les coliphages (bactériophages d'E. coli) et les bactéries d'origine entérique traditionnellement utilisées comme indice.

RÉSUMÉ ADMINISTRATIF

Les techniques de dénombrement des bactéries traditionnellement utilisées comme indices de la salubrité de l'eau, telles que le total des coliformes, des E. coli et des streptocoques fécaux entre autres, ne sont pas fiables si les échantillons sont conservés pour des périodes prolongées (plus de 24 heures).

La Section des laboratoires de microbiologie a examiné plusieurs nouveaux indices de la qualité microbienne de l'eau dans le but de mettre au point un ensemble de paramètres microbiologiques qui seraient moins susceptibles de se déteriorer pour une période de 48 à 72 heures. L'une de ces techniques consiste à mesurer la quantité de bactériophages d'E. coli qui se trouvent dans les échantillons. Le présent rapport décrit une étude portant sur trois cours d'eau canadiens et ayant pour but d'évaluer la possibilité d'employer les coliphages comme indice de la qualité de l'eau et de déterminer le lien entre cet indice et les indices traditionnels basés sur les taux de bactéries fécales.

Il faudra d'autres données pour compléter l'évaluation. Cependant, il semble que les coliphages soient plus stables que les indices traditionnels de salubrité de l'eau et que leur présence soit en corrélation avec celle des bactéries. D'autres études sur l'incidence des coliphages dans les nappes d'eau du Canada sont prévues dans un avenir proche. Les données issues de ces études seront ensuite comparées avec celles de l'étude sur la présence des coliphages comme indice de la qualité des sources d'eau potable, financée par le Centre de recherche et développement international et se déroulant sur trois continents.

INTRODUCTION

The availability of microbiological services within Environment Canada has long been hampered by the necessity of processing water, effluent and sediment samples for microbial water quality indicator bacteria within 24 hours. The traditional health indicator bacterial enumeration techniques, such as total coliforms, fecal coliforms, E. coli, fecal streptococci, Pseudomonas aeruginosa are not reliable if there is a prolonged shipping time.

In an attempt to develop a set of microbilogical parameters which would be more amenable to preservation and stability over a 48-72 hour period, the Microbiological Laboratories Section staff have investigated several techniques. One enumerative procedure which has shown great promise as a microbial water quality indicator is the use of bacteriophage, more specifically E. coli coliphage. This procedure would allow the submission of samples to NWRI from the Canada-wide Inland Waters Directorate water quality monitoring network.

An excellent review on the use of coliphage as an indicator of fecal pollution can be found in the Atlantic Research Corporation report "Evaluation of coliform bacteria and bacteriophage relationships in assessment of water quality" by W. Scott, P. O'Neill, M. Wilkinson and J. Kitchens, prepared for the National Science Foundation, Washington, D.C. A portion of this report is presented in condensed version below.

Bacteriophages are virus-like entities that invade bacterial cells. A virulent phage infects the host bacterial cell by attaching to the cell membrane and injecting its genetic material into the cell. The phage genetic material takes over the operation of the bacterial cell compelling the cell metabolism to manufacture new phages. The phage components are synthesized sequentially within the host cell and assembled into intact phage particles. Late in the process, an enzyme is released which destroys the cell wall of the host bacterium, releasing thousands of new phages into the environment. The newly released phages are capable of adsorbing onto new host cells and beginning another replication cycle. Some bacteriophages can multiply only in a particular strain of bacteria while others can multiply in different species of closely related genera. It is generally believed that whenever bacteria are present, bacteriophages capable of attacking them are present also.

Coliphage is the general name applied to bacteriophages which attack bacteria of the coliform group. This group of bacteria is present in waters where fecal pollution occurs and is routinely used to indicate the sanitary quality of water. Research has shown that coliphages can also be utilized to determine the sanitary quality of water.

Coliphages which attach to the cell wall show specificity for antigenic determinent. The coliphages can therefore infect and multiply at the expense of not only Escherichia coli but related gram

negative rods which have the same antigenic group and sufficient DNA homology. Thus phages that grow in Escherichia coli may also reproduce on strains of Aerobacter, Enterobacter and even Serratia and vice versa.

In an excellent review of the literature on bacteriophages, Scarpino (1978) states "Correlations appear to exist in fresh and marine waters between fecal bacterial pathogens, such as Salmonella and Shigella species, and fecal indicator bacteria such as E. Coli and their bacteriophages". Guelin (1948 and 1950) established the importance of bacteriophages as an indicator of fecal contamination by observing a correlation between coliform and coliphage levels. He also recovered phage when the pathogenic bacteria host was not present. Bosco (1961 and 1963) sampled the Tiber River and sea water and observed that bacteriophages could be an epidemiological tool in assessing water quality.

Kott et al. (1969) suggested phage levels to indicate the quality of sea water: less than 10 phage per 100 mL of water was low pollution; 100 phage per 100 mL of water was moderate and recent; and 1000 phage per 100 ml of water was heavy and recent pollution.

Coliform to coliphage ratios have been calculated by several authors. Kenard and Valentine (1974) sampled sewage effluent and various natural waters and established a correlation between coliforms and coliphages. However, the fecal coliform to coliphage ratio varied from 2/1 to 40/1. Therefore, it would appear that a linear

correlation between coliforms and coliphages is of greater value than a simple ratio since a linear correlation would tend to hold over a wide range of contamination.

Increasing the detection sensitivity for bacteriophages in water has concerned several research groups. Kott (1966) used the Most Probable Number Technique (MPN) to determine the number of phages in a water sample. This method could detect two plaque forming units (p.f.u.) per 100 mL of sample. However, the test took 24-30 hours to perform. Graves (1972) used this method and was impressed with its ease and quickness.

Primrose and Day (1977) developed a filtering method for phage assay. With this method they could detect 12 p.f.u./100 mL of river water. Kenard and Valentine (1974) could detect 4 p.f.u./100 mL of water because they used 25-1 mL samples. Thurma *et al.* (1977) could detect 50 p.f.u./100 mL of water.

The survival of bacteriophages in chlorinated water has also been studied. Kott *et al.* (1974) found that 99.5% of the total coliforms and 50% of the coliphages were removed after chlorination. Wolf and Mixson (1976) found that 99.99% of the total coliforms were removed after 80 minutes exposure to chlorine. However, only 76% of the phages were inactivated (using *E. coli* K12).

Bacteriophages, because they are so easily detected, are being examined for other uses in the water treatment area. Bacteriophages of *Serratia marcescens* have been used as tracers for

the reduction of pathogenic bacteria during sewage treatment in South Africa (South African Council Sc. and Ind. Res., 1963). Kott et al. (1974) and Vaughn and Metcalf (1975) have attempted to relate bacteriophages and enteric virus levels in water systems. According to Scarpino (1975) coliphages may serve as valid indicators for enteric viruses in some environmental situations such as sewage treatment effluent.

From the previous studies, it appears that bacteriophages are potentially useful indicators of water quality. However, many variables which influence the relationship of bacteria and their bacteriophages as well as the detection of those bacteriophages are not understood. Therefore, a three-river Canadian study was undertaken to evaluate the use of coliphage as indicators of water quality and to study their relationship to traditional fecal bacterial indicators.

METHODS

Analytical Techniques

Coliphage

The technique used to measure coliphage concentrations was a slight modification of ASTM procedure D4201-82 Standard Test Method for Coliphages in Water.

In this technique a measured water sample (5 mL) was added to a tube of melted modified nutrient agar (5.5 mL) to which .08 mL TPTZ [2,3,5-triphenyl tetrazolium chloride, 1% (W/V) in ethanol] was added after melting. One mL of E. Coli C host culture was added and the mixture poured into a petri dish. Plates were incubated at 35°C and plaques counted at 6 and 24 hours.

E. Coli

The membrane filter procedure using mTEC agar developed by Dufour et al. (1981) was used to enumerate Eschericia coli concentrations. Only the yellow, urease negative colonies were enumerated as E. coli.

Fecal Coliforms

Two procedures were used to enumerate fecal coliform populations, membrane filtration (MF) and the Most Probable Number (MPN) multiple tube technique. The MF procedure was based on the use of MFC agar with incubation at 44.5°C as detailed by Dutka (1978). The MPN procedure was based on the use of A-1 Broth (16th Edition APHA Standard Methods, 1985) with incubation at 44.5°C for 24 hours. All positives were confirmed in EC Broth.

Fecal Streptococci

The membrane filtration procedure using KF agar with incubation at 35°C for 48 hours was used in this study to estimate fecal streptococci densities (APHA, 1985).

Sample Collection

Water samples for this study were collected from three rivers; the Fraser River near New Westminister, British Columbia, the St. Lawrence, downstream from Montreal near sewage treatment plant outfalls, and the Ottawa River, with samples being collected within the city of Ottawa and several miles downstream. All water samples were collected in 500 to 1000 mL aliquots from the top one metre of surface water. The samples were then packed in melting ice and shipped via courier to the National Water Research Institute in Burlington, Ontario. Samples were usually processed 24-48 hours after collection with a few taking 72 hours due to transport problems.

Longevity Study

Two ten day longevity or survival studies (November 26, 1984 and Janaury 28, 1985) were performed to evaluate the stability of coliphage samples maintained at refrigeration temperatures (4°C). For comparison fecal coliform estimates (mFC technique) and *E. Coli* estimates (mTEC technique) were performed.

RESULTS AND DISCUSSION

Tables 1, 2 and 3 summarize the fecal coliform (mFC), fecal coliform (A1 broth), E. coli (mTEC), fecal streptococci (KF) and coliphage counts from St. Lawrence River stations on August 8, 1984, September 6, 1984 and October 24,1984. Table 4 summarizes the FC/FS ratio based on membrane filtration counts for the St. Lawrence River samples. From Tables 1-3, it can be seen that the fecal coliform counts were consistently greater than 100/100 mL with the majority of the counts being 1000 or higher. Similarly E. coli counts, with the exception of four samples, were all greater than 100/100 mL and the majority of samples contained counts greater than 1000/100 mL. For these same samples the coliphage counts varied from 0 to 1735/100 mL. From Table 4 it can be seen that all the FC/FS ratios were 4:1 or greater, an indication that the pollution is of human fecal origin and relatively recent.

Tables 5, 6 and 7 present fecal coliform and E. coli coliphage ratios for 6 and 24 hour coliphage counts in the St. Lawrence River samples. Basically, Table 5 presents fecal coliform/coliphage and E. coli/coliphage ratios for each sampling site over the study period while Tables 6 and 7 examine the ratios by grouping them under various E. coli and fecal coliform density ranges. As expected the E. coli/coliphage ratios are slightly smaller than the fecal coliform/coliphage ratios. There does not appear to be sufficient data yet for a clear picture to emerge.

Tables 8 to 13 summarize the fecal coliform (mFC), fecal coliform (Al broth), E. coli (mTEC), fecal streptococci (KF) and coliphage data collected from the Ottawa River stations on May 17/84, June 12/84, July 18/84, August 15/84, September 12/84 and October 17/84. Examination of these tables shows that fecal coliform and E. coli populations rapidly increased from relatively low levels in May to 10 to 10000 fold increases by mid-August. Fecal streptococci and coliphage counts also increased over this time period but not to the extent of the fecal coliforms and E. coli.

Some stations produced erratic unexplained results, e.g. 5.4C August results and 14.1 September and October results. Table 14 presents fecal coliform/fecal streptococci ratios over the study period. There is a tendency for the number of FC/FS ratios greater than 4:1 to increase over the summer with August samples showing the greatest number of FC/FS ratios greater than 4:1. July and October produced the next highest number of stations showing FC/FS ratios greater than 4:1. The implication of these results are that human fecal pollution of the Ottawa River tend to increase and maximize in the late July to October period. The data also contains many difficult to explain items such as station 14.90 in August has an FC/FS ratio of 69:1, then in September the ratio is 1:6 while in October a 12:1 ratio is shown. Prior to August, May has a 1.6:1 ratio, June a 0.7:1 ratio and July has a 24:1 ratio. A series of unknown events seem to be occurring at some of the Ottawa stations.

Tables 15, 16 and 17 present fecal coliform and E. coli coliphage ratios for 6 and 24 hour coliphage counts in the Ottawa River samples. As with the FC/FS ratios maxima, FC and E. coli/ coliphage ratios tend to reach their maxima in August. Six hour and 24 hour coliphage ratios varied widely, usually with the 6 hour FC and E. coli ratios being the highest. At a later date after sufficient data have been collected a statistical analysis of fecal coliform, E. coli and coliphage data will be undertaken.

Tables 18, 19 and 20 summarize the fecal coliform (mFC), fecal coliform (Al broth), E. coli (mTEC), fecal streptococci (KF) and coliphage counts from Fraser River stations on November 7, 1984, December 3, 1984 and January 16, 1985. Maximum counts at all stations appear to take place in January with the possible exception of November 7 counts of stations SIA and SIB.

The fecal coliform/fecal streptococci ratios shown in Table 21, show a similar pattern to those found in the Ottawa River samples, especially samples for Stations A and N. It is observed that as counts increase the fecal coliform/fecal streptococci ratio tend to increase so that ratios of 4:1 or greater become common; indicating perhaps that human fecal pollution is affecting the area during this period. The S and D stations with minor exceptions show FC/FS ratios greater than 4:1. Again, it is noted that samples collected during certain months indicate that the fecal pollution load is of animal and land runoff origin or distant human sewage, then during another month

(January for the Fraser River) fecal coliform/E. coli counts dramatically increase indicating that the sampled waters become affected by human fecal pollution. One possible explanation for these results is that the samples may have been collected shortly after a rainstorm and that sewage treatment plants became overloaded and raw sewage was dumped into the rivers. However, this hypothesis has not been verified.

Tables 22, 23 and 24 present fecal coliform and E. coli coliphage ratios for 6 and 24 hour coliphage counts in Fraser River samples. As with Ottawa River and St. Lawrence River samples, when fecal coliform and E. coli counts increase drastically, the fecal coliform and E. coli coliphage ratios increase. The coliphage counts appear to be less influenced by climatic events than are the traditional bacteriological indicators.

Table 25 presents data from two minor longevity studies involving coliphage, fecal coliform and E. coli. In the wastewater treatment plant clarifier samples, it can be seen that coliphage counts are very stable for the first 96 hours, and at the end of seven days preservation under melting ice conditions, there is a 0-50% reduction in coliphage densities. Very surprisingly, the fecal coliform and E. coli densities in the clarifier samples remained fairly stable for 72-96 hours: this stability may be real for these samples or may be due to dilution manipulations.

Burlington Bay water samples again indicate that coliphage counts are very stable for a period of at least 96 hours under melting ice conditions. However, in the less polluted bay water samples, fecal coliform and E. coli counts behaved as expected and showed significant decreases in populations with increased holding times.

The minor longevity comparison study again reaffirms earlier literature reports that coliphage populations are much more stable in water samples held for various periods of time.

From this preliminary study on the use of coliphage as indicators of water quality, it is obvious that coliphage populations are much more stable than traditional bacteriological indicators and do not exhibit the great seasonal swings of bacterial populations. Use of ratio reporting, e.g. fecal coliform/coliphage appears to give inconsistent results especially when seasonal effects are occurring. The phage numbers may be low when high fecal coliform counts are occurring due to specificity of the coliphage host, E. coli C, or perhaps many of the fecal coliform are not E. coli (perhaps Klebsiella, Citrobacter or E. freundii). Another problem with ratio reporting is the acknowledgement that traditional membrane filtration techniques only estimate 5-75% of the true coliform, fecal coliform population (McFeters, LeChevellier and Domek, 1984; Dutka, Kuchma and Kwan, 1979). Thus, when ratios between fecal coliforms E. coli and coliphage are computed, we never know what portion of the actual population we are measuring and thus our ratios will vary

widely. Thus this inability to acurately estimate traditional bacterial indicator populations makes it very difficult to realistically compare the relationship between coliphage counts and bacterial counts. It is obvious more data are required to evaluate the usefulness of coliphage as water quality indicators. However, from our data and the literature, it is obvious that coliphage are more stable seasonally and that if no coliphage are found, only very low number of E. coli or fecal coliforms will also be found.

Future plans call for more studies on the incidence and number of coliphage in Canadian waters. Later this data will be compared to the data obtained from the International Development Research Centre (Ottawa) funded three-continent study on coliphage as an indicator of the quality of drinking water source water.

Six and 24 hour phage counts give at times widely diverse counts. One of these variations is due to our not recognizing the minute pin point plaques as no magnification is used to read the plates. Other count variations are due to late bursts and some plaques overgrowing smaller plaques especially if the plates are crowded. Dilutions will solve this problem.

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TABLE 1 St. Lawrence River Samples for Coliphage Study, received August 8, 1984. All counts based on 100 mL sample

Sample	Fecal Coliform (mFC)	Fecal Coliform A-1 Broth (EC Confirmed)	*E. coli* (mTEC)	Fecal Streptococci (KF)	Coliphage	
					6 hrs	24 hrs
13R	3700	5400	1400	100	15	35
13K	2500	1300	1000	68	40	55
14R	9200	16,000	2000	390	45	115
14K	10,000	9200	7000	780	55	120
15R	10,000	5400	16,000	140	75	125
15K	9700	16,000	13,000	160	90	160
16R	5700	2400	700	88	40	240
16K	4900	5400	400	100	75	270
17R	380	1100	80	10	5	15
17K	200	330	100	14	0	5
27R	860	790	510	170	0	10
27K	560	1700	140	26	10	35
31R	1100	1100	300	92	5	25
31K	1100	2200	300	130	0	20
39R	760	580	60	92	5	5
39K	510	790	60	46	5	30
40R	2400	1700	1800	82	10	35
40K	2300	790	800	110	0	15
41R	11,000	9200	4900	170	50	115
41K	7500	9200	1300	210	90	150
68B	4200	2800	1500	110	40	1735
69R	3700	5400	3700	150	10	25
69K	4200	3500	2500	100	5	10
70R	6400	3500	1900	120	40	200
70K	3300	5400	1400	150	55	200

TABLE 2 St. Lawrence River Samples for Coliphage Study, received September 6, 1984. All counts based on 100 mL sample

Sample	Fecal Coliform (mFC)	Fecal Coliform A-1 Broth (EC Confirmed)	*E. coli* (mTEC)	Fecal Streptococci (KF)	Coliphage	
					6 hrs	24 hrs
13R	3800	3500	2400	56	40	65
13K	5300	3500	2600	28	25	50
14R	4300	5400	2400	280	50	75
14K	3500	3500	900	260	75	110
15R	6700	9200	1800	100	50	85
15K	8200	5400	2400	150	65	110
31R	250	490	130	28	10	10
31K	240	790	100	66	0	0
39R	380	790	210	38	15	5
39K	460	330	260	32	15	20
40R	1200	3500	330	64	15	25
40K	800	5400	160	76	5	5
41R	10,000	16,000	2800	380	60	135
41K	4500	2400	3800	260	45	205
68R	12,000	5400	800	310	90	235
68K	4600	9200	800	210	70	225
69R	TNTC	>16,000	TNTC	380	15	65
69K	6200	16,000	1600	500	20	85
70R	5400	2200	1500	820	50	215
70K	1700	2400	600	150	60	185

TNTC = too numerous to count.

TABLE 3 St. Lawrence River Samples for Coliphage Study, received October 24,1984. All counts based on 100 mL sample

Sample	Fecal Coliform (mFC)	Fecal Coliform A-1 Broth (EC Confirmed)	*E. coli* (mTEC)	Fecal Streptococci (KF)	Coliphage	
					6 hrs	24 hrs
13R	3400	1600	2400	130	85	145
13K	2600	1600	1500	74	110	140
14R	4700	>1600	2100	290	55	100
14K	5100	>1600	2500	330	65	120
15R	11,000	>1600	1900	160	20	50
15K	7700	>1600	4900	200	5	35
16R	3400	>1600	1600	180	5	60
16K	2900	1600	900	180	35	95
17R	490	350	290	10	25	40
17K	570	1600	320	16	25	35
27R	6800	>1600	2300	170	70	125
27K	3200	>1600	2300	150	70	95
31R	160	170	140	10	10	10
31K	120	130	140	12	0	10
39R	330	240	170	14	0	15
39K	190	350	160	16	5	5
40R	4000	>1600	2700	140	25	50
40K	3600	>1600	1900	94	5	20
41R	6200	>1600	1800	490	-	100
41K	4000	>1600	1700	360	-	150
68R	1700	920	60	160	80	150
68K	1200	920	110	150	20	110
69R	3300	>1600	1900	220	120	600
69K	2600	1600	1500	190	70	365
70R	2200	>1600	1400	200	15	25
70K	1400	>1600	2000	180	10	45

TABLE 4 St. Lawrence River Coliphage Study, Fecal Coliform - Fecal Streptococci Ratios. All counts based on 100 mL sample

Sample	August			September			October		
	Fecal* Coliform	Fecal** Streptococci	FC/ FS	Fecal Coliform	Fecal Streptococci	FC/ FS	Fecal Coliform	Fecal Streptococci	FC/ FS
13K	2500	68	37	5300	28	189	2600	74	35
13R	3700	100	37	3800	56	68	3400	130	26
14K	10,000	780	13	3500	260	14	5100	330	16
14R	9200	390	24	4300	280	15	4700	290	16
15K	9700	160	61	8200	150	55	7700	200	39
15R	10,000	140	71	6700	100	67	11,000	160	69
16K	4900	100	49	-	-	-	2900	180	16
16R	5700	88	65	-	-	-	3400	180	19
17K	200	14	14	-	-	-	570	16	36
17R	380	10	38	-	-	-	490	10	49
27K	560	26	22	-	-	-	3200	150	21
27R	860	170	5	-	-	-	6800	170	40
31K	1100	130	9	240	66	4	120	12	10
31R	1100	92	12	250	28	9	160	10	16
39K	510	46	11	460	32	14	190	16	12
39R	760	92	8	380	38	10	330	14	24
40K	2300	110	21	800	76	11	3600	94	38
40R	2400	82	29	1200	64	19	4000	140	29
41K	7500	210	36	4500	260	17	4000	360	11
41R	11,000	170	65	10,000	380	26	6200	490	13
68K	4200	110	38	4600	210	22	1200	150	8
68R	-	-	-	12,000	310	39	1700	160	11
69K	4200	100	42	6200	500	12	2600	190	14
69R	3700	150	25	-	380	-	3300	220	15
70K	3300	150	22	1700	150	11	1400	180	8
70R	6400	120	53	5400	820	7	2200	200	11

* Fecal coliform = mFC
** Fecal streptococci = KF

TABLE 5 St. Lawrence Coliphage Study - Ratio of Fecal Coliform and *E. coli* counts to 6 and 24 hour Coliphage Counts. All counts based on 100 mL sample.

Sample	August				September				October			
	Fecal* Coliform 6 hr Phage	*E. coli** 6 hr Phage	Fecal Coliform 24 hr Phage	*E. coli* 24 hr Phage	Fecal Coliform 6 hr Phage	*E. coli* 6 hr Phage	Fecal Coliform 24 hr Phage	*E. coli* 24 hr Phage	Fecal Coliform 6 hr Phage	*E. coli* 6 hr Phage	Fecal Coliform 24 hr Phage	*E. coli* 24 hr Phage
13K	62	25	45	18	212	104	106	52	24	14	19	11
13R	247	93	106	40	95	60	59	37	40	28	23	17
14K	182	127	83	58	47	12	32	8	79	39	43	21
14R	204	44	80	17	86	48	57	32	85	38	47	21
15K	108	144	61	81	126	37	75	22	1540	980	220	140
15R	133	213	80	128	134	36	79	21	550	95	220	38
16K	65	5	18	2	-	-	-	-	83	26	31	10
16R	143	18	24	3	-	-	-	-	680	320	57	27
17K	-	-	40	20	-	-	-	-	23	13	16	9
17R	76	16	25	5	-	-	-	-	20	12	12	7
27K	56	14	16	4	-	-	-	-	46	33	34	24
27R	-	-	86	51	-	-	-	-	97	33	54	18
31K	-	-	55	15	-	-	-	-	-	-	12	14
31R	220	60	44	12	25	13	25	13	16	14	16	14
39K	102	12	17	2	31	17	23	13	38	32	38	32
39R	152	12	152	12	25	14	76	42	-	-	22	11
40K	-	-	153	53	160	32	160	32	720	380	180	95
40R	240	180	69	51	80	22	48	13	160	108	80	54
41K	83	14	50	9	100	85	22	19	-	-	27	11
41R	220	98	96	43	167	47	74	21	-	-	62	18
68K	105	38	2	1	66	11	20	4	60	6	11	1
68R	-	-	-	-	133	9	51	3	21	1	11	.4
69K	840	500	420	250	310	80	73	9	37	21	7	4
69R	370	370	148	148	-	-	-	-	28	16	6	3
70K	60	25	17	7	28	10	9	3	140	200	31	44
70R	160	48	32	10	11	30	25	7	147	93	88	56

* Fecal coliform = mFC
** E. coli = mTEC

TABLE 6 St. Lawrence River Coliphage Study. Distribution of Fecal Coliform/6 hr Coliphage Ratios within Various Fecal Coliform Count Ranges (mFC).

August				September				October			
Fecal Coliform Count Ranges				Fecal Coliform Count Ranges				Fecal Coliform Count Ranges			
<100	100<1000	1000<10,000	10,000+	<100	100<1000	1000<10,000	10,000+	<100	100<1000	1000<10,000	10,000+
-	56	60	220	-	25	28	133	-	16	21	550
	76	63			25	47			20	24	
	102	65			31	66			23	28	
	152	83			160	80			38	37	
		105				86				40	
		108				95				46	
		133				100				60	
		142				108				79	
		160				126				83	
		182				134				85	
		204				167				97	
		220				212				140	
		240				310				147	
		246								160	
		370								680	
		804								720	
										1540	

TABLE 7 St. Lawrence River Coliphage Study. Distribution of *E. coli*/6 hr Coliphage Ratios within Various *E. coli* Count Ranges.

August				September				October			
E. coli Count Ranges				*E. coli* Count Ranges				*E. coli* Count Ranges			
0-100	100-1000	1000-10,000	10,000+	0-100	100-1000	1000-10,000	10,000+	0-100	100-1000	1000-10,000	10,000+
12	5	14	144	-	9	30	-	1	6	14	-
12	14	25	213		10	36			12	16	
16	18	25			11	37			13	21	
	60	38			12	47			14	28	
		44			13	48			26	33	
		48			14	60			32	33	
		93			17	80				38	
		98			22	84				38	
		128			32	104				93	
		180								95	
		370								108	
		500								200	
										320	
										380	
										980	

TABLE 8 Ottawa River Samples for Coliphage Study, received May 17, 1984. All counts based on 100 mL sample

Sample	Fecal Coliform (mFC)	Fecal Coliform A-1 Broth (EC Confirmed)	*E. coli* (mTEC)	Fecal Streptococci (KF)	Coliphage	
					6 hrs	24 hrs
1.8	30	33	4	10	10	-
3.6A	120	95	120	76	0	-
3.6*	56	110	40	100	10	-
3.6B	20	33	14	6	10	-
3.6C	50	79	8	14	0	-
3.6D	44	49	20	20	0	-
5.4A	34	170	12	24	5	-
5.4B	24	31	20	22	5	-
5.4C	32	70	26	16	10	-
5.4D	38	49	32	24	5	-
13.5	28	49	4	24	5	-
14.1	32	46	0	8	10	-
14.9A	38	110	16	60	0	-
14.9B	40	49	28	12	10	-
14.9C	50	23	6	20	20	-
14.9D	22	49	16	14	5	-
17.7A	300	1600	150	100	130	-
17.7B	38	49	8	12	5	-
17.7C	14	49	16	16	10	-
17.7D	130	350	60	48	15	-
BC	7900	>1600	2000	1100	320	-
RR	30	49	14	28	5	-
GRA	26	49	6	18	5	-
GRB	16	33	12	48	10	-
GRB*	20	23	20	32	20	-

*Duplicate sample.

TABLE 9 Ottawa River Samples for Coliphage Study, received June 13, 1984. All counts based on 100 mL sample

Sample	Fecal Coliform (mFC)	Fecal Coliform A-1 Broth (EC Confirmed)	*E. coli* (mTEC)	Fecal Streptococci (KF)	Coliphage	
					6 hrs	24 hrs
1.8	290	130	60	240	0	-
3.6A	4000	1600	1900	270	10	-
3.6*	6000	>1600	82	90	0	-
3.6B	30	49	18	180	10	-
3.6C	30	49	18	40	0	-
3.6D	24	79	12	28	10	-
5.4A	190	350	90	500	10	-
5.4B	310	240	100	690	15	-
5.4C	30	49	12	44	5	-
5.4D	50	33	36	58	10	-
14.1	34	33	16	820	0	-
14.9A	500	540	110	490	5	-
14.9B	120	79	22	560	0	-
14.9C	50	79	24	170	5	-
14.9D	50	79	12	72	5	-
17.7A	1600	3500	1000	210	25	-
17.7B	40	130	12	52	5	-
17.7C	40	170	22	160	5	-
17.7D	140	130	14	130	10	-
BC	3700	5400	1100	400	10	-
Temp	1700	>1600	700	270	60	-
RR	290	540	220	150	20	-
GRA	12	8	10	180	10	-
GRB	16	8	2	52	0	-
GRB*	20	5	4	18	5	-

*Duplicate sample.

TABLE 10 Ottawa River Samples for Coliphage Study, received July 18, 1984. All counts based on 100 mL sample

Sample	Fecal Coliform (mFC)	Fecal Coliform A-1 Broth (EC Confirmed)	*E. coli* (mTEC)	Fecal Streptococci (KF)	Coliphage	
					6 hrs	24 hrs
1.8	54	110	32	230	0	15
1.8*	62	79	32	440	5	15
3.6A	470	350	70	220	20	15
3.6B	400	1600	110	360	15	15
3.6C	340	350	26	360	10	15
3.6D	500	540	54	390	15	25
5.4A	600	1600	180	360	5	25
5.4B	750	920	30	350	5	15
5.4C	410	540	42	330	0	25
5.4D	490	350	100	370	15	30
13.5	6000	16,000	3600	790	305	1005
14.1	900	920	50	290	15	50
14.9A	12,000	>1600	5000	410	325	935
14.9B	700	1600	320	340	10	25
14.9C	700	920	150	250	10	30
14.9D	1000	920	200	42	15	85
17.7A	5100	9200	7000	430	180	800
17.7B	1100	1600	90	140	30	50
17.7C	720	350	270	260	20	30
17.7D	290	540	700	100	0	25
GRA	80	130	6	56	0	0
GRB	1040	920	240	98	0	20
RR	140	49	28	68	10	10
RR*	130	70	42	74	15	20
BCB	22,000	5400	2000	670	0	490
BC*	10,000	16,000	2000	800	25	360

*Duplicate sample.

TABLE 11 Ottawa River Samples for Coliphage Study, received August 15, 1984. All counts based on 100 mL sample

Sample	Fecal Coliform (mFC)	Fecal Coliform A-1 Broth (EC Confirmed)	E. coli (mTEC)	Fecal Streptococci (KF)	Coliphage	
					6 hrs	24 hrs
1.8	180	33	110	510	5	85
3.6A	45,000	54,000	34,000	710	30	175
3.6B	2200	3500	1700	750	15	60
3.6C	410	1300	230	980	20	50
3.6D	1300	3500	740	610	45	135
5.4A	17,000	13,000	10,000	390	25	90
5.4B	11,000	4900	5000	470	65	120
5.4C	<2	0	<2	<2	0	0
5.4D	1700	3300	610	670	5	10
13.5	15,000	14,000	10,000	560	90	540
14.1	85,000	160,000	50,000	4900	785	1265
14.9A	19,000	18,000	1400	630	115	345
14.9B	2600	3300	2800	410	10	45
14.9C	2200	3300	2200	360	5	35
14.9D	110,000	54,000	50,000	1600	Not done	
17.7A	12,000	7000	11,000	450	70	280
17.7B	6000	7900	2000	460	30	190
17.7C	3100	2300	140	350	25	105
17.7D	3000	2200	1300	400	40	65
GRA	300	170	60	88	30	20
GRB	2400	2800	1600	270	5	5
GRB*	2600	2300	900	210	35	40
RR	680	330	490	810	170	205
BC	24,000	28,000	21,000	3500	70	210

*Duplicate sample.

TABLE 12 Ottawa River Samples for Coliphage Study, received September 12, 1984. All counts based on 100 mL sample

Sample	Fecal Coliform (mFC)	Fecal Coliform A-1 Broth (EC Confirmed)	E. coli (mTEC)	Fecal Streptococci (KF)	Coliphage	
					6 hrs	24 hrs
1.8	120	240	82	110	5	35
3.6A	210	490	130	190	10	35
3.6B	120	330	110	170	25	90
3.6C	180	330	120	150	30	40
3.6D	200	1300	126	200	15	60
5.4A	170	330	130	150	0	25
5.4B	180	790	100	140	15	30
5.4C	170	490	120	160	20	30
5.4D	170	490	110	190	15	40
13.5	7400	4900	1800	340	95	200
14.1	<2	2	0	0	1195	1375
14.9A	5700	35,000	2500	500	270	365
14.9B	180	490	120	160	40	25
14.9C	170	490	100	120	10	40
14.9D	130	79	64	80	225	290
17.7A	6200	28,000	800	320	55	270
17.7B	210	490	96	110	5	30
17.7C	160	2400	120	120	30	65
17.7D	170	230	130	160	10	55
GRA	50	11	34	70	5	15
GRB	20	27	8	90	15	15
GRB*	14	17	16	68	10	10
RR	180	540	190	170	25	20
BC	820	330	330	190	70	290
14.9 Comp	150	79	110	130	0	10

*Duplicate sample.

TABLE 13 Ottawa River Samples for Coliphage Study, received October 17, 1984. All counts based on 100 mL sample

Sample	Fecal Coliform (mFC)	Fecal Coliform A-1 Broth (EC Confirmed)	*E. coli* (mTEC)	Fecal Streptococci (KF)	Coliphage	
					6 hrs	24 hrs
1.8	130	130	135	96	20	35
3.6A	600	920	260	90	25	40
3.6B	180	350	130	84	30	65
3.6B*	170	350	82	84	40	65
3.6C	140	350	100	100	20	75
3.6D	140	540	74	80	30	70
5.4A	330	>1600	60	68	5	75
5.4B	240	240	110	84	30	55
5.4C	140	920	38	62	20	45
5.4D	180	350	72	80	20	70
13.5	2600	>1600	130	150	285	710
14.1	4	<2	<2	<2	100	175
14.9A	2200	>1600	2000	160	290	875
14.9B	450	920	70	58	5	10
14.9C	600	920	68	40	20	65
14.9D	560	540	26	46	30	70
17.7A	1300	1600	1100	160	425	650
17.7B	530	1600	320	78	75	290
17.7B*	550	540	140	94	10	90
17.7C	600	>1600	94	64	40	75
17.7D	810	350	150	50	15	35
GRA	4	8	6	15	5	0
GRB	9	4	11	22	5	10
BC	830	920	560	64	70	405
RR	88	64	62	22	20	20
LI	120	350	96	92	25	95

*Duplicate sample.

TABLE 14 **Ottawa River Coliphage Study, Fecal Coliform - Fecal Streptococci Ratios, May to October. All counts based on 100 mL sample.**

Sample	May			June			July			August			September			October		
	F.C.*	F.S.**	FC/FS	F.C.	F.S.	FC/FS	F.C.	F.S.	FC/FS	F.C.	F.S.	FC/FS	F.C.	F.S.	FC/FS	F.C.	F.S.	FC/FS
1.8	30	10	3.0	290	240	1.2	54	230	0.2	180	510	0.4	120	110	1.1	130	96	1.4
3.6A	120	76	1.6	4000	270	15	470	220	2.1	45,000	710	63	210	190	1.1	600	90	6.7
3.6B	20	6	3.3	30	180	0.2	400	360	1.1	2200	750	2.9	120	170	0.7	180	84	2.1
3.6C	50	14	3.6	30	40	0.7	340	360	0.9	410	980	0.4	180	150	1.2	140	100	1.4
3.6D	44	20	2.2	24	28	0.9	500	390	1.3	1300	610	2.1	200	200	1.0	140	80	1.8
5.4A	34	24	1.4	190	500	0.4	600	360	1.7	17,000	390	44	170	150	1.1	330	68	4.9
5.4B	24	22	1.1	310	690	0.5	750	350	2.1	11,000	470	23	180	140	1.3	240	84	2.9
5.4C	32	16	2.0	30	44	0.7	410	330	1.2	<2	<2	-	170	160	1.1	140	62	2.3
5.4D	38	24	1.6	50	58	0.9	490	370	1.3	1700	670	2.5	170	190	0.9	180	80	2.3
13.5	28	24	1.2	-	-	-	6000	790	7.6	15,000	560	27	7400	1800	4.1	2600	150	17
14.1	32	8	4.0	34	820	0.04	900	290	3.1	85,000	4900	17	<2	<2	-	4	<2	-
14.9A	38	60	0.6	500	490	1.0	12,000	410	29	19,000	630	30	5700	500	11	2200	160	14
14.9B	40	12	3.3	120	560	0.2	700	340	2.1	2600	410	6.3	180	160	1.1	450	58	7.8
14.9C	50	20	2.5	50	170	0.3	700	250	2.8	2200	360	6.1	170	120	1.4	600	40	15
14.9D	22	14	1.6	50	72	0.7	1000	42	24	110,000	1600	69	130	80	1.6	560	46	12
17.7A	300	100	3.0	1600	210	7.6	5100	430	12	12,000	450	27	6200	320	19	1300	160	8.1
17.7B	38	12	3.2	40	52	0.8	1100	140	7.9	6000	460	13	210	110	1.9	530	78	6.8
17.7C	14	16	0.9	40	160	0.3	720	260	2.8	3100	350	8.9	160	120	1.3	600	64	9.4
17.7D	130	48	2.7	140	130	1.1	290	100	2.9	3000	400	7.5	170	160	1.1	810	50	16
BC	7900	1100	7.2	3700	400	9.3	22,000	670	33	24,000	3500	6.9	820	190	4.3	830	64	13
RR	30	28	1.1	290	150	1.9	140	68	2.1	680	810	0.8	180	170	1.1	88	22	4.0
GRA	26	18	1.4	12	180	0.07	80	56	1.4	300	88	3.4	50	70	0.7	4	15	0.3
GRB	16	48	0.3	16	52	0.3	1040	98	11	2400	270	8.9	20	90	0.2	9	22	0.4

F.C.* = Fecal coliform (mFC)
F.S.** = Fecal Streptococci (KF)

TABLE 15 Ottawa River Coliphage Study - Ratio of Fecal Coliform and *E. coli* counts to 6 and 24 hour Coliphage Counts. All counts based on 100 mL sample.

Sample	May		June		July				August				September				October			
	FC*	*E. coli***	FC	*E. coli*	Fecal Coliform		*E. coli*		Fecal Coliform		*E. coli*		Fecal Coliform		*E. coli*		Fecal Coliform		*E. coli*	
	6 hr Phage	6 hr Phage	6 hr Phage	6 hr Phage	6 hr Phage	24 hr Phage	6 hr Phage	24 hr Phage	6 hr Phage	24 hr Phage	6 hr Phage	24 hr Phage	6 hr Phage	24 hr Phage	6 hr Phage	24 hr Phage	6 hr Phage	24 hr Phage	6 hr Phage	24 hr Phage
1.8	3	0.4	290	60	54	3.6	32	2.1	36	2.1	22	1.3	24	3.4	16	2.3	6.5	3.7	6.8	3.9
3.6A	120	120	400	190	24	31	3.5	4.7	1500	260	1100	19	21	6.0	13	3.7	24	15	10	6.5
3.6B	2	1.4	3	1.8	27	27	7.3	7.3	150	37	110	28	4.8	1.3	4.4	1.2	6.0	2.8	4.3	2.0
3.6C	50	8.0	30	18	34	22	2.6	1.7	20	8.2	12	4.6	6	4.5	4	3.0	7.0	1.9	5.0	1.3
3.6D	44	20	2.4	1.2	33	20	3.6	2.2	29	9.6	16	5.5	13	3.3	8.4	2.1	4.7	2.0	2.5	1.1
5.4A	6.8	2.4	19	9	120	24	36	7.2	680	190	400	110	170	6.8	130	5.2	66	4.4	12	0.8
5.4B	4.8	4.0	20.7	6.7	150	50	6	2.0	170	92	77	42	12	6.0	6.7	3.3	8.0	4.4	3.7	2.0
5.4C	3.2	2.6	6	2.4	410	16	42	1.7	1	1	1	1	8.5	5.7	6	4.0	7.0	3.1	1.9	0.8
5.4D	7.6	6.4	5	3.6	33	16	6.7	3.3	340	170	120	61	11	4.3	7.3	2.8	9.0	2.6	3.6	1.0
13.5	5.6	0.8	N.D.[1]	N.D.	20	6.0	12	3.6	170	28	110	18	78	37	19	9.0	9.1	3.7	0.5	0.2
14.1	3.2	0.1	34	16	60	18	3.3	1.0	110	68	64	39	0	0.0	0	0.0	0.0	0.0	0.0	0.0
14.9A	3.8	1.6	100	22	37	13	15	5.3	170	55	12	4.1	21	16	9.3	6.8	7.6	2.5	6.9	2.3
14.9B	4.0	2.8	120	22	70	28	32	13	260	58	280	62	4.5	7.2	3	4.8	90	45	14	7.0
14.9C	2.5	0.3	10	4.8	70	23	15	5.0	440	63	440	63	17	4.3	10	2.5	30	9.2	3.4	1.0
14.9D	4.4	3.2	10	2.4	67	12	13	2.4	N.D.	N.D.	N.D.	N.D.	0.6	0.4	0.3	0.2	19	8.0	0.9	0.4
17.7A	2.3	1.2	64	40	28	6.4	39	8.8	170	43	160	39	110	23	15	3.0	3.1	2.0	2.6	1.7
17.7B	7.6	1.6	8	2.4	37	22	3	1.8	200	32	67	10	42	7.0	19	3.2	7.1	1.8	4.3	1.1
17.7C	1.4	1.6	8	4.4	36	24	13	9.0	120	30	56	13	5.3	2.5	4	1.8	15	8.0	2.4	1.3
17.7D	8.7	4.0	14	1.4	290	12	700	28	75	46	32	20	17	3.1	13	2.4	54	23	10	4.3
BC	24.7	6.3	370	110	22,000	45	2000	4.1	340	110	300	100	12	2.8	4.7	1.1	12	2.0	8.0	1.4
RR	6.0	2.8	14.5	11	14	14	2.8	2.8	4	3.3	2.9	2.4	7.2	9.0	7.6	9.5	4.4	4.4	3.1	3.1
GRA	5.2	1.2	1.2	1.0	80	80	6	6.0	10	15	2	3	10	3.3	6.8	2.3	0.8	4.0	1.2	6.0
GRB	1.6	1.2	16	2	1040	52	240	12	480	480	320	320	1.3	1.3	0.5	0.5	1.8	0.9	2.0	1.1

* Fecal coliform = mFC
** *E. coli* = mTEC

N.D.[1] = Not done

TABLE 16 Ottawa River Coliphage Study. Distribution of Fecal Coliform/6 hr Coliphage Ratios within Various Fecal Coliform Count Ranges (mFC).

May			June			July			
Fecal Coliform Count Ranges			Fecal Coliform Count Ranges			Fecal Coliform Count Ranges			
<100	100<1000	1000<10,000	<100	100<1000	1000<10,000	<100	100<1000	1000<10,000	10,000+
1.0	2.3	24.7	1.2	14	28	12	8.7	20	37
1.4	8.7		2.4	14	64	54	14	28	400
1.6	120		3.0	19	370	80	23	37	22000
2.0			4.0	21	400		27	1040	
2.5			5.0	100	6000		33		
3.0			6.0	120			33		
3.2			8.0	290			34		
3.2			8.0				36		
3.8			10				60		
4.0			10				67		
4.4			16				70		
4.8			30				70		
5.2			34				120		
5.6							150		
5.6							290		
6.0							410		
6.8									
7.6									
7.6									
44									
50									

TABLE 16 Ottawa River Coliphage Study. Distribution of Fecal Coliform/6 hr Coliphage Ratios within Various Fecal Coliform Count Ranges (mFC). cont'd

August				September			October		
Fecal Coliform Count Ranges				Fecal Coliform Count Ranges			Fecal Coliform Count Ranges		
<100	100<1000	1000<10,000	10,000+	<100	100<1000	1000<10,000	<100	100<1000	1000<10,000
-	4	29	110	1.3	0.6	21	0.8	4.7	3.1
	10	74	160	1.4	4.5	78	1.8	6.0	7.6
	21	75	170	10	4.8	110	4.4	6.5	9.1
	36	120	170		5.3			7.0	
		150	170		6.0			7.0	
		200	340		7.2			7.1	
		260	680		8.5			8.0	
		340	1500		11			9.0	
		440			12			12	
		480			12			15	
					13			19	
					17			24	
					17			30	
					21			54	
					24			66	
					42			90	
					150				
					170				

TABLE 17 Ottawa River Coliphage Study. Distribution of *E. coli*/6 hr Coliphage Ratios within Various *E. coli* Count Ranges (mTEC)

May			June			July		
E. coli Count Ranges			*E. coli* Count Ranges			*E. coli* Count Ranges		
<100	100<1000	1000<10,000	<100	100<1000	1000<10,000	<100	100<1000	1000<10,000
0.1		6.3	0.8	11	190	2.6	6	12
0.3			1.0	12	820	2.8	7.3	15
0.4			1.2	22		2.8	13	39
0.8			1.4	40		3.0	14	80
1.0			1.8	40		3.3	15	2000
1.2			2.0	110		3.5	32	
1.2			2.4			3.6	36	
1.2			2.4			6.0	240	
1.4			2.4			6.4	700	
1.6			3.6			6.7		
1.6			4.4			32		
2.4			4.8			42		
2.6			6.7					
2.8			9.0					
2.8			16					
3.2			18					
4.0			22					
4.0			60					
4.0								
6.4								
8.0								
16								
20								
120								

TABLE 17 Ottawa Coliphage Study. Distribution of *E. coli*/6 hr Coliphage Ratios within Various *E. coli* Count Ranges (mTEC). cont'd

August				September			October		
E. coli Count Ranges				*E. coli* Count Ranges			*E. coli* Count Ranges		
<100	100<1000	1000<10,000	10,000+	<100	100<1000	1000<10,000	<100	100<1000	1000<10,000
2	3.0	12	64	0.3	3.0	9.3	0.9	0.5	7.0
	12	33	110	0.5	4.0	19	1.2	2.6	
	16	56	160	1.6	4.0		1.9	3.7	
	22	67	300	6.7	4.4		2.2	4.3	
	26	77		6.8	4.7		2.4	4.3	
	120	110		10	6.0		2.5	5.0	
		110		16	7.3		3.1	6.8	
		280		19	7.6		3.4	8.0	
		320			8.4		3.6	10	
		400			13		10	10	
		440			13		12		
					14		14		
					130				

TABLE 18 Fraser River Samples for Coliphage Study, received November 7, 1984. All counts based on 100 mL sample

Sample	Fecal Coliform (mFC)	Fecal Coliform A-1 Broth (EC Confirmed)	*E. coli* (mTEC)	Fecal Streptococci (KF)	Coliphage	
					6 hrs	24 hrs
A1A	440	540	200	550	15	50
A1B	420	1700	210	690	30	110
A2A	410	350	310	650	55	180
A2B	590	350	430	790	30	85
A3A	440	540	180	620	35	80
A3B	480	540	240	1300	35	65
N1A	230	1100	180	630	60	180
N1B	320	350	190	750	10	35
N2A	440	350	360	760	60	105
N2B	400	540	290	980	35	160
N3A	600	540	830	1000	65	160
N3B	460	1700	400	1000	70	160
S1A	8100	>16,000	4300	970	55	180
S1B	8600	5400	4200	980	65	115
S2A	4500	3500	1800	890	75	140
S2B	4400	16,000	1600	700	35	130
S3A	2200	1600	960	1600	30	135
S3B	1200	1600	900	830	60	150
S17	4400	3500	2600	890	55	145

TABLE 19 Fraser River Samples for Coliphage Study, received December 3, 1984. All counts based on 100 mL sample

Sample	Fecal Coliform (mFC)	Fecal Coliform A-1 Broth (EC Confirmed)	*E. coli* (mTEC)	Fecal Streptococci (KF)	Coliphage	
					6 hrs	24 hrs
A1A	190	130	60	840	20	50
A1B	240	220	90	570	20	70
A2A	310	920	130	170	30	50
A2B	230	1100	90	320	25	90
A3A	310	220	150	130	75	135
A3B	190	220	80	130	30	85
N1A	270	350	120	970	30	65
N1B	270	540	140	680	25	60
N2A	370	23	50	700	0	40
N2B	190	170	60	490	15	55
N3A	260	240	100	630	15	65
N3B	260	130	70	810	35	75
S1A	1200	1700	890	150	25	55
S1B	1400	>1600	660	280	30	110
S2A	1300	920	680	100	35	100
S2B	1300	920	800	190	70	130
S3A	1300	1700	1300	180	40	60
S3B	1900	920	970	220	15	135
S10A	5900	5400	3900	570	85	205
S10B	4000	5400	2400	670	40	165

TABLE 20 Fraser River Samples for Coliphage Study, received January 16, 1985. All counts based on 100 mL sample

Sample	Fecal Coliform (mFC)	Fecal Coliform A-1 Broth (EC Confirmed)	*E. coli* (mTEC)	Fecal Streptococci (KF)	Coliphage	
					6 hrs	24 hrs
A1A	8300	5400	7200	1400	120	295
A1B	9200	16,000	9200	1500	130	295
A2A	10,000	16,000	7600	1600	120	270
A2B	10,000	16,000	7000	1000	105	320
A3A	8500	9200	9500	1400	120	315
A3B	8800	9200	5800	770	70	245
D1A	3600	2400	3200	580	105	255
D1B	3000	5400	3100	710	115	260
D2A	4200	2400	3300	540	110	225
D2B	4800	2400	3000	900	50	220
D3A	3600	1100	2900	620	95	285
D3B	3500	3500	2800	850	85	205
N1A	8500	>16,000	6900	900	45	195
N1B	6700	2400	5200	800	80	205
N2A	9700	9200	7700	1900	90	245
N2B	8200	16,000	4400	860	85	265
N3A	1500	16,000	1500	1200	85	320
N3B	8900	5400	5600	1300	120	255
S1A	6400	5400	4800	930	135	330
S1B	5400	3500	4200	840	115	325

TABLE 21 Fraser River Coliphage Study, Fecal Coliform - Fecal Streptococci Ratios. All counts based on 100 mL sample

Sample	November			December			January		
	Fecal* Coliform	Fecal** Streptococci	FC/ FS	Fecal Coliform	Fecal Streptococci	FC/ FS	Fecal Coliform	Fecal Streptococci	FC/ FS
A1A	440	550	0.8	190	840	0.2	8300	1400	5.9
A1B	420	690	0.6	240	570	0.4	9200	1500	6.1
A2A	410	650	0.6	310	170	1.8	10,000	1600	6.3
A2B	590	790	0.7	230	320	0.7	10,000	1000	10.0
A3A	440	620	0.7	310	130	2.4	8500	1400	6.1
A3B	480	1300	0.4	190	130	1.5	8800	770	11.4
N1A	230	630	0.4	270	970	0.3	8500	900	9.4
N1B	320	750	0.4	270	680	0.4	6700	800	8.4
N2A	440	760	0.6	370	700	0.5	9700	1900	5.1
N2B	400	980	0.4	190	490	0.4	8200	860	9.5
N3A	600	1000	0.6	260	630	0.4	1500	1200	1.3
N3B	460	1000	0.5	260	810	0.3	8900	1300	6.8
S1A	8100	970	8.4	1200	150	8.0	6400	930	6.9
S1B	8600	980	8.8	1400	280	5.0	5400	840	6.4
S2A	4500	890	5.1	1300	100	13.0			
S2B	4400	700	6.3	1300	190	6.8			
S3A	2200	1600	1.4	1300	180	7.2			
S3B	1200	830	1.4	1900	220	8.6			
S17	4400	890	4.9						
S10A				5900	570	10.3			
S10B				4000	670	6.0			
D1A							3600	580	6.2
D1B							3000	710	4.2
D2A							4200	540	7.7
D2B							4800	900	5.3
D3A							3600	620	5.8
D3B							3500	850	4.1

* Fecal coliform = mFC
** Fecal streptococci = KF

TABLE 22 Fraser River Coliphage Study - Ratio of Fecal Coliform and *E. coli* Counts to 6 and 24 hour Coliphage Counts. All counts based on 100 mL sample.

Sample	November				December				January			
	Fecal* Coliform 6 hr Phage	*E. coli** 6 hr Phage	Fecal Coliform 24 hr Phage	*E. coli* 24 hr Phage	Fecal Coliform 6 hr Phage	*E. coli* 6 hr Phage	Fecal Coliform 24 hr Phage	*E. coli* 24 hr Phage	Fecal Coliform 6 hr Phage	*E. coli* 6 hr Phage	Fecal Coliform 24 hr Phage	*E. coli* 24 hr Phage
A1A	29	13	8.8	4.0	9.5	3.0	3.8	1.2	69	60	28	24
A1B	14	7.0	3.8	1.9	12	4.5	3.4	1.3	71	71	31	31
A2A	7.4	5.6	2.3	1.7	10	4.3	6.2	2.6	83	63	37	28
A2B	20	14	6.9	5.1	9.2	3.6	2.6	1.0	95	67	31	22
A3A	13	5.1	5.5	2.3	4.1	2.0	2.3	1.1	71	79	27	30
A3B	14	7.4	7.4	3.7	6.3	2.7	2.2	0.9	130	83	36	24
N1A	3.8	3.0	1.3	1.0	9.0	4.0	4.2	1.8	190	150	44	35
N1B	32	19	9.1	5.4	11	5.6	4.5	2.3	84	65	33	25
N2A	7.3	6.0	4.2	3.4	-	-	9.3	1.3	110	86	40	31
N2B	11	8.3	2.5	1.8	13	4.0	3.4	1.1	97	52	31	17
N3A	9.2	13	3.7	5.2	17	6.7	4.0	1.5	18	18	4.7	4.7
N3B	6.6	6.0	2.9	2.5	7.4	2.0	3.5	0.9	74	47	35	22
S1A	150	78	45	25	48	36	22	16	47	36	19	15
S1B	130	65	75	36	47	22	13	6.0	47	36	17	13
S2A	60	24	32	13	37	19	13	6.8				
S2B	130	46	34	12	19	11	10	6.2				
S3A	73	32	16	7.1	32	32	22	22				
S3B	20	15	8.0	6.0	130	65	14	7.2				
S17	80	47	30	18	-	-	-	-				
S10A					69	46	29	19				
S10B					100	60	24	15				
D1A									34	31	14	13
D1B									26	27	12	12
D2A									38	30	19	15
D2B									96	60	22	14
D3A									38	31	13	10
D3B									41	33	17	14

** Fecal coliform KF

TABLE 23 Fraser River Coliphage Study. Distribution of Fecal Coliform/6 hr Coliphage Ratios within Various Fecal Coliform Count Ranges (mFC).

November			December			January		
Fecal Coliform Ranges			Fecal Coliform Ranges			Fecal Coliform Ranges		
<100	100<1000	1000<10,000	<100	100<1000	1000<10,000	<100	100<1000	1000<10,000
-	3.8	20	-	4.1	19	-	-	18
	6.6	60		6.3	32			26
	7.3	73		7.4	37			34
	7.4	80		9.0	47			38
	9.2	120		9.2	48			38
	11	130		9.5	69			41
	13	150		10	100			47
	14			11	130			47
	14			12				69
	20			13				71
	29			17				71
	32							74
								83
								84
								95
								96
								97
								110
								130
								190

TABLE 24 Fraser River Coliphage Study. Distribution of *E. coli*/6 hr Coliphage Ratios within Various *E. coli* Count Ranges (mTEC).

November			December			January		
E. coli Ranges			*E. coli* Ranges			*E. coli* Ranges		
<100	100<1000	1000<10,000	<100	100<1000	1000<10,000	<100	100<1000	1000<10,000
-	3.0	24	2.0	2.0	32	-	-	18
	5.1	46	2.7	4.0	46			27
	5.6	47	3.0	4.3	60			30
	5.7	65	3.6	5.6				31
	6.0	78	4.0	11				31
	7.0		4.5	19				33
	7.4		6.7	22				36
	8.3			36				37
	13			65				47
	13							52
	14							60
	15							60
	19							63
	32							65
								67
								71
								79
								83
								86
								153

TABLE 25 Coliphage, Fecal Coliform and *E. coli* Longevity Comparison Study

Source and Test		Period of Time Held under Iced Conditions						
		0 hr	24 hr	48 hr	72 hr	96 hr	7 days	10 days
Wastewater Treatment Plant								
Clarifier								
January 28, 1985								
Coliphage	/100 mL	41,000	40,000	29,000	36,000	38,000	29,000	32,000
Fecal coliform (mFC)	/100 mL	9,000,000	12,000,000	11,000,000	6,000,000	15,000,000	2,000,000	4,000,000
E. coli (mTEC)	/100 mL	4,000,000	4,000,000	6,000,000	2,000,000	11,000,000	lost	3,000,000
November 26, 1984								
Coliphage	/100 mL	40,000	30,000	45,000	45,000	40,000	40,000	20,000
Fecal coliform (mFC)	/100 mL	3,400,000	1,100,000	1,100,000	1,100,000	1,500,000	1,200,000	1,800,000
E. coli (mTEC)	/100 mL	1,000,000	1,100,000	800,000	1,000,000	1,000,000	820,000	1,700,000
Burlington Bay								
November 26, 1984								
Coliphage	/100 mL	40	80	40	85	50	25	30
Fecal coliform(mFC)	/100 mL	6800	4400	2700	2800	4200	500	600
E. coli (mTEC)	/100 mL	2200	1400	400	100	1100	200	100
January 28, 1985								
Coliphage	/100 mL	40	40	35	50	45	20	5
Fecal coliform(mFC)	/100 mL	41	19	12	10	5	7	4
E. coli (mTEC)	/100 mL	24	8	5	5	8	6	1