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AN INVESTIGATION OF THE KAMLOOPS SEWAGE LAGOONS

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By

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RÉSUMÉ

En novembre 1981, on a procédé à une brève étude des étangs de stabilisation des eaux usées de Kamloops afin d'évaluer quelques aspects de l'exploitation et du rendement de ces bassins. Quatre jours de suite, on a prélevé des échantillons étalonnés dans le temps à trois endroits différents du système d'étangs; ensuite, on en a analysé divers paramètres chimiques et physiques aussi bien que la présence de métaux. On a procédé à des analyses bactériologiques sur les échantillons prélevés aux différents endroits du système de bassins ainsi que pour les eaux réceptrices (rivière Thompson). L'évaluation du bassin de déchlorination, conduite sur une période de deux semaines, ainsi qu'un bio-essai avec poissons en continu dans l'effluent final n'ont pas donné des résultats entièrement satisfaisants.

Le rendement du bassin de stabilisation est évalué à l'intérieur des limites de cette courte étude; plusieurs conclusions et recommandations sont apportées dans ce rapport.

ABSTRACT

A brief study of the Kamloops sewage lagoons was carried out in November, 1981 in order to assess some aspects of lagoon operation and performance. Composite samples at three stations across the lagoon system were taken each day for four days and analyzed for several chemical and physical parameters as well as metals. Bacteriological analyses were carried out on samples taken at several locations in the lagoon system and the receiving waters (Thompson River). An evaluation of the dechlorination lagoon conducted over a two week period and an on site continuous fish bioassay on the final effluent were not entirely successful.

Lagoon performance is assessed within the limits of this short study and several conclusions and recommendations are made.

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CONCLUSIONS AND RECOMMENDATIONS

1. Although the lagoons are slightly organically overloaded, relative to recommended design, the BOD_5 removal was excellent at the time of the study. However, this may not always be the case, particularly in late spring and early summer when the lagoons are less efficient.

2. None of the Gulf Refinery effluent characteristics analyzed at the time of this study should adversely affect the lagoon treatment.

3. Further analyses, particularly for metals and pathogens, will be required prior to a decision on the ultimate disposition of lagoon 1 sludge. Provincial and federal guidelines/regulations must be adhered to for disposal on agricultural land.

4. Acceptable disinfection was achieved and lagoon 4 provided adequate dechlorination at the time of the study.

5. Long term monitoring of chlorine usage and lagoon 4 effluent coliform levels in conjunction with factors affecting bacteria survival, will provide guidelines for optimizing chlorine dosage.

6. Jar tests should be performed on lagoon 3 effluent on a regular basis in order to determine the optimum alum dosage as the wastewater quality changes.

7. Reliable influent flow measurement as well as flow measurement between lagoons (or, alternatively, depth measurement in each lagoon) should be provided for continuous monitoring of water loss (exfiltration and/or evaporation) and lagoon loadings, and to assist lagoon operation decisions with regard to effluent discharge rate and optimum lagoon volumes.

8. Consideration should be given to constructing two small alternating settling ponds at the influent to lagoon 4 that would contain most of the alum-precipitated solids and miminize the deposition of these solids throughout the lagoon.

9. If and when these lagoons become substantially organically overloaded alternatives are available to improve performance including:
   - i) mechanical aeration.
   - ii) baffling to maximize retention time.
   - iii) addition of a 5th lagoon.
   - iv) and possibly, recirculation.

10. Consideration should be given to installation of a self-cleaning fine screen on the raw sewage for the removal of non-biodegradables, particularly if the primary sludge is determined to be suitable for disposal on agricultural land. Fine screening will also minimize unsightly floatables on the lagoons.

11. The sometimes-high levels of phosphorous and suspended solids in the final effluent are, to a varying extent, due to algae. If these elevated levels are deemed unacceptable, the installation of a suspended solids removal process such as microscreening should be considered. (Alternatively, the coagulation/sedimentation operation could be relocated to the lagoon 4 effluent.)

12. Notwithstanding the problems associated with the continuous bioassay apparatus, the effluent was apparently non-acutely toxic despite the high ammonia concentrations (22.5 to 23.5 mg/L). However, at marginally higher temperatures and/or pH, this effluent could be rendered acutely toxic. It is recommended, therefore, that this condition be monitored and the lagoons be upgraded as necessary to eliminate toxic discharges to the Thompson River.

13. The Kamloops climate (hot and dry) is particularly conducive to effluent land disposal (e.g. irrigation and rapid infiltration); land disposal of the lagoon effluent should continue to be investigated as the ultimate environmentally-appropriate disposal method for the treated Kamloops sewage. Ground disposal eliminates the need for phosphorous reduction, and therefore the concomitant costs associated with alum, and in the case of rapid infiltration disinfection may also be unnecessary.

14. The use of floating (no roots to dislodge when harvesting) aquatic plants has undergone considerable investigation in recent years as a means of upgrading lagoons. These plants reduce effluent suspended solids and phosphorous levels partly by reducing algae concentrations. The use of plants such as water hyacinths in lagoon 4 could improve effluent quality while at the same time reducing or eliminating the need for alum. An appropriate study would be necessary to determine the effectiveness and net costs of employing such plants at Kamloops.

1 INTRODUCTION

In the fall of 1981 the Environmental Protection Service carried out an evaluation of the City of Kamloops sewage lagoons with particular emphasis on lagoon 4 dechlorination. A tracer study of lagoon 4 using a lithium salt was undertaken to evaluate the lagoon residence time and flow pattern. Total residual chlorine analyses were carried out daily at 17 stations in the lagoon over a 2 week period. Bacteriological analyses were performed on samples from some of the lagoon 4 chlorine stations over four days, as well as on nine river stations and on lagoon influents. Due to problems monitoring chlorine and to a temporary shutdown of the treatment system, a full evaluation of the dechlorination process was not accomplished.

In addition to the dechlorination investigation four sets of samples were taken of the influent raw sewage, lagoon 3 effluent, and lagoon 4 effluent and analyzed for several physical and chemical parameters including metals. Also, a continuous bioassay was run on the final effluent and 3 sludge samples from lagoon 1 were analyzed for metals.

In order to assess the impact of the Gulf Refinery effluent which discharges to the Kamloops sewer system, two 24 hour composite samples (taken by refinery personnel) were analyzed for several parameters including metals.

Chlorine residual analyses were performed in situ using an Epco Chlortect chlorine monitor (forward amperometric titration). Some samples were also analyzed using other residual chlorine analytical techniques that included the back titration method using the amperometric titrator or the iodometric procedure, and a Hach CN-70 kit (DPD colourimetric method). All bacteriological analyses were carried out on site in EPS's mobile laboratory. Lagoon and refinery samples were preserved as required and shipped in coolers via courier to EPS's West Vancouver laboratory for analyses.

2 PROCESS DESCRIPTION

A plan of the Kamloops facultative lagoons is presented in Figure 1. The flow pattern at the time of the study is indicated by the arrows. Lagoon 1 was out of service for drying and eventual removal of the accumulated sludge.

The physical characteristics of the lagoons are presented in Table 1, showing that if all lagoons are in service the total surface area is 74.5 ha and the total volume 21.9 x 10^5 m^3. The total volume is the estimated maximum based on the design maximum depths. Due to sludge accumulation over the years the maximum depths, and therefore, the volumes, will now be somewhat less. Furthermore, because the lagoon system is operated with an intermittent discharge (Table 2), the lagoon volumes are variable and seldom at maximum. Also, due to inflow and outflow configurations short-circuiting may occur.

According to the operating personnel, the influent raw sewage flow rate is fairly consistent between 20 000 and 22 000 m^3/d.

The sewage flows by gravity through the first 3 lagoons and then is transferred by a submersible pump and buried pipeline to the 4th lagoon. Liquid alum (48.5% $Al_2(SO_4)_3 \cdot 14H_2O$) is injected into the transfer pump suction by a metering pump at a rate of about 3.4 L/min (45 IGPH) for phosphorus removal. Disinfection is accomplished with the injection of a gaseous chlorine solution into the transfer pump discharge at the chlorination system's maximum capability of 180 kg/d (400 lb/day).

Effluent is discharged by gravity through a buried line and short outfall to the Thompson River. The rate is manually controlled with a valve and the volume is totalized by an inline meter.

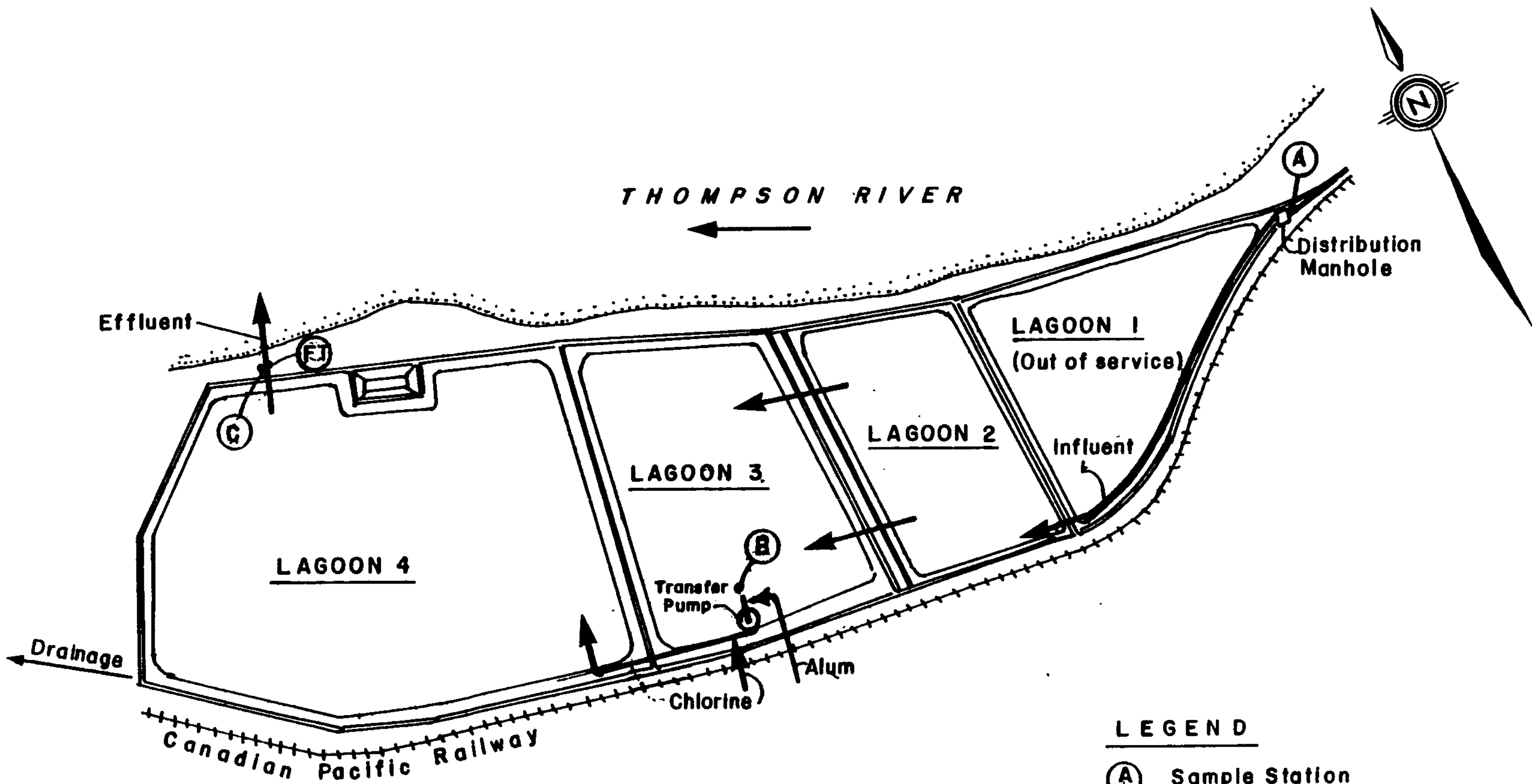

FIGURE 1 KAMLOOPS LAGOONS PROCESS SCHEMATIC

TABLE 1 KAMLOOPS LAGOONS PHYSICAL CHARACTERISTICS

LAGOON	MAXIMUM VOLUME ($x10^5$ m^3)[1]	MAXIMUM DEPTH (m)[1]	SURFACE AREA (ha)
1	1.9	1.83	10.4
2	1.8	1.83	9.8
3	5.6	3.35	16.7
4	12.6	3.35	37.6
TOTAL	21.9		74.5
- excluding Lagoon 1	20.0		64.1

1 Reference 1

TABLE 2 KAMLOOPS LAGOONS DISCHARGE SCHEDULE

DATE	RECOMMENDED DISCHARGE
April 1 to April 30	minimum, no more than influent
May 1 to September 30	influent or higher depending on effluent and river conditions
October 1 to November 30	as necessary to bring down levels while maintaining adequate dilution
December 1 to March 31	none

3 DISCUSSION OF RESULTS

Composite samples of the raw influent, lagoon 3 effluent, and lagoon 4 effluent (final) were taken daily from November 2 to 5, 1981, preserved, and forwarded to the EPS laboratory in West Vancouver for analyses. Each composite sample consisted of 4 two litre grab samples taken 1 hour apart within the period 0800 to 1200. These samples were analyzed for several physical/chemical parameters and extractable metals. The results are discussed in Sections 3.1 and 3.2, respectively.

3.1 Physical/Chemical

The physical/chemical results are presented in Table 3. The influent (sample station A) data shows that over the 4 days of sampling the raw sewage became more dilute, particularly the last 2 days. The influent sample results on November 5 indicate that the raw sewage was relatively dilute (e.g. BOD_5 = 70 mg/L, surfactants = 1.7 mg/L, TPO_4 = 3.3 mg/L), not only compared to the previous 3 days but also to typical raw sewage. The reason for this is not known, however it suggests infiltration and/or inflow of relatively clean water into the sewer system. As there was no precipitation during or immediately prior to the sampling period, the source(s) was likely springs, the Thompson River, or excess water usage.

The effluent (sample station C) BOD_5 results are quite low and within the required limit, but the suspended solids (NFR) are erratic and quite high due to the presence of algae and crustaceans (e.g. Cladocera and Copepoda) and/or resuspended settled solids as the result of wind and the shallow depth of lagoon 4. The reduction in ammonia across the lagoons was minimal, and probably due to the low retention time and seasonally cool temperatures. The reduction in phosphorous across lagoon 4 was

TABLE 3 KAMLOOPS LAGOONS ANALYTICAL RESUTLS[1]

SAMPLE STATION:	NOV 2			NOV 3			NOV 4			NOV 5		
PARAMETER	A[2]	B[3]	C[4]	A	B	C	A	B	C	A	B	C
BOD_5	140	35	10	135	27	8	100	9	10	70	40	4
COD	385	195	75	270	165	70	260	195	75	250	190	70
TOC	85	62	22	88	47	22	57	58	22	50	52	22
TR	433	360	339	432	356	326	382	372	316	370	350	310
TVR	223	142	84	208	136	88	180	136	70	170	130	70
NFR	273	100	54	144	86	24	154	84	27	130	80	190
OIL & GREASE	41	29	44	113	16	37	55	16	46	20	17	21
SURFACTANTS	2.5	1.6	0.9	2.6	1.7	1.2	1.9	2.0	1.1	1.7	2.0	1.0
PHENOLS	0.015	0.04	< 0.015	0.03	0.015	< 0.015	< 0.015	0.015	< 0.015	< 0.015	< 0.015	< 0.015
CYANIDE (CN)	< 0.03	< 0.03	< 0.03	< 0.03	< 0.02	< 0.02	< 0.03	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
NH_3 (N)	40.6	19.5	23.0	25.0	22.0	23.5	23.5	21.0	22.5	25.2	22.5	22.5
NITRITE (N)	0.013	0.027	0.012	0.0084	0.019	0.0058	0.014	0.025	0.0068	0.016	0.027	0.0067
NITRATE (N)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
TOTAL PO_4 (P)	6.06	4.94	2.93	5.48	4.55	1.72	3.98	5.44	1.36	3.30	4.30	1.17
TOTAL ALK ($CaCO_3$)	156	163	123	144	148	122	141	161	123	140	164	124
HARDNESS	73.5	77.1	76.3	77.3	69.2	64.2	80.0	79.5	76.1	72.0	75.8	73.6
pH	7.6	7.6	7.7	7.2	7.3	7.6	7.4	7.5	7.7	7.3	7.5	7.6

1 All results in mg/l except pH
2 Raw sewage sampled at diversion manhole
3 3rd lagoon effluent sampled at transfer pump suction
4 4th lagoon effluent sampled at manhole

substantial although the effluent did not always meet the required effluent level of 1.5 mg/L, probably due to the high level of algae and/or resuspended alum floc.

3.2 Metals

The water samples were analyzed for extractable metals by emission spectrophotometry and the results are presented in Table 4. None of the results are unique except for the increased aluminum concentration across lagoon 4 which can be attributed to the addition of alum.

3.3 Gulf Oil Refinery

The refinery process wastewater is treated in an API oil separator followed by a storage lagoon prior to discharge into the City of Kamloops sewer system. In order to determine whether there were any unusually high constituent concentrations, analyses were run on two 24 hour final effluent composite samples collected by the refinery. The results are presented in Table 5 and show that concentrations were all quite low particularly for the constituents of primary concern, phenols and cyanide. It seems likely that there is an error in the phenol values, as the refinery consistently reports much higher values, generally in the range 10 to 30 mg/L.

The metal results are presented in Table 6 and the levels are not unusually high.

3.4 Sludge

Three grab samples of the drying sludge in lagoon 1 and one sample from the sludge bank in lagoon 4 were analyzed for metals. Lagoon 1

TABLE 4 KAMLOOPS LAGOONS EXTRACTABLE METALS RESULTS (mg/L)

SAMPLE STATION:	NOV 2			NOV 3			NOV 4			NOV 5		
PARAMETER	A	B	C	A	B	C	A	B	C	A	B	C
As	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075
Ba	0.031	0.0196	0.0138	0.0284	0.0153	0.008	0.0348	0.0219	0.0087	0.0272	0.0202	0.0078
Be	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cd	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Co	< 0.0075	< 0.0075	< 0.0075	< 0.0075	< 0.0075	< 0.0075	< 0.0075	< 0.0075	< 0.0075	< 0.0075	< 0.0075	< 0.0075
Cr	< 0.0075	< 0.0075	< 0.0075	< 0.0075	< 0.0075	< 0.0075	< 0.0075	< 0.0075	< 0.0075	< 0.0075	< 0.0075	< 0.0075
Cu	0.131	0.0533	0.0377	0.0986	0.0375	0.0218	0.117	0.0722	0.0222	0.106	0.0648	0.0182
Hg	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.056	< 0.05	< 0.05	< 0.05
Mn	0.0235	0.0304	0.0498	0.0208	0.0273	0.0344	0.0242	0.0342	0.0448	0.0222	0.0315	0.0427
Mo	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015
Ni	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
P	6.94	5.83	2.83	6.71	4.09	1.72	4.7	5.54	1.25	4.42	5.38	1.18
Pb	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
Sb	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
Se	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075	< 0.075
Sn	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Sr	0.136	0.137	0.121	0.147	0.119	0.0978	0.151	0.142	0.117	0.143	0.133	0.112
Ti	0.0152	0.005	0.0073	0.022	< 0.004	0.0108	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
V	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Zn	0.0967	0.0477	0.0396	0.0846	0.0299	0.0189	0.104	0.0475	0.0246	0.0699	0.0415	0.0186
Al	0.281	0.065	3.38	0.362	1.03	1.99	0.278	0.124	1.95	0.262	0.145	1.78
Fe	0.279	0.318	0.719	0.286	0.327	0.491	0.405	0.39	0.579	0.361	0.388	0.5
Si	4.95	5.94	6.30	5.06	5.39	5.30	4.67	6.12	6.16	4.48	5.91	5.97
Mg	6.09	6.42	6.40	6.77	5.78	5.41	7.35	6.50	6.36	6.09	6.23	6.17
Na	32.5	42.0	41.7	35.4	37.6	35.0	29.8	44.3	43.5	31.1	42.0	41.8
Ca	19.4	20.3	20.0	19.8	18.2	16.8	19.9	21.1	20.0	18.8	20.1	19.3

TABLE 5 GULF REFINERY EFFLUENT RESULTS[1]

PARAMETER	NOVEMBER 3	NOVEMBER 4
BOD_5	31	32
COD	195	180
TOC	50	48
TR	1070	890
TVR	130	100
NFR	30	21
OIL & GREASE	56	26
SURFACTANTS	1.7	1.3
PHENOLS	0.06	0.05
CYANIDE (CN)	0.04	0.03
NH_3 (N)	3.2	3.8
NITRITE (N)	0.015	0.022
NITRATE (N)	$<$ 0.01	0.012
TOTAL PO_4 (P)	2.60	2.41
TOTAL ALKALINITY ($CaCO_3$)	110	106
HARDNESS	109.0	99.1
pH	7.2	7.6

1 All results in mg/L except pH

TABLE 6 GULF REFINERY EFFLUENT EXTRACTABLE METALS (mg/L)

PARAMETER	NOVEMBER 3	NOVEMBER 4
As	< 0.075	< 0.075
Ba	0.0762	0.0818
Be	< 0.001	< 0.001
Cd	0.057	0.0166
Co	< 0.0075	< 0.0075
Cr	< 0.0075	< 0.0075
Cu	0.0371	0.0346
Hg	< 0.05	0.05
Mn	0.0593	0.0656
Mo	< 0.015	< 0.015
Ni	< 0.04	< 0.04
P	2.58	2.19
Pb	< 0.04	< 0.04
Sb	< 0.04	< 0.04
Se	< 0.075	< 0.075
Sn	< 0.1	< 0.1
Sr	0.730	0.774
Ti	< 0.004	< 0.004
V	< 0.02	< 0.02
Zn	0.105	0.0606
Al	0.143	0.137
Fe	0.736	0.65
Si	6.75	7.78
Mg	5.76	5.15
Na	218.0	222.0
Ca	34.2	31.2

provides sedimentation for the raw sewage and therefore the settled solids are equivalent to primary sludge. The metals content is very important in determining environmentally-acceptable disposal of this potentially useful sludge. The results are presented in Table 7.

In general, sludge samples from lagoon 1 had slightly higher metal concentrations than sludges from other B.C. communities (4). The lagoon 4 sludge generally had considerably lower concentrations than lagoon 1, except for phosphorous and aluminum as expected.

The Provincial government is expected to issue "Guidelines for Sludge Application to Land" in the near future, and Agriculture Canada presently has regulations governing allowable metal concentrations for sludge applied to land. These guidelines and regulations should be consulted during the decision process regarding the ultimate disposition of these sludges.

3.5 Bacteriological

Detailed results and discussion of the bacteriological analyses are presented in Appendix 1. The total and fecal coliform results for the lagoons are summarized in Table 8. The influent mean fecal count of 2.2 x 10^6/100 mL is on the low end of typical raw sewage. Very little reduction occurred across lagoon 2 which was probably due to the low residence time as a result of the low level, and short-circuiting due to the flow pattern. Lagoon 3 provided a larger coliform reduction due to the longer residence time. The low counts in lagoon 4 and the final effluent are due to the chlorination of lagoon 3 effluent. Due to the low fecal counts and small number of samples there is no significant difference between the results of the five sample stations in lagoon 4.

The Thompson River was sampled upstream of the Weyerhauser pulp-mill outfall, downstream of the mill outfall and downstream of the lagoon discharge (Figure 2). An across-river transect consisting of 3 sample stations was made at each location. The fecal and total coliform results

TABLE 7 KAMLOOPS LAGOONS SLUDGE METAL RESULTS[1]

LOCATION:	LAGOON 1	LAGOON 1	LAGOON 1	LAGOON 4
DATE:	Nov 2/81[2]	Nov 3/81[3]	Nov 4/81[4]	Nov 4/81[5]
PARAMETER				
Ba	379.0	502.0	928.0	132.0
Be	0.301	0.27	0.388	< 0.18
Cd	7.84	10.5	12.4	< 0.656
Cr	129.0	150.0	203.0	112.0
Cu	1300	1680	1700	370.0
Mn	241.0	210.0	302.0	147.0
Mo	28.0	27.9	27.7	5.41
Ni	58.6	49.6	46.4	< 6.56
Pb	821.0	867.0	597.0	86.4
Sn	355.0	471.0	414.0	< 16.4
Sr	75.0	66.8	97.7	157.0
V	46.8	43.0	52.1	40.5
Zn	2470	1400	1560	178.0
Ti	800.0	664.0	647.0	481.0
Si	2660	2650	2230	3340
Mg	7150	6880	9150	4710
P	4080	5190	6540	41800
Ca	14500	14900	16700	11900
Na	1050	1210	1940	1130
Al	15200	15600	18900	85800
Fe	20900	17000	23200	11400

1 mg/kg dry weight basis
2 eastern end
3 northwest corner
4 southwest corner
5 at dock near inflow

TABLE 8 SUMMARY OF LAGOON COLIFORM RESULTS

		FECAL COLIFORM (MF/100mL)			TOTAL COLIFORM (MF/100mL)		
SAMPLE STATION	STATION DESCRIPTION	NO. OF SAMPLES	RANGE	MEAN	NO. OF SAMPLES	RANGE	MEAN
KL01	influent raw sewage	7	$7.0x10^5$-$4.2x10^6$	$2.2x10^6$	4	$2.0x10^6$-$2.8x10^7$	$1.3x10^7$
KL02	lagoon 2 effluent	4	$8.8x10^5$-$2.1x10^6$	$1.3x10^6$	-	-	-
KL03	lagoon 3 effluent	4	$3.0x10^5$-$5.4x10^5$	$4.2x10^5$	-	-	-
2	lagoon 4[1]	3	< 10 - 10	10	-	-	-
9	lagoon 4[1]	3	< 10 - 40	20	-	-	-
11	lagoon 4[1]	3	< 10 - 10	10	-	-	-
12	lagoon 4[1]	3	< 10 -110	47	-	-	-
KL05	lagoon 4 effluent	4	10 - 80	33	4	10-$5.7x10^3$	$1.5x10^3$

1 see Figure 3

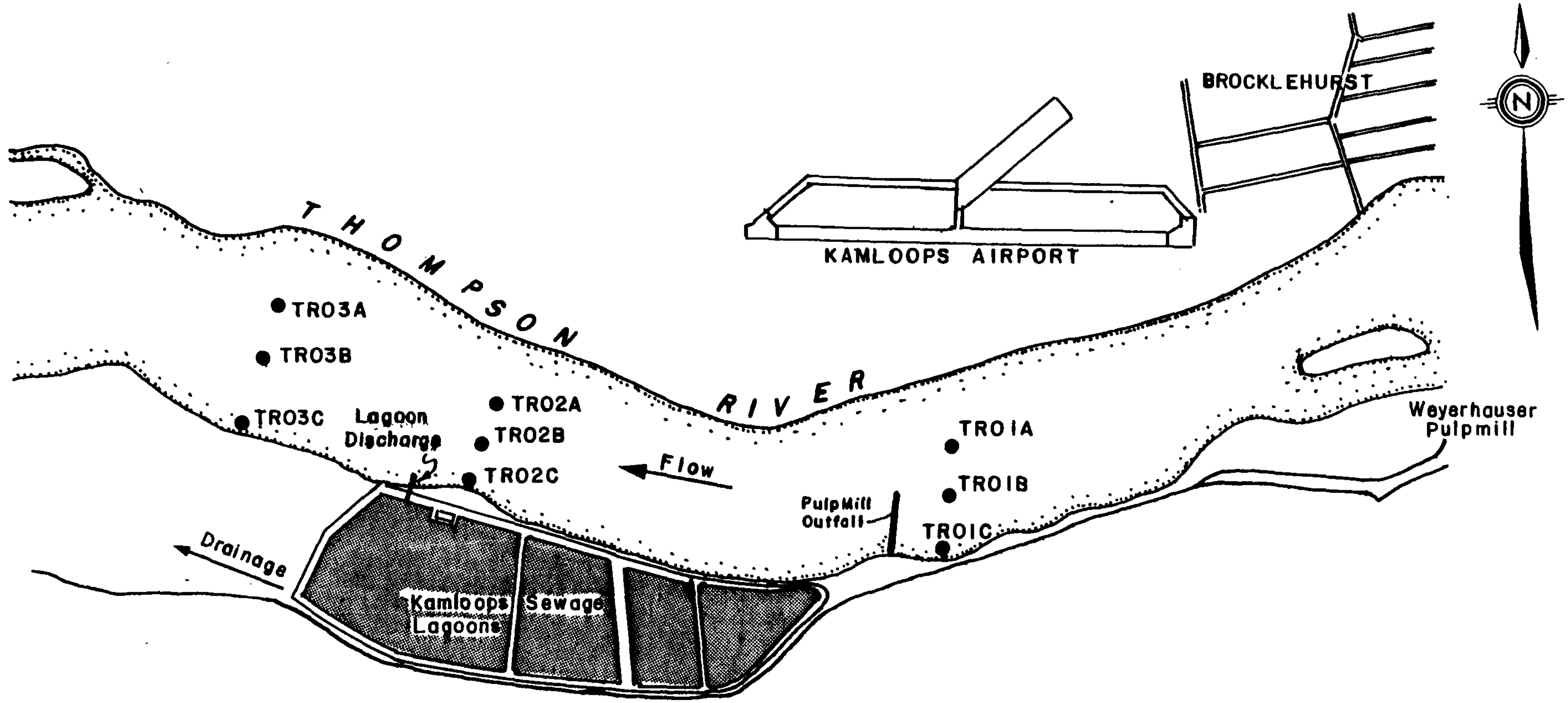

FIGURE 2 THOMPSON RIVER BACTERIOLOGICAL SAMPLE STATIONS

TABLE 9 SUMMARY OF THOMPSON RIVER COLIFORM RESULTS

		FECAL COLIFORM (MF/100mL)			TOTAL COLIFORM (MF/100mL)		
SAMPLE TRANSECT	TRANSECT LOCATION	NO. OF SAMPLES	RANGE	MEAN	NO. OF SAMPLES	RANGE	MEAN
TR01	upstream of pulpmill outfall	7	2 - 80	18	8	4 - 86	28
TR02	downstream of pulpmill outfall	9	4 - 330	44	9	2 - 890	119
TR03	downstream of lagoon discharge	8	2 - 24	10	8	2 - 84	32

are summarized in Table 9, and indicate that the lagoon discharge had no apparent effect on the river coliform levels at the time of the study.

3.6 Total Residual Chlorine

One of the primary objectives of the study was to assess the natural dechlorination occurring in lagoon 4. This involved daily in situ total residue chlorine (TRC) analyses at 17 stations (Figure 3) over a twelve day period. Results of the monitoring are shown in Table 10. TRC values were variable throughout the basin and no apparent consistency is noted in the data. Unstable readings observed during the period October 31 to November 2 were attributed to instrument problems encountered as a result of damage sustained by the Chlortect instrument in transit to Kamloops. (The Chlortect had been repaired in the field prior to October 28 and its performance on the next three days was very good. However, its satisfactory operation was short-lived. Following further repairs, acceptable operation of the instrument was regained and this was maintained for the rest of the survey.) Comparable chlorine monitoring was performed daily using other standard chlorine analytical methods as previously mentioned. A statistical assessment, described in Appendix 2, shows that the Chlortect gave "valid" readings although they averaged 30% lower than TRC values obtained by the other methods. Two reasons may account for this discrepancy: firstly, interferences in the wastewater samples, which are supposedly eliminated in the back titration methods, may have yielded a lower reading although the instrument manufacturer had stated previously that this situation would not be the case; and secondly, the electronic components of the instrument may have been damaged and caused a consistent reduction in the readings.

Assuming the data is reliable (+30%), the variability of TRC values observed throughout the lagoon would indicate short-circuiting.

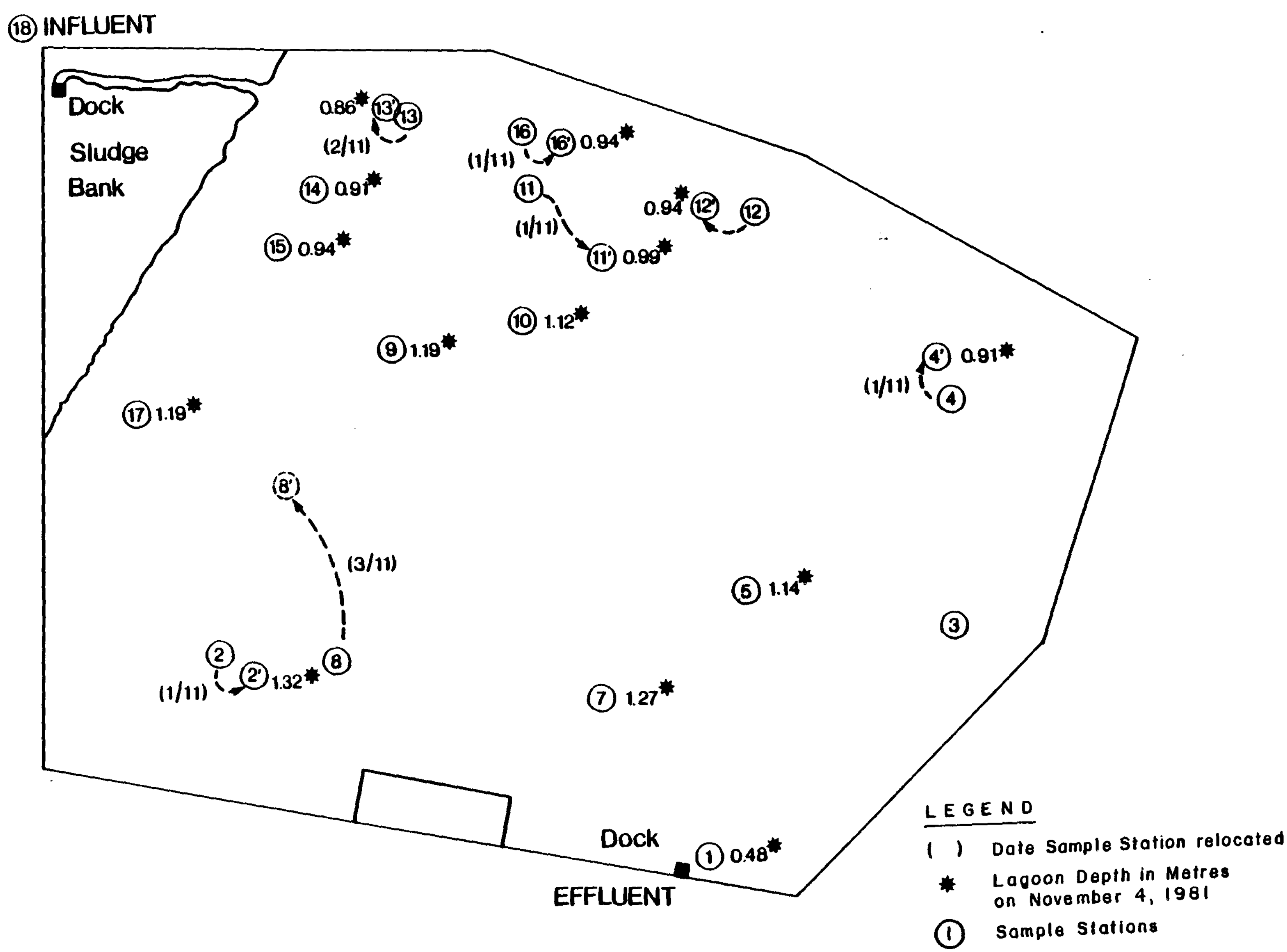

FIGURE 3 LAGOON 4 TOTAL RESIDUAL CHLORINE SAMPLE STATIONS

TABLE 10 LAGOON 4 TOTAL RESIDUAL CHLORINE RESULTS (ug/l)

Date (1981)	29/10	30/10	31/10	1/11	2/11	3/11	4/11	5/11	6/11	7/11 am	7/11 pm	8/11 am	8/11 pm	9/11
Cl_2 Feed Rate (kg/d)	180	180	136	136	136	Off[1]	Off[1]	180[2]	180	180	180	180	180	180
Sample Station														
18	760	1080	(156)[3]	(500)[3]	(2000)[3]	-	-	10	750	1000	-	710	-	771
13	265	139				102	0		63	320	232	159	303	42
14	284	90				x	0	0	0	x		2	x	5
15	314	51				x	x		0	2	x	12		x
16	13	5				36	1	x	4	x	99	3	7	x
17	2	27				x			1	10		2		x
9	3	1				x	4	x	1	x	1	0		16
10	14	1				x	3	x	1	44	39	4	x	54
11	14	1				x	3	x	1	2	38	0		8
12	30	1				x	2	x	2	x	59	0	x	x
2	1	1				x		x	0	x		22		v
3	2	1				x		16	x	x		0		x
4	2	1				x		x	x	x	x	0	x	x
5	11	1				x		x	x	x		0		x
7	2	1				x		x	x	x	x	13	x	x
8	1	1				x	4	x	1	x	x	6		x
1	3	1			(235	x	18	x	0	x	x	140	x	x

Data reported are only those values that gave stable readings on the Chlortect monitor.

x Indicates values that registered at a negative level (indicating chlorine demand in the water).

1 Treatment Plant Shutdown.

2 Chlorine feed interrupted.

3 Chlortect malfunctioned.

From Table 10, a significant TRC drop occurred from station 18 to 13. Moving further from the influent into the lagoon, TRC values decreased more slowly, and also became more variable. Assessing the first two days, TRC decayed quickly to minimum levels, probably in 10-20 hours, as shown by the levels at stations 16,17, and 9-12. After November 2, readings became variable and evidence of chlorine demand became apparent. High TRC levels at the effluent or in sections of the lagoon represented short circuiting of chlorinated wastewater moving through the lagoon.

It was noted that an ecosystem of higher life forms such as freshwater crustaceans had developed in the lagoon. This would indicate that minimal levels of chlorine must exist in areas of the basin all year round (10). Rapid decay of the chlorine and evidence of a chlorine demand at many of the sites indicated a presence of reduced sulfur compounds (expected in a facultative pond). Very limited field analyses for $S^{=}$ and $SO_3^{=}$ were performed. The results show that low levels of $SO_3^{=}$ were present but $S^{=}$ was not detected.

3.7 Lagoon 4 Flow Pattern

An assessment of the water movement through lagoon 4 was made during the survey.

A mean daily volume reduction of 18 500 m^3/d, determined from soundings, occurred in lagoon 4 from October 29 to November 4. Based on this reduction and an influent flow rate determined to be 40 700 m^3/d (except on November 3rd and 4th when the flow was zero), the mean daily discharge rate would have been approximately 47 500 m^3/d. The lagoon 4 effluent flow meter indicated a mean daily discharge rate of 14 600 m^3/d for this period. Therefore, assuming these flow measurements were accurate, approximately 32 900 m^3/d was exfiltrating from the lagoon. This rate of exfiltration is unreasonable based on the raw sewage flow. The reason for this discrepancy is not known; although the tracer results are thought to be correct no information on the transfer pump was available to confirm pump capacity. Observation from an aircraft identified a full drainage ditch immediately west of lagoon 4 whose likely source was lagoon 4.

A concentrated lithium chloride solution (7 875 mg/L) was prepared in the alum feed day-tank and pumped into the transfer line from lagoon 3 to determine flow rates to the lagoon and mixing patterns and retention time in lagoon 4.

It was determined that the alum pump rate was 3.41 L/min and the transfer pump delivered a flow of 40 700 m^3/d (approximately twice the reported influent flow rate). Based on approximated lagoon volumes of 5.2×10^5 m^3 (October 29) and 4.1×10^5 m^3 (November 4) and an influent rate of 40 700 m^3/d, the theoretical retention time in the lagoon dropped from 12.7 to 10 days over the seven day period.

Proof of a shorter actual retention time was determined from the tracer study. Figure 4 shows the sequence of lithium transfer through the lagoon. There was complete dispersion of lithium throughout the basin by the 6th day. There was also an indication of channeling in lagoon 4 as noted by the presence of lithium at the effluent by the third day.

3.8 Miscellaneous

On November 4 soundings and Secchi disc measurements were made at most of the stations in lagoon 4; the results are presented on Figure 3. As the results indicate the mean depth was approximately 1 metre (40"). Soundings made on October 29 were approximately 0.3 m greater. The Secchi disc measurements ranged between 40 cm (16") and 46 cm (18") reflecting the high concentration of algae in the lagoon. Determination of pH levels were conducted daily at each station. The temperature of the lagoon was also monitored every day, and some analyses for reduced sulphur compounds ($SO_3^=$, $S^=$) were also performed. A record of the daily amount of ultra-violet (UV) irradiation was made with the use of a UV monitor

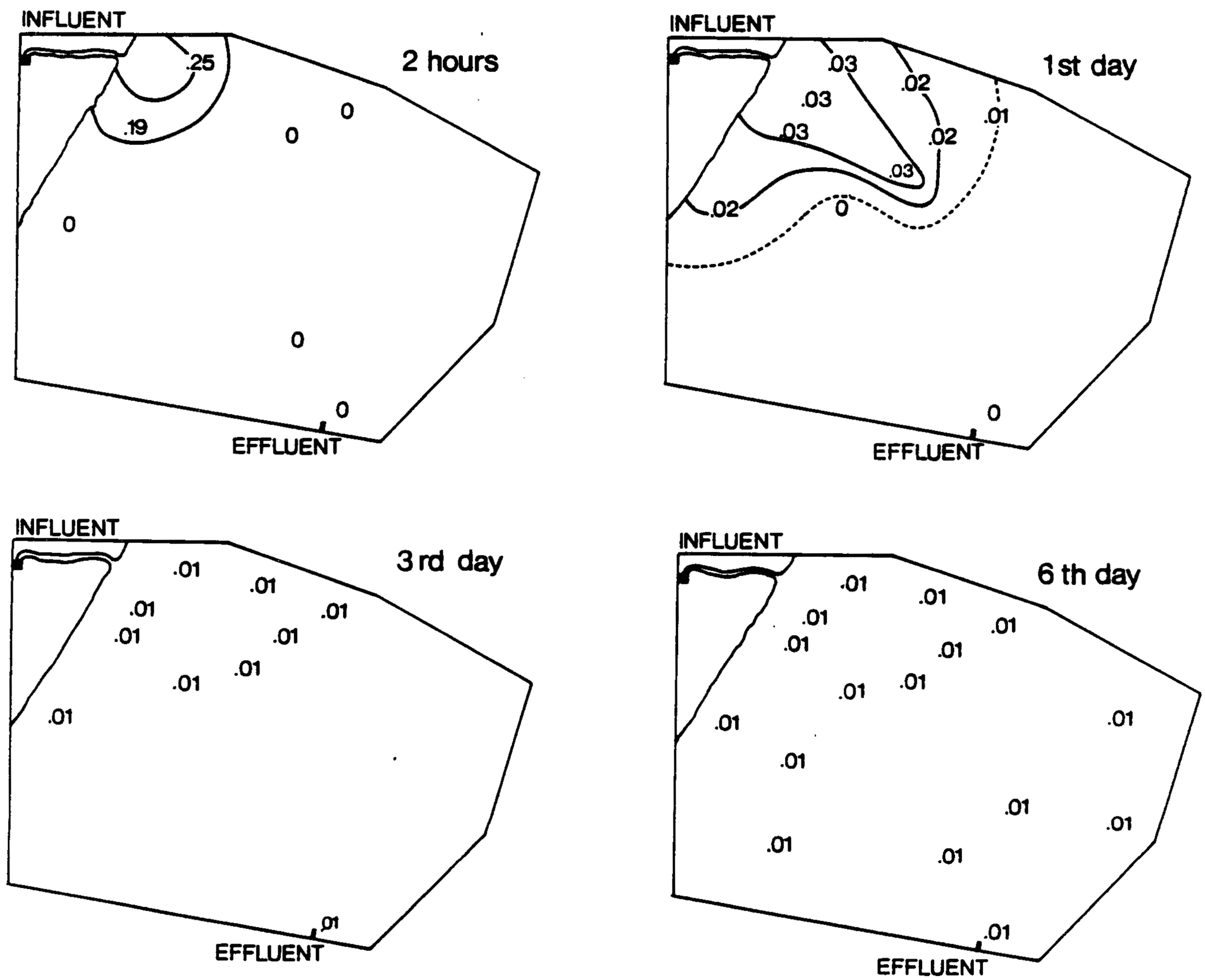

FIGURE 4 LAGOON 4 LITHIUM TRACER RESULTS

located at the control building. Daily means and ranges for pH temperature and UV irradiation are shown in Table 11.

The temperature and pH values determined at Kamloops were found to be comparable to those levels of a chlorinated municipal effluent used in a laboratory-scale investigation of natural chlorine decay (9). The mean level of ultraviolet radiation monitored at Kamloops was approximately 50% of the level applied in the laboratory studies.

It had been anticipated that the expressions being developed in the laboratory for dechlorination could be tested at full-scale conditions with the Kamloops lagoon system. The model developed was

$$-\frac{d}{dt}[Cl] = K_1 [Cl] [X] + K_2 [Cl]$$

where [X] represents organic carbon concentration and the second order term was found to be significant only when UV radiation was present. The kinetic coefficients (K_1 and K_2) used in the model to test the lagoon system are given in Appendix 4.

Based on a mean TOC influent loading of 55 mg/L, the chlorine level would be expected to decay in 2 hours to 96% of its initial level under zero UV radiation and to 86% of its initial level under zero UV radiation of $2 mW/cm^2$. Using the decay of TRC from station 18 (Table 10) to station 13 (or 14, 15, 16) with an approximate time span of 2 hours, the chlorine levels dropped very much more than the predicted 4 to 14%. Obviously, other dechlorination features (not investigated at bench scale) contributed to this more rapid decay; factors such as reduced sulfur compounds and chlorine interactions with algae and other material in the lagoon.

A continuous bioassay using rainbow trout was set up on the final effluent. Although an LC_{50} was not determined due to equipment malfunctions, no fish died in the 100% effluent sample. (The bioassay results are presented in Appendix 3).

TABLE 11   LAGOON 4 pH, TEMPERATURE AND UV IRRADIATION LEVELS

PARAMETER	DAILY MEAN	RANGE
pH	7.48	6.05 - 8.05
Temperature (°C)	6.7	5.8 - 9.0
UV (mW/cm^2)	0.90	0.72 - 1.12
Daily UV peak levels (mW/cm^2)	1.92	0.93 - 2.60

4 PROCESS EVALUATION

Complete evaluation of a facultative lagoon treatment system would require a full year's study in order to assess lagoon behaviour under all conditions of weather, lagoon volume, and influent quality. Although the scope of this study was very limited some observations and estimations of lagoon performance and capabilities can be made.

4.1 Organic Loading and Residence Time

Several design parameters can be calculated from the volumes and surface areas (Table 1) including organic loading and theoretical residence time. For the organic loading determination the average influent rate and BOD_5 concentration are assumed to be 21 000 m^3/d and 140 mg/L, respectively. A summary of the results for Kamloops are compared to typical design values in Table 12.

Organically, the Kamloops lagoons appear to be overloaded relative to typical design criteria. However, from the influent BOD_5 results (Table 1) the BOD_5 may average less than 140 mg/L. If 100 mg/L is assumed, which is quite low for municipal sewage and would indicate considerable infiltration/inflow, the loading would be about 28 kg/ha/d (25 lb BOD_5/acre/day), still on the high side of recommended design. This does not mean that the Kamloops lagoons are overloaded, only that they may be approaching this condition as influent loadings increase; the true measure of capacity of course, is the effluent organic levels.

The theoretical residence time is higher than stated as typical design for facultative lagoons and would therefore seem more than adequate. However, the actual retention time will be considerably less due to deviation from plug flow, settled sludge accumulation since start up, and exfiltration. Also, because of intermittent discharge practiced at Kamloops the lagoons are operating at less than maximum volume much of

TABLE 12 KAMLOOPS LAGOONS OPERATING CHARACTERISTICS

	KAMLOOPS	TYPICAL DESIGN REF. 2	TYPICAL DESIGN REF. 3
Organic Loading (kg BOD_5/ha/d)	39.5	24	17 - 35
(lb BOD_5/acre/day)	32.5	20	15 - 30
Theoretical Residence Time (d)	95	50 - 60	--

the time. Another reason the Kamloops lagoons are apparently organically overloaded but have adequate theoretical residence time is because lagoons 3 and 4 are 3.35 metres deep compared to a recommended design for facultative lagoons of 0.6 to 2.4 metres (2,3); in other words, the surface area to volume ratio is less at Kamloops than typical facultative lagoon design.

4.2 Phosphorous Removal

Effluent phosphorus reduction is accomplished by coagulation/ sedimentation using alum. A 48.5% solution of alum is injected into the suction of the lagoon 3 transfer pump at a rate of about 3.4 L/min (45 IGPH). The capacity of the transfer pump was determined during the tracer study and was found to discharge about 41 000 m^3/d. This resulted in an alum (as $Al_2(SO_4)_3 . 14H_2O$) concentration of about 78 mg/L, compared to the recommended dosage of 150 mg/L (1). Alum requirements depend on several factors including pH, temperature, alkalinity, and phosphorus concentration, and therefore can vary as these parameters vary. Consequently in order to optimize alum dosage, jar tests should be routinely performed (once/week initially) and the transfer and alum pump capacities verified.

4.3 Chlorination/Dechlorination

According to the treatment facility operators the chlorine (gas) dosage rate is usually maintained at 180 kg/d (400 lb/day), the maximum capability of the chlorination equipment. The chlorine solution is injected into the transfer line between lagoons 3 and 4. Therefore, when effluent is not being pumped from lagoon 3 to 4 chlorination ceases, as was the case from October 26 to 28 and November 3 to 5. Assuming a flow rate of 40 700 m^3/d, the chlorine dosage is 4.4 mg/L. After an estimated chlorine/wastewater contact time of 10 minutes (calculated retention time in the sewer line between cells 3 and 4) a median chlorine residual of 0.9 mg/L (Station 18) was found. This compares with a recommended chlorine dosage for an activated sludge effluent of 2.0 to 9.0 mg/L with a chlorine residual of 0.5 mg/L after 15 minutes of contact (8).

The bacteriological and total residual chlorine results were discussed in Sections 3.5 and 3.6, respectively. As previously noted the lagoon 4 coliform levels were low and the lagoon effluent had no apparent effect on Thompson River coliform levels. These results suggest that the level of chlorination was more than adequate. The quantity of chlorine required should be less than that of a comparable activated sludge effluent due to the residence time provided by lagoon 4 and the natural reduction in bacteria levels that will occur as a result of exposure to sunlight, algae, and predators, and varying temperatures prior to discharge; the alum should also reduce coliform level by removing solids-associated bacteria from the water column. The actual concentration of chlorine required to provide adequate disinfection and meet the permit effluent total coliform level of 5000 MPN/100 mL will vary depending on wastewater quality, lagoon residence time, and weather. Also it has been reported (5) that high levels of algae will consume the chlorine and reduce its effectiveness as a bactericide, while the bactericidal effect of large algal populations will tend to reduce chlorine requirements; which effect is greater is not discussed. The natural coliform decay rate can vary substantially from summer to winter, and can be as much as 16 times greater in summer (6), mostly due to sunlight (7). Therefore, lagoon 4 effluent should be routinely monitored (e.g. once/week) for coliform levels, and correlated with chlorine usage and other parameters including hours of light and residence time. Such monitoring will provide guidelines for optimum chlorine dosage and may demonstrate that less chlorine is required (perhaps none some of the time). Due to the variations in lagoon 4 residence time and seasonal discharges, long term (about 2 years) monitoring may be required to establish seasonal chlorine requirements but the potential saving in chlorine could easily offset the sampling and analytical costs.

Apart from cost reduction, less chlorine usage will minimize effluent toxicity and may reduce lagoon 4 organic loading by lessening algal cell lysis.

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NOMENCLATURE

m	metre
m^3	cubic metre
cm	centimetre
mg	milligram
kg	kilogram
L	litre
mL	millilitre
mW	milliwatt
MF	membrane filtration
LC_{50}	concentration in a bioassay at which 50% of the fish die
BOD_5	5 day biochemical oxygen demand
IGPM	imperial gallons per minute
IGPH	imperial gallons per hour
lb	pound

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APPENDIX 1

BACTERIOLOGICAL RESULTS

By

B.H. Kay

1 INTRODUCTION

Bacteriological sampling and analysis were carried out November 3-5, 1981 at several locations in the lagoon system and across 3 transects (9 stations) in the Thompson River. All samples were analyzed on site in EPS' mobile laboratory. The bacteriological sampling schedule and station descriptions are presented in Tables 1A and 2A, respectively. The daily results are presented in Tables 6A and 7A and a summary in Table 3A.

2 LAGOONS

2.1 Total coliform measurements

Total coliform measurements were made on the influent (KL01) and final effluent (KL05). The mean total coliform for 4 influent samples was $1.3x10^7$/100 mL which dropped to a mean of $1.5x10^3$/100 mL in the final effluent. It should be noted that the mean final effluent count is skewed by a single high measurement of $5.7x10^3$/100 mL on Nov.4. The cause of this high count is not known and was not observed in the fecal coliform measurements.

2.2 Fecal coliform measurements

Samples of influent (KL01), lagoon 2 effluent (KL02), lagoon 3 effluent (KL03), lagoon 4 (KL04A-KL04D) and final effluent (KL05) were analyzed for fecal coliforms. Percent reduction of fecal coliforms at each treatment stage is presented in Table 4A. Treatment in lagoon 2 did not effect a significant reduction in fecal coliform levels and levels remained relatively high throughout lagoon 3 prior to chlorination. Samples collected at four locations in lagoon 4 indicated virtually 100% of the fecal coliforms were killed through chlorination and there did not appear to be a significant regrowth of indicator bacteria in the final treatment lagoon and effluent.

2.3 Fecal streptococci measurements

All samples collected for fecal coliform analysis were also analyzed for fecal streptococci. Percent reduction across the lagoon system is presented in Table 4A and the calculated fecal coliform: fecal streptococci ratios are presented in Table 5A. The influent ratio of 4.7 is consistent with literature data for municipal wastewater (ie., human sewage). The ratios increase with increased retention time suggesting the fecal coliform organisms are better able to survive in the lagoon environment.

2.4 Standard Plate Count measurements

These measurements were made on the influent and final effluent samples. Unfortunately, difficulties were encountered with respect to external contamination and improper incubation temperatures and therefore the results are not conclusive. The data did indicate that bacteria levels were reduced approximately 98% prior to discharge.

3 RIVER SAMPLING

Thompson River samples were collected above the Weyerhauser discharge (TR01), above the lagoon discharge (TR02) and below the lagoon discharge (TR03). Variations in TC, FC and FS values at all stations in the river were not considered significant and the lagoon discharge did not result in an increase in indicator bacteria levels in the river. High TC and FC values were noted at TR02B on November 3. The source of this contamination was not identified and subsequent samples returned to low levels.

Standard plate count measurements were extremely variable and were subject to the difficulties alluded to earlier. Nevertheless, the increase in the bacteria count downstream of the pulpmill discharge is an expected result, since both the pulpmill and sewage lagoon discharges are introducing bacteria into the river system.

TABLE 1A BACTERIOLOGICAL SAMPLING SCHEDULE

DATE:	November 3		November 4		November 5	
Sample Station	Time	Parameter	Time	Parameter	Time	Parameter
KL01	1100h	TC,FC,FS,SPC	0800h	TC,FC,FS,SPC	0800h	TC,FC,FS,SPC
	1300h	TC,FC,FS,SPC	1100h	FC,FS,SPC	1100h	FC,FS,SPC
			1300h	FC,FS,SPC	1300h	FC,FS,SPC
KL02	0800h	FC,FS	0800h	FC,FS	0800h	FC,FS
					1300h	FC,FS
KL03	0800h	FC,FS	0800h	FC,FS	0800h	FC,FS
					1300h	FC,FS
KL04A-D	1100h	FC,FS	1100h	FC,FS	1100h	FC,FS
KL05	0800h	TC,FC,FS,SPC	0800h	TC,FC,FS,SPC	0800h	TC,FC,FS,SPC
					1300h	TC,FC,FS,SPC
TR01-TR03	once daily	TC,FC,FS,SPC	once daily	TC,FC,FS,SPC	once daily	TC,FC,FS,SPC

TABLE 2A BACTERIOLOGICAL SAMPLE STATION DESCRIPTIONS

KL01	Influent sewage
KL02	Composite sample of lagoon 2 effluent collected from discharges at NW and NE corners
KL03	At dischage pump from lagoon 3
KL04A	Lagoon 4
KL04B	Lagoon 4
KL04C	Lagoon 4
KL04D	Lagoon 4
KL05	Lagoon 4 effluent
TR01A	Thompson R.- 100 m upstream of Weyerhauser discharge - Airport Side
TR01B	" " " " " - Mid Channel
TR01C	" " " " " - Lagoon Side
TR02A	" - 175 m " of lagoon discharge - Airport Side
TR02B	" " " " " - Mid Channel
TR02C	" " " " " - Lagoon Side
TR03A	" - 300 m downstream of lagoon discharge - Airport Side
TR03B	" " " " " - Mid Channel
TR03C	" " " " " - Lagoon Side

TABLE 3A SUMMARY OF BACTERIOLOGICAL DATA

Sample Station	Total Coliform/100mL # of Samples	Total Coliform/100mL Range	Total Coliform/100mL Mean	Fecal Coliform/100mL # of Samples	Fecal Coliform/100mL Range	Fecal Coliform/100mL Mean	Fecal Streptococci/100mL # of Samples	Fecal Streptococci/100mL Range	Fecal Streptococci/100mL Mean	Standard Plate Count/ml # of Samples	Standard Plate Count/ml Range	Standard Plate Count/ml Mean
KL01(0800)	2	$2.0x10^6$-$5.1x10^6$	$3.5x10^6$	2	$9x10^5$-$1.1x10^6$	$1.0x10^6$	2	$1.0x10^5$-$3.0x10^5$	$2.0x10^5$	2	$8.8x10^5$-$2.3x10^7$	$1.2x10^7$
KL01(1100)	1	-	$2.8x10^7$	3	$2.4x10^6$-$4.2x10^6$	$3.3x10^6$	3	$2.0x10^5$-$1.0x10^6$	$5.3x10^5$	3	$2.3x10^6$-$1.2x10^7$	$5.9x10^6$
KL01(1300)	1	-	$1.5x10^7$	3	$7.0x10^5$-$2.4x10^6$	$1.8x10^6$	3	10^5-$1.0x10^6$	$6.0x10^5$	3	$1.6x10^6$-$4.5x10^6$	$3.0x10^6$
KL01(all data)	4	$2.0x10^6$-$2.8x10^7$	$1.3x10^7$	8	$7.0x10^5$-$4.2x10^6$	$2.2x10^6$	7	10^5-$1.0x10^6$	$4.6x10^5$	8	$8.8x10^5$-$2.3x10^7$	$6.3x10^6$
KL02	-	-	-	4	$8.8x10^5$-$2.1x10^6$	$1.3x10^6$	4	$4x10^4$-$1.9x10^5$	$1.1x10^5$	-	-	-
KL03	-	-	-	4	$3.0x10^5$-$5.4x10^5$	$4.2x10^5$	4	$1.2x10^4$-$4.0x10^5$	$2.5x10^4$	-	-	-
KL04A	-	-	-	3	< 10-110	65	3	< 10-10	< 10	-	-	-
KL04B	-	-	-	3	< 10-10	< 10	3	< 10-< 10	< 10	-	-	-
KL04C	-	-	-	3	< 10-40	< 20	3	< 10-20	< 13	-	-	-
KL04D	-	-	-	3	< 10-10	10	3	< 10-10	< 10	-	-	-
KL05	4	10-$5.7x10^3$	$1.5x10^3$	4	10-80	33	4	< 10-< 10	< 10	4	$2x10^4$-$2.6x10^5$	$1.3x10^5$
River												
TR01 A	2	30-86	58	2	2-10	6	2	19-48	34	2	56-410	233
TR01 B	3	4-40	21	3	6-80	33	3	8-18	14	3	58-130	95
TR01 C	3	8-24	14	2	5-8	7	3	14-18	16	3	69-190	116
TR02 A	3	2-32	20	3	4-16	11	3	8-26	17	3	50-208	136
TR02 B	3	2-890	302	3	4-330	115	3	10-30	18	3	* 69-$1.1x10^4$	$4.6x10^3$
TR02 C	3	16-58	34	3	4-10	7	3	16-24	22	3	*330-$3.3x10^3$	$2.1x10^3$
TR03 A	3	2-26	16	3	2-6	5	3	10-24	16	3	*110-$3.6x10^3$	$2.1x10^3$
TR03 B	3	4-60	26	3	8-24	14	3	20-32	26	3	*104-$3.0x10^3$	$1.6x10^3$
TR03 C	2	42-84	63	2	10-12	11	3	30-32	31	2	*350-3400	$1.9x10^3$

* high counts may be due to external contamination

TABLE 4A PERCENT REDUCTION OF FECAL COLIFORMS AND FECAL STREPTOCOCCI AT VARIOUS TREATMENT STAGES

	% REDUCTION FROM INFLUENT		
	Post-Lagoon 2	Post-Lagoon 3	Final Effluent
Fecal Coliform	40.9	80.9	99.9985
Fecal Streptococci	76.1	94.6	100
(Total Coliform	-	-	99.988

TABLE 5A FC:FS RATIOS AT VARIOUS TREATMENT STAGES

TREATMENT STAGE	FC:FS RATIO
Influent	4.7
Post-Lagoon 2	11.8
Post-Lagoon 3	16.8
Final Effluent	3.3

TABLE 6A DAILY BACTERIOLOGICAL RESULTS - KAMLOOPS SEWAGE LAGOONS

SAMPLE STATION	DATE (1981)	COUNT PER 100 mL TOTAL COLIFORM	FECAL COLIFORM	FECAL STREPTOCOCCI	35°C PLATE COUNT/mL(48h)
KL01 (0800h)	Nov. 4	5.1×10^6	1.1×10^6	3.0×10^5	2.3×10^7
	5	2.0×10^6	9.0×10^5	1.0×10^5	8.8×10^5
KL01 (1100h)	Nov. 3	2.8×10^7	4.2×10^6	1.0×10^6	1.2×10^{7a}
	4		3.4×10^6	4.0×10^5	3.6×10^6
	5		2.4×10^6	2.0×10^5	2.3×10^6
KL01 (1300h)	Nov. 3	1.5×10^7	7.0×10^5	10^5	4.5×10^{6a}
	4		2.3×10^6	1.0×10^6	2.9×10^6
	5		2.4×10^6	2.0×10^5	1.6×10^6
KL02 (composite)	Nov. 3		1.2×10^6	4.0×10^4	
	4		8.8×10^5	1.9×10^5	
	(0800)5		9.8×10^5	5.0×10^4	
	(1300)5		2.1×10^6	1.5×10^5	
KL03	Nov. 3		3.0×10^5	1.2×10^4	
	4		5.0×10^5	2.0×10^4	
	(0800)5		5.4×10^5	4.0×10^4	
	(1300)5		3.4×10^5	3.0×10^4	
KL04A	Nov. 3		20	< 10	
	4		110	10	
	(1600)5		< 10	10	
KL04B	Nov. 3		10	< 10	
	4		10	< 10	
	(1600)5		< 10	10	
KL04C	Nov. 3		40	< 10	
	4		< 10	< 10	
	(1600)5		10	20	
KL04D	Nov. 3		< 10	10	
	4		10	< 10	
	(1600)5		< 10	< 10	
KL05	Nov. 3	10	20	< 10	2.0×10^4
	4	5.7×10^3	10	10	2.6×10^{5b}
	(0800)5	110	80	< 10	1.1×10^{5b}
	(1300)5	130	20	< 10	1.3×10^{5b}

a = 24 hour plate count
b = estimate only; possible external contamination
NOTE: unless otherwise stated all collection times are 0800h

TABLE 7A DAILY BACTERIOLOGICAL RESULTS - THOMPSON RIVER

SAMPLE STATION	DATE (1981)	COUNT PER 100 mL TOTAL COLIFORM	FECAL COLIFORM	FECAL STREPTOCOCCI	35°C PLATE COUNT/mL(48h)
TR01 A	Nov. 3	30	2	19	56[a]
	4	86	10	48	410
TR01 B	Nov. 3	40	80	8	58[a]
	4	18	14	18	96
	5	4	6	16	130
TR01 C	Nov. 3	10	6	18	69[a]
	4	24	8	14	89
	5	8	-	16	190
TR02 A	Nov. 3	32	12	16	50[a]
	4	26	16	26	149
	5	2	4	8	208
TR02 B	Nov. 3	890	330	14	69[a]
	4	14	4	30	2.8×10^3[b]
	5	2	10	10	1.1×10^4[b]
TR02 C	Nov. 3	28	10	24	330[a]
	4	58	6	16	3.3×10^3[b]
	5	16	4	26	2.7×10^3[b]
TR03 A	Nov. 3	26	2	10	3.6×10^3
	4	20	6	24	2.5×10^3[b]
	5	2	6	14	110
TR03 B	Nov. 3	60	24	32	3.0×10^3
	4	14	10	26	1.6×10^3[b]
	5	4	8	20	109
TR03 C	Nov. 3	84	12	32	350
	4	42	10	10	3.4×10^3[b]

a = 24 hour plate count
b = estimates only; possible external contamination

APPENDIX 2

DISCUSSION OF TOTAL RESIDUAL CHLORINE RESULTS

By

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A statistical evaluaton of the data was undertaken to assess the correlation of total residual chlorine (TRC) values obtained using the Chlortect monitor versus values determined using one of the amperometric back titration, iodometric back titration or D.P.D. portable field unit techniques.

The Chlortect was repaired initially on October 28 and readings were taken throughout the lagoon. The values appeared normal and it was felt the unit was operating properly. Because of the damage sustained by the instrument in transit to Kamloops, it was decided to monitor the Chlortect's performance by conducting comparative analyses using one or more alternative residual chlorine analytical methods.

Chlorine monitoring at each station was conducted using an amperometric measurement instrument (Chlortect) supplied by EPCO Incorporated. Comparative chlorine analyses was performed by back titration using the iodometric method (Standard Methods procedure: 408C)[1] or a Wallace and Tiernan Amperometric titrator (Standard Methods Procedure: 408B). A DPD colourimetric method was also carried out using a Hach CN-70 kit. Back titrations were done on samples at the lagoon control building while other (DPD and Chlortect) analyses were done in situ.

Comparative analyses were performed beginning October 29. It was noted that the performance of the Chlortect deteriorated between this date and November 2, with respect to both comparative analyses and TRC values in the lagoon. It was discovered that air was being drawn into the Chlortect's reactor and this problem was quickly eliminated. After being repaired on November 2, the Chlortect results were more consistent. Only data collected from November 3 to the end of the survey were used in the statistical assessment. Total residual chlorine levels varied from location to location although operation of the Chlortect was stable.

To evaluate the performance of the Chlortect, a regression analysis of the comparison data has been performed. It was assumed that the amperometric and/or the other methods provided reliable chlorine results.

It was decided that for this field operation, a detection limit of 50 ug/L was acceptable for the amperometric, iodometric or DPD techniques and therefore all TRC results less than 50 ug/L that were determined have been discarded in the statistical analysis. The data are presented in Figure 1A. Table 8A lists the comparative data collected from the use of two or more chlorine analytical techniques on the same wastewater sample. The comparison among the other chlorine analytical methods (Figure 1A) indicates a reasonably good correlation. (Note that the DPD analysis gave higher readings than other methods.) Simple modeling using least squares (regression analysis) of the data was performed following statistical procedures described in Box, Hunter & Hunter[2] and Snedecor & Cochran[3]. An attempt was made to assess the data with the linear regression passing through the origin. The basis behind this attempt was that both methods should produce zero readings when the TRC = 0 ug/L. An expression was developed but it was found to be a poor fit. A linear regression of the form y = ax + b was then applied where y = Chlortect reading and x = value determined by one of the other chlorine analysis methods. The line found was y = 0.71 x + 79 (ug/L) and is presented in Figure 2A complete with the 95% confidence limits.

The regression line for the correlation between the Chlortect readings and TRC values by the other methods had a slope of + 0.713 implying that a Chlortect reading represented 71% of a value obtained by another method. This might mean that the data from the Chlortect was suppressed due to chemical interferences in the wastewater. Although the data appears scattered, there was good correlation; this was confirmed using a paired data statistical analysis. The regression analysis yielded a correlation coefficient of 0.87, which is high, and implies that if the application of the amperometric, iodometric and DPD methods are valid, then the values obtained by the Chlortect are acceptable as well, although the individual readings are probably 30% less than the actual chlorine level. The consequence of this decision

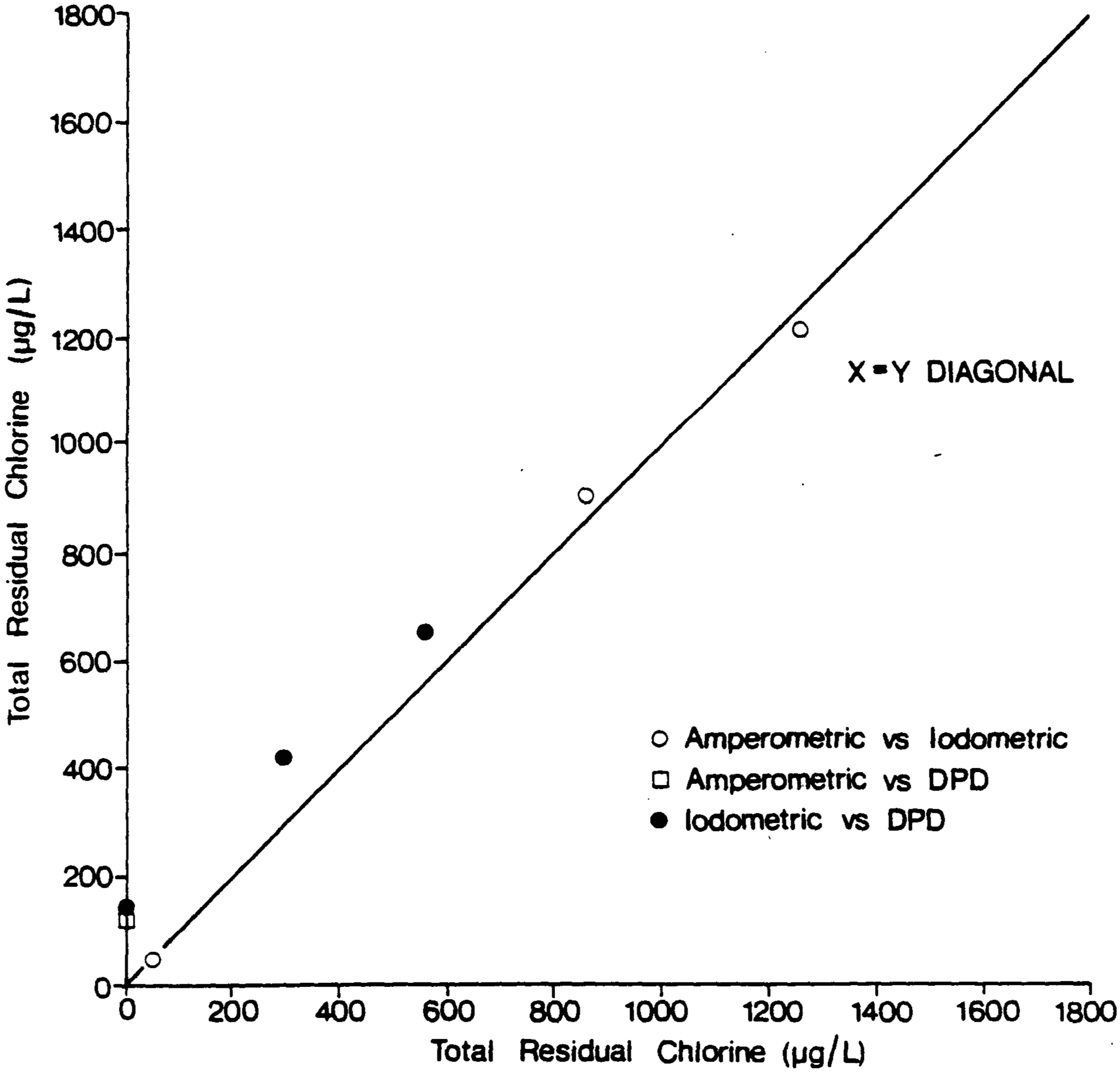

FIGURE 1A CORRELATION OF ALTERNATE CHLORINE ANALYSIS METHODS

TABLE 8A COMPARATIVE TOTAL RESIDUAL CHLORINE RESULTS

Chlortect (ug/L)	Amperometric (ug/L)	Iodometric (ug/L)	DPD (ug/L)
102	101		
775	859	900	
63	50	50	
1028	1620		
320	303		
232	202		
99	51		
468		404	
422		354	
710	1212		
303	556		
390		556	650
217		303	420
900			1500
1020			1500
920			1200

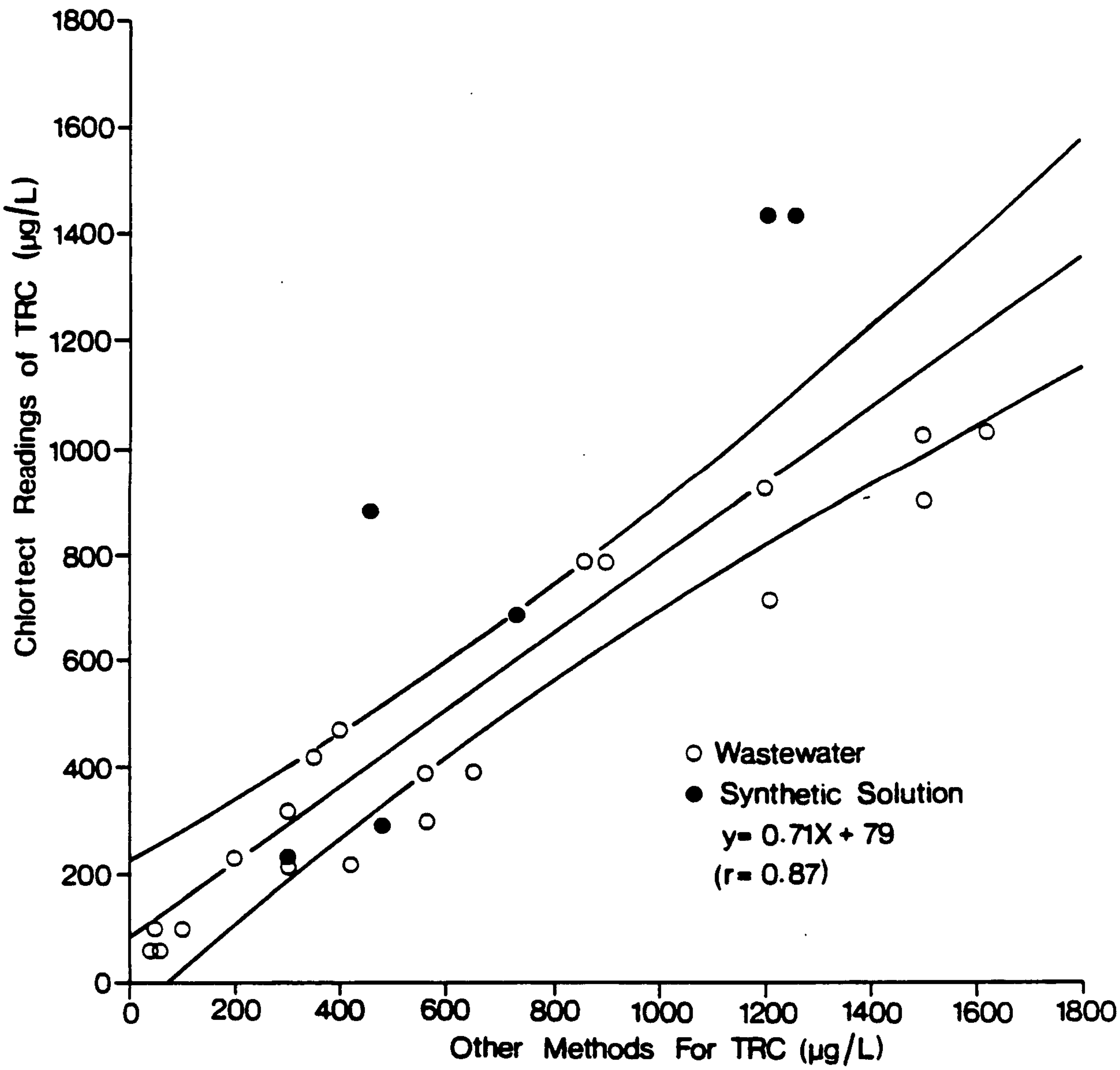

FIGURE 2A CORRELATION OF CHLORTECT READINGS VERSUS TOTAL RESIDUAL CHLORINE LEVELS BY OTHER METHODS is that the data is valid insofar as there were chlorine levels at the stations identified.

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1. APHA-AWWA-WPCF. "Standard Methods for the Examination of Water and Wastewater". 15th Edition, Washington, D.C. 1981.

2. Box, G.E.P., et al. "Statistical Methods". 6th Edition. Iowa State University Press. Iowa. 1972.

3. Snedecor, G.W. and W.G. Cochran. "Statistics for Experimenters". John Wiley and Sons Inc. Toronto. 1978.

APPENDIX 3

BIOASSAY RESULTS

By

D. Moul

1 OBJECTIVE

Determine the acute lethal toxicity of the lagoon effluent.

2 TERMINOLOGY

An aquatic bioassay is any test in which aquatic organisms are used to detect or measure the presence or effect of one or more substances, wastes, or environmental factors, alone or in combination, on aquatic organisms. (Standard Methods, 1975).

Acute - involving a stimulus, severe enough to bring about a quick response, usually within 96 hours for fish.

Lethal - causing death, or sufficient to cause it, by direct action.

A continuous flow or flow through fish bioassay is one in which measured quantities of dilution water and toxicant solution are mixed and delivered to test vessels containing fish to give a continuous flow-through of the test toxicant. [Flow-through tests are desirable for wastes that are suspected of having a high bio-chemical oxygen demand.]

96 hour LC_{50} - this term refers to median lethal concentration or that level of a measurable lethal agent required to kill the 50th percentile in a group of test organisms, over the time period of 96 hours. The 50th percentile is meant to represent the average organism.

LT_{50} - this term refers to median lethal time or the time to death of the 50th percentile organism in a specified concentration or level of measurable lethal agent. The maximum exposure time may be specified.

3 MATERIALS AND METHODS

The Aquatic Toxicity Laboratory's Mobile Laboratory containing a continuous flow-through diluter was used for the survey.

On site acute lethal continuous flow-through bioassays were performed.

The diluter permits the replication of 5 effluent concentrations and of a fresh water control. It is constructed so that the sample and the dilution water are withdrawn from header tanks and are combined in mixing chambers to obtain specified concentrations (dilutions). These concentrations are then split (to create replicates) and are delivered at a fixed flow rate to twelve 30 liter test vessels into which 10 fish are added. The fish mortalities in each vessel are monitored over 96 hours and the results are plotted on semi-log paper to establish LT and LC_{50} values.

The test species used were underyearling salmo gairdneri (Rainbow trout) which ranged in size from 3.8 cm to 4.7 cm in length and from 0.4 grams to 1.0 grams in weight. The fish were acclimated to the dilution water and to laboratory conditions a week prior to their use. There were no fish mortalities while being held. Ten fish were used as the test population in each test vessel.

The effluent sample source was at a manhole access point on the buried discharge pipe, which led from the 4th lagoon into the Thompson River. (Sample Station C in Figure 1 in the text).

The dilution water was transported to the mobile laboratory from a collection site in the Thompson River upstream of the sewage lagoon discharge and immediately upstream of the diffuser outfall of the Weyerheuser Pulp and Paper Mill.

All test volumes were 30 liters. The test solution flow rate was 150 mL/min which permitted a 90% molecular replacement of test solution over 7.2 hours.

The following test dilutions were used; 100%, 87%, 75%, 65%, 56% and a control.

The sample effluent and diluent water were aerated in the header tanks. Dissolved oxygen was measured in the test vessels and was recorded initially and as the assay progressed.

The pH in one of the 100% concentration test vessels was monitored continously using an Orion pH meter and a Varian Strip Chart recorder. Temperatures from a variety of sources were monitored at 6 hour intervals by means of a Pulsar Multiple Channel thermograph.

4. RESULTS AND DISCUSSION

LC_{50} and LT_{50} values were not established. The effluent was not toxic over the period tested. There were no fish mortalities. There were no control fish mortalities. Further evidence of the effluent's lack of toxicity were the numerous live daphnia in the effluent.

The pH of the 100% effluent remained at 7.5 throughout the test period. The pH of the dilution water was 7.7 throughout the test period.

The dissolved oxygen values were as follows:

D.O in ppm

	a) 100%	b) 100%	a) control	b) control
Nov. 3	10.2	9.9	11.5	11.7
Nov. 4	8.6	8.2	9.2	9.9
Nov. 5	9.9	9.2	10.5	11.5

The temperature values were as follows:

DATE	TIME	P_1	P_2	P_4	P_6
Nov. 3	0500	11.4	11.1	9.1	11.5
	1100	11.3	11.0	10.8	11.6
	1700	11.2	10.2	9.9	12.4
	2300	10.4	9.6	11.5	11.9
Nov. 4	0500	8.8	7.9	6.6	10.4
	1100	8.0	8.2	9.6	8.9
	1700	8.3	8.3	8.8	9.8
	2300	8.5	7.4	7.8	8.3
Nov. 5	0500	7.2	6.4	6.8	6.8
	1100	7.1	7.1	8.1	6.9
	1700	8.5	6.7	7.1	8.7
	2300	8.3	5.6	6.3	7.6
Nov. 6	0500	7.8	4.8	6.2	6.5

P_1 - Fish holding tank
P_2 - Dilution water header tank
P_4 - Effluent header tank
P_6 - Fresh water control

The diluter did not function properly. A problem involving the vacuum-dependent mixing system occurred. Although the problem was successfully corrected later for the duration of the survey the diluter continually malfunctioned. Proper solution mixing could never be managed. Consequently, the delivery rate of solution to the test vessels (which was dependent upon accurate mixing) could not be maintained or stabilized.

Although a 90% solution exchange in 7.2 hours was never attained it was noted that the 100% concentrations and fresh water controls (which were not dependent upon the mixing process) were being replenished - albeit intermittently.

Results obtained were only for the 100% concentrations and for their controls and only for a 72 hour period.

APPENDIX 4

CHLORINE REDUCTION CORRELATION

KINETIC COEFFICIENTS FOR ACTUAL SECONDARY EFFLUENT

CONDITION	PARAMETER	VALUE
Simultaneous reactions		
0 mW/cm^2 U.V.	K_{10}	1.27×10^{34}
	E_1	47370.0
	K_{20}	1.012
	E_2	4387.0
2 mW/cm^2 U.V.	K_{10}	1.39×10^{7}
	E_1	10257.0
	K_{20}	16.28
	E_2	5641.0
First order reaction only		
0 mW/cm^2 U.V.	K_{20}	48.1
	E_2	6501.0
2 mW/cm^2 U.V.	K_{20}	50.3
	E_2	6170.0

Where $K_1 = K_{10}\, e^{(-E_1/RT)}$ etc., for the

expression $-\frac{d[Cl]}{dt} = K_1 [Cl] [X] + K_2 [Cl]$

The units for the parameters are:

$K_2 = min^{-1}$

$K_1 = L \cdot mole^{-1} \cdot min^{-1}$

$E = cal \cdot mole^{-1}$