INTERNATIONAL PACIFIC SALMON FISHERIES COMMISSION

APPOINTED UNDER A CONVENTION
BETWEEN CANADA AND THE UNITED STATES FOR THE
PROTECTION, PRESERVATION AND EXTENSION OF
THE SOCKEYE AND PINK SALMON FISHERIES
IN THE FRASER RIVER SYSTEM

PROGRESS REPORT
No. 31

ACUTE TOXICITY AND DETOXIFICATION OF KRAFT PULP MILL EFFLUENT

BY

R. W. GORDON and J. A. SERVIZI

NEW WESTMINSTER, B. C.
CANADA
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ABSTRACT

Substandard detoxification by a biobasin with 24 hour treatment time and acute toxicity of effluent bypassing treatment prompted this 10 month study. The mill employed an effluent diversion system whereby contaminated effluents could be diverted to a spill lagoon for transfer to the biobasin. Records indicated that diversions ranging from minutes to hours occurred virtually each day and the spill lagoon functioned as a surge basin.

A bench scale aerated treatment unit simulating a plug flow aerated lagoon was used to determine whether combined effluent, a mixture of biobasin and bypass effluents, could be consistently detoxified by additional treatment. Results indicated that detoxification was variable when estimated treatment times in the bench unit were 29 and 58 hours. Correlation with a simultaneous study by another researcher to isolate toxic compounds indicated some cases of substandard detoxification coincided with peaks in resin acid content and toxic neutral compounds were also implicated. However, at 99 hours treatment time, detoxification met Federal Regulations and Provincial Objectives and BOD reduction averaged 83%.

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INTRODUCTION

Numerous salmon frequent the waters of the Fraser River during completion of their varied life cycles including large runs of sockeye salmon (Oncorhynchus nerka) and pink salmon (Oncorhynchus gorbuscha). Effluents from industrial developments in the vicinity of Prince George, B.C. constitute a hazard to salmon unless satisfactorily detoxified before discharge. Of particular concern are effluents from three kraft pulp mills. One of these mills, Prince George Pulp and Paper (PGPP) daily produced an average 400 air dry tons (ADT) of kraft pulp and 300 ADT of kraft paper.

Prince George Pulp and Paper began operation in May, 1966, and had a mean effluent discharge of 30 MGD. Bleach plant effluent and other noxious wastes leaving the mill (approx. 45%, mill flow) were treated in an aerated biobasin having a nominal 24 hr detention and a total aeration capacity of 370 horsepower. Effluents believed nontoxic were discharged via the clear-bypass sewer (approx. 55%, total mill flow). Treated effluent from the aerated biobasin joined the clear-bypass sewer and the resultant combined effluent was diffused in the Fraser River (FIGURE 1).

Save-alls were used in the mill to aid in controlling suspended solid (SS) losses to the biobasin and to the Fraser River via the clear-bypass sewer. There were no out-plant facilities for solids removal from the clear-bypass. There was a 2 hr stilling zone at the biobasin outlet for recovery and recycle of biological solids. Mill design included a Gate Box center which permitted diversion of contaminated water from the clear-bypass to an emergency spill lagoon and then to the biobasin by pumping (FIGURE 1). Detection of contamination was dependent upon alarms triggered by high conductivity and by judgment of operators.

Since the mill began operation, routine 4-day bioassays of clear-bypass, biologically treated and combined effluents were conducted under

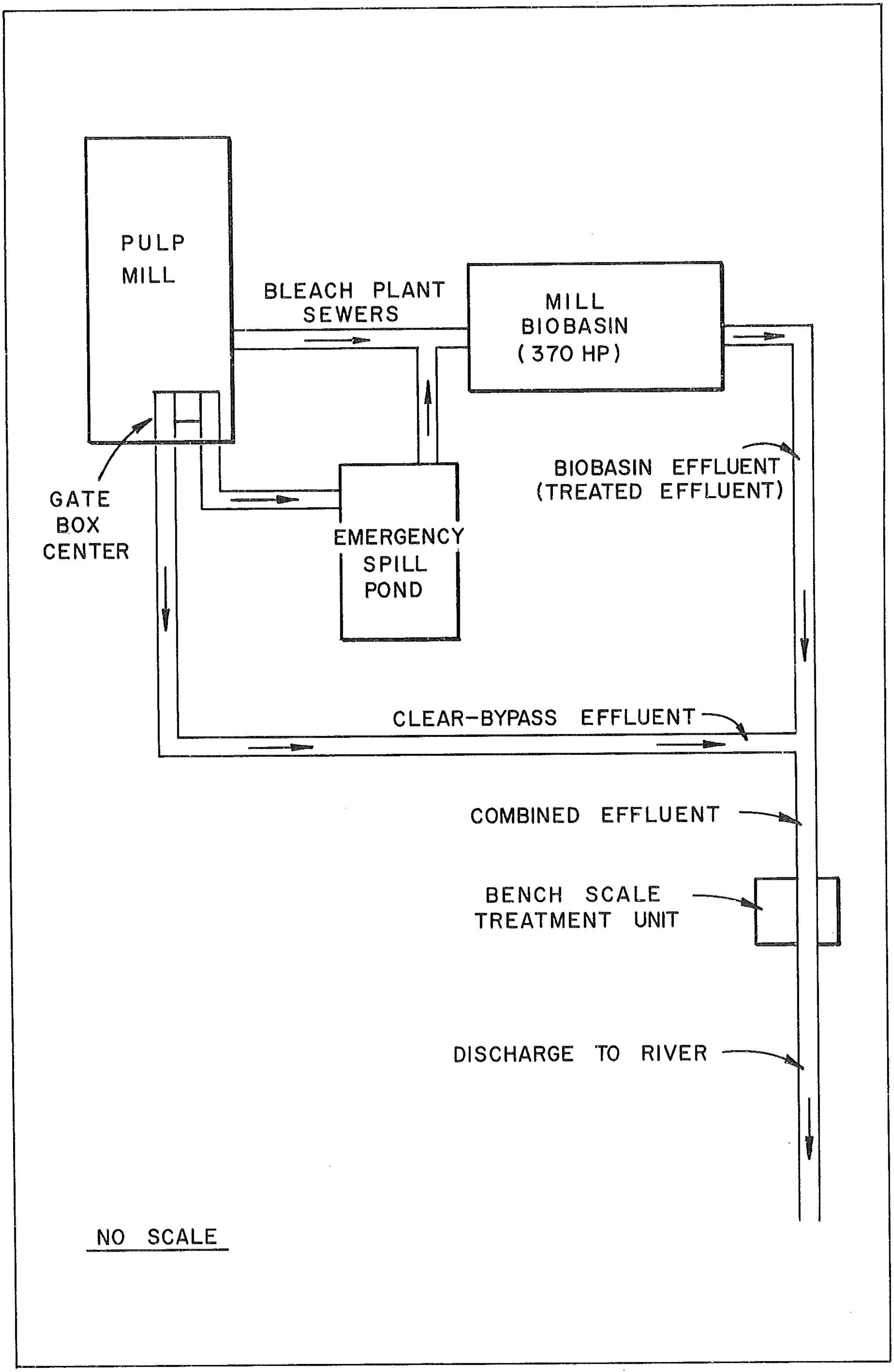

FIGURE 1 - Prince George Pulp and Paper effluent disposal system.

authority of the Canada Department of Fisheries and later under auspices of Canada Department of Environment (Environmental Protection Service). Frequent failure of effluents to meet a detoxification standard of 100% survival of juvenile salmon during a 4-day bioassay at 65% v/v effluent has been of considerable concern. In order to determine whether additional biological treatment would consistently detoxify combined effluent, a 10-month joint study among Canada Department of the Environment, Prince George Pulp and Paper, and the International Pacific Salmon Fisheries Commission (IPSFC) commenced August 15, 1972 using a bench scale aerated treatment unit simulating a plug flow aerated lagoon. In addition, effluent samples were fractionated (Dept. of Environment) in an effort to identify specific toxic compounds and attempts were made to correlate substandard detoxification with mill operating conditions.

METHODS

A technician of Environment, Canada, Environmental Protection Service (EPS) was stationed at Prince George Pulp and Paper in order to collect effluent samples and operate the bench scale treatment unit. The bench unit was extended as required to obtain scheduled treatment times of 24, 48 and 72 hr on combined effluent.

The bench unit was installed in an insulated hut at the site of a Parshall flume located in the combined sewer 60 ft downstream of confluence of the clear-bypass sewer and biobasin treated sewer (FIGURE 1). The Parshall flume was 26 ft below ground, therefore PGPP installed a variable speed peristaltic metering pump to lift the combined effluent through a 7/16 inch diameter stainless steel pipe to the delivery apparatus of the bench unit. Combined effluent was delivered at the rate of 1,200 ml/min to a 1.5 gal headbox equipped with stainless steel screens to aid in removal of suspended solids from combined effluent. From the headbox the effluent entered a constant head 3 inch wide by 10 inch long by 3 inch deep splitter box which apportioned the combined effluents at the rate of 92 ml/min to the bench unit and 92 ml/min to a composite sample. Excess effluent at the splitter box was returned to the combined sewer. Combined effluent flow rate was calculated to deliver 35 U.S. gal per day to each of the composite sample and bench units. However, high suspended solids content of combined effluent frequently plugged the 7/16 inch delivery pipe and head box screen and the 35 gal daily samples were not always procured. Consequently treatment times in the bench unit were generally longer than scheduled due to the plugging. This aspect will be discussed later in more detail. Biological solids were started in the bench unit using seed from the mill biobasin.

Bench scale treatment unit components were 6.7 ft long by 0.85 ft wide with a liquid depth of 10 inches. Components were divided into four sections connected by 1.5 x 4 inch rectangular ports. These sections were further divided into four subsections by baffles. One component was used to obtain 24 hr treatment; two components for 48 hr treatment; and three components for 72 hr treatment. In other words, to increase treatment times, bench scale components identical in size were connected in series.

Dissolved oxygen in the bench unit was maintained in the 0.5 to 4 mg/l range with a metered flow of oil-free compressed air (TABLE 1). A Model 51A Oxygen Meter (Yellow Springs Instrument Co.) was used for dissolved oxygen measurements. Mean temperatures in the bench unit were 70, 66 and 69^{O}F for 24, 48 and 72 hr treatment periods, respectively (TABLE 1). Temperature in the mill biobasin averaged 75^{O}F for the entire study and ranged from 73 to 77^{O}F. Temperatures in the bench unit were deliberately kept lower than in the mill biobasin in order to eliminate the possibility that temperatures higher than those obtainable outdoors would encourage unrealistically efficient biological treatment. Nitrogen and phosphorous were not added to the bench unit, however nutrients were added to the mill biobasin at the daily average rate of BOD/N/P of 100/5/1.0. Some nutrient would have been carried in the biobasin effluent to the combined flow and hence into the bench unit. However, nutrient levels were not measured in the combined effluent entering the bench unit nor were they measured in the bench unit discharge.

TABLE 1 - Mean DO and Temperature in bench unit.

SCHEDULED TREATMENT PERIOD (hr)	MEAN DISSOLVED OXYGEN (mg/l) Section			MEAN TEMPERATURE (°F) Section		
	Inlet	Mid	Outlet	Inlet	Mid	Outlet
24	2.4	2.3	2.4	73	70	67
48	1.5	2.1	2.4	73	66	62
72	1.4	2.6	4.0	77	69	66

Samples of clear-bypass, biobasin, combined, and bench unit effluents were forwarded to IPSFC Sweltzer Creek Laboratory on a 5-day per week basis (later extended to 7 days per week) via overnight freight shipment. Effluent samples were shipped in 5 gal plastic containers and arrived at Sweltzer Creek about 16-19 hr after collection. A total of 209 samples each of combined effluent and bench unit effluent were examined along with 201 biobasin treated samples and 185 clear-bypass samples.

Measurements for pH and toxicity were determined on effluents immediately after samples arrived at Sweltzer Creek. Since clear-bypass effluent was strongly alkaline upon occasion, selected samples were neutralized before bioassay. Samples were not filtered prior to shipment nor before bioassay.

All effluent samples were 24 hr composites except the biobasin effluent which was a grab sample. However, a grab sample from the biobasin approximated a composite sample owing to mixing action of the aerators.

Five day BOD's (Standard Methods, 1971) of combined and bench unit effluents were measured by the EPS technician at the mill.

Bioassays to determine acute toxicity of effluents were static 30 liter effluent-water mixtures in 10 gal glass aquariums. Ten juvenile sockeye salmon were exposed for 4 days to effluent-water mixtures of combined effluent and bench unit treated effluent at concentrations of 90, 65, 45, 25 and 0% v/v (control). Clear-bypass effluent and mill biobasin treated effluent were bioassayed at 65% v/v only. Effluent-water mixtures were aerated with oil-free compressed air to keep dissolved oxygen near saturation at bioassay temperatures of 39 to 46°F. The mean wet weight of juvenile sockeye during the study was 1.2 gm, ranging from 0.17 gm to 2.1 gm. Mean weight of fish per unit volume in aquariums was 0.41 gm/l and ranged from 0.06 gm/l to 0.71 gm/l. Standard Methods (1971) states that the weight of all fish in a bioassay container must not exceed 1 gm per liter of test solution. Environment Canada's "Guidelines for the Pulp and Paper Effluent Regulations (1972)" states that the volume of liquid to weight of fish should be 2 liters per gram, and the solution changed daily. It is generally accepted current practice to conduct bioassays at 0.5 gm of fish or less per liter of test solution, whenever possible.

In order to check whether tolerance of fish was consistent during the study, samples from populations used in the study were bioassayed approximately each 3 weeks using dehydroabietic acid as reference toxicant at 1.63, 1.93 and 2.79 mg/l. These bioassays indicated tolerance was consistent throughout the study. Dehydroabietic acid is a toxic resin acid isolated from kraft mill effluent (Rogers 1973; Leach and Thakore 1973).

Bioassays were performed on additives used or planned for use in various mill processes and for which toxicity information was not available. Some substances, not considered to be additives by the mill, were bioassayed as well. Additives were bioassayed at concentrations up to and sometimes exceeding 10 times those expected in various mill streams. Ninety-six hr static bioassays similar to those conducted on mill effluent were used to examine additives for acute toxicity.

Selected samples of toxic and nontoxic combined effluent and bench unit effluent were forwarded to Environment Canada for fractionation and identification of toxic compounds (Rogers and Mahood 1974). Isolated fractions were returned to Sweltzer Creek Laboratory for bioassay.

RESULTS

BOD Reduction by Bench Scale Treatment Unit

As mentioned, three treatment times were studied in the bench unit. During the 24 and 48 hr treatment periods, samples were forwarded to Cultus Lake on a 5 day per week basis: Seventy-two hr treatment samples were obtained on a 7 day per week basis.

Although treatment times of 24, 48 and 72 hr were desired, suspended solids in the combined effluent frequently plugged the 7/16 inch delivery line to the bench unit and the head box screen, reducing flow and increasing actual treatment times. Estimated mean treatment times in the bench unit were calculated from volumes of bench unit treated effluent forwarded to the Sweltzer Creek Laboratory each day (TABLE 2). Treatment time exceeded the scheduled value on almost every day of the study. The terminology 24, 48 and 72 hr treatment will be used in the text, with the understanding that treatment times were actually longer.

TABLE 2 - Scheduled and estimated mean treatment time in bench unit.

Scheduled Treatment Time hr	Estimated Mean Treatment Time hr
24	29
48	58
72	99

The BOD of combined effluent entering the bench unit averaged 161 mg/l and varied from less than 40 mg/l to more than 1,000 mg/l (FIGURE 2). Values for bench unit BOD which appear in FIGURE 2 are offset to account for scheduled treatment time in the bench unit. Therefore, combined effluent BOD's are above those for bench unit effluent. Data in FIGURE 2 are not plots of consecutive days of the calendar but rather are plots of days in a given month for which data were obtained.

Bench unit BOD load during the 24 hr treatment period was generally lower than during 48 and 72 hr periods. However, high BOD loads were not well assimilated by the 24 hr treatment system. For example, in September, combined effluent BOD peaks exceeding 350 mg/l resulted in bench unit BOD's greater than 180 mg/l (FIGURE 2). A similar, but less severe case occurred in January. During the 48 hr treatment period, BOD load was high and as a consequence treated effluent BOD averaged about the same as for 24 hr treatment (TABLE 3). However, the 48 hr treatment system was able to absorb high BOD loads better than the 24 hr system, although treatment performance deteriorated in early April. The 72 hr treatment achieved the most uniform, lowest BOD's and the highest percent removal of those tested (FIGURE 2, TABLE 3). The 72 hr system was capable of assimilating shock loads without upset. For example, on one occasion in May, a combined effluent BOD of 390 mg/l was reduced to 16 mg/l

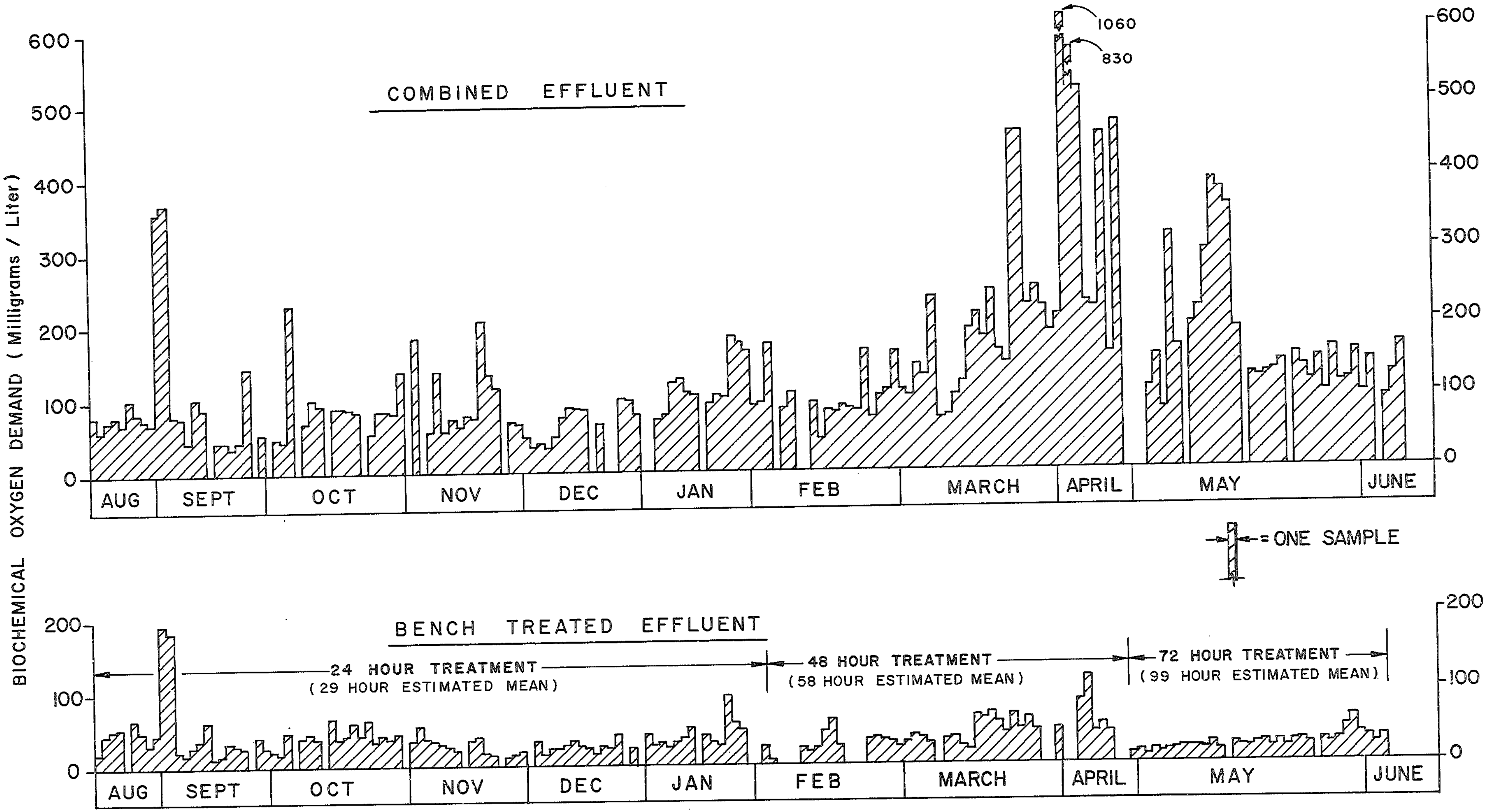

FIGURE 2 - Effect of biological treatment in bench unit on BOD.

(96% removal). In order to obtain stable, efficient BOD removal, 72 hr treatment (99 hr estimated mean treatment time) was required. This result is similar to the performance reported for full scale and bench units treating bleached kraft mill effluent for 96 hr (Servizi and Gordon 1973).

TABLE 3 - Biochemical Oxygen Demand of bench unit effluent.

SCHEDULED TREATMENT[a] TIME	MEAN BIOCHEMICAL OXYGEN DEMAND (mg/l)		
	Combined Effluent (Inlet)	Treated Effluent (Outlet)	Per Cent Removal
24 hr (Aug. 15-Feb. 2)	95	40	53
48 hr (Feb. 3-April 11)	214	43	73
72 hr (April 30-June 6)	173	23	83

[a] Estimated mean treatment times were 29, 58 and 99 hr, respectively.

The trend of BOD of combined effluent was examined to determine whether peaks were correlated with mill operations. The peak on September 6 and 7 coincided with start-up of the mill following shutdown for Labor Day. Since process upsets sometimes occur during start-up or shutdown of a mill, high BOD may result. Peaks of lesser magnitude occurred from October to mid-March and appear similar to normal variability in BOD observed elsewhere (Servizi and Gordon 1973). Between mid-March and mid-May, BOD of combined effluent was commonly very high. The high BOD coincided with pulping of less seasoned chips (compared to those used earlier) from mid-March into April but the proportion of such chips decreased thereafter.

Records show that diversions lasting from minutes to hours of contaminated effluent to the spill lagoon via the gate box center occurred nearly every day. Contamination by solids, process liquors, condensates and soaps were among the causes for diversion of effluent to the spill lagoon.

Effluents were transferred from the spill lagoon to the biobasin via pumping to the bleach plant sewer. Theoretical detention time of effluents in the spill lagoon was estimated at 8 to 10 days by the mill Technical Department. Transfer of effluent from the spill lagoon to the biobasin was nearly continuous. Thus, although the spill lagoon acted as a surge basin for effluents before transfer to the biobasin, some peaks in BOD may have been related to transfer of highly contaminated wastes from the spill lagoon.

Although soaps occur normally during pulping, the amount of soap is greater for chips with less seasoning. The majority of soaps (saponified resin acids) were washed from the pulp to be recovered along with black liquor. However, black liquor and soaps carried over in washed pulp entered the screen room where some liquor and soaps were extracted and discharged in the brown white water to the clear-bypass sewer.

Soaps are entrained in black liquor and rise to the surface of black liquor storage and soap skim tanks. Soaps recovered can be sold for further processing. Spills of soap may occur owing to difficulty in detecting the level of soap in a tank using instrumental methods. Since soap floats, its presence in a sewer may not have always been detected by conductivity alarms and thus soaps may have been discharged via the clear-bypass from time to time. Records between March 24 and June 12 showed that soaps overflowed into sewers on 8 occasions and were diverted to the spill lagoon on 6 of these. In view of the foregoing factors, especially carry-over of soaps and black liquor to brown white water, it appears probable that high BOD of combined effluent between mid-March and mid-May was associated with soap production arising from pulping less seasoned chips than were used earlier.

Toxicity Reduction by Biological Treatment

The main object of this study was to investigate whether additional biological treatment would remove the chronic acute toxicity of PGPP combined effluent. As mentioned before, combined effluent is composed of clear-bypass effluent (approximately 55% and biobasin effluent approximately 45%). Therefore, approximately 45% of the combined flow had already received a nominal 24 hr of biological treatment. Effluent from the spill lagoon reduced detention time in the biobasin since it was being transferred there virtually continuously, hence treatment time is referred to as a nominal 24 hr. The bench unit treatment plant provided additional treatment time for the combined effluent. Acute toxicities of biobasin treated and clear-bypass effluents were measured using a mixture of 65% effluent and 35% water. Ninety percent of biobasin treated effluent samples were lethal and mortality was generally 100%. It is evident that the nominal 24 hr aerated lagoon at PGPP was not detoxifying effluent (FIGURE 3). Clear-bypass effluent was not treated before release to the river because original mill design intended this effluent to consist of nontoxic process waters. However, 88% of clear-bypass samples were lethal and mortality was usually 100% (FIGURE 3).

The average pH of clear-bypass effluent was 7.7 and ranged from 6.5 to 11.2. However, when mixed with dilution water for bioassay at 65% v/v, pH was usually near neutrality. To assess whether alkaline pH was responsible for part of the acute toxicity in the clear-bypass, some highly alkaline samples were neutralized before bioassay but in every case acute toxicity remained.

Combined effluent was a mixture of biobasin and clear-bypass effluents and was generally lethal (94% of samples) at 90% v/v (FIGURE 4). Even at concentrations of 65, 45, and 25% v/v combined effluent was lethal 89, 76 and 60% of the time, respectively (FIGURES 5, 6 and 7).

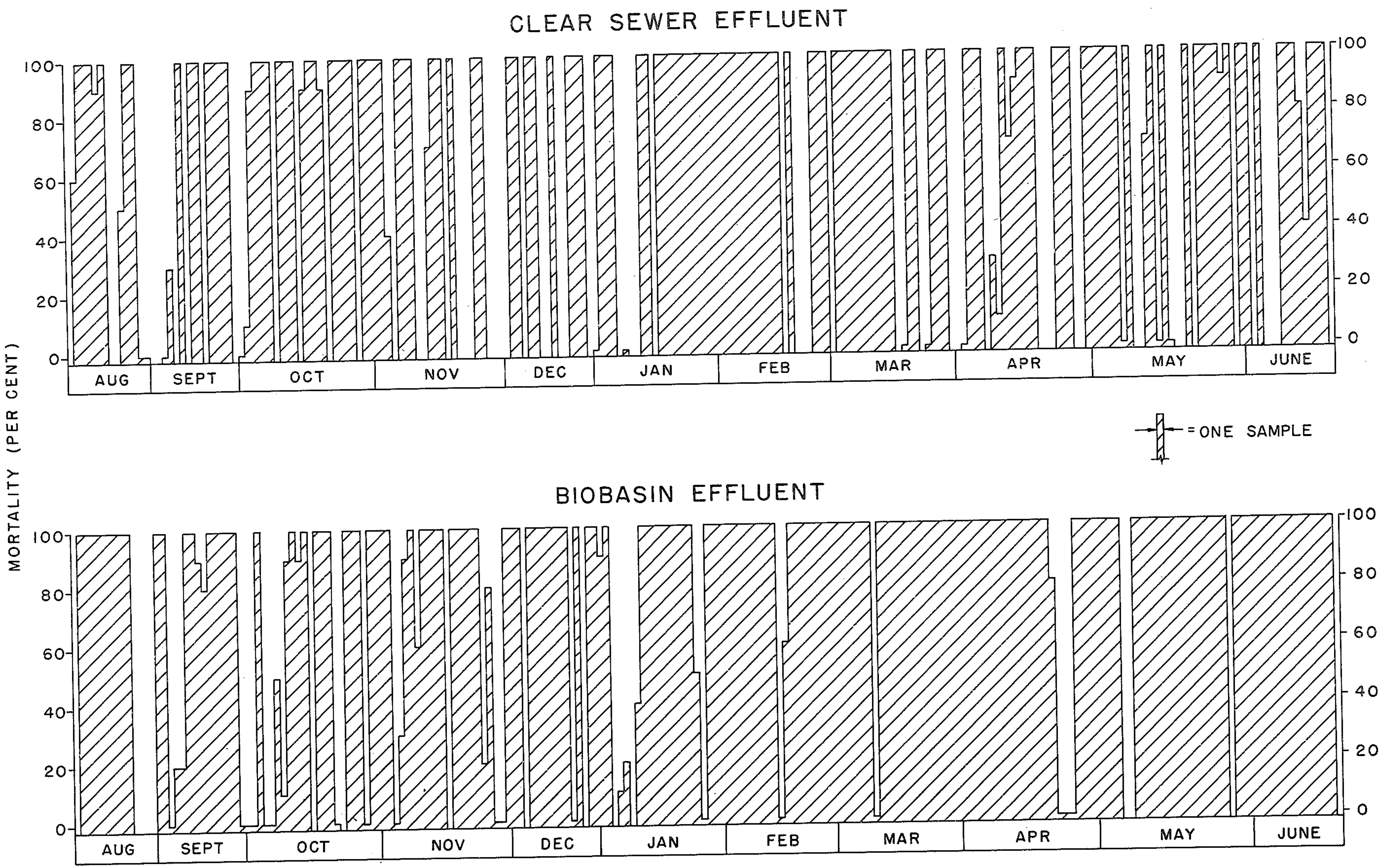

FIGURE 3 - Clear-bypass effluent and biobasin effluent toxicity at 65% concentration (v/v).

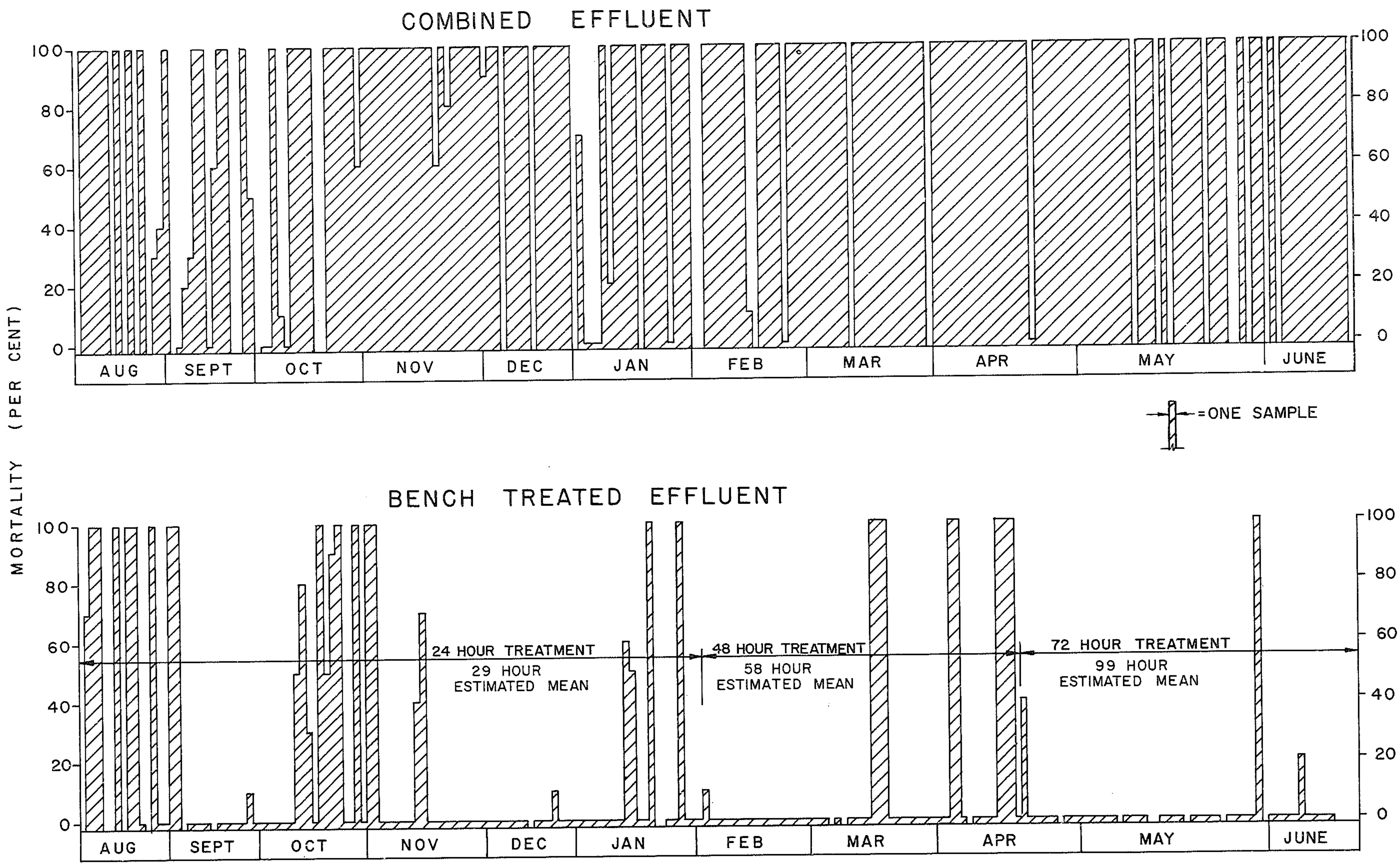

FIGURE 4 - Effect of biological treatment in bench unit on toxicity, 90% concentration (v/v).

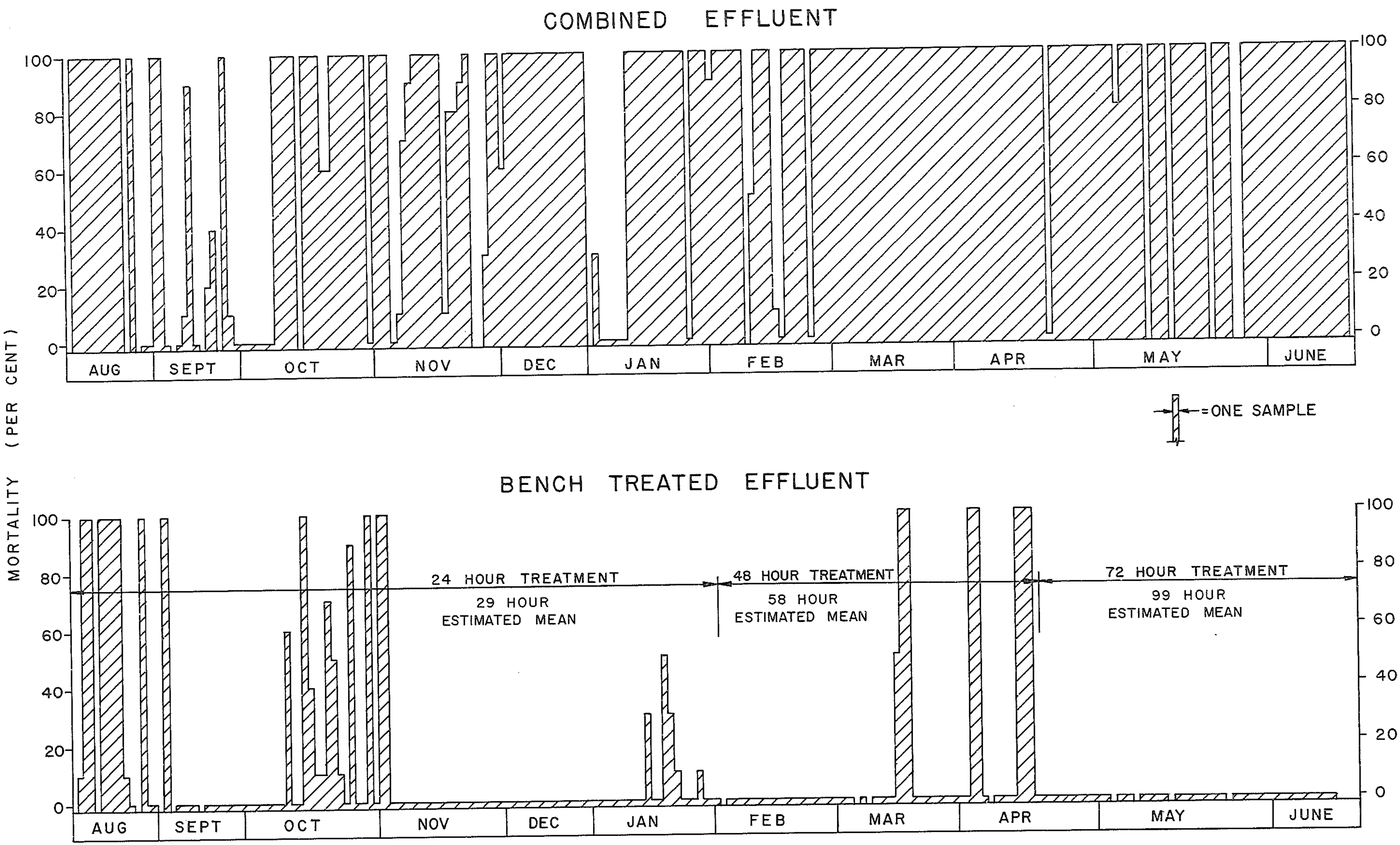

FIGURE 5 - Effect of biological treatment in bench unit on toxicity, 65% concentration (v/v).

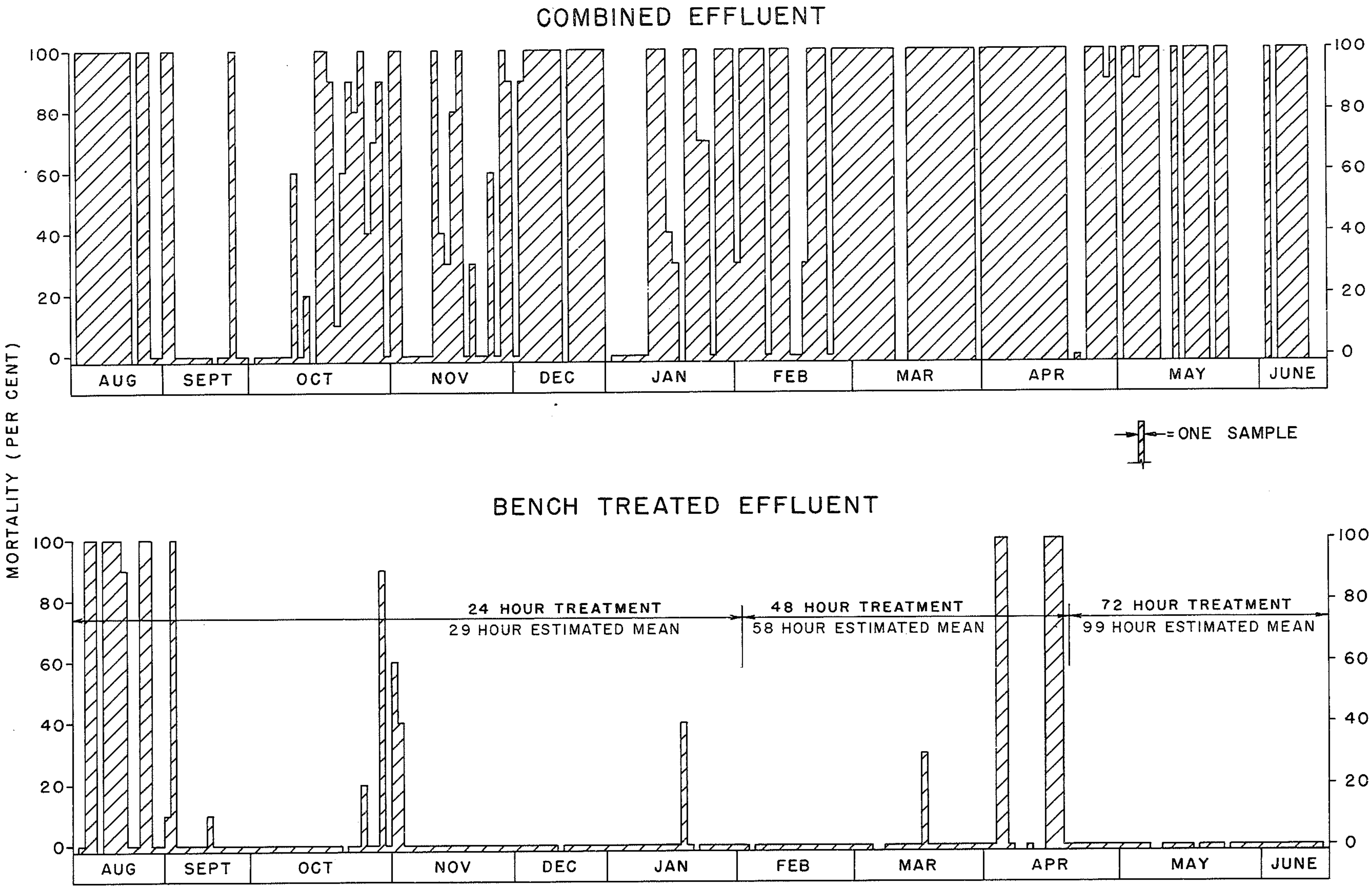

FIGURE 6 - Effect of biological treatment in bench unit on toxicity, 45% concentration (v/v).

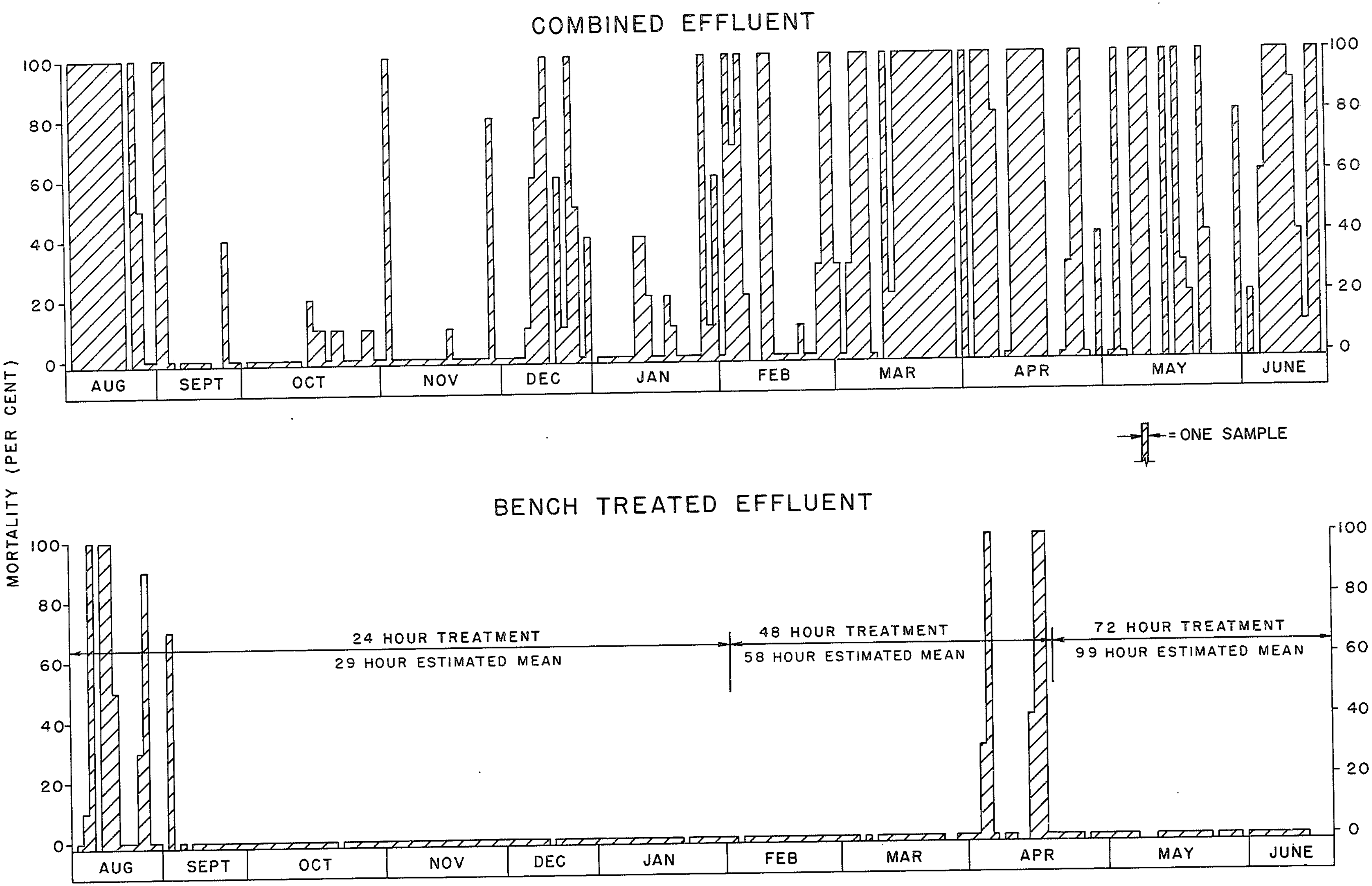

FIGURE 7 - Effect of biological treatment in bench unit on toxicity, 25% concentration (v/v).

As with BOD, acute toxicity of mill effluents were examined to determine whether there were correlations with mill operations. Clear-bypass effluent was generally lethal at 65% v/v (FIGURE 3) which may reflect the effect of brown white water; an effluent demonstrated acutely toxic elsewhere (Howard and Walden 1971). Biobasin effluent was also generally lethal at 65% v/v, thus variation in mill operations were not reflected in this effluent characteristic. Owing to dilution in bio-assays, the greatest variation in acute toxicity was noted for combined effluent at 25% v/v (FIGURE 7). Combined effluent was frequently lethal during August and on September 6 and 7. The latter dates coincided with mill start-up following shutdown for Labor Day. Analyses of selected samples of combined effluent obtained in August-September indicated resin acid contents were great enough to cause acute toxicity at 25% v/v and neutral compounds may have contributed to toxicity on September 6 (Rogers and Mahood 1974). High concentrations of resin acids may have been associated with loss of soaps to sewer, but mill records did not confirm this.

Combined effluent was frequently lethal at 25% v/v in December. Analysis of three samples indicated resin acids alone would not have accounted for toxicity, (Rogers and Mahood 1974) thus soaps were not implicated and the cause of toxicity was not ascertained.

Combined effluent was generally lethal at 25% v/v from March through June. Peaks of resin acid content exceeded 10 mg/l in March and April, and neutral compounds were relatively abundant; obvious reasons for toxicity of combined effluent during that period (Rogers and Mahood 1974). On the other hand, resin acid contents of 6 samples collected from mid-May into June were not believed great enough to be solely responsible for acute toxicity of combined effluent at 25% v/v. However, based upon 3 effluent samples collected in June, neutral compounds may have contributed to toxicity (Rogers and Mahood 1974).

As described previously, soaps (saponified resin acids) occur in greater quantity when less seasoned chips are pulped and it appears they played a major role in toxicity of combined effluent from mid-March into April and a lesser role in May and June. Neutral compounds were implicated as contributing to toxicity.

Mortalities of fish bioassayed in 90, 65, 45, and 25% v/v bench unit effluent were plotted directly below corresponding mortalities for combined effluent in FIGURES 4, 5, 6 and 7. Biological oxidation in the bench unit reduced toxicity, but effluents did not always meet Federal regulations (80% survival or more at 65% v/v) or Provincial "A" Level Objectives (50% survival or more at 90% v/v). Failure of the bench treatment system to detoxify effluents was examined to determine if it was correlated with mill operation. High levels of resin acids in combined effluent in August were lowered by treatment in bench unit but remained in the toxic range (Rogers and Mahood 1974) and bench treated effluent was often acutely toxic (FIGURES 4 and 5). As explained previously, the cause of high resin acids during this period was not ascertained.

Substandard detoxification on September 6 and 7 coincided with start-up of the mill, and as explained previously, process upsets are not unusual at such times. As in August, high levels of resin acids were not lowered sufficiently to eliminate them as a source of toxicity (Rogers and Mahood 1974).

Other occurrences of substandard detoxification during 24 hr treatment of combined effluent could not be related to mill operations. It was evident that 24 hr treatment was too short to maintain consistent detoxification (TABLE 4).

High levels of resin acids occurred in combined effluent commencing in mid-March but were lowered to near nonlethal levels during 48 hr bench unit treatment except for a peak in April (Rogers and Mahood 1974). However, substandard detoxification occurred in spite of reduction in resin acid content. Neutral compounds were implicated as contributing to residual toxicity, although not in every instance. Lethal concentrations of resin acids in selected samples of combined effluent in May and June were lowered to nonlethal levels by 72 hr treatment in the bench unit (Rogers and Mahood 1974). As discussed previously, soaps associated with pulping less seasoned chips were believed the cause of high resin acids.

TABLE 4 - Toxicity of bench unit effluent.

Bench Treated Effluent Concentration % v/v	Scheduled Treatment Time (hr)[a] 24	48	72
	Per Cent of Samples Toxic		
90	29	18	7
65	25	16	0
45	15	13	0
25	8	11	0

[a] Estimated mean treatment times were 29, 58 and 99 hr, respectively.

Comparison of detoxification by 48 and 72 hr treatment indicates the latter (99 hr estimated mean treatment time) was able to maintain consistent detoxification better in spite of highly toxic combined effluent. During 72 hr treatment only 7% of samples were toxic at 90% v/v and none were toxic at lower effluent concentrations (TABLE 4). It should be noted that 72 hr was the scheduled treatment but 99 hr was the estimated actual mean treatment time.

Bioassay of Mill Additives

Numerous additives are available to the pulping industry to aid in the production of pulp. Acute toxicities of 22 additives submitted by PGPP were measured at concentrations up to 10 times those expected in mill effluents.

Fourteen of the additives were nontoxic when bioassayed at 10 times the concentration expected in mill effluent and eight demonstrated varying degrees of toxicity (TABLE 5). Rexonic T and Arquad 2HT-75 were being considered for future use in the mill, however their use should be re-examined in view of their toxicities. Action 30 and Alchem 228 were toxic at levels somewhat higher than might occur in mill effluent, and thus should be viewed with caution. Rosin size paste is a sizing agent used in the production of paper and most of it is retained with the paper. The amount lost to sewer, if any, is unknown but is of concern since the material is lethal at concentrations in excess of 2.5 mg/l.

The three deresinating additives, Rexol 25JM-1, Igepal CO-630, and Nopco 149A are all low foaming, nonionic surfactants believed to be of the same basic chemical composition. The amount of active ingredient contained in each product is believed to be the basic difference between these additives. The deresinating additives might have a significant effect on the toxicity of pulp mill effluent in view of the relatively high toxicity demonstrated by the samples bioassayed. Studies by Canada Dept. of Environment to isolate toxic substances from effluents may determine if residual deresinating agents or other additives are sources of toxicity in final mill effluent.

DISCUSSION

Biobasin and clear-bypass effluents were nearly always toxic at 65% v/v. Combined effluent, being a mixture of the two aforementioned effluents, was toxic 89% of the time at 65% v/v. The record of performance was poor (FIGURES 3 and 5) throughout the study, regardless of operating conditions at the mill. The results are contrary to Environment Canada regulations which specify at least 80% survival during bioassays at 65% v/v (Environment Canada 1972). Furthermore, 94% of samples of combined effluent were acutely

TABLE 5 - Bioassay of mill additives.

Additive	Estimated Maximum Concentration in Mill Effluents mg/l			Bioassay Concentration mg/l	Mortality* Per Cent 4 Day Exposure	Mean Weight of Fish Volume gm/l
	Treated	Clear	Combined			
Amres 212	11	6	4	115	0	0.85
				15	0	0.85
				8	0	0.85
Hercules	4	2	1	> 500**	0	0.75
Hercules Eff. 101	5	3	2	> 500**	0	0.75
Alchem D-184	0.5	0.25	0.15	5.0	0	0.85
				0.25	0	0.85
Hi-PHloc	0.2	0.1	0.06	2.0	0	0.85
				0.15	0	0.85
Nalcolyte 675	0.02	0.015	0.008	0.25	0	0.90
				0.025	0	0.90
Felt Cleaner D134	0.00018	0.00011	0.00007	2.0	0	0.47
				0.2	0	0.47
Prevent	0.5	0.3	0.2	5.0	0	0.85
				0.6	0	0.85
Prepare	1.5	0.9	0.5	15	0	0.85
				1.5	0	0.85
Bubond	-	-	0.3	3.0	0	0.40
				0.5	0	0.40
Bufloc 30	-	-	0.3	3.0	0	0.40
				0.5	0	0.40
Percol 140	-	-	0.3	3	0	0.13
				2	0	0.13
Alum	120	72	45	1,200	0	0.47
				120	0	0.47
Starch	8	5	3	80	0	0.06
				8	0	0.06
Rexonic T	3	1.8	1.1	30	100	0.42
				4	100	0.42
				2	0	0.42
Action 30	3	1.8	1.1	30	80	0.42
				4	0	0.42
Arquad 2HT-75	Retained with pulp; loss to sewer not estimated.			40	100	0.5
				20	100	0.5
				10	0	0.5
Rosin Size Paste	Retained with paper; loss to sewer not estimated.			3	100	0.55
				2.75	90	0.55
				2.50	0	0.55
Alchem 228	1	0.6	0.4	7	100	0.90
				6	80	0.75
				5.25	30	0.75
				5.0	0	0.75
Rexol 25JM-1	9	5	3	10	100	0.93
				5	100	0.77
				3.75	80	0.05
				3.00	10	0.05
				2.75	0	0.05
Igepal co-630	9	5	3	10	100	0.15
				5.5	100	0.15
				3.75	100	0.15
				3.00	100	0.15
				2.50	10	0.15
				2.00	0	0.15
Nopco 149A	9	5	3	10	100	0.15
				8	90	0.15
				7.5	30	0.15
				5	10	0.15

* Aerated, static bioassays, 5 or 10 fish per concentration.

** Additive difficult to keep in solution.

toxic at 90% v/v (FIGURE 4) and failed to meet B.C. Pollution Control Board (1971) objectives of 50% survival at 90% v/v effluent. On the other hand, effluent from scheduled 72 hr bench unit treatment (99 hr estimated mean treatment time) of combined effluent was nontoxic 93 and 100% of the time at 90 and 65% v/v, respectively (TABLE 4). It is evident that in order to meet Federal and Provincial effluent toxicity regulations and objectives, treatment is required for combined effluent.

This study has shown combined effluent was consistently detoxified at an estimated 99 hr treatment time in the bench unit. In another study, comparison of detoxification in laboratory and full scale treatment systems indicated a laboratory system was generally slightly more consistent, although performance of the two units were similar in the absence of shock loads (Servizi and Gordon 1973). Furthermore, aerated lagoons providing between 4 and 5 days treatment have been selected by modern kraft mills in B.C. as the best practical technology for effluent treatment. In view of the foregoing factors, addition to the present treatment system of an aerated lagoon capable of approximately 4.5 days treatment time for combined flow is recommended.

Experience has shown that in-plant devices alone are not adequate to consistently protect aerated lagoons from excessive deposition of solids derived from mill sewers. Therefore, good practice dictates that an aerated lagoon be preceded by primary sedimentation to assure that treatment capacity of the lagoon is not reduced by accumulation of solids.

Although treatment of combined effluent, as described above, can be expected to detoxify effluents sufficiently to meet Federal regulation and Provincial objectives, the system must be protected by both in-plant and out-plant control of shock loads. Evidence presented herein indicated soaps and black liquor were a probable source of high loadings during certain periods of the study. The importance of controlling high loads was apparent in another study where black liquor and condensate spills, especially the former, were cited as usually responsible for substandard detoxification in an aerated lagoon treating kraft mill effluent (Servizi and Gordon 1973). Treatment facilities can be protected from shock loads by use of spill lagoons, however, in-plant facilities should be capable of controlling spills so that they are infrequent and ample time is allowed to drain the spill lagoon in a manner which will not shock the treatment system.

CONCLUSIONS

1. Combined effluent was generally acutely toxic to fingerling sockeye salmon and failed to meet Provincial and Federal government objectives and regulations.

2. Resin acids were implicated as primary factors contributing to highly toxic combined effluents but neutral compounds apparently contributed to toxicity as well.

3. Combined effluent was consistently detoxified by an estimated mean of 99 hr of biological treatment. Addition to the present treatment system of an aerated lagoon capable of approximately 4.5 days treatment time, is recommended in order to meet governmental objectives and regulations for this mill. Addition of primary sedimentation to protect the aerated lagoon from accumulating solids originating in the combined effluent is recommended.

4. In-plant facilities are required to lessen the occurrence of spills or other upsets. However, a spill lagoon should be retained to absorb the shock of spills and upsets which escape in-plant control.

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