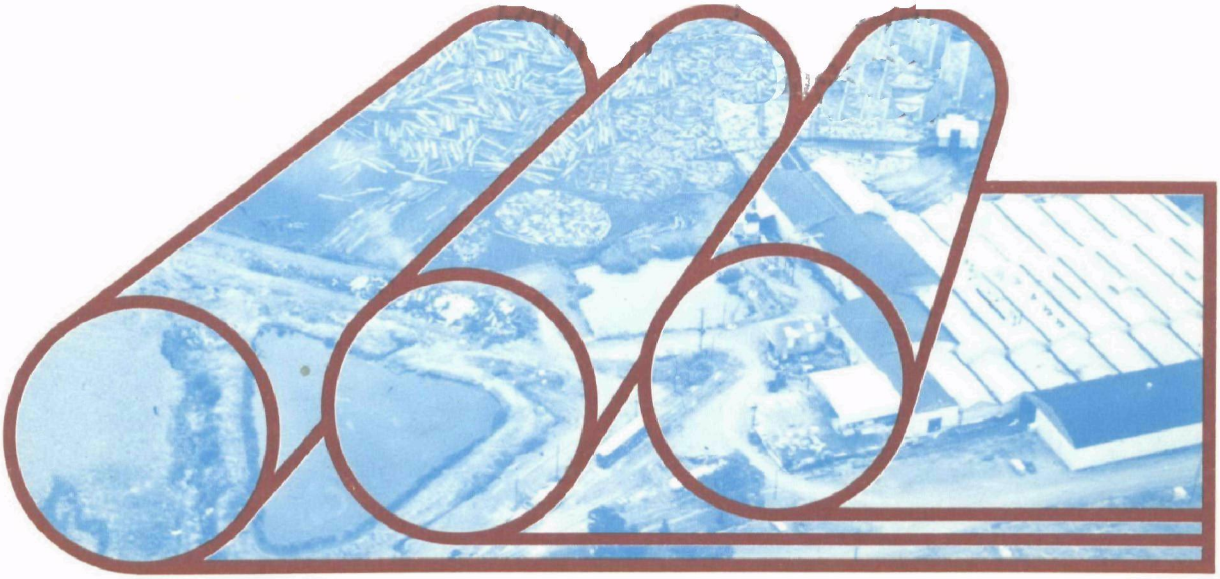
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
NORTHWEST REGION, PACIFIC NORTHWEST WATER LABORATORY



plywood plant glue wastes disposal

march • 1969

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PLYWOOD PLANT GLUE WASTES DISPOSAL

Final Report

A Technical Projects Report
No. FR-5

by

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ABSTRACT

In the States of Oregon, Washington, Idaho, Montana, and California, 158 plywood plants generate an estimated 6.2 million gallons of wastewater per day from the cleanup of glue mixing equipment and glue spreaders. Some of the wastes are toxic to fish and all are high in pollutional strength. Treatment of these glue wastes varies from plant to plant, but generally consists only of solids separation or the removal of suspended matter. Biological treatment investigations showed that BOD removals of 90+ percent can be attained where protein and urea glues are involved; however, this process proved unworkable for the phenolic glues and the process of incineration was shown to have good potential. Wastewater reuse offers the best waste disposal answer for the phenolic glues and possibly also for the protein and urea glues.

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PLYWOOD PLANT GLUE WASTES DISPOSAL

INTRODUCTION

Problem

The cleanup of glue spreaders at plywood mills produces a waste that is high in pollutional strength, though quite low in volume. At the present time, the State of Oregon rates this waste as its primary water pollution problem, based on the number of complaints received.

The plywood industry uses three basic types of glue: the blood-soya, or protein variety, for interior grade plywood; the phenolic formaldehyde variety used primarily for exterior grade plywood; and a urea formaldehyde glue used for hardwood paneling. Each presents its own waste disposal problem and any combination of these may compound the problems.

The blood-soya glues produce an alkaline waste with a high oxygen demand. Coagulation of the glue solids may cause large masses of solids resulting in sewer stoppage. The waste also supports the growth of *Sphaerotilus* sp.

Phenolic formaldehyde glues produce a toxic, alkaline waste which creates color, taste, and odor problems in a receiving water.

The urea formaldehyde glue wastes differ from the others, being acidic in nature. These glues are used for less than

8 percent of the plywood production in the study area. For this reason, most of the work here reported had to do with the blood-soya and phenolic glues.

Authority

The Pacific Northwest Water Laboratory of the Federal Water Pollution Control Administration, Northwest Region, was requested by the Oregon State Sanitary Authority, letter dated January 19, 1966, to study methods for disposing of glue wastes from plywood plants. Authorization for this study was from the Federal Water Pollution Control Act, as amended.

Objectives and Scope

This study was carried out to determine the magnitude and extent of the problem created by the disposal of glue wastes, review the characteristics of plywood glue wastes, and recommend methods of treatment for these wastes.

The study area includes the States of Oregon, Washington, Montana, Idaho, and California. Basic information on plywood plants was collected from plants in all five states, while field work was confined to plants in Oregon that are representative of the industry.

Acknowledgments

Acknowledgment is made of the American Plywood Association's valuable assistance in conducting a survey of waste generation and disposal practices at its member plants.

Special thanks are tendered to the Borden Chemical Company at Springfield, Oregon, for its donation of glue ingredients and assistance in explaining and defining techniques involved in preparing the glue mixes.

Thanks are expressed also to the personnel of the many plants visited for their great interest and cooperation.

SUMMARY

Findings

1. Approximately 158 plywood plants in the study area generate an estimated 6.2 million gallons of waste per day from the cleanup of glue spreaders and glue mixing equipment.

2. Average water usage at four plants surveyed ranged from 18,800 to 76,500 gallons per day. This variation has no apparent relationship to type of glue used or amount of plywood produced.

3. Less than 250 gallons of water are needed to wash down a glue spreader.

4. Based upon the production of surveyed plants, phenolic and protein glues each contribute approximately 48 percent of the total waste with urea glue contributing the remaining 4 percent.

5. All three types of glue studied exhibit high pollutional strength. Chemical oxidation demands (COD) measured were 177,000 mg/kg protein glue, 653,000 mg/kg phenolic glue and 195,000 mg/kg urea glue. The protein and phenolic glues are alkaline in nature while the urea glue is slightly acidic. The protein and urea glues possess adequate nutrients for biological treatment while the phenolic glue requires supplemental additions of nitrogen and phosphorus.

6. The discharge of untreated glue waste has a damaging effect upon the biota of receiving waters.

7. The protein glue wastewaters exhibited an average 96-hour median tolerance limit (TL_m) of 4,500 mg/l on guppies while the phenolic glue wastewaters proved more toxic with an average 96-hour TL_m of 1,140 mg/l.

8. Seventy-three percent of the plants surveyed provide settling devices of various types which remove the wood chips and a portion of the glue solids; seventeen percent of the plants surveyed dump raw wastes into city sewers, rivers, the ocean, and other receiving waters.

9. Most settling tanks and basins in use at plants are inadequately maintained, leading to very low removal efficiencies.

10. Biological treatment employing detention times of 8, 12, and 16 hours were used for the protein glue while 16 hours and 5 days were used for the urea glue. At all these detention times, Biochemical Oxygen Demand (BOD) removals of 90+ percent were achieved at loadings as high as 50 lbs BOD/100 lbs Mixed Liquor Suspended Solids (MLSS).

11. Attempts to acclimate a biological system to handle phenolic glue waste were not successful.

12. Neutralization and settling of protein or phenolic glue wastewater using either alum, sulfuric acid, or hydrochloric acid removed 99+ percent of the COD and TOC. These good removals were accompanied by the production of large amounts of sludge ranging from 0.65 $ft.^3$/lb phenolic glue for acid neutralization to 0.98 $ft.^3$/lb phenolic glue for alum neutralization.

13. Glue solids can be burned at high temperatures producing only small percentages of ash. Based upon the wet weight of the glue ash, productions of ash ran 4.12 percent, 6.12 percent, and nil for phenolic, protein, and urea glue, respectively.

Conclusions

1. Far more water is used at most plants than is required to wash down the spreaders and glue mixing equipment.

2. Biological treatment is an effective method for treating protein or urea glue wastes. Nutrient addition and acclimation are not needed.

3. Biological treatment was not found to be feasible for wastes containing phenolic glues.

4. Neutralization was found to be a feasible treatment process. However, provision must be made for handling the large amounts of sludge produced.

5. Wastewater reuse is by far the most feasible treatment system for phenolic glue waste.

6. If a wastewater reuse system proves workable for protein and urea glues, the problem of glue waste can be eliminated.

Recommendations

It is recommended that:

1. The practice of discharging untreated glue wastes to municipal sewer systems or receiving waters be discontinued.

2. All plants take the necessary steps to reduce their waste volumes. This reduction is a necessity if a system of wastewater reuse or incineration is to be employed.

3. All plants install and properly maintain adequate size settling tanks or basins for the removal of suspended matter. Screening of the waste prior to settling would improve the operation of the settling device by removing large glue solids and wood fragments. Screenings and sludge from these settling tanks and basins should be disposed of by incineration, landfill, or another acceptable method.

4. Plants using phenolic glues develop and utilize a wastewater reuse system, thus eliminating the need for waste discharge. If a reuse system cannot be used, incineration should be investigated before considering neutralization.

5. Plants using protein or urea glues investigate the possibilities of wastewater reuse. If this process proves infeasible, incineration or biological treatment could be used.

PLANT SURVEY

Plywood plants vary in many respects such as size, type of waste generated, and waste disposal methods. To gain an understanding of the plywood industry, this study employed two methods: the first involved visits to 52 plants, all in the State of Oregon; the second obtained from the American Plywood Association (APA) information which the Association itself collected in a survey of its member plants concerning production, operations, waste generation, and disposal practices.

To obtain a good response, the APA supervisors filled out questionnaires on their routine visits to the plants in their respective districts. This gave a 100 percent return for the APA plants. From Tables 1 and 2 it can be seen that the APA survey represented about 67 percent of all plants, and 70 percent of the plywood production in the study area, a representative sample of the industry.

TABLE 1

NUMBER AND PERCENTAGE OF PLANTS SURVEYED[a/]

State	Number of Plants	Number of Plants Surveyed	% of Plants Surveyed
California	22	11	50
Idaho	4	2	50
Montana	6	4	67
Oregon	92	59	64
Washington	34	30	88
TOTALS	158	106	67

a/ APA Survey, 1967

TABLE 2

1966 PLANT PRODUCTION - BY TYPE AND GRADE - OF PLANTS SURVEYED[a/]

State	Softwood Production (Sq. Ft. 3/8" Basis) Interior Grade	Softwood Production (Sq. Ft. 3/8" Basis) Exterior Grade	Hardwood Production (Sq. Ft. 3/8" Basis)	Total Production (Sq. Ft. 3/8" Basis)
California	345,480,000	230,820,000	---	576,300,000
Idaho	112,200,000	27,000,000	---	139,200,000
Montana	274,764,000	118,836,000	---	393,600,000
Oregon	2,760,048,000	2,874,252,000	11,460,000	5,645,760,000
Washington	889,272,000	1,165,800,000	310,128,000	2,365,200,000
TOTALS	4,381,764,000	2,416,708,000	321,588,000	9,120,060,000
PERCENT OF TOTAL	48.0	48.4	3.6	100.0

a/ APA Survey, 1967

PLYWOOD PLANT CHARACTERISTICS

Location and Number

The locations of the 158 plywood plants in the five-state study area are shown on Figure 1. The plants are concentrated in the Willamette and Rogue River Valleys in Oregon and the Puget Sound area in Washington. Table 1 shows the distribution of the 158 plants by state. As can be seen, Oregon has 92 plants or approximately 58 percent of the total. Table 3 breaks down the plants surveyed by type of plywood produced. Comparison of the tables shows that a good cross-section was obtained by the survey.

TABLE 3

NUMBER OF PLANTS BY TYPES OF PLYWOOD[1/]

State	Softwood Plants	Hardwood Plants	Mixed Plants	Total Plants
California	17	4	1	22
Idaho	4	0	0	4
Montana	6	0	0	6
Oregon	84	2	6	92
Washington	22	2	10	34
TOTALS	133	8	17	158

Production

Despite a slump in new housing starts, plywood demands have continued to grow. This growth is expected to continue, increasing

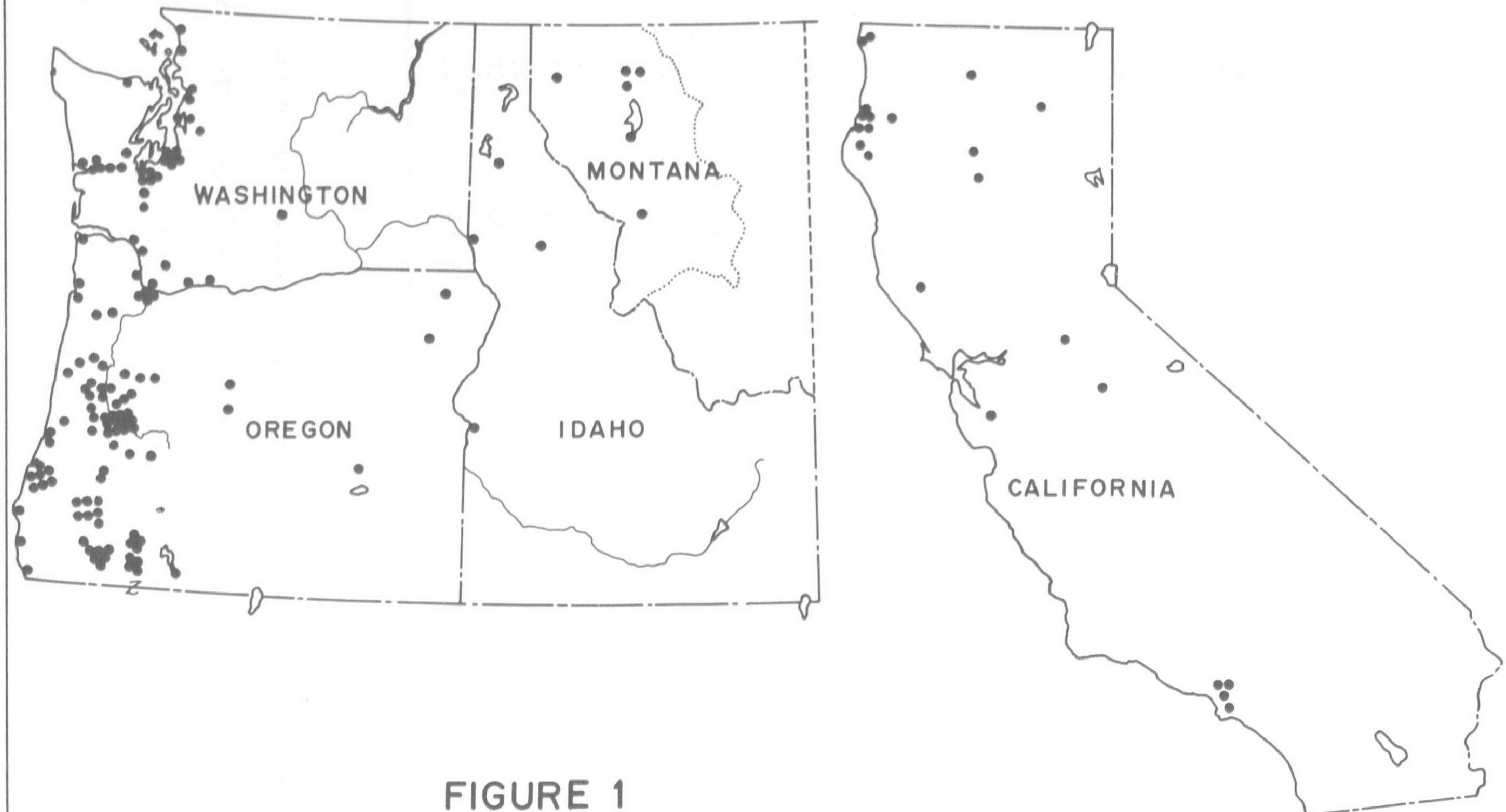


FIGURE 1
PLYWOOD PLANT LOCATIONS

an estimated eightfold by the year 2000[2/]. This expected growth rate is shown in Figure 2.

Plywood production for 1966, a normal year, is given in Table 4. These data give the hardwood and softwood production by states and show that, in the study area, the softwood makes up 92.1 percent of the total. The State of Oregon in 1966 produced 64 percent of the total plywood for the five states in the study area.

TABLE 4

1966 PLANT PRODUCTION BY TYPES OF PLYWOOD[1/]

State	Softwood Production (Sq.Ft. 3/8" Basis)	Hardwood Production (Sq.Ft. 3/8" Basis)	Total Production (Sq.Ft. 3/8" Basis)
California	1,277,000,000	115,500,000	1,392,500,000
Idaho	293,100,000	---	293,100,000
Montana	456,000,000	---	456,000,000
Oregon	7,948,350,000	499,450,000	8,447,800,000
Washington	2,150,600,000	427,500,000	2,578,100,000
TOTALS	12,125,050,000	1,042,450,000	13,167,500,000
%	92.1	7.9	

Table 2 gives the 1966 production for the plants surveyed. In this table, the softwood production is further divided into interior and exterior grades. The survey shows that the production totals for interior and exterior grades are very similar, being 48.0 and 48.4 percent, respectively. Hardwood plywood production accounts for the remaining 3.6 percent.

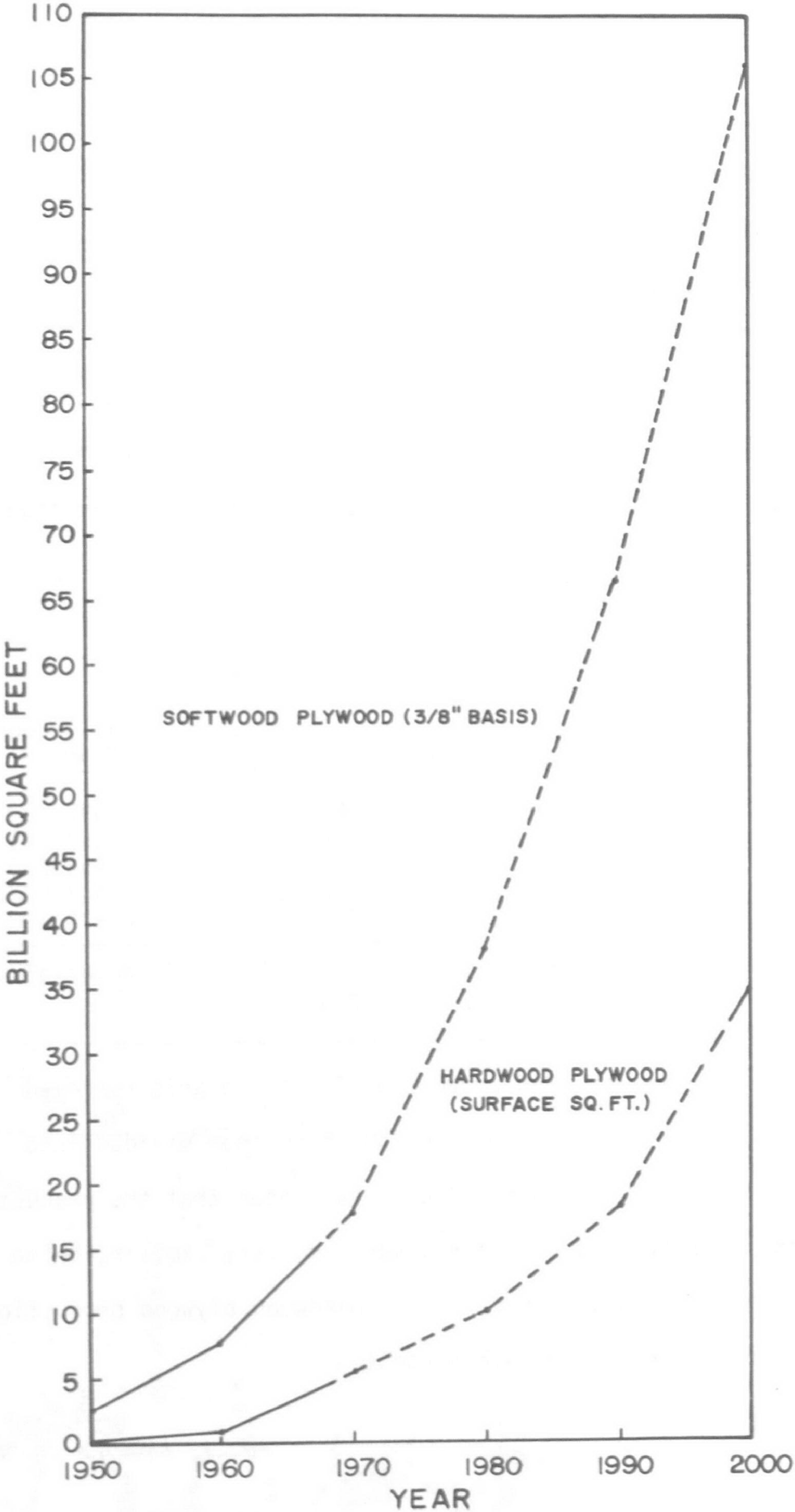


FIGURE 2. PROJECTED GROWTH IN DEMAND FOR PLYWOOD, 1950 - 2000

Operations

To help understand the plywood operations, a flow chart of a complete plant is shown in Figure 3. This flow chart also indicates sources of solid and liquid wastes.

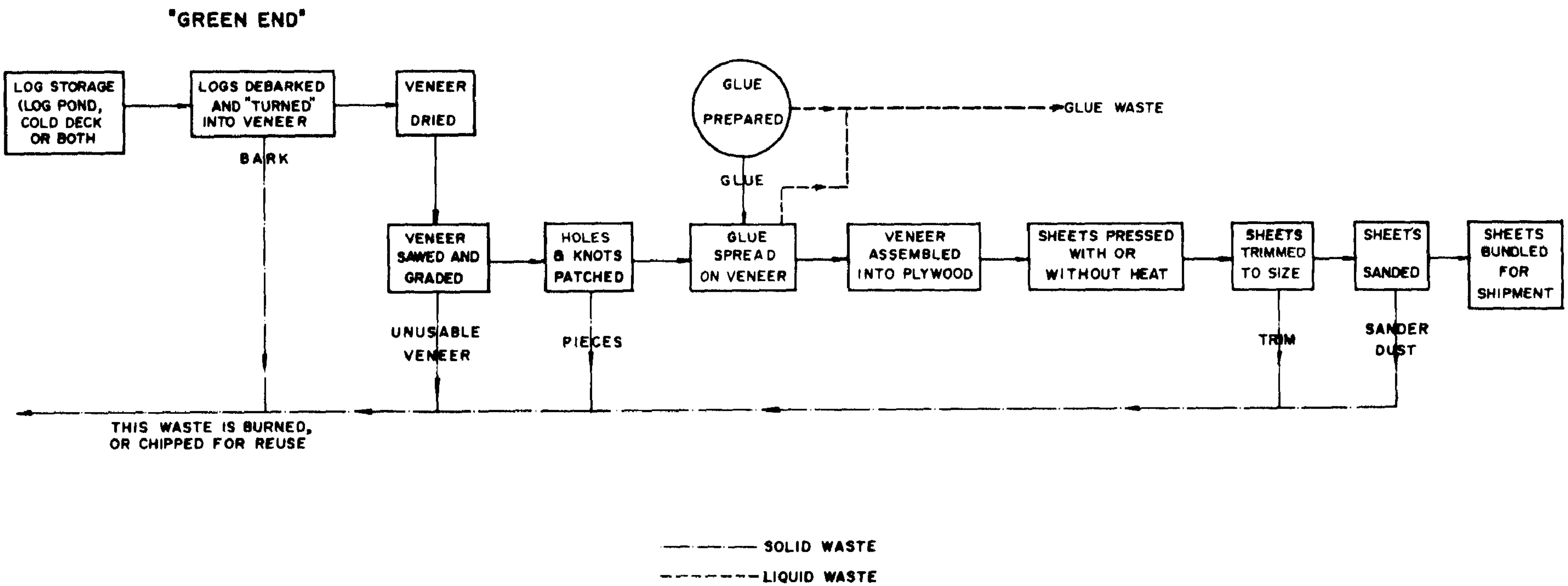
Green End

The green end of a plant involves the storage and handling of logs through the process of turning them into veneer. Storage of logs may be in a log pond, a cold deck, or a combination of both. Log ponds at plywood plants usually serve further as a disposal site for the glue wastes. This rids the plant of the glue waste but usually complicates pollution problems caused by the log storage. Cold decking also causes some pollution problems; water sprayed over the logs to keep them from checking usually finds its way into the log pond or to another receiving water body. Table 5 presents data on green ends, log ponds, and cold decks. Of the plants surveyed, 82.1 percent have green ends. Of those having green ends, 63.2 percent have log ponds, and 59.4 percent have cold decks. Table 6 presents more detailed information on the log ponds. The average size log pond for the plants surveyed was 17 acres, with a range from 0.5 to 100 acres.

Layup

The first potential source of glue waste is the washdown of kettles and equipment used for mixing and storing the glue. A typical plant, producing 100 million square feet (3/8 inch basis)

FIGURE 3. PLYWOOD PLANT FLOW DIAGRAM



of plywood per year, approximately 50 percent exterior and 50 percent interior grades, makes up about 11 batches per day of protein glue and 9 batches per day of phenolic glue. This amounts to approximately 400,000 pounds of phenolic and 350,000 pounds of protein glue per month. The mixing equipment may not always be washed between batches or in some cases, may not be washed at all, but if it is washed, only a small amount of water should be used. Thus, any waste generated by this phase of the operation is a small but highly concentrated part of the total. A glue-mixing area from a typical plant is shown in Figure 4-A.

TABLE 5

GREEN ENDS, COLD DECKS, AND LOG PONDS[a]

State	Plants Surveyed with Green Ends (%)	Plants Surveyed with Cold Decks (%)	Plants Surveyed with Log Ponds (%)
California	90.9	72.7	27.3
Idaho	100.0	100.0	0.0
Montana	100.0	100.0	16.7
Oregon	83.1	57.6	72.9
Washington	73.3	50.0	56.7

[a] APA Survey, 1967

The second source of glue waste is the spreaders. A glue spreader from a typical plant can be seen in Figure 4-B.

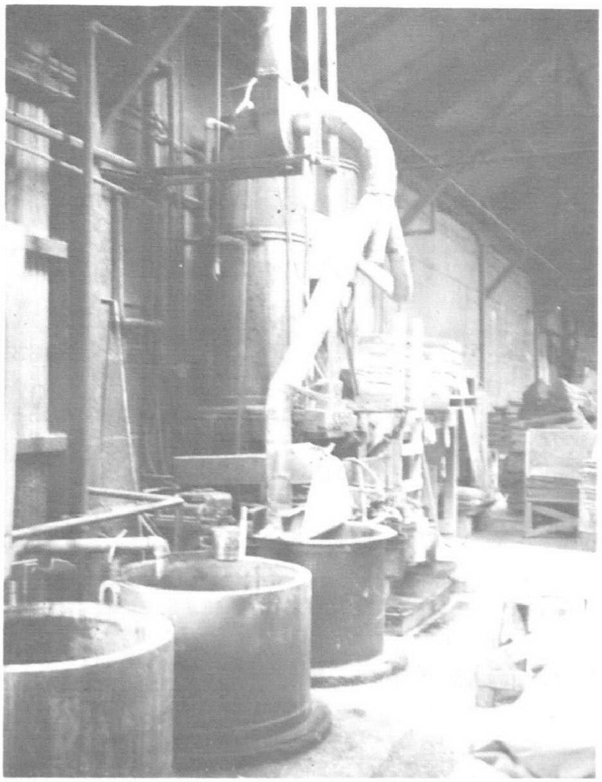
TABLE 6

NUMBER AND SIZE OF LOG PONDS AT PLANTS SURVEYED[a/]

State	Number of Plants With Ponds	Total Size of Ponds (Acres)	Avg. Size of Ponds (Acres)	Max. Size of Ponds (Acres)	Min. Size of Ponds (Acres)
California	6	88.5	14.8	30.0	2.5
Idaho	0	0.0	0.0	0.0	0.0
Montana	1	7.5	7.5	7.5	7.5
Oregon	43	865.5	20.1	100.0	1.5
Washington	17	169.5	10.0	75.0	.5
TOTAL	67	1,131.0			
AVERAGE FOR 5 STATES			16.9		
MAXIMUM SIZE FOR 5 STATES				100.0	
MINIMUM SIZE FOR 5 STATES					.5

a/ APA Survey, 1967

FIGURE 4



A. GLUE MIXING EQUIPMENT

B. GLUE SPREADER

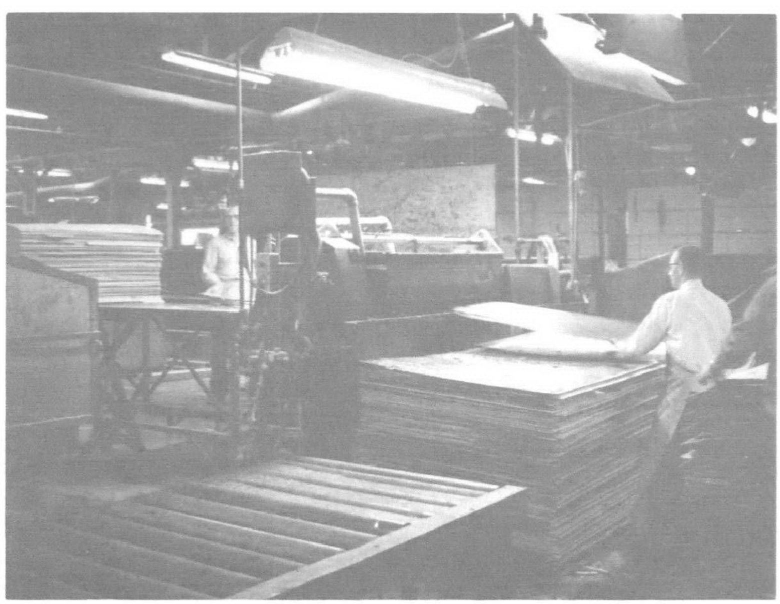


Table 7 gives data on the number of spreaders in the plants surveyed. As can be seen, the plants have from one to nine spreaders each, with a plant average of three. Of more interest is the number of spreader shifts per day as these, along with type of glue used, determine the number of washdowns. Table 8 contains data on spreader shifts for the surveyed plants. The plants surveyed average slightly over six spreader shifts per day with a range of from one to twenty. The spreaders are usually washed down once per shift when protein glue is used and at least once per day for phenolic glue. The difference is due to the fact that the protein glues have a pot life of six to eight hours, whereas the phenolic glue lasts almost indefinitely. Whereas spreaders using phenolic glue need be washed down only once per day, the accumulation of wood chips in the pans usually necessitates a rinsing at the end of each 8-hour shift.

TABLE 7

NUMBER OF GLUE SPREADERS FOR PLANTS SURVEYED[a/]

State	Number	Average/ Plant	Max./ Plant	Min./ Plant
California	24	2.2	4	1
Idaho	3	1.5	2	1
Montana	10	2.5	4	2
Oregon	179	3.0	9	1
Washington	94	3.1	6	1
TOTAL	310			
Average		2.9		
Maximum			9	
Minimum				1

[a/] APA Survey, 1967

TABLE 8

NUMBER OF SPREADER SHIFTS FOR PLANTS SURVEYED[a/]

State	Total Number	Average Plant	Max./ Plant	Min./ Plant
California	42	3.8	7	1
Idaho	8	2.0	5	3
Montana	25	6.3	11	4
Oregon	406	6.9	20	2
Washington	185	6.2	16	1
TOTAL	666			
AVERAGE		6.3		
MAXIMUM			20	
MINIMUM				1

a/ APA Survey, 1967

Trends

Three trends of the plywood industry are of interest from a water pollution standpoint. These trends involve production, adhesive consumption, and glue application.

As was pointed out earlier, plywood production is expanding at a fairly rapid rate. The year 2000 will see an estimated eightfold increase over present prodution[2/]. This means that waste treatment efficiencies will have to improve as more waste is generated. For example, if 90 percent treatment is required in 1967, 98.75 percent treatment will be necessary in 2000 to maintain the same pollutional load on receiving waters.

The second trend concerns the adhesives used by the industry. Table 9 shows current and projected adhesive consumption for the plywood industry. From this table, we see that, as of now, phenolic glues are being used for a portion of western interior grades as well as for all of southern interior grades. This table also shows that, by 1975, phenolic glues will be used for almost all softwood plywood production. This trend toward all phenolic glues is due to decreasing costs of phenolic resins and problems with failures of interior plywood of inferior quality which were exposed for short periods of time to exterior environments. Problems such as these moved the Los Angeles Department of Building and Safety to rule that all softwood plywood for construction must use exterior glue[3/].

TABLE 9

CURRENT AND PROJECTED ADHESIVE CONSUMPTION IN THE PLYWOOD INDUSTRY[4/]

(Million of Ponds)

Plywood Type	1965 Phenolic	1965 Urea	1965 Protein	1975 Phenolic	1975 Urea	1975 Protein
Western Exterior	81	--	--	194	--	--
Western Interior	14	--	104	137	--	--
Southern Exterior	--	--	--	91	--	--
Southern Interior	10	--	--	86	--	--
Hardwood	--	55	--	--	120	--
TOTALS	105	55	104	508	120	Nil

Innovations are being sought in the area of glue application. One idea involves extruding the glue onto the veneer as opposed to rolling it on with a conventional spreader. Another idea employs a paper glue line where a dry sheet of glue is placed between the sheets of veneer. A new process, if found, might eliminate the glue spreader and the subsequent waste produced from its washdown.

WASTE CHARACTERISTICS

Waste Quantity

Measured Waste Discharge

Waste flows were measured at four plants over periods ranging from six weeks to several months. Measurement schemes differed at each plant according to equipment availability and accessibility to the waste stream. These plants are referred to by number and pertinent data are shown in Table 10.

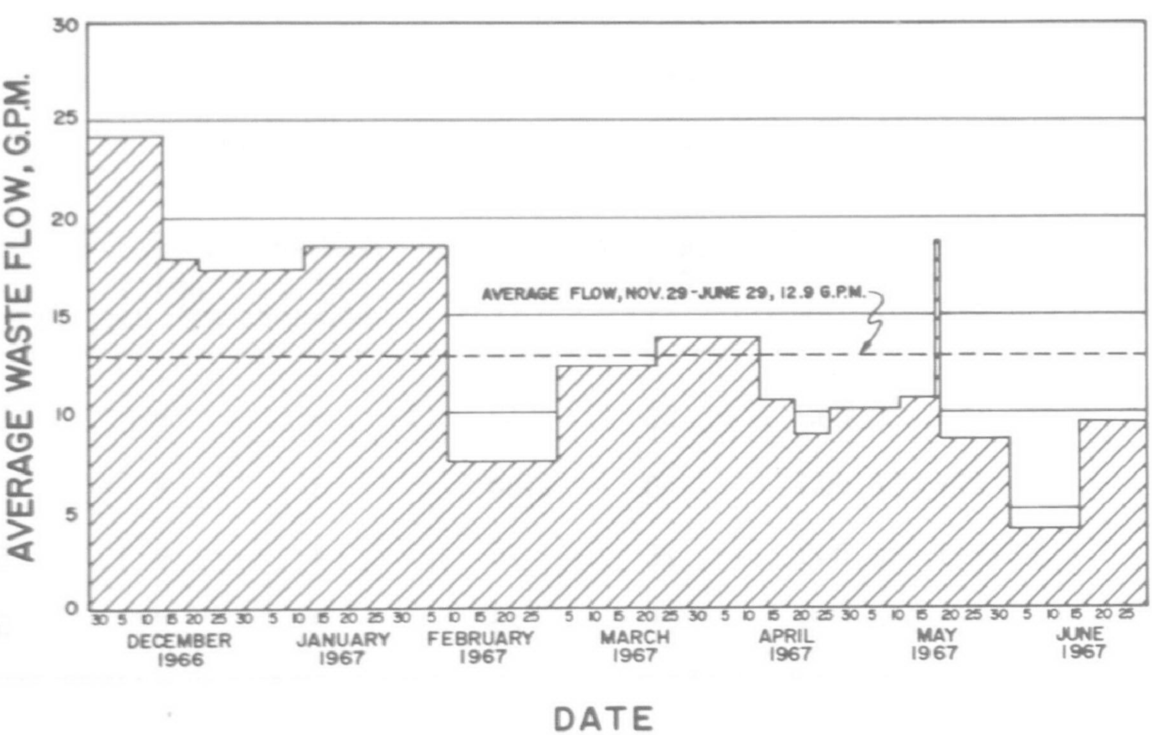
TABLE 10

CHARACTERISTICS OF PLANTS USED IN DISCHARGE STUDY

Plant Number	1966 Production[1/] (Sq.Ft. 3/8" Basis)	Exterior Grade (%)	Interior Grade (%)	Number of Spreaders	Spreader Shifts Per Day	Days Worked Per Week
1	100,000,000	50	50	4	8	5
2	135,000,000	0	100	3	9	5
3	100,000,000	25	75	4	9	5
4	70,000,000	75	25	2	6	5

At Plant Number 1, a water meter was placed in the washwater line adjacent to one of the four glue spreaders. This meter was read at various time intervals over a seven month period. The meter readings were multiplied by four, and the average flows were computed. Figure 5 shows these flows for the seven month

FIGURE 5
AVERAGE GLUE WASTE FLOWS
(PLANT 1)



period. The average flow for the seven month period was 12.9 gpm, and the average flow for the working days in the period was 18.2 gpm.

At Plant Number 2, a 45-degree V-notch weir and water level recorder were installed in a ditch between the plant and the settling pond. This proved to be a bad arrangement as the weir was soon plugged with glue and wood chips. The weir was removed and an alternate plan was sought. At this plant, the settling pond effluent was pumped into the log pond with the pump being controlled by a set of probes. The recorder was placed on the pond. The pond area was measured and the flow was determined. This setup was used for 7 weeks and proved to be the easiest to maintain. Figure 6 shows the daily average flows for the period. The average flow for the 7 weeks was 24.4 gpm and the average flow for the working days was 30.2 gpm.

At Plant Number 3, a 60-degree V-notch weir and level recorder were installed in a ditch located downstream from the plant's settling tank. This setup was used for 6 weeks and required only minor maintenance. Figure 7 shows the daily average flows for the period. The average flow for the period was 17.9 gpm and the average flow for the working days was 21.6 gpm.

At Plant Number 4, a 16-inch rectangular weir and level recorder were installed in the last compartment of the plant's settling tank. This setup was used for 6 weeks. Figure 8 shows the daily average flows for the period. The average flow for the

FIGURE 6

DAILY AVERAGE GLUE WASTE FLOWS

(PLANT 2)

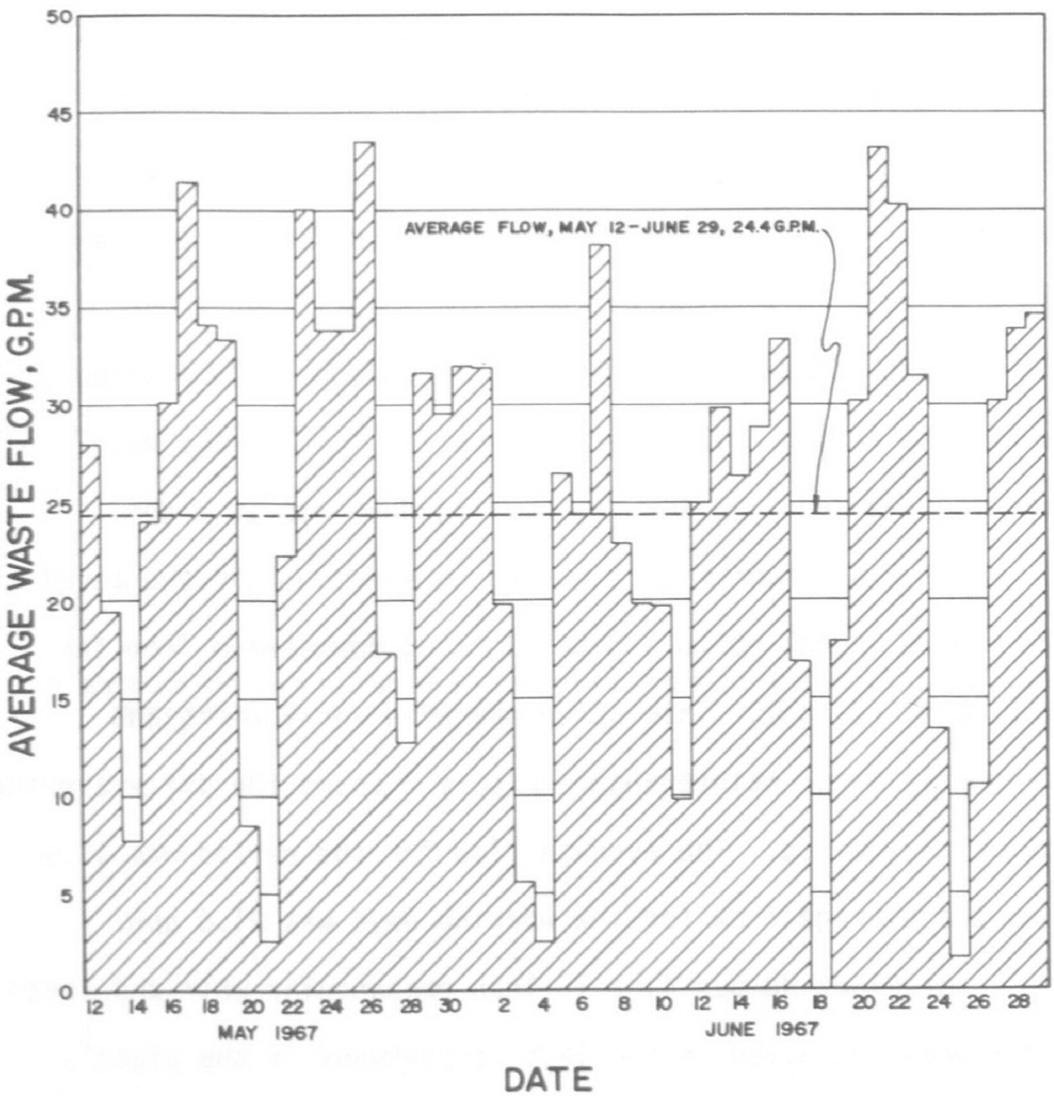


FIGURE 7
DAILY AVERAGE GLUE WASTE FLOWS
(PLANT 3)

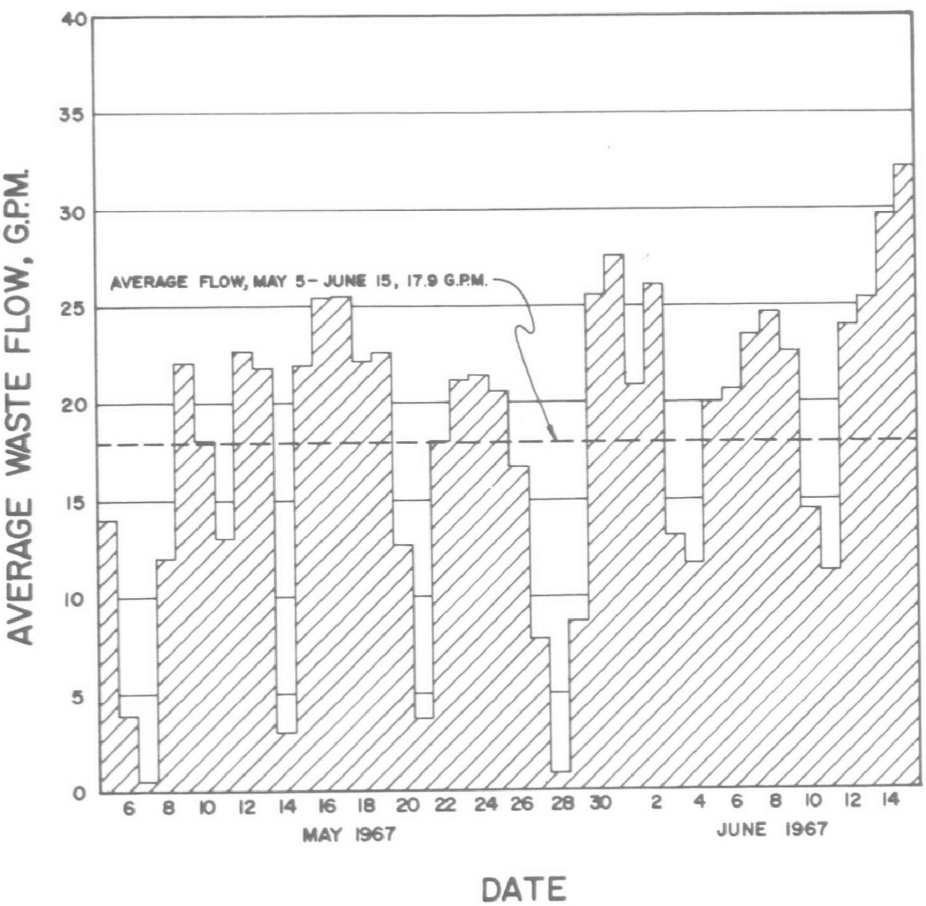
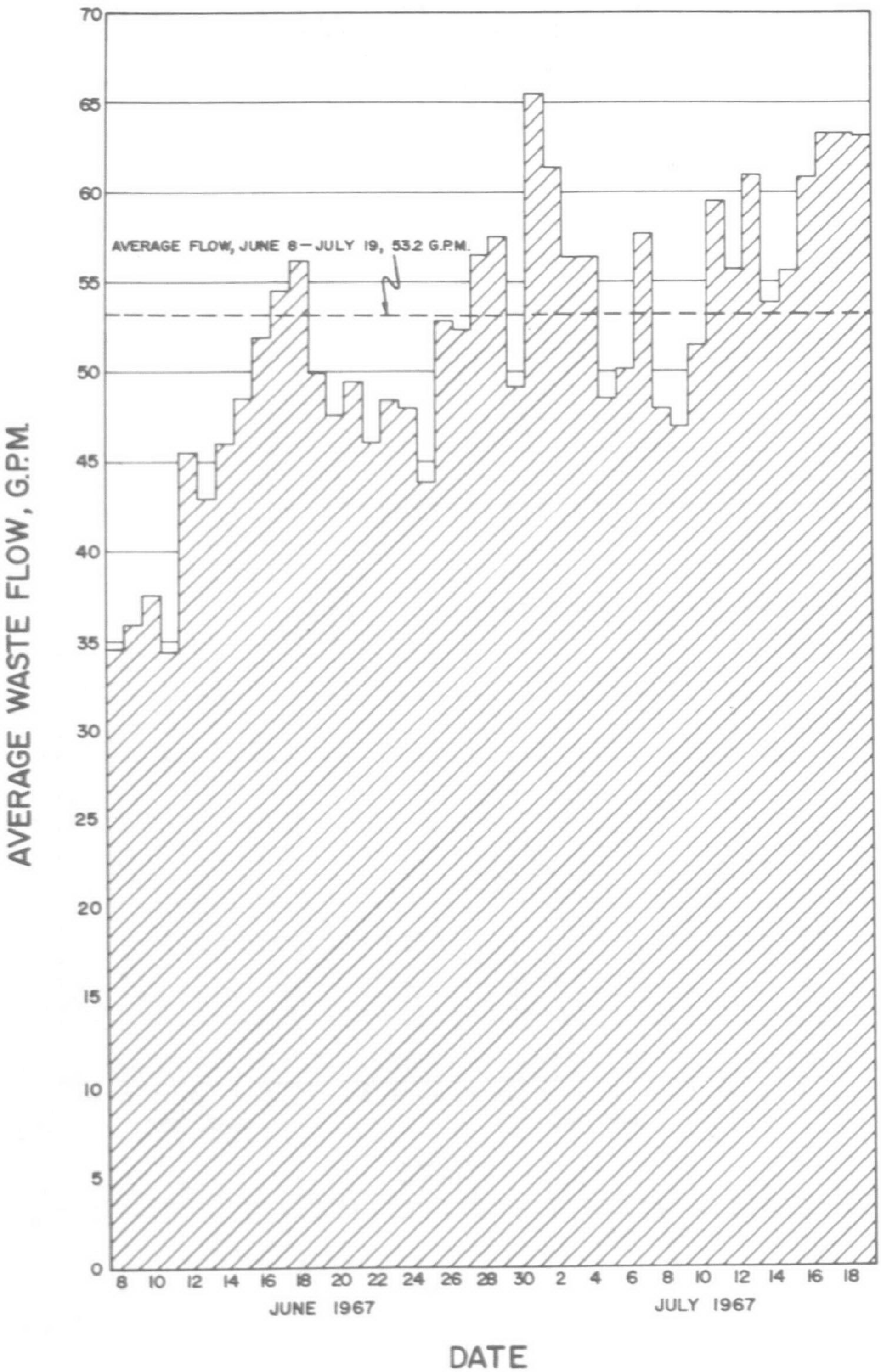


FIGURE 8
DAILY AVERAGE GLUE WASTE FLOWS
(PLANT 4)



period was 53.2 gpm and the average flow for the working days was 54.0 gpm.

Table 11 compiles the flow data for the four plants. As can be seen, the average flows vary widely. This variance should have been a result of the spreader shifts per day and the types of glue used, but this was not found to be true. Plant Number 4, with the fewest spreader shifts per day and the highest percentage of exterior grade production, should have the smallest flow but, as can be seen, its flow is much higher than flows of any of the other three. At Plant Number 4, water use differs only slightly on working and nonworking days, further indicating that water is being used when spreaders are not being washed down.

The flow from Plant Number 1 was much lower than that of any of the other three. This may be due to the manner in which the flow was calculated. Here, actual amounts of water used for washdown were measured, eliminating any other discharges which may get into the waste stream farther down the line, such as the washdown water from the glue mixing area.

At two plants, the daily maximum and minimum flows were recorded. The average is shown in Table 11 as a percentage of the average flow for the total days measured. The maximum for the two plants averaged 213 percent while the minimum was 60 percent.

The average discharge for the four plants was 27.1 gpm or 39,000 gpd. When multiplied by the 158 plants in the study

TABLE 11

GLUE WASTE DISCHARGE MEASUREMENTS

Plant Number [a/]	Days Measured	Average Discharge for Days Measured (gpm)	Average Discharge Working Days (gpm)	Maximum Average Daily Discharge (% Avg. Discharge for total days)	Minimum Average Daily Discharge (% Avg. Discharge for total days)
1	212	12.9	18.2	--	--
2	49	24.4	30.2	--	--
3	42	17.9	21.6	211	53
4	42	53.2	54.0	215	67

[a/] See Table 9 for Plant Descriptions

area, it results in a discharge of 6.2 million gallons per day of glue waste.

In conclusion, it can be seen that, under present conditions of inexpensive water and little concern over the destination and pollutional effects of the waste, the flow from different plants will vary markedly, depending upon plant practices.

Calculated Waste Discharges

Two spreader washdowns were observed, both of these at Plant Number 1 where a water meter had been installed in the washwater line. The first washdown required 210 gallons, took approximately 35 minutes, and resulted in an average discharge of 7 gpm.

Assume that 250 gallons at 7 gpm is needed to wash down a spreader. To flush out lines or troughs, an additional 10 minutes at 7 gpm is added, giving a total of 70 gallons for flushing. This gives a total of 320 gallons for each washdown. The average interior plywood plant with six spreader shifts and a washdown at the end of each shift would generate 1,920 gallons of waste per day. To this should be added the contribution from the washdown of glue mixing equipment. A plant making 10 batches of glue per day and washing down its equipment after each batch should add approximately 300-500 gpd of waste. The total glue waste discharge should then be around 2,300 gpd per plant. A plant in southern Oregon, which reuses its waste, has reduced its waste discharge to approximately 1,200 gallons per day. Here they run five spreader shifts, rinsing after each shift, and washing down once a day. The reuse system employed at this plant is further explained in the section entitled TREATMENT AND CONTROL. The 1,200 gallon per day flow measured at this point and the conservative estimate of 2,300 gallons per day are considerably less than the 18,500 to 76,500 gallons measured at Plants 1 through 4. This great difference can be traced to the fact that water is allowed to run in the waste lines when glue is not being washed off the equipment. This practice has been followed for one or more of the following reasons. First, some plant personnel feel that diluting the glue waste reduces their pollution problems. Second, lines become plugged on occasion and water is kept running in an effort to prevent this. Third, forgetfulness and poor plant practices account for the excess amounts of water used.

It is concluded that the glue waste discharges could and should be reduced considerably. This could easily be done through better in-plant practices and through the development of new techniques such as the use of steam instead of water for cleaning the metal parts of equipment.

The problem of plugged lines could possibly be solved by using better line flushing techniques, minimizing waste line lengths, using teflon coated pipes or a combination of these.

Waste Quality

Chemical Investigations

Many different glue formulas are used by the plants in the study area. However, the actual ingredients of the glues vary only slightly. Table 12 lists the ingredients of typical protein, phenolic and urea glue mixes. The pentachlorophenol or phenolic formaldehyde resin listed under protein glue is added only when a toxic mix is required. This toxic mix makes the glue more resistant to biological degradation.

Because all glues could not be chemically analyzed, typical protein, phenolic and urea glues were chosen. These were Borden's Casco S-230[a/] glue, Borden's Cascophen 31[a/] and Borden's Casco Resin 5H[a/]. The Casco S-230 mix contains neither pentachlorophenol nor phenolic formaldehyde resin. The ingredients of these glues were obtained from the producing company and the glues were mixed in the laboratory. These prepared glues were then chemically analyzed. Table 13 lists the results of these analyses. The phenolic glue with a COD of 653,000 mg/kg and a phenol concentration of 514 mg/kg is the strongest and most toxic of the three glues analyzed. Whereas, the phenolic glue has a high COD and phenolic concentration, it is the most deficient in nutrients, having nitrogen and phosphorus concentrations of 1,200 mg/kg and 120 mg/kg, respectively.

a/ Use of product and company names is for identification only and does not constitute endorsement by the U. S. Department of the Interior or the Federal Water Pollution Control Administration.

TABLE 12

INGREDIENTS OF TYPICAL PROTEIN, PHENOLIC & UREA GLUE MIXES

Protein Glue for Interior Grade Plywood

Water
Dried Blood
Soya Flour
Lime
Sodium Silicate
Caustic Soda
Formaldehyde Doner for Thickening
Pentachlorophenol [b]
Phenolic Formaldehyde Resin [b]

Phenolic Glue for Exterior Grade Plywood

Water
Furafil[a]
Wheat Flour
Phenolic Formaldehyde Resin
Caustic Soda
Soda Ash

Urea Glue for Hardwood Plywood

Water
Defoamer
Extender (Wheat Flour)
Urea Formaldehyde Resin

[a] Residue from furfural extraction of corn cobs and oat hulls

[b] May be added to produce a toxic glue

TABLE 13

AVERAGE CHEMICAL ANALYSIS OF PLYWOOD GLUE

Analysis and Units	Phenolic Glue[a/]	Protein Glue[b/]	Urea Glue[c/]
COD, mg/kg	653,000	177,000	421,000
BOD, mg/kg	--	88,000	195,000
TOC, mg/kg	176,000	52,000	90,000
Total Phosphate, mg/kg as P	120	260	756
Total Kjeldahl Nitrogen, mg/kg as N	1,200	12,000	21,300
Phenols, μg/kg	514,000	1,810	
Suspended Solids, mg/kg	92,000	59,000	346,000
Dissolved Solids, mg/kg	305,000	118,000	204,000
Total Solids, mg/kg	397,000	177,000	550,000
Total Volatile Suspended Solids, mg/kg	84,000	34,000	346,000
Total Volatile Solids, mg/kg	172,000	137,000	550,000

[a/] Borden's Cascophen 31 which is similar to Borden's Cascophen 382

[b/] Borden's Casco S-230

[c/] Borden's Casco Resin 5H

Pollutional Effects

Stream Survey. A biological survey of Anderson Creek, Tillamook County, Oregon, was undertaken to more fully assess the impact of plywood glue waste on a small stream.

Anderson Creek, a small tributary to the Tillamook River, is approximately three miles long. This stream was selected because of its accessibility, size, and absence of other waste streams. For the first half mile of its length, it is an intermittent stream, flowing in the bottom of a large ditch. The creek is shallow, with a maximum depth of approximately three feet. It flows through a marshy area in its lower reaches. The original mouth of the creek is now blocked off and the last 1,000 feet of flow is through a man-made channel. Large check valves at the end of the channel prevent the Tillamook River from back-flowing into Anderson Creek during high tides. The primary source of water in the upper reaches appears to be surface drainage from an adjacent airstrip, groundwater seepage, and the discharge from the plywood plant. Flow measurements in the creek below the waste outfall in the late summer ranged from 120 to 220 gpm. The Oregon State Water Resources Board determined that the minimum flow necessary to maintain fish life was 0.4 cfs (180 gpm)[5/].

The plywood plant, referred to earlier as Plant Number 1[a], discharges its waste into Anderson Creek about 2.2 miles upstream from its mouth. The waste flow from the plant averages 12.9 gpm.

Ten sampling stations were established on Anderson Creek. As shown in Figure 9, four were upstream and six were downstream from the waste outfall. Three elements of the Anderson Creek biota were sampled: benthic fauna, planktonic algae and attached algae. Observations of the water surface and stream bottom were also noted, as well as occasional determinations for dissolved oxygen and pH. The results of the Anderson Creek survey showed that the creek supported a fairly well balanced aquatic community upstream from the waste outfall. The introduction of the waste, however, severely degraded the stream as indicated by studies of the benthic fauna and phytoplankton flora.

A quantitative bottom survey revealed that benthic animals commonly associated with clean water conditions were absent at sampling stations established downstream from the outfall. The benthic forms which colonized artificial substrate samplers, placed both upstream and downstream from the outfall for six week intervals during a six month period, consistently

[a]Information regarding this plant can be found in Table 10.

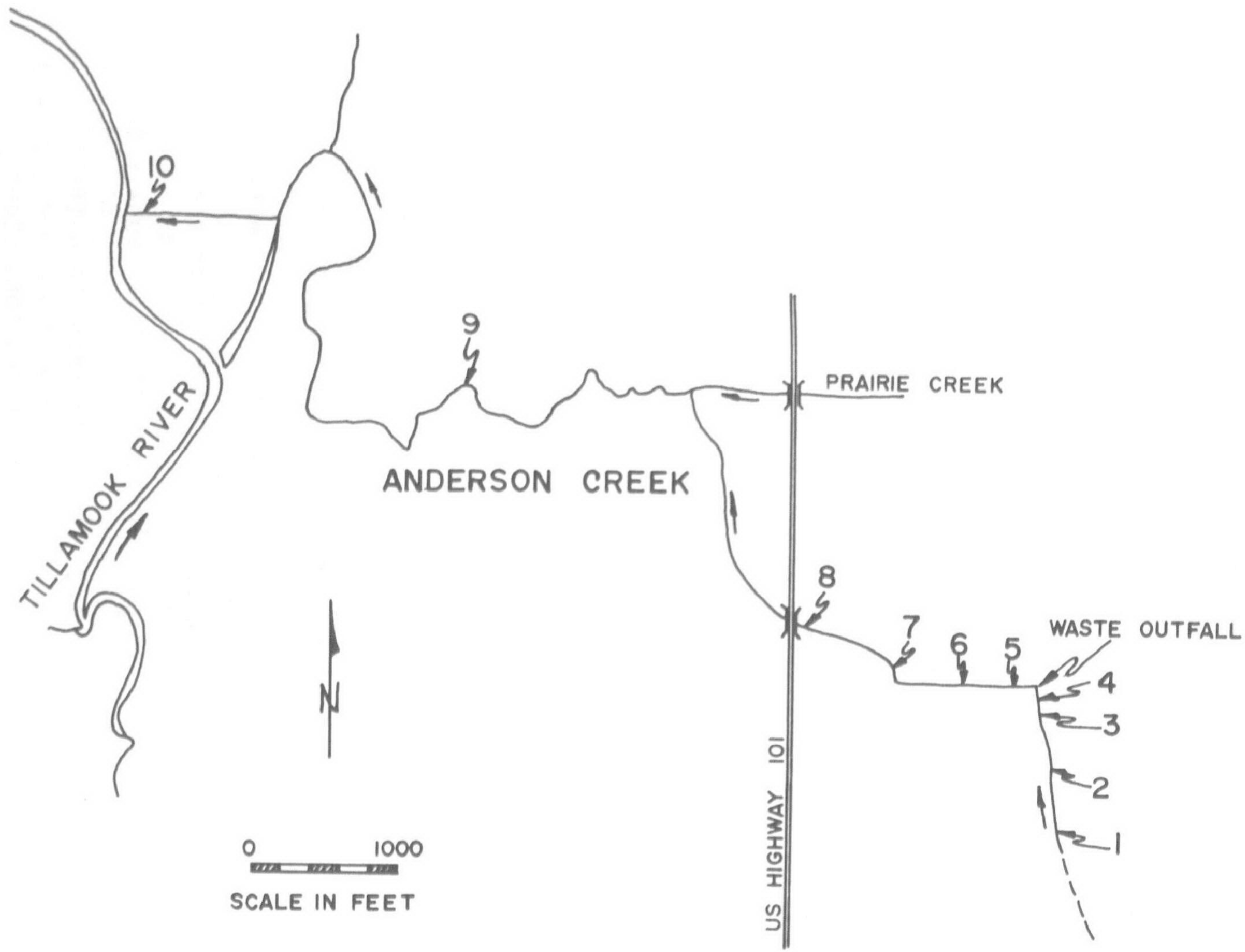


FIGURE 9. ANDERSON CREEK SAMPLING SITES

revealed severe degradation. There were some indications of stream recovery at the mouth of the creek, about 2.2 miles below the outfall.

The phytoplankton populations were greatly reduced by the volumes of incoming waste. Also, downstream from the outfall, they included certain forms commonly associated with polluted conditions.

Observations on the physical appearance of the stream showed badly polluted conditions downstream from the plywood plant. Obnoxious slime growths, dark, foamy water and foul odors were common. There was also some evidence of oxygen depletion due to the wastes. Table 14 lists some of the physical conditions observed at the ten sampling stations.

The presence of untreated plywood glue wastes creates an unhealthy climate for the normal inhabitants of a stream bottom. These organisms are important links in the aquatic life food chain and their absence or depletion can effectively eliminate a stream's ability to support a resident fish population. The associated slime growths can have a very deleterious effect on fish spawning beds.

TABLE 14

ANDERSON CREEK - PHYSICAL OBSERVATIONS

Station	Depth Ft.	Width Ft.	Approx. Distance Below Outfall, Mi.	Bottom Type	Remarks
AC-1	2.5-3	6-8	---	Coarse Sand, Silt, Wood Fibers	Small Pool. Abundant reeds and emergent vegetation.
AC-2	.75	2-3	---	Coarse Sand, Silt	Much green filamentous algae on bottom. Abundant vegetation.
AC-3	2-3	6-8	---	Silt, Coarse Sand	Small pool. Much vegetation and green filamentous algae.
AC-4	.5-.75	2	---	Gravel, Rock	Riffle.
AC-5	.5	6	.03	Gravel, Rock	Riffle. Bottom slime-covered, foul odor. Water red to black and foamy in summer. Clearer in Fall.
AC-6	.75	5	.10	Gravel, Rock	Bottom slime-covered. Oil slick and foul odor in Spring. Abundant filamentous algae on banks.
AC-7	.75	4	.22	Gravel, Rock	Bottom slime-covered. Long strands *Sphaerotilus* in Spring. Black oily substance on banks.
AC-8	1-2	6-12	.34	Gravel, Rock	Riffle. Abundant vegetation at shore. *Sphaerotilus* strands, oil slick. Water dark.
AC-9	1-2	50	1.13	Ooze, Silt	Marshy, profuse vegetation, almost stagnant.
AC-10	3	10-12	2.23	Clay, Silt	No vegetation, steep banks. Water dark.

Toxicity Studies. A brief series of acute toxicity bioassays was conducted to further evaluate the characteristics of plywood glue wastes. Three glues were tested to compare their relative toxicity.

The toxicity bioassay is designed to test acute toxicity only. It is essentially a test in which a certain number of organisms are exposed to various concentrations of a waste for given periods of time. The results are often expressed in terms of the median tolerance limit (TL_m).

The methods used in conducting the bioassays were essentially those described by Douderoff et al., and Standard Methods, with minor modifications[6,7]. Static or non-flowing tests were conducted and, although certainly not representative of stream conditions, were believed adequate for the screening of relative toxicity.

Three species of fish were used: young guppies, (*Poecilia reticulata*), chinook salmon fry (*Oncorhynchus tshawytscha*) and coho salmon fry (*Oncorhynchus kisutch*). Guppies were used in the majority of tests in order to have a uniform test organism and because of handling ease.

In a system of daily solution renewal on guppies, the median tolerance limits for 96 hours for Casco S-230, an interior glue, averaged 4,500 mg/l while Cascophen 382, an exterior glue, averaged 1,140 mg/l. Guppies tested in Cascophen 31, also an

TABLE 15

ACUTE TOXICITY CHARACTERISTICS OF VARIOUS PLYWOOD GLUES

Glue	Fish	No. Tests	Critical Concentration Range, mg/l	96 hour TL_m, mg/l Avg.	Range	Glue Age, Days	Solution Renewal
Casco S-230	Guppy	1	1,800-10,000	7,200	--	Fresh	None
	Guppy	2	1,800-10,000	4,500	4,200-4,800	Fresh	Daily
	Guppy	2	1,800-10,000	2,650	2,400-2,900	34-36	Daily
Cascophen 382	Guppy	2	650- 2,400	1,325	1,200-1,400	48-55	None
	Guppy	3	650- 2,400	1,140	830-1,400	48-76	Daily
Cascophen 31*	Guppy	1	280- 1,000	500	--	14	Daily
	Guppy	1	320- 1,000	700	--	150	None
	Chinook	1	100- 230	140	--	150	None

*First Batch

exterior glue, had a 96 hour TL_m of 500 mg/l.

In a non-renewal system, the exterior glues exhibited a much lower decrease in toxicity than the interior glue. This would indicate a more persistent form of toxicity. The interior glue seemed to increase in toxicity after a long-term storage, in contrast to the exterior glues. A comparison test between young guppies and chinook salmon fry in a non-renewal system using Cascophen 31 revealed 96 hour TL_m values of 700 mg/l for the guppies and only 140 mg/l for the salmon. Acute toxicity characteristics of the various plywood glues studies can be found in Table 15.

The State of Washington tested wastewaters from several plywood glues on various species of salmon in both fresh and salt water[8/]. A phenolic glue similar in composition to Cascophen 31 and Cascophen 382 was tested in aerated, non-renewed fresh water on chinook salmon weighing about 2 gms. The apparent tolerance level at 72 hours was reported to be 450 - 950 ppm. The apparent 72 hour tolerance level of the chinook fry tested at the Pacific Northwest Water Laboratory with Cascophen 31, in a non-aerated, non-renewal system, was 100 - 180 mg/l.

As stated earlier, the above tests were undertaken to determine relative toxicity. To determine the chronic effects of plywood glue to endemic fish, long-term studies should be undertaken. These studies, utilizing a continuous flow-through system, would involve the evaluation of untreated and treated glue wastewaters. It might also be advisable to conduct field studies using live boxes above and below typical glue waste outfalls.

TREATMENT AND CONTROL

Methods in Use

Many different disposal methods for glue waste are in use at the present time. The methods vary from discharging untreated waste directly to streams, to systems involving municipal treatment plants. Table 16 lists 23 different schemes used by the 106 plants surveyed. As can be seen, 77 plants employ some type of settling tank or pond. The settling tanks commonly consist of one or more 1,000-gallon septic tanks. These settling devices remove some of the glue solids and the wood chips. Table 17 lists the chemical analyses of the settled effluent for three of the plants used in the discharge survey[a/]. Comparison of Table 13 and Table 17 shows a significant increase in the dissolved solids/suspended solids ratio after the settling operation, indicating a reduction of suspended solids. A similar comparison also shows little reduction in phenols, phosphates, and total kjeldahl nitrogen.

The removal of suspended solids is further evidenced by the filling of settling devices, necessitating their periodic clean-out. This clean-out is needed every 1 to 3 months, depending upon the tank size, number of washdowns, and types of glues used. In these tanks and ponds, lack of proper maintenance

[a/] Information regarding the three plants can be found in Table 10.

TABLE 16

DISPOSAL METHOD OF PLANTS IN SURVEY

Disposal System	California	Idaho	Montana	Oregon	Washington	TOTAL
	Number of Plants Using System					
Field Spreading	1			2		3
Log Pond (N. O.)[a/]	1					1
Log Pond, Field Spreading	1					1
Log Pond, S. L. R. O. [b/]	1			4		5
Municipal Sewer		1		5	1	7
Settling Pond (N. O.)	1		1	5	1	8
Settling Pond, Log Pond (N. O.)				3		3
Settling Pond, S. L. R. O.				1	1	2
Settling Pond, Waste Burner				1		1
Settling Tank, (Further Disposal Unknown)			2	8	4	14
Settling Tank, Field Spreading	2			2	3	7
Settling Tank, Log Pond (N. O.)				4	1	5
Settling Tank, Log Pond, Field Spreading				1		1
Settling Tank, Log Pond, S. L. R. O.	1			3		4
Settling Tank, Municipal Sewer			1	4		5
Settling Tank, Settling Pond (N. O.)					1	1
Settling Tank, Settling Pond, Field Spreading				1		1
Settling Tank, Settling Pond, Slough		1				1
Settling Tank, Settling Pond, S. L. R. O.	1			1		2
Settling Tank, S. L. R. O.				8	12	20
Settling Tank, Waste Burner				1	1	2
S. L. R. O.	2			4	5	11
Other [c/]				1		1

a/ Non-overflow

b/ Stream, Lake, River or Ocean

c/ Waste is put in drums and hauled to land disposal

TABLE 17

CHEMICAL ANALYSIS OF SETTLED EFFLUENT

Analysis & Units	#2 Plant [a]	#3 Plant [b]	#4 Plant [c]
pH	11.6	9.4	10.8
COD, mg/l	1814	1917	1621
TOC, mg/l	772	723	540
Total Phosphate, mg/l	15	9	12
Total Kjeldahl Nitrogen, mg/l	110	64	3
Phenol, μg/l	1667	1790	222
Suspended Solids, mg/l	148	356	330
Dissolved Solids, mg/l	1479	1458	790
Total Solids, mg/l	1627	1814	1120
Total Volatile Suspended Solids, mg/l	125	338	322
Total Volatile Solids, mg/l	1122	1267	919

[a] Average of 2 grab samples

[b] Average of 3, 24-hour composite samples

[c] Average of 2, 24-hour composite samples

leads to poor efficiencies and subsequent problems. Usually, these tanks are not cleaned until they are completely filled, resulting in zero or even negative efficiencies.

Table 16 also shows that 18 plants employ some type of non-overflow system to dispose of their waste. In such a system, the rates of evaporation and infiltration exceed that of the waste input. Because of the plugging nature of glue solids, evaporation probably accounts for most of the moisture lost.

Twelve of the plants surveyed dispose of their waste in municipal treatment systems. Wood chips and glue solids contained in these wastes plug the municipal sewers and overload treatment plant screening and grit removal processes. The high pH of the waste may raise the plant's pH to the point that problems arise with secondary and digestion processes. Adjustment of pH and the use of settling tanks or ponds should make the waste amenable to conventional waste treatment. The settling would also help dampen out any slugs of toxic materials, such as phenolic compounds, which can upset the balance of a biological system.

Eleven of the plants listed in Table 16 discharge their wastes with no treatment whatever. The majority of these plants are located on large bodies of water such as Puget Sound, the Pacific Ocean, or the Columbia River.

Biological Treatment Studies

Biological treatment studies were undertaken to determine the feasibility of this method for the treatment of plywood glue wastes. A secondary purpose was to determine what problems, if any, might occur if this type of waste were discharged into a municipal treatment system. The studies were conducted on a pilot plant scale and parameters such as nutrient addition, BOD loadings and efficiencies were investigated.

Two different pilot plant systems were used in the studies. Most of the work was done in a conventional activated sludge system patterned after one used by Ettinger[9/]. The system which is shown in Figure 10 included primary sedimentation, aeration, secondary sedimentation and sludge recycle. Pertinent data on the system are listed in Figure 10. Figure 11 depicts these systems as they were used at the Pacific Northwest Water Laboratory.

The second system was used only on the urea glue waste. This was a complete mix system consisting of aeration, sedimentation, and sludge recycle. The same aeration tank, minus the baffles, was used as in the first system described. The aeration period of the second system was maintained at five days. A special secondary settler was constructed which had a detention time of two hours.

Protein Glue Studies

Studies involving biological treatment of protein glue were conducted for a three month period. During this time, the

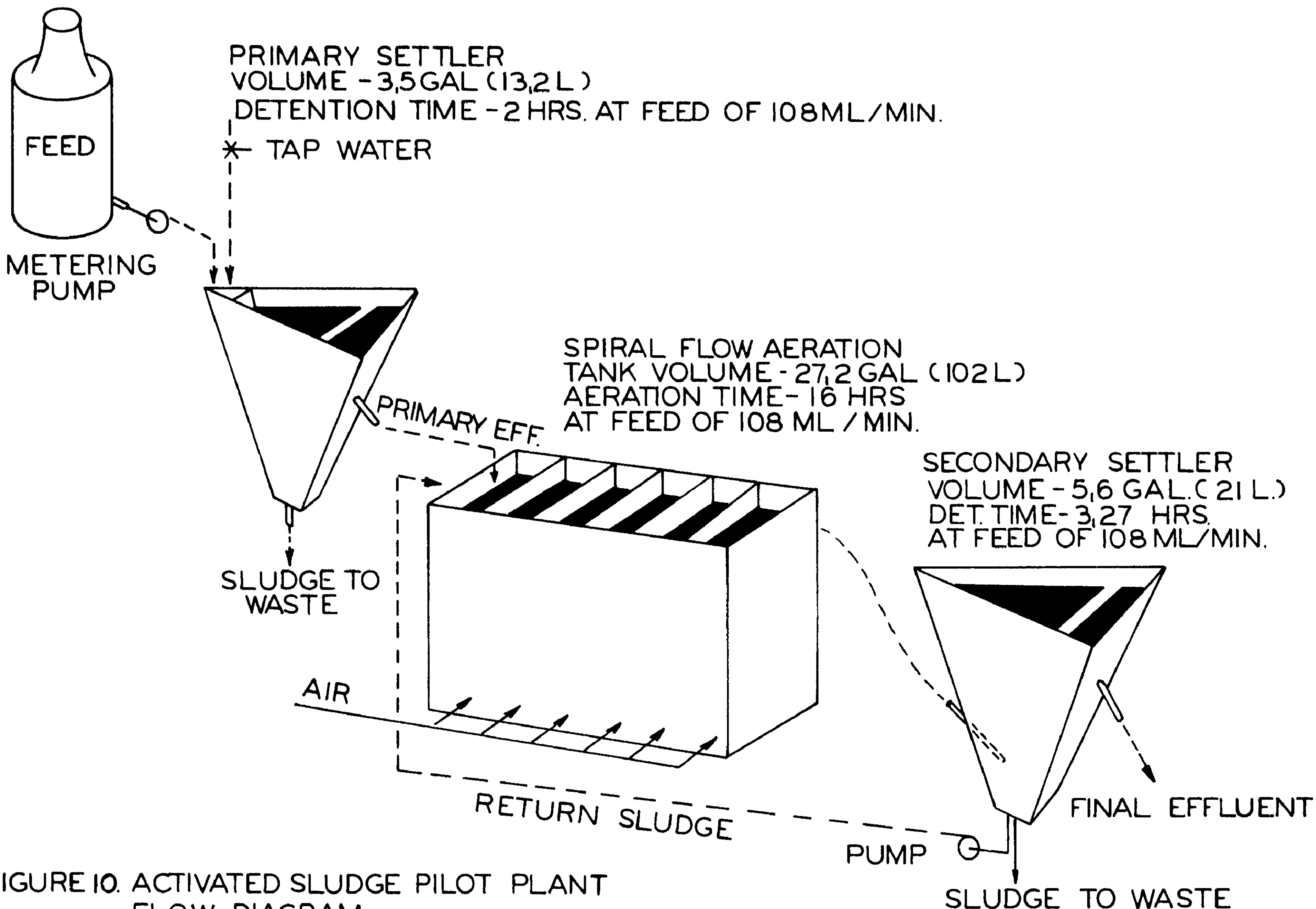


FIGURE 10. ACTIVATED SLUDGE PILOT PLANT FLOW DIAGRAM

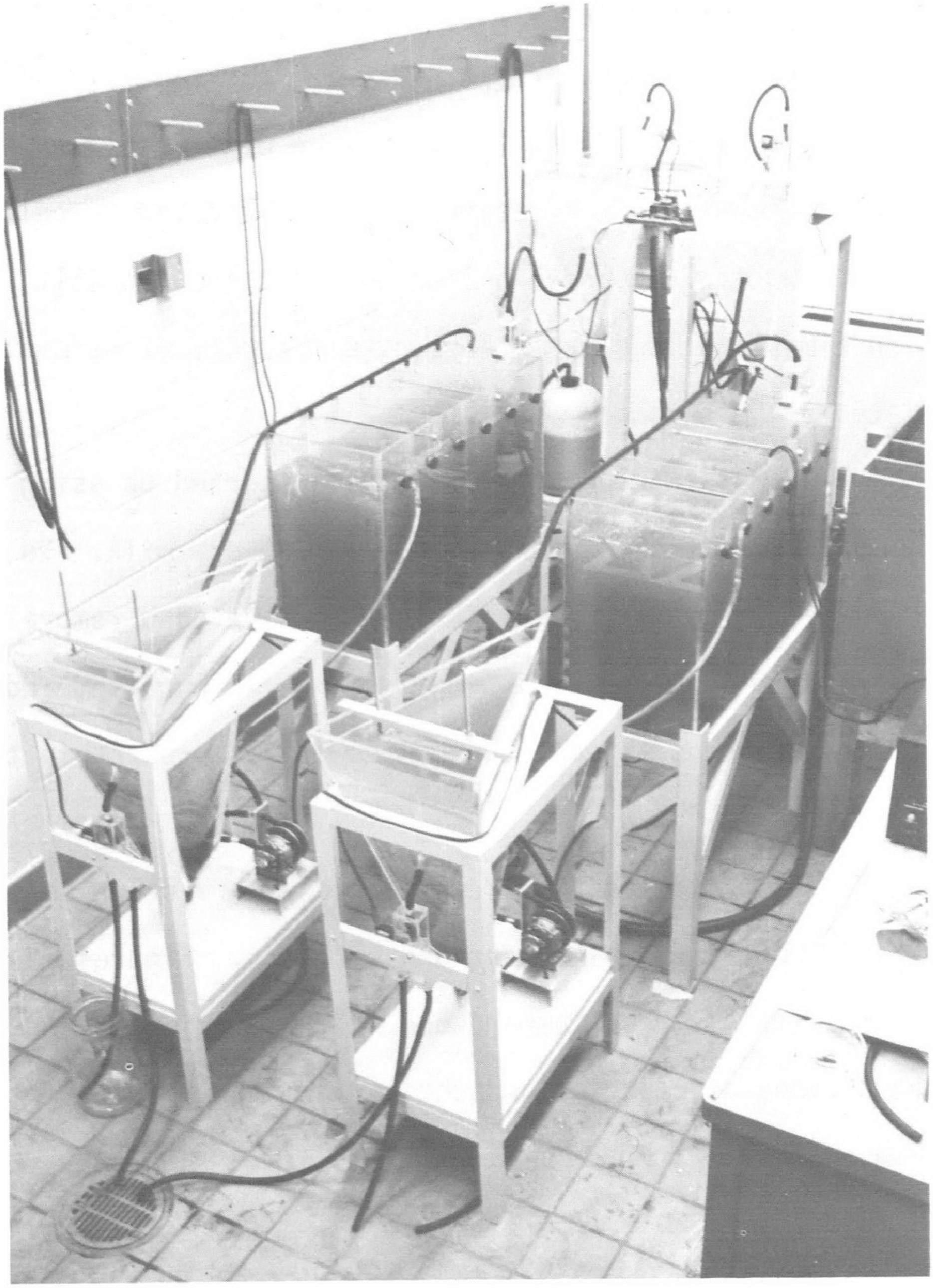


FIGURE 11. ACTIVATED SLUDGE PILOT PLANTS

BOD loading was varied from 5 to 52 lb/100 MLSS. Three different detention times were studies with the majority of the work done at 16 hours. Table 18 lists some of the data compiled from the three months of operation. As can be noted, excellent removals of BOD and suspended solids were attained at all detention times and loadings. Also, the majority of removal took place in the secondary system.

The protein glue pilot plant was started up using mixed liquor from studies done with a feed of dry milk. No problems were encountered using this method and good removals were experienced from the beginning. Inorganic nutrient additions were not deemed necessary because of the levels present in the glue.

For the protein glue, correlations were drawn between the BOD and COD's of the influent and effluent. Figures 12 and 13 show the results of these comparisons. The equations of the calculated lines of best fit and the correlation coefficient are as follows:

$$\text{Influent COD} = 77.6 + 1.3(\text{Influent BOD}) \quad r = .97$$

$$\text{Effluent COD} = 39.9 + 1.8(\text{Effluent BOD}) \quad r = .89$$

A relationship was also drawn up relating the influence of loading on BOD removal, as plotted in Figure 14. The calculated relation between loading and removal obtained from the data was

TABLE 18

BIOLOGICAL TREATMENT OF PROTEIN GLUE[a/]

Detention Period (Hours)	Lb BOD/100 lb MLSS	% Removal Primary & Secondary Treatment BOD	% Removal Primary & Secondary Treatment SS	% Removal Secondary Treatment BOD	% Removal Secondary Treatment SS
16	5.8	93	50	91	-
16	10.6	93	50	91	-
16	12.4	94	-	93	-
16	13.3	93	87	93	-
16	13.5	91	76	90	-
16	14.2	96	96	92	87
16	16.3	96	83	95	57
16	16.6	98	97	98	90
16	20.1	97	-	97	-
16	20.5	96	87	95	-
16	22.0	95	93	94	90
16	23.6	97	97	97	89
16	25.3	96	-	95	-
16	26.4	97	98	97	92
16	37.7	95	94	95	86
16	41.2	95	95	95	86
12	39.4	86	93	83	93
12	57.2	95	90	94	87
8	52.0	91	85	91	78

[a/] Borden's Casco S-230

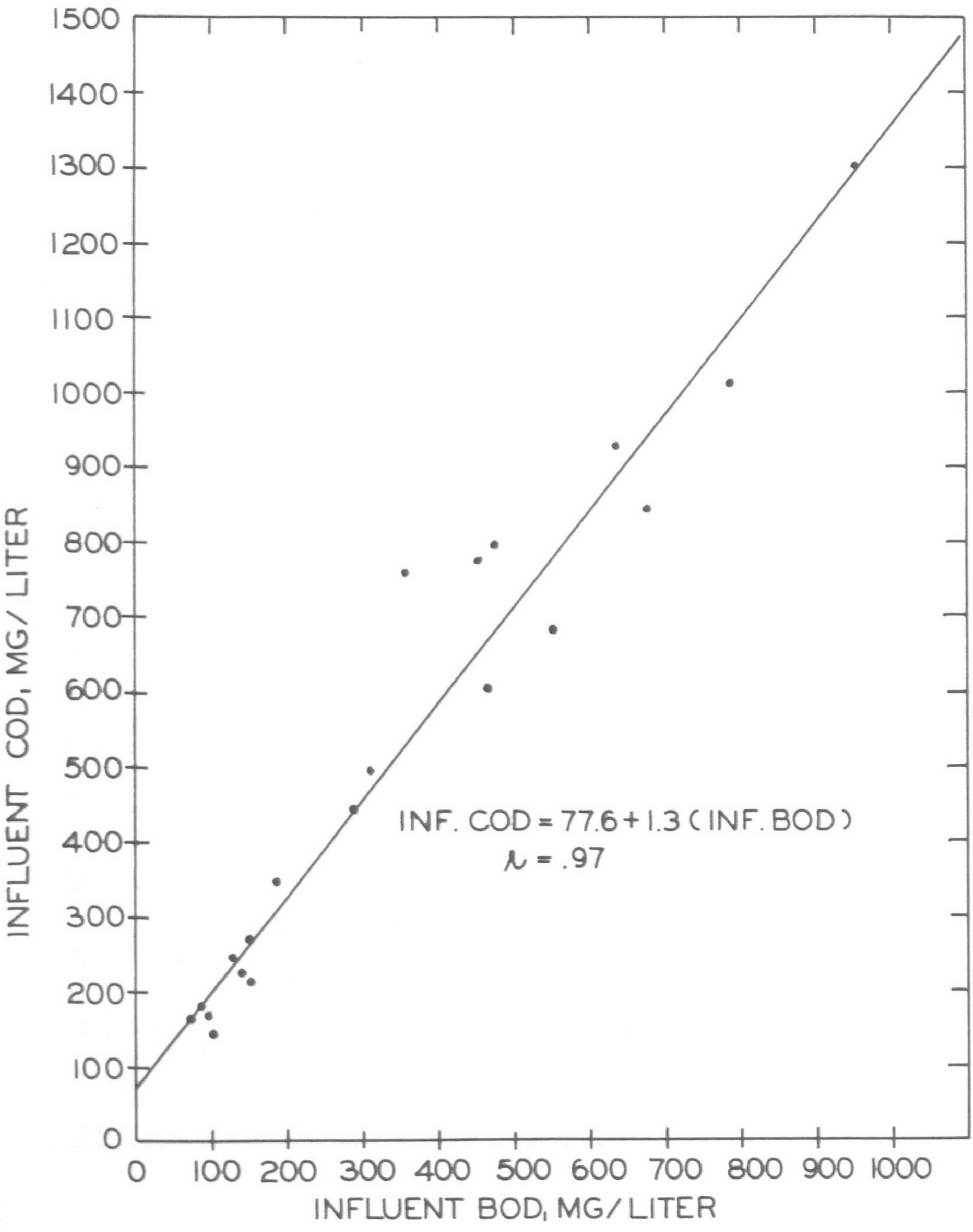


FIGURE 12. BOD VS. COD FOR BORDEN'S CASCO S-230

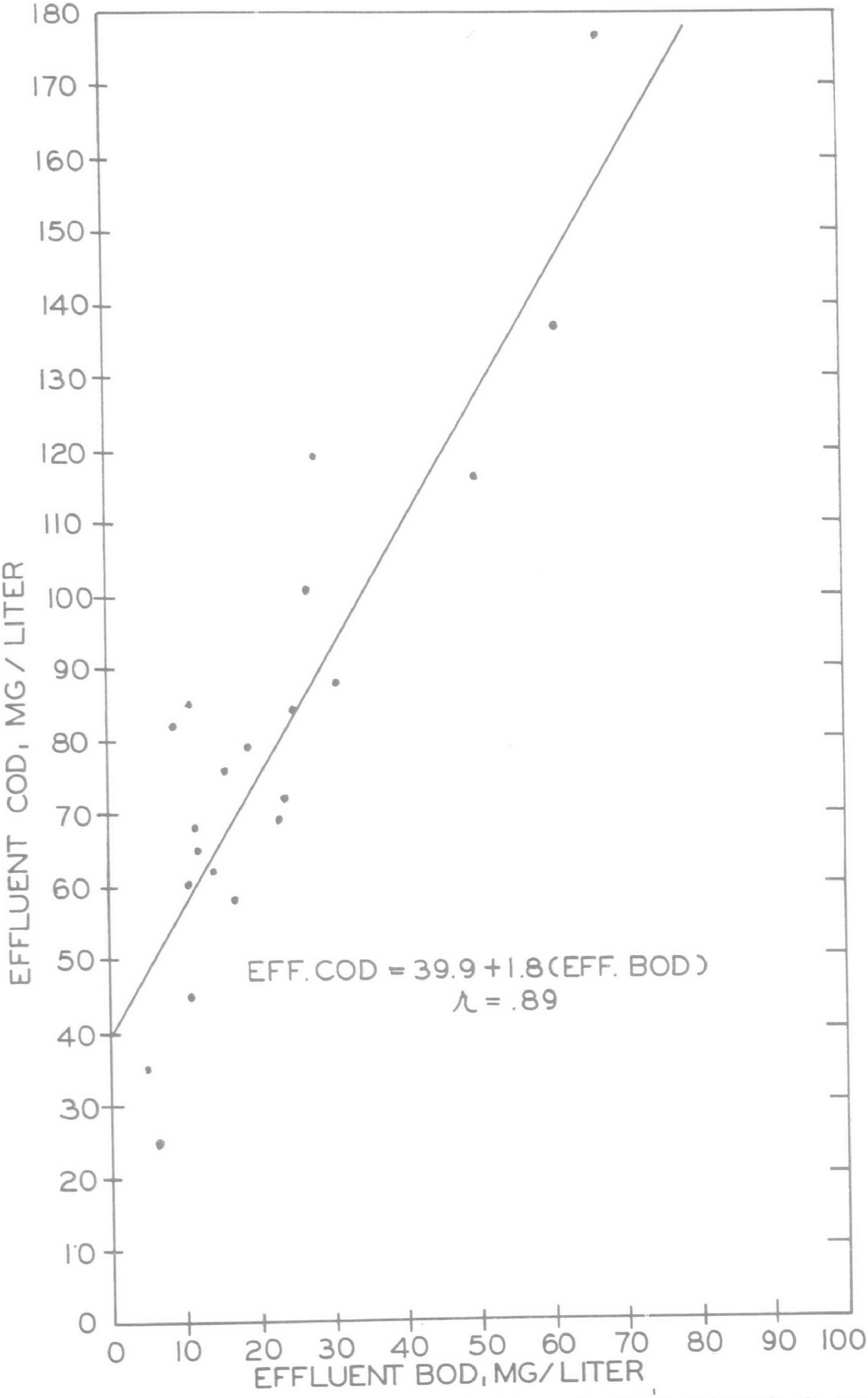


FIGURE 13. BOD VS. COD FOR BORDEN'S CASCO S-230 PROTEIN GLUE

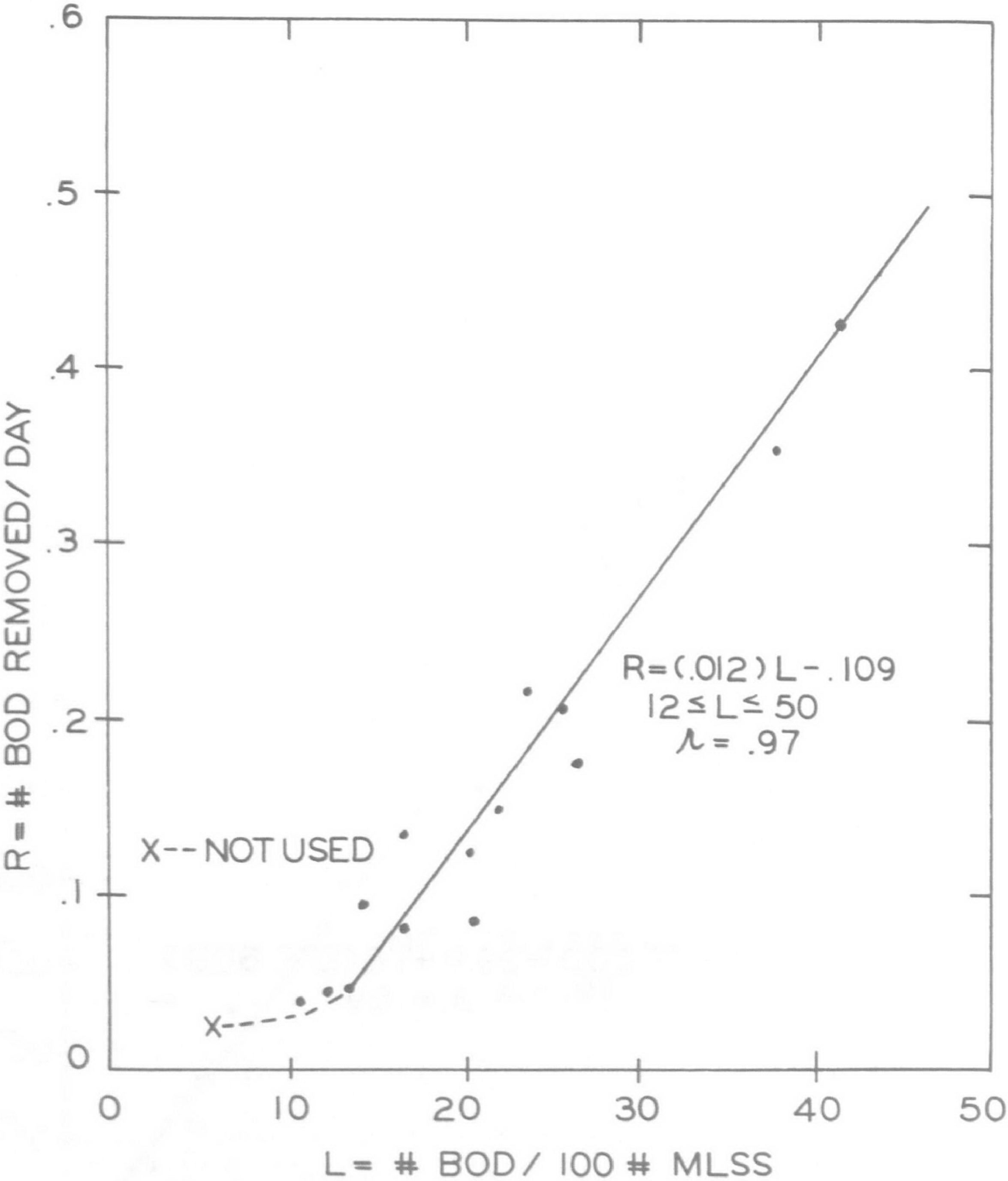


FIGURE 14. INFLUENCE OF LOADING ON BOD REMOVAL FOR BORDEN'S CASCO S-230 PROTEIN GLUE

as follows:

$$\text{lb BOD Removed/Day} = (.012)\ \text{lb BOD/100 lb MLSS} - .109$$

$$12 \leq \text{lb BOD/100 lb MLSS} \leq 50$$

$$r = .97$$

Although good removals were obtained on the protein glue, some operational problems were encountered. The largest problem was with Sphaerotilus growth in the mixed liquor which bulked the sludge and caused a considerable problem in settling. This problem was solved by raising the pH of the aeration tank to 11.0 with calcium hydroxide ($Ca(OH)_2$) which killed all the biological life. The pH slowly subsided and in approximately 10 days, the biological life, minus the Sphaerotilus, had returned. The problem occurred twice during the operation with the protein glue.

By employing a conventional activated sludge system, protein glues were efficiently treated, and it is probable that other forms of biological treatment would prove feasible. Problems encountered appear to be no worse than those in a domestic system.

Phenolic Glue Studies

Studies involving the biological treatment of phenolic glue were conducted for a four month period. At the end of this time, the studies were discontinued as no results of any consequence had been attained.

The pilot plant at start-up utilized some of the mixed liquor from the protein glue aeration tank, at a loading of 5 lb COD/100 lb MLSS. Because the phenolic glue was low in inorganic nutrients, these were added in the forms of ammonium hydroxide (NH_4OH) and phosphoric acid (H_3PO_4) to bring the COD/N/P ratio up to 100/5/1. For a short time, the system appeared to be operating normally. However, after three or four weeks, the solids began to drop off in the aeration tank.

The problems associated with the pilot plant were complicated in that laboratory BOD data could not be obtained on the phenolic glue. The phenol concentrations, while quite high (514 mg/kg), were still in the approximate range of 500 mg/l found by McKinney et al. to be biologically treatable with proper acclimation[10/]. Special seed acclimazation studies were performed to no avail.

The plant was started up again using a mixed feed of protein and phenolic glue. This approach worked for a longer time than the first, but it too eventually failed.

A third attempt was made. This time raw sewage, bottom muds from an outfall near a phenolic waste discharge, and mixed liquor from the protein glue aeration tank were used in an effort to acclimate a group of organisms to degrade the glue. This, too, ended like the others.

In conclusion, all attempts to acclimate the biological system to treat phenolic glue resulted in failure. If a system could, in fact, be acclimatized, the operational problems involved would require skilled supervision which, in most cases, would not be provided.

Urea Glue Studies

Studies involving urea glue were conducted on two different activated sludge systems, the second a result of special pilot plant studies done in connection with a Federal demonstration grant.

The urea glue studies were started when the protein glue work was finished. Mixed liquor used for the protein glue was fed into the urea waste and no problems were encountered. Inorganic nutrient levels in the urea glue were adequate so no nutrients were added. After running one and one-half months at 16 hours detention time, the second system, with a detention time of five days, was initiated. The system, run at 16 hour detention time, included both primary and secondary treatment, whereas secondary treatment only was used in the 5-day detention time study.

Table 19 lists the results of the urea glue tests to date. As can be seen, excellent BOD and suspended solids removals were achieved with both systems. The BOD removals

TABLE 19

BIOLOGICAL TREATMENT OF UREA GLUE[a/]

Detention Period	Loadings Lb BOD/100 lb MLSS	% Removal[b/] BOD	SS
16 hours	10.3	81	72
16 hours	10.7	84	91
16 hours	14.7	89	97
16 hours	17.9	90	92
5 days	4.3	90	93
5 days	23.3	98	98
5 days	24.9	94	97
5 days	28.4	94	96
5 days	30.0	87	87
5 days	30.7	93	98
5 days	44.8	96	98

[a/] Borden's Casco Resin 5H

[b/] 16 hour; Primary & Secondary
5 Day; Secondary

ranged from 81 to 98 percent and those for suspended solids from 72 to 98 percent.

The only problem encountered was fermentation, believed to have been caused by allowing the feed to set too long before a new batch was made. To remedy this situation, feed was prepared each day. The plant was dumped and started up again using mixed liquor from a municipal treatment plant. Within a week and a half, the mixed liquor in the aeration tank was over 2,000 mg/l which indicates that urea glue wastes are amenable to biological treatment.

Solids production was very high for the biological system used and preliminary figures indicate that the cost and problems involved in the solids handling phase of treatment may make the system prohibitive.

Physical-Chemical Treatment Studies

Neutralization

Due to the high pH of both the phenolic and protein glue, neutralization was investigated. Neutralization was envisioned not only as a possible complete treatment process, but also as a necessary pretreatment step to subsequent processes or discharge to municipal treatment systems or receiving waters. The investigation of the process of neutralization involved preparing titration curves for the various glue wastes plus bench scale studies.

Figure 15 shows titration curves for the alkaline, phenolic and protein glues while Figure 16 is for the slightly acidic urea glue. As can be seen, the phenolic and protein glues are highly buffered, requiring large amounts of acidity for neutralization. The urea glue, by comparison, is only slightly acid and, therefore, was not studied further.

Bench scale studies were conducted to evaluate such parameters as COD and TOC reduction and sludge production. These studies were conducted by using a specified concentration of glue in water. Equal volumes of this mixture were placed in beakers to which varying amounts of neutralizing agent were added. The solutions were mixed at 90 RPM's for five minutes and allowed to settle for four hours after which samples of the supernatant and sludge were withdrawn for analysis. Three different neutralizing agents: alum ($Al_2(SO_4)_3 \cdot 18H_2O$), sulfuric acid ($H_2SO_4$), and hydrochloric acid (HCl) were tested on the protein glue, while only sulfuric acid and alum were tested on the phenolic glue. Figures 17 and 18 show the results of these investigations for the protein and phenolic glues, respectively. In these figures, COD or TOC per gram of glue for the supernatant is plotted against pH. Optimum dosages of chemical were arbitrarily chosen where minimum TOC or COD in the supernatant was attained with minimum chemical added. These optimum treatment dosage points are shown by X's on the

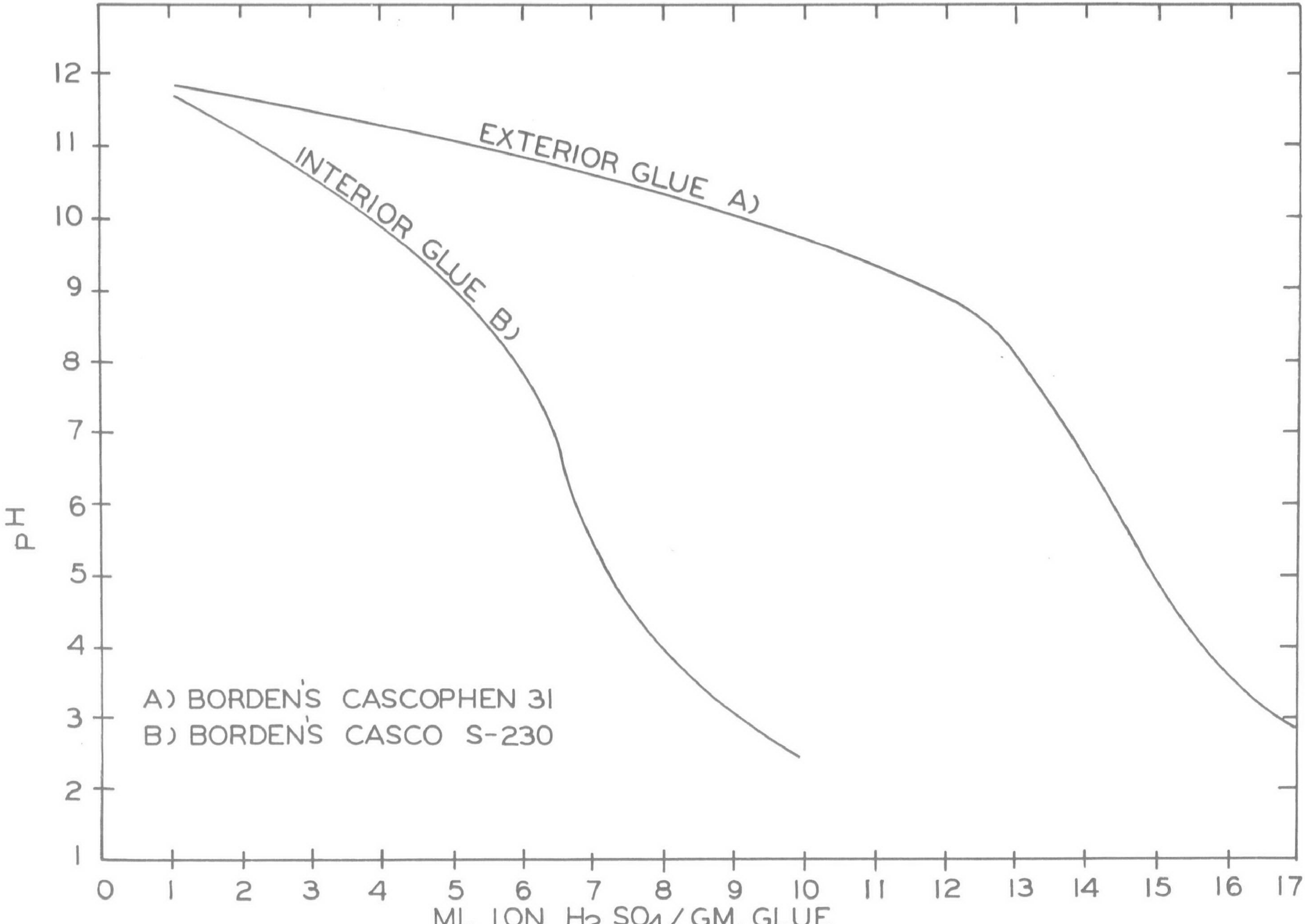


FIGURE 15. TITRATION CURVES FOR PHENOLIC & PROTEIN GLUE

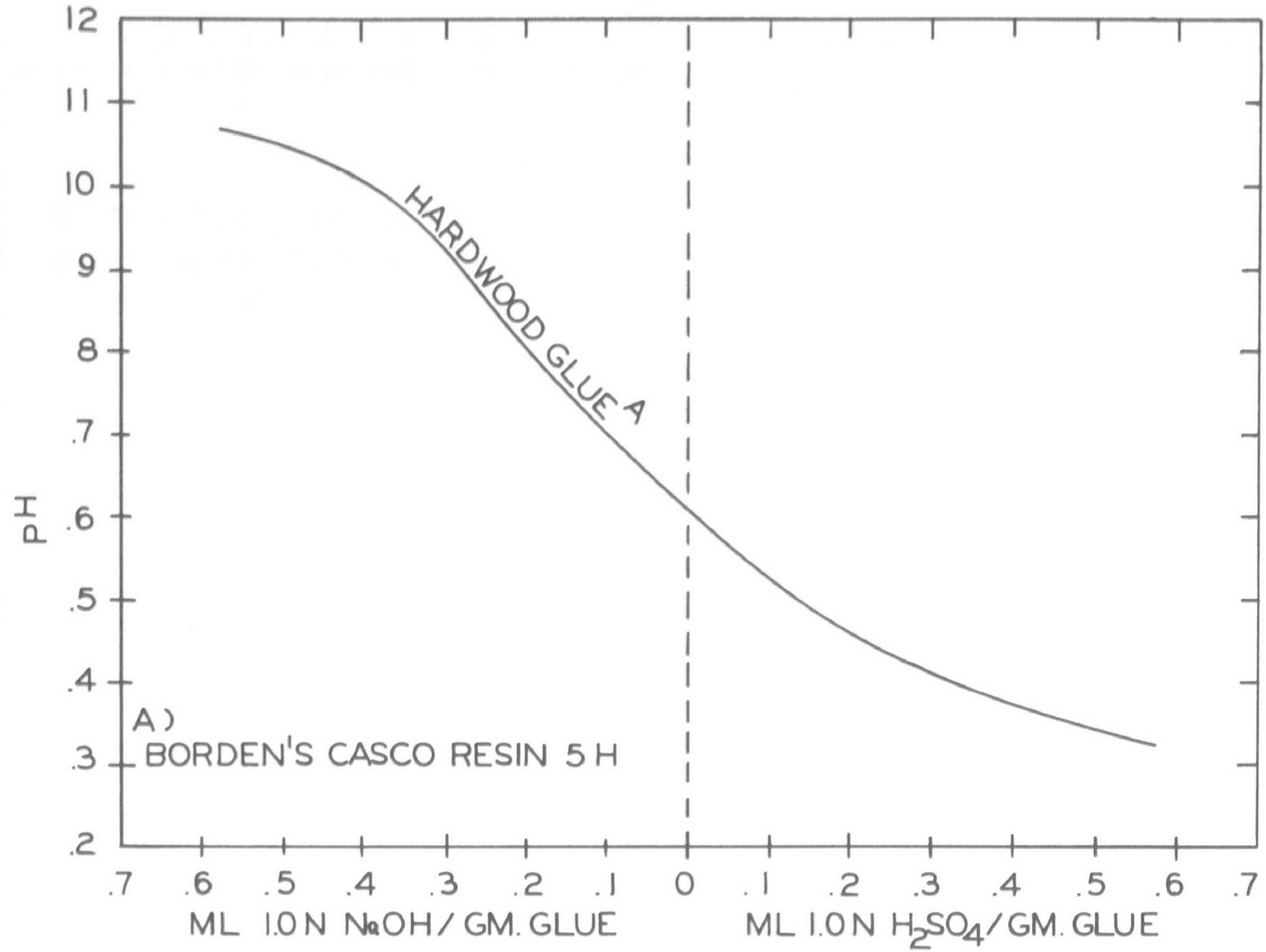


FIGURE 16. TITRATION CURVE FOR HARDWOOD GLUE

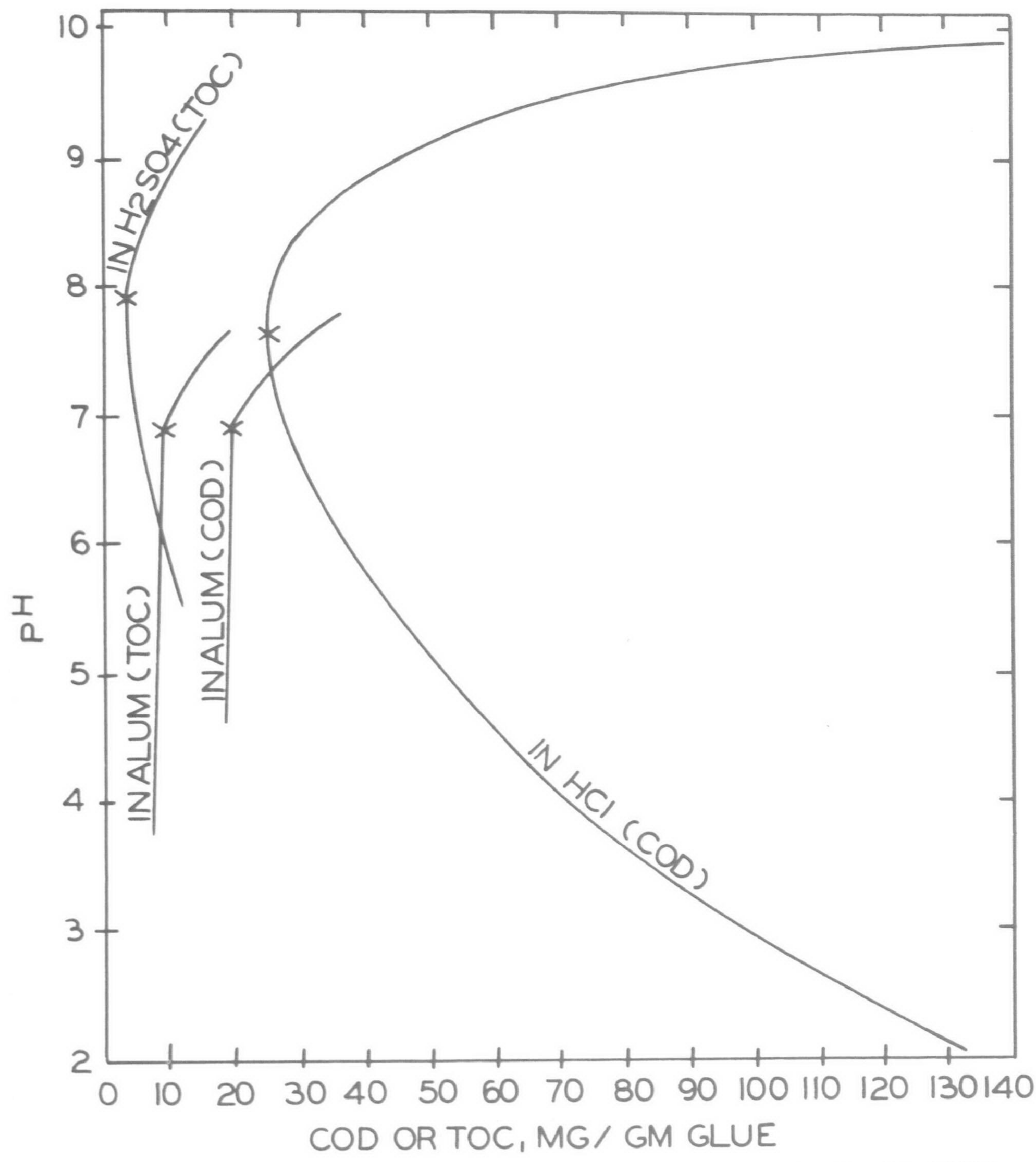


FIGURE 17 COD AND TOC OF SUPERNATANT VS. pH FOR PROTEIN GLUE

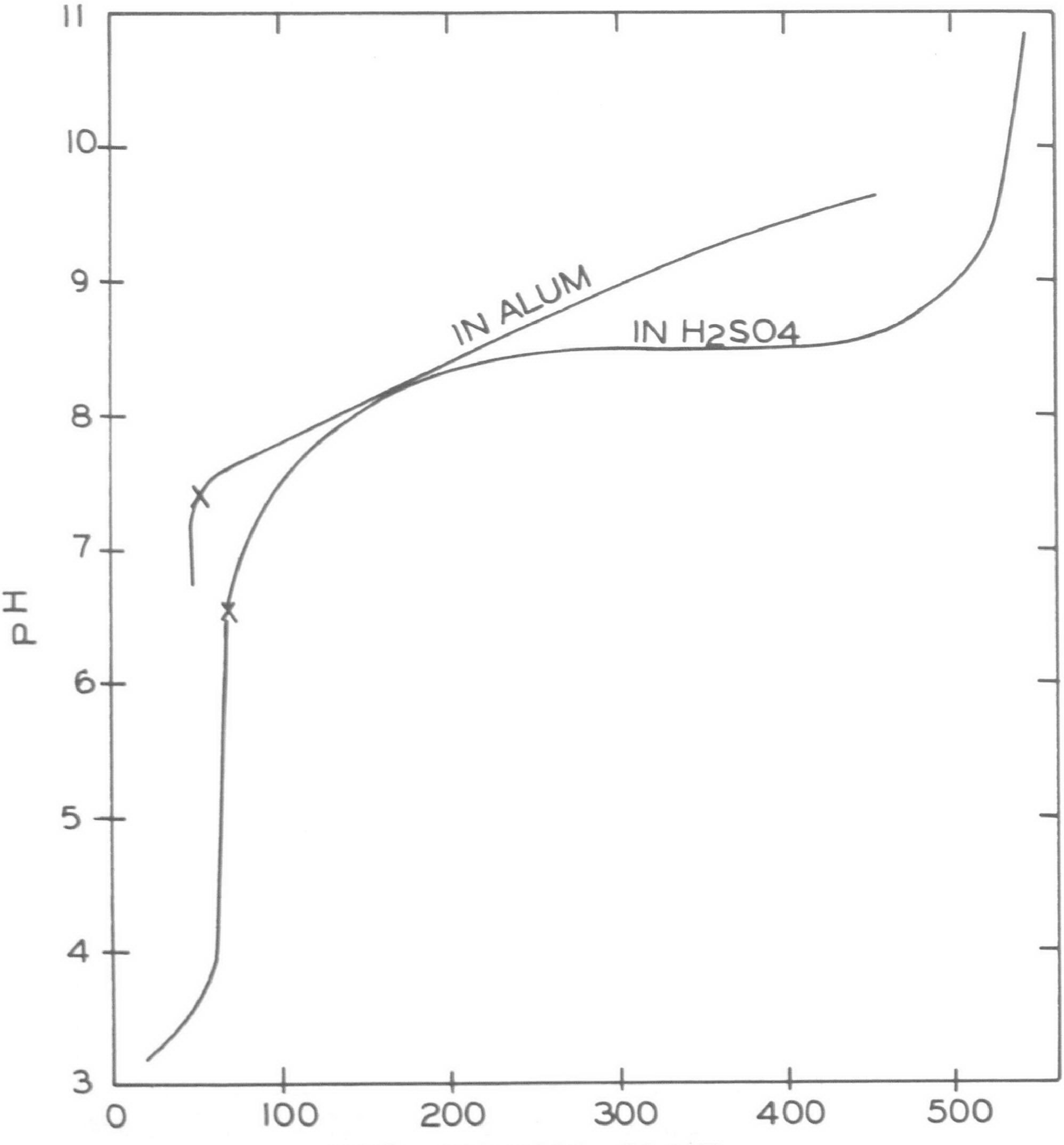


FIGURE 18. COD OF SUPERNATANT VS. pH FOR PHENOLIC GLUE

curves. As can be seen, most of the points are very close to a pH of 7.0. Tables 20 and 21 compare the various neutralizing agents at the optimum dosages. For the protein glue, H_2SO_4 has the cheapest chemical cost and produces the best supernatant. For the phenolic glue, alum produces the best supernatant, but H_2SO_4 produces less sludge and has a lower chemical cost. Virtually, 100 percent removal of COD was obtained by neutralization of protein or phenolic glue with either acid or alum. When alum was used on the phenolic glue, it was evident that some flocculation was taking place as well as neutralization. This flocculation accounts for the greater removal of COD and for the increased sludge production. It is emphasized that, in the final analysis, chemical costs may be small in comparison to other costs such as these associated with chemical feeding and sludge handling.

Table 21 shows that large volumes of sludge are produced from the neutralization of phenolic glue. For acid neutralization, 40 ml of sludge/gm of glue (.65 ft^3/lb glue) were produced as compared to 60 ml/gm glue (.98 ft^3/lb glue) for alum neutralization. These large amounts of sludge could present many problems, especially if they proved hard or expensive to dewater.

From the standpoint of producing a dischargeable effluent, neutralization or neutralization-flocculation has proved a feasible process. However, problems associated with the great amount of sludge produced make other alternative processes more attractive.

TABLE 20

NEUTRALIZATION OF PROTEIN GLUE WASTE[a/]

	Acid (1N H_2SO_4)	Alum (1N $Al_2(SO_4)_3 \cdot 18H_2O$)	Acid (1N HCl)
Optimum Treatment Dosage, ml/gm glue	0.63	0.67	0.62
COD supn't, mg/gm glue[b/]	--	19.5	26.0
TOC, supn't, mg/gm glue [c/]	3.2	9.0	--
pH	7.9	6.9	7.6
Cost of Chemicals/ 100 lb glue	$.16	$.36	$.34

[a/] Borden's Casco S-230

[b/] Initial COD, 176,000 mg/gm glue

[c/] Initial TOC, 52,000 mg/gm glue

TABLE 21

ALUM VS H_2SO_4 FOR NEUTRALIZATION OF PHENOLIC GLUE WASTE[a/]

	Acid (1N H_2SO_4)	Alum (1N $Al_2(SO_4)_3 \cdot 18H_2O$)
Optimum Treatment Dosage, ml/gm glue	1.38	1.40
COD supn't mg/gm glue[b/]	67.0	50.0
pH	6.8	7.4
Total gms solids produced/ gm glue	0.24	0.46
Total Volume sludge, ml/gm glue	40.0	60.0
Cost of chemicals/100 lb glue	$.35	$.75

[a/] Borden's Cascophen 31

[b/] Initial COD, 653,000 mg/gm glue

Incineration of Waste

Due to the low volume of waste, high organic content of the waste, and availability of existing sources of heat, disposal by incineration offers a promising solution to the glue waste problem.

Three of the plants surveyed are at the present time using waste burners to dispose of their glue wastes. Because these metal "teepees" burn rather inefficiently and their use may be prohibited in the near future, some other means of incinerating is needed. One large corporation is considering using its Dutch ovens which burn at temperatures of 1800 to 2000°F. If sander dust is burned, the temperature can go as high as 2500°F.

An ash test was made on samples of protein and phenolic glue. These were run at 600°C (1112°F) and at 1000°C (1832°F). The results of these tests are shown in Table 22. The tests indicated that at 1000°C (1832°F) very little ash remains. The protein glue produced 4.12 and 23.40 percent ash, based upon wet and dry weight, respectively, at 1000°C (1832°F). The phenolic glue produced 6.12 and 15.76 percent ash, based upon the wet and dry weight, respectively, at 1000°C (1832°F). A plant with three spreaders running six spreader shifts per day and washing down at each shift would generate about 12 pounds of ash per day. This is a small percentage of the total ash produced in a furnace of the type now used at plywood mills.

TABLE 22

INCINERATION TEST FOR PHENOLIC, PROTEIN AND UREA GLUE

Glue	Based on Wet Weight of Glue % Ash @ 600°C	% Ash @ 1000°C	Based on Dry Weight Glue Solids % Ash @ 600°C	% Ash @ 1000°C
Phenolic[a/]	4.58	4.12	26.08	23.40
Protein[b/]	13.37	6.12	34.48	15.76
Urea[c/]	Nil	Nil	Nil	Nil

a/ Borden's Cascophen 382

b/ Borden's Casco S-230

c/ Borden's Casco Resin 5H

Examining Table 13, one sees that incineration offers the best potential for urea glue waste disposal as the solids are nearly 100 percent volatile. For this reason, the percent ash values in Table 22 are reported as nil.

If incineration is to be used as a disposal method, certain problems must be overcome. One of the biggest of these problems is in transporting the glue waste from the spreaders to the incinerator. Plugging must be minimized so that maintenance of pumps and lines is low.

Another problem lies in injecting the waste into the furnace. Many attempts to use spray nozzles have failed due to plugging problems. The best alternative seems to be in applying the waste to the hog fuel before it is burned.

Questions involving potential air pollution and scaling of burners must also be answered before incineration is an acceptable method of disposal.

Wastewater Reuse

A southern Oregon plywood plant has implemented a reuse system which has successfully solved its waste disposal problems. This plant has two spreaders which run for five spreader shifts per day. Annual production is around 100,000 square feet (3/8-inch basis) all of which is exterior grade. Seventeen to 18 batches of glue per day are mixed requiring 535 pounds of water per batch for an approximated total of 1,150 gallons. Spreaders at the plant are rinsed once per shift and washed once per day. The mix tanks are scraped but not washed before each batch mix. Lines from the glue storage tank to the spreaders are never flushed out and no problems have resulted in three and one-half years of operation. The plant superintendent claims that by excluding air from these lines they will never plug. Before rinsing or washing down the spreaders, all excess glue is scraped from the rollers and the pan. Very little water is then required to wash off what remains. Instead of the common 1- or 1 1/2-inch water line for washing, a 1/2- or 3/4-inch hose has been found to be adequate. Using these practices, the total waste volume runs less than 1,150 gallons per day.

The waste flows from the spreaders to a 1,000 to 2,000 gallon settling tank. Before entering the tank, the waste drops through a 1/8-inch screen which removes the chips, knots and larger glue solids. These solids are periodically dumped into a hopper to drain further before they are burned. The solids which settle in the tank are pumped out on the average of every two months. These solids are disposed of at a sanitary landfill. A 1/2-horsepower irrigation pump pumps the liquid from the tank through a 1-inch plastic line to a 1,000-gallon storage tank located on the roof of the plant directly over the glue mixing area. Flat valves in the two tanks control the operation of the pump. Steam is used in winter to keep the waste in the roof storage tank from freezing. However, this problem could be overcome by locating the tank inside the plant. Figure 19 is a schematic drawing of the waste reuse system. Figure 20 shows a picture of the settling tank and roof storage tank.

The cost of the system, minus the settling basin and lines to it from the spreaders, was estimated at $500. Besides solving the waste problem, the company actually received other benefits from their system. First, they have reduced the amount of caustic needed in making their glue, due to the caustic returned in the waste. Secondly, they have increased the resin content of their mix, thus producing a better adhesive. They have also increased the viscosity of their glue, much to the surprise of the glue manufacturer.

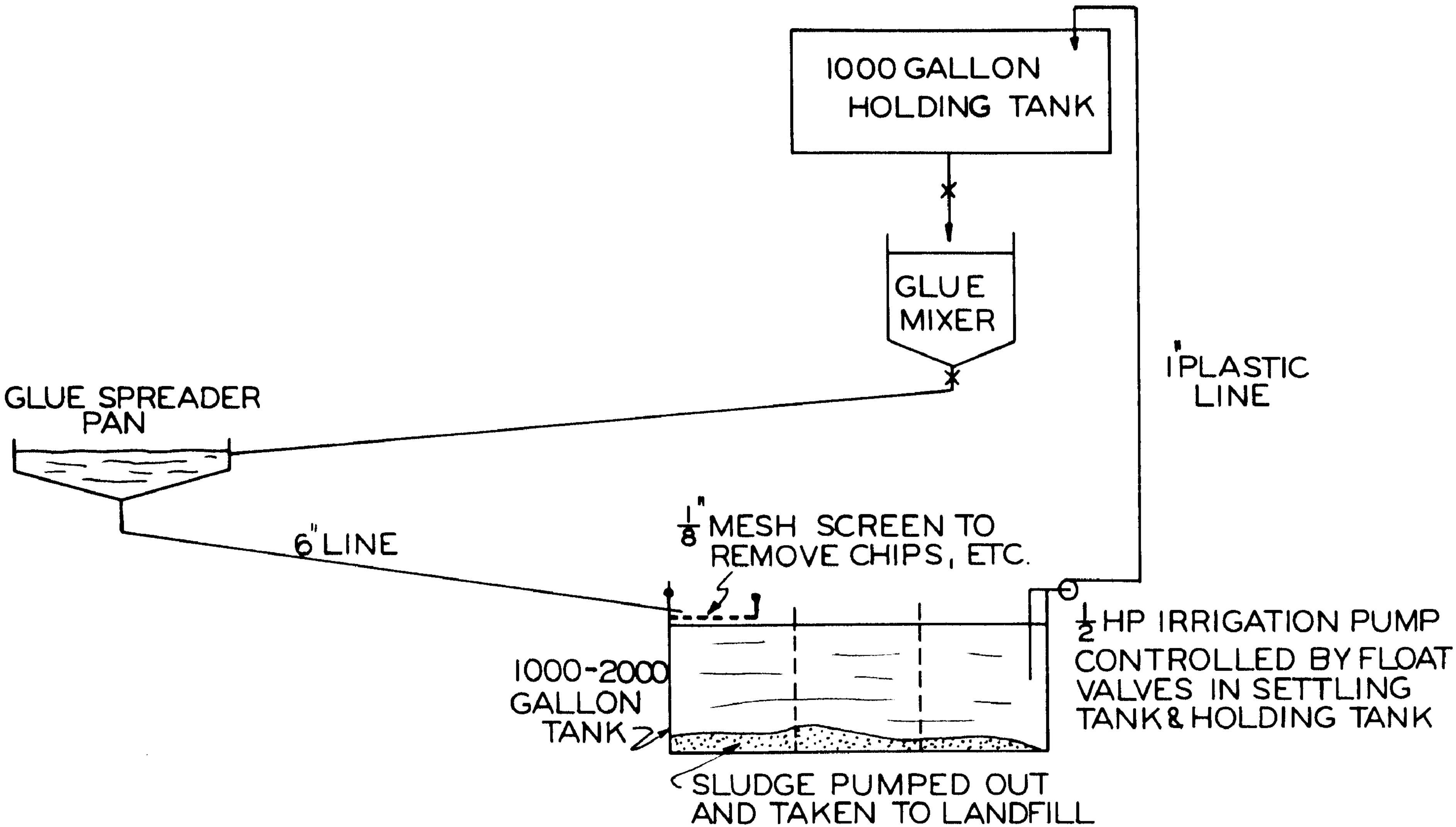


FIGURE 19. REUSE SYSTEM FLOW DIAGRAM

FIGURE 20. REUSE SYSTEM SHOWING SETTLING TANK, PUMP AND ROOF STORAGE TANK

The system might be further improved by using some steam for cleaning metal parts and teflon-coated glue pans for easier clean-out.

Reuse, as employed at this plant, could be utilized at any plant where phenolic glues are used. Reuse systems for wastes from protein and urea glue are not being employed at the present time, but should be tried. If the plant uses different glues, the wastes must be kept separate if reuse is to be practiced. Important in this southern Oregon plant's reuse of its wastewater is the great reduction in volume of washwater that can be achieved through better in-plant practices.

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DEFINITION OF TERMS

Algae -- Simple plants, many microscopic, containing chlorophyll.

Biota -- All the living organisms of a region.

BOD -- Biochemical Oxygen Demand. A measure of the amount of oxygen required for the biological decomposition of dissolved organic solids to occur under aerobic conditions and at a standardized time and temperature.

COD -- Chemical Oxygen Demand. A measure in terms of the amount of oxygen required to chemically oxidize all organic compounds, with a few exceptions, and some reduced inorganic compounds.

Cold Deck -- A method of log storage where logs are stacked in piles and kept wet to prevent checking by use of sprinklers located on top of the stack.

Conductivity -- Referred to as specific conductance at a specified temperature (25°C). The opposite of resistance and used as a measure of the concentration of total ionized solids in water. Reported in micromohos (μMHOS).

Dissolved Solids -- Solids which are in solution.

Exterior Grade Plywood -- Plywood made with 100 percent waterproof glue and a high grade veneer.

Fauna -- The entire animal life of a region.

Flora -- The entire plant life of a region.

gpm -- Gallons per minute.

Green End -- Portion of a plywood plant involving the storage and handling of logs through the process of turning them into veneer.

Interior Grade Plywood -- Plywood made with a moisture resistant (but not waterproof) glue.

µg/l -- Micrograms per liter (1000 µg/l = 1 mg/l).

mg/l -- Milligrams per liter (100 mg/l = 1 gm/l).

mgd -- Million gallons per day.

MLSS -- Mixed liquor suspended solids.

pH -- The negative log of the hydrogen ion concentration. The pH scale is usually represented as ranging from 0 to 14, with a pH of 7 representing neutrality. Acid conditions increase as pH values decrease, and alkaline conditions increase as pH values increase.

Phenols -- (C_6H_5OH). The monohydroxy derivative of benzene, known as carbolic acid. Phenols are waste products of oil refineries, coke plants, and some chemical producing facilities. Phenols are used extensively in the synthesis of phenolic type resins. Concentration of phenols in the order of .01 to .1 mg/l are detectable by taste and odor tests.

Phytoplankton -- Plant Microorganisms, such as certain algae, living unattached in the water.

Plankton -- Aquatic plant and animal organisms of small size, mostly microscopic, that have relatively small powers of locomotion or drift in the water subject to wave action and currents.

Sphaerotilus sp. -- Slime-forming bacteria.

Spreader Shift -- One spreader running one shift (8 hours).

Supernatant -- The liquid overlaying the solids which have settled.

Suspended Solids -- Solids that float on the surface or are in suspension in water, sewage, or other liquids.

TL_m -- Medium tolerance limit. The concentrations of material which 50 percent of the test animals can survive for the length of the test period.

TOC -- Total Organic Carbon. Reported as carbon (C).

Total Kjeldahl Nitrogen -- Organic nitrogen and nitrogen in the form of ammonia (NH_3). Does not include nitrogen in the form of nitrates (NH_3^-) and nitrites (NO_2^-).

Total Phosphate -- Phosphorus in organic and inorganic forms. Phosphorus and nitrogen are nutrients necessary for maintaining biological growth.

Total Solids -- The sum of the suspended and dissolved solids.

Total Volatile Solids -- The quantity of solids in water, sewage, or other liquids lost on ignition of the total solids at 600°C (1112°F).

Total Volatile Suspended Solids -- The quantity of solids in water, sewage, or other liquids lost on ignition of the suspended matter at 600°C (1112°F).

Veneer -- A thin sheet of wood turned off a log by a lathe and used in the production of plywood.