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STATE OF THE ART: Wastewater Management in the Beverage Industry

Industrial Environmental Research Laboratory
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STATE OF THE ART:
WASTEWATER MANAGEMENT IN THE BEVERAGE INDUSTRY

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DISCLAIMER

FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This study was designed to investigate, primarily through literature, the impact of beverage industry wastes on water pollution and the methods available to combat the associated problems. The report includes the malt liquor, malting, soft drink, flavoring, wine and brandy, rum, and distilled spirits industries. For further information contact the Food and Wood Food and Wood Products Branch of IERL-Ci.

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ABSTRACT

The general purpose of this paper is to investigate, through the literature, the water pollution impact caused by the wastes from the beverage industry and the methods available to combat the associated problems. The size of each industry is discussed along with production processes, wastewater sources and effluent characteristics. Wastewater management techniques are described in terms of in-plant recycling, by-product recovery and end-of-pipe treatment along with the economics of treatment.

The malt liquor, malting, soft drinks and flavoring industries primarily dispose of their effluents in municipal sewers. In-plant recycling and by-product recovery techniques have been developed in these industries to reduce their raw waste load. The wine and brandy and distilled spirits industries in many cases must treat their own effluents so they have developed wastewater management systems including industry-owned treatment plants that yield good effluents. The technology to adequately treat rum distillery wastewater has not been demonstrated.

The information basis for this paper was a literature search, an effluent guidelines report done for EPA, limited site visits, personal communications and an unpublished report conducted for EPA that included questionaire surveys of the industries.

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LIST OF ABBREVIATIONS AND CONVERSION FACTORS

ABBREVIATIONS

%	--percent
bbl	--barrel
BOD	--biochemical oxygen demand
BOD_5	--5-day biochemical oxygen demand
bu	--bushel
°C	--degrees Celsius
cm	--centimeter
COD	--chemical oxygen demand
cu yd	--cubic yard
gm	--gram
gpd	--gallons per day
gpm	--gallons per minute
ha	--hectare
kg	--kilogram
kkg	--1000 kilograms
kw-hr	--kilowatt-hour
l	--liter
lb	--pound
m	--meter
mg	--milligram

ABBREVIATIONS

MGD, mgd	--million gallons per day
mgy	--million gallons per year
ml	--milliliter
sec	--seconds
SIC	--standard industrial classification
ss	--suspended solids
yr	--year

CONVERSION FACTORS

3.785 l = 1 gal = 128 ounces

31 gal = 1 barrel (beer)

.4536 kg = 1 lb

1 bushel = 0.03524 m^3

(a) barley = 21.7 kg

(b) malt = 15.4 kg

(c) distillers grain = 25 kg

metric ton = 1000 kg

1 hectare = 2.471 acres

SECTION I

INTRODUCTION

The U.S. beverage industry is very large and diversified with total shipments worth over $14 billion in 1974 (67). This report will cover the extent and type of wastewater produced by this industry along with wastewater management schemes that have been either employed or investigated.

Available literature was used as the primary information basis and over 80 references are cited. This was accomplished by personal survey, three computer conducted searches and the cooperation of the representative trade associations. The libraries of certain trade associations contain an excellent collection of waste management related literature.

A second source of information is an unpublished report. This was a questionnaire survey of the beverage industry conducted for EPA under Contract No. 1412-914. A few personal contacts with people in the industry were made to obtain specific information along with a general overview of the industry.

The beverage industry was divided into six segments for study. They are listed below with their standard industrial classification number, production value, and wastewater volume (61, 64, 66, 67).

SIC	Industry	Production 10^9 \$/yr	Wastewater Volume 10^6 m^3/yr (1968)
2082	Malt Liquor	$4.8/74	220
2083	Malt Industry	0.22/67	30
2084	Wine and Brandy	1/74	11
2085	Distilled Liquors Except Brandy	1.6/74	68
2086	Canned and Bottled Soft Drinks	6.5/74	23
2087	Flavorings and Extracts	1.5/71	3.8

The approach used to describe each industry and its water pollution control problems is basically the same. The location of each industry is investigated, including geographical location within the United States, as is the associated climate (if it is a factor) plus the industry's proximity to population centers (rural or urban). Total size of each industry is included along with individual plant sizes where they are relevant. Growth projections for the industries are also included.

A general production scheme is given for each industry because individual processes can vary between facilities. This general scheme is also used to identify the specific wastewater sources. Whenever the information was available, these sources along with the total effluent were characterized using standard water quality parameters.

This report discusses the wastewater management techniques that have been used or investigated by each industry. These management methods are discussed in terms of recycling, by-product recovery and wastewater treatment. An economic analysis of these methods proved very difficult in many cases. Frequently, no cost data are presented in the original articles or they may be too old to be relevant. However, costs estimates are made where they are feasible and are presented in Section IX.

SECTION II

SUMMARY AND CONCLUSIONS

Waste management in the malt liquor industry is generally split between the small and large breweries with respect to the extent of recycling and by-product recovery. The smaller breweries are more likely to sewer the spent grain press liquor, trub, excess yeast, and lost beer, and dispose of spent grains and hops wet. The larger breweries are involved in recycling and by-product recovery to varying degrees. The technology exists for extensive by-product recovery and with increasing municipal surcharges, the practice of this technology is likely to increase.

Only two breweries operate their own wastewater treatment systems. With the present trend to locate in rural areas and smaller towns, the possible contribution to the municipal treatment system will become more significant. This will necessitate the expansion of municipal systems to handle the brewery waste which is high in organics, solids, and volume, and is variable in flow and strength.

The malt industry is a large discharger of wastewater with over 7000 liters per 1000 kg of barley processed. Approximately 80 percent of the plants discharge to municipal treatment and can contribute up to 20 percent of the flow and 50 percent of the BOD_5. The wastes present no unusual waste treatment problems if the system is designed to handle the industry's contribution.

By-product recovery is very limited in the malting industry, but a potential exists for utilizing the malt sprouts and roots. These can be combined with spent grains, hops, and trub from brewery operations to produce a cattle feed. This would require a convenient source of these wastes from the brewery operation and may not be practical for malt houses operating independently from breweries.

The mode of wastewater management in the wine industry is dependent upon whether the winery operates a still and upon the geographic location. Brandy stillage can be a problem due to its high BOD_5 (10,000 mg/l), SS, and acidity. These characteristics along with the seasonal nature of the industry make it difficult to treat by conventional biological methods. At the present all U.S. brandy distilleries are located in California's central valleys. The conditions there, hot, dry summers and sandy soils, make for ideal land disposal of both stillage and winery wastes. Eastern wineries require biological treatment due to heavier rainfall, cooler climate, and the recreational nature of lakes and streams receiving their discharge.

By-products of the wine industry are the fertilizer and soil conditioner values of pomace and stems. Pomace is also successfully blended into livestock feed.

A potential exists for tartrate recovery and grape seed oil production. The tartrate is contained in the pomace, stillage, lees, and argols. The technology exists for recovery of tartrate from each of these sources, but the market is such as to not make it feasible at present.

Grape seed oil, produced in Europe since World War I has the characteristics of a good salad oil. The flavor is pleasant, it is resistant to clouding at cool temperatures, and is stable while frying. Production of the oil is not practiced in the United States at present.

Grain distilleries have a wastewater that is a potentially strong, high volume effluent. Complete or partial recovery of the spent grains, widely practiced in the industry, is essential in reducing the waste load. The smaller distilleries haul the spent grains away wet as livestock feed while the larger ones operate a R"dry house" to concentrate the stillage for both livestock and poultry feed. Treatment of the remaining wastes in biological treatment systems has been successful and about 50 percent of the plants discharge to municipal systems.

Rum producing distilleries have a stillage waste that is of high temperature, 80-90°C, high strength, BOD_5 of 60,000 mg/l, and has a dark brown color. Due to the predominantly soluble nature of the stillage solids, recovery is not practiced on a commercial scale. Promising pilot-plant work might lead to full-scale by-product recovery of potassium salts from the stillage.

Biological treatment methods center mainly on anaerobic systems due to the high oxygen demand of an aerobic system treating these wastes. Methane recovery has possibilities in reducing treatment costs by anaerobic methods. For treatment prior to discharge, an aerobic system with solids removal would be needed following the anaerobic system. Most of the rum distilleries are located in Puerto Rico where the wastewaters are not treated prior to disposal.

The soft drink and flavoring and extracts industries almost universally discharge to municipal treatment where they produce no significant problem. Wastewater form the soft drink industry is chiefly bottle washing and rinsing and washwater is the main waste generator in the flavoring and extracts industry. For both industries, water conservation will significantly reduce the wastewater volumes.

Estimated yearly capital and operating costs of treatment for the industries using activated sludge vary from $49,000 for a typical soft drink canner to $3.1 million for an old large brewery. Surcharges for municipal treatment vary but have been estimated from $8.00 to $2700/mo depending on the strength and volume of the wastewater.

SECTION III

S.I.C. 2082 MALT LIQUOR

Industry Description

The malt liquor industry in the United States is the world's largest with total sales of 17.4 million m^3 in 1973 worth $4.3 billion. Per capita consumption was 112 l/yr in 1973. The brewing industry is a very heavy user of water with about 100 facilities discharging in excess of 230 million m^3 of wastewater/yr (67).

Breweries are scattered through the United States with most large facilities located in or near large urban areas. In recent years, the southern states as a geographical area have shown the greatest percentage increase in production but the north central states still account for 45 percent of the total U.S. brewing capacity. Table 1 gives geographic distribution of U.S. breweries.

TABLE 1. GEOGRAPHIC DISTRIBUTION OF BREWERIES AND CAPACITY, 1974 (39)

Region	Plant Numbers	Percent	Total Year Capacity 10^6 m^3 (10^6 bbl)	Percent
Northeast	30	30	3.67 (31.3)	20
North Central	30	30	8.34 (71.1)	45
South	25	25	4.69 (40.0)	25
West	15	15	2.03 (17.3)	10
TOTALS	100	100	18.70 (159.7)	100

In recent years, the trend has been toward more production with fewer facilities. In 1967, 185 breweries produced about 12.7 million m^3 of beer and by 1973 129 breweries produced 17.4 million m^3. This trend will likely continue. As a whole, the industry is projected to grow at a rate of 6.7% per year making shipments worth $7.3 billion by 1980 (67). This growth will result from an increased number of people in the 18-44 age group.

Production Methods and Wastewater Sources

The basic processes and raw materials used to make beer are quite standard throughout the industry. A general outline of these procedures and the resulting wastes is given below. A process diagram is shown in Figure 1.

The brewing of beer is a batch process. First, the cereal grains (rice or corn) are cooked to solubilize the starches. Then, the grains are mixed with malt to allow the malt enzymes to convert the starches to sugars. This mixture of malt and grains is referred to as the "mash." The mash is sent to the mash filter press to remove the spent grain which is a valuable by-product. The remaining clear liquor (wort) is sent to the brew kettle where hops are added for flavor. The mixture is boiled to coagulate the undesirable protein (trub). Then, the hops are strained out in the hop jack and the wort is pumped to the wort cooler where the trub is removed as a sludge-like sediment. Frequently, the cooled wort is filtered with diatomaceous earth to remove any residual trub. The clear wort is sent to the fermentor where yeast is added to convert the sugars to alcohol and carbon dioxide. After the fermentation is complete, the excess yeast is removed and the beer is cooled and placed in primary storage. After sufficient aging in primary storage, the beer is filtered, carbonated, and placed in secondary storage to await packaging. The filters remove the residual yeast. The beer may be filtered again just prior to packaging. The product is sold in bottles, cans, or barrels.

Figure 2 gives a summary of the raw materials used to make a cubic meter of beer and Table 2 gives a breakdown of water usage within the brewery.

TABLE 2. WATER USAGE WITHIN A BREWERY (2)

Process	Water Usage (m^3/m^3 beer)
Cooling Water	1.42
Process Water	3.6
Bottle Washing	2.9
Misc.	3.1

Wastewater Characteristics

Although there may be large temporal variations in production, most breweries operate throughout the year. Generally, breweries combine all the individual waste streams except cooling water into a single stream. Brewing effluents are high in soluble organics, low in nutrients and high in temperature. Table 3 lists some of the characteristics of a brewery's total effluent and Table 4 shows the differences in effluent

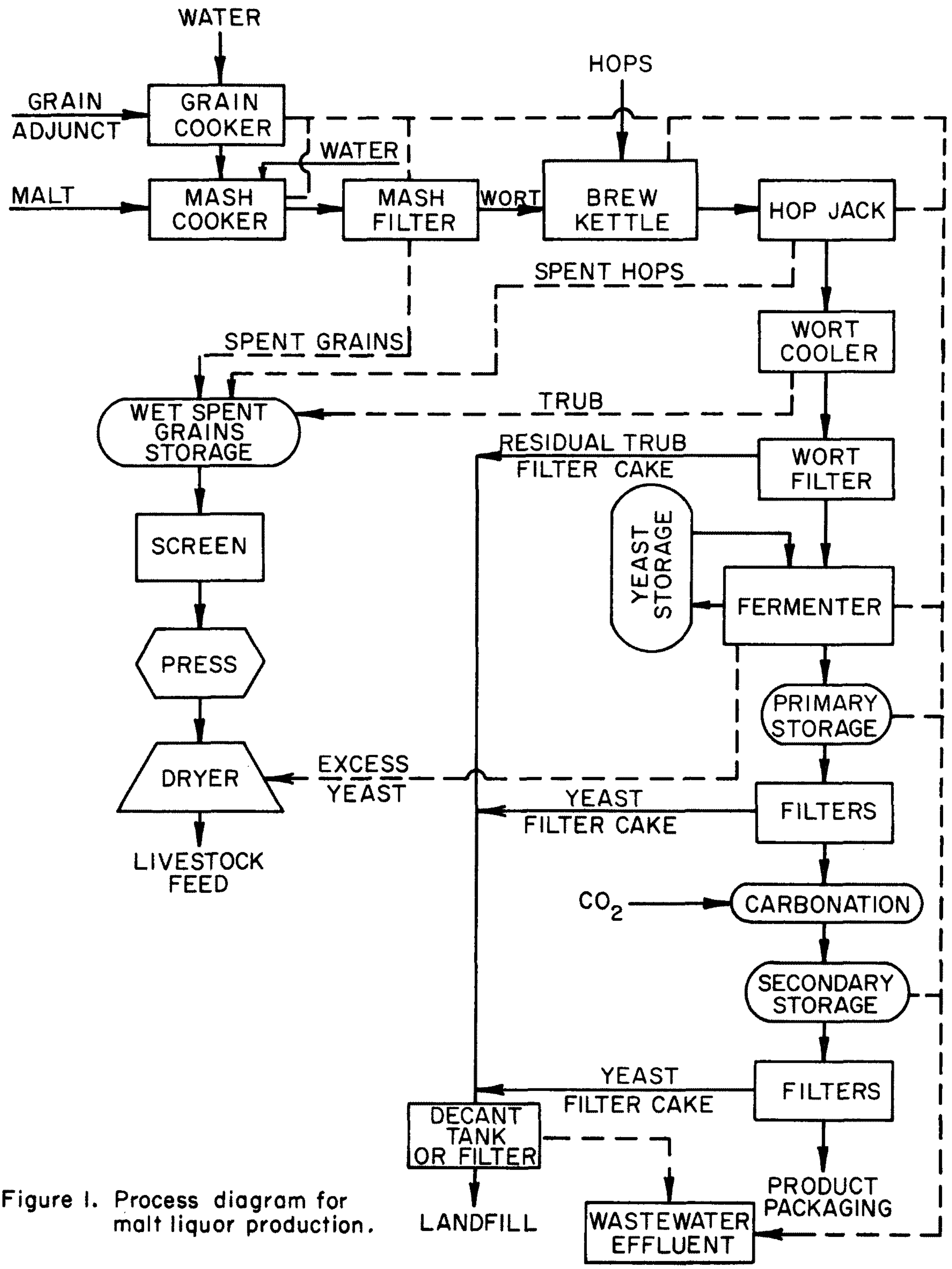


Figure 1. Process diagram for malt liquor production.

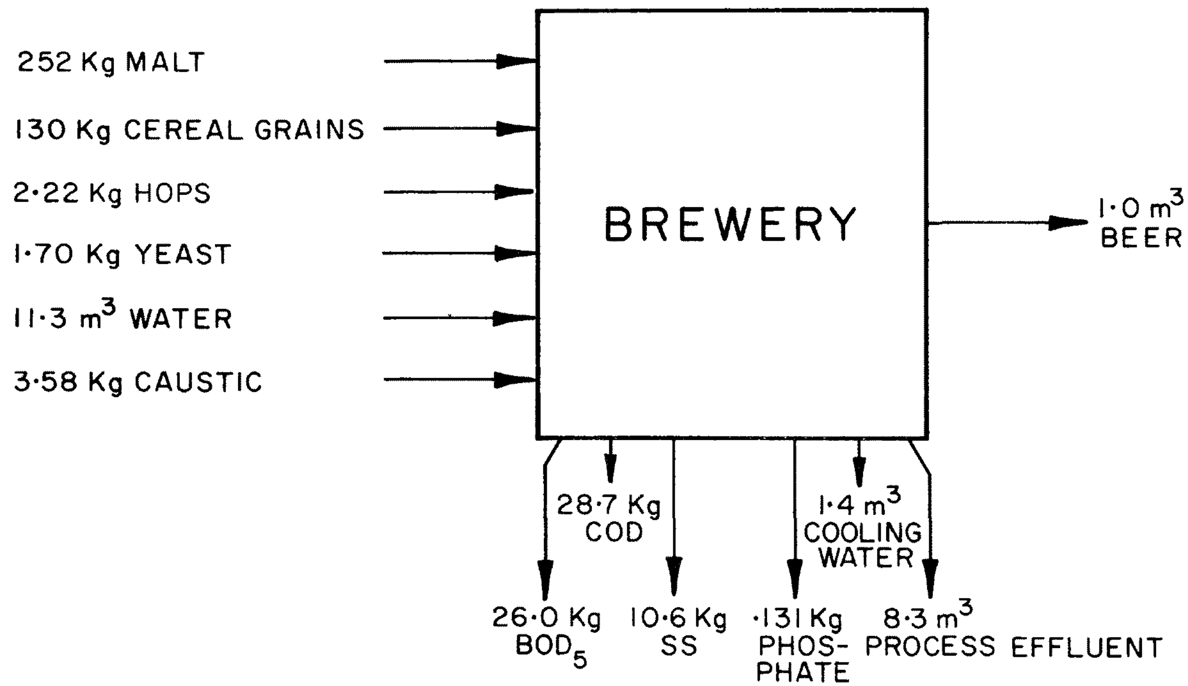


Figure 2. Brewery input-output characteristics (2).

characteristics for different classes of breweries. Discrepancies in flow and wastewater characteristics are due to different sources of information.

A breakdown of individual process effluents is given in Tables 5-8. Spent yeast and trub are major sources of pollutants accounting for about 56% of the total BOD_5 and 44% of the SS assuming no recovery (30).

TABLE 3. BREWERY TOTAL EFFLUENT CHARACTERISTICS (2, 37, 72, 58)

Characteristic	Average	Range
BOD_5 (mg/l)	1718	1622-1784
(kg/m^3 beer)	10.4	9.43-11.8
SS (mg/l)	817	723-957
(kg/m^3 beer)	4.18	3.83-4.79
pH	7.4	6.5-8.0
Temp. (°C)	30	28-32
Process Effluent Volume (m^3/m^3 beer)	6.9	5.5-8.3

TABLE 4. EFFLUENT CHARACTERISTICS FOR DIFFERENT CLASSES OF BREWERIES (58)

	Brewery Classification							
	New Large		Old Large		Effl. Limited		Other	
Characteristic	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
BOD_5 (kg/m^3 beer)	10.5	3.01	18.8	2.13	1.74	--	8.47	7.46
SS (kg/m^3 beer)	3.86	1.58	7.34	2.51	1.08	--	3.63	3.75
Process Effluent Volume (m^3/m^3 beer)	5.41	--	11.03	--	1.62	--	7.71	--

TABLE 5. SOURCES OF POLLUTANTS FROM A BREWERY (30)

Source	BOD_5 (kg/m^3 beer)	BOD_5 (%)	SS (kg/m^3 beer)	SS (%)
Yeast	3.71	30	2.55	30
Trub	3.21	26	1.24	14
Hops	0.39	3	0.77	9
Pressed Grain Liquor	0.85	7	0.50	6
Drain & Rinse	2.09	17	0.85	10
Filter Effluent	0.50	4	1.58	19
Bottling	1.20	10	0.66	8
Misc.	0.42	3	0.35	4
TOTAL	12.4	100	8.50	100

TABLE 6. PRINCIPAL WASTE STREAMS FROM THE BREWING PROCESS (4)

Source	BOD_5 (mg/l)	SS (mg/l)
Washings from kettles, cookers and grain separators	200-7,000	100-2,000
Screen and press liquor	15,000	20,000
Trub	50,000	28,000
Yeast	150,000	800
Clarification precipitates	60,000	100
Spent filter aid	--	--
Beer	90,000	4,000
Cleaning solutions	1,000	100

TABLE 7. RAW WASTE CONTRIBUTIONS FROM IN-PLANT SOURCES (2)

Source of Raw Waste	Brewery Industry Mean Raw Waste Volume (m^3/m^3 beer)
Cooling water	1.40
House cleaning	0.70
Aging	0.40
Filtration	0.70
Fermentation	0.30
Brewing	1.20
Malting	--
Other	3.60
TOTAL	8.30

TABLE 8. TYPICAL CONCENTRATIONS OF WASTES DISCHARGED FROM SPECIFIC BREWERY OPERATIONS (36)

Brewing Operation	SS (mg/l)	BOD_5 (mg/l)
Cereal cooker	300	700
Mash tun	300	2,000
Lauter tun	3,000	10,000
Spent grain tank (or press)	10,000	15,000
Brew kettle	100	300
Hot wort tank (inc. trub)	5,000	10,000
Wort cooler	20	30
Fermentation tanks	2,000	5,000
Ruh chiller	30	700
Ruh tanks (primary aging)	20,000	30,000
Primary filtration	30,000	40,000
Aging tanks	600	10,000
Final filtration	500	100
Finished beer tanks	200	50
NON-RETURNABLES		
Rinser	3	20
Pasteurizer	--	50
RETURNABLES		
Prerinse	200	500
Final rinse	10	10
Pasteurizer	20	30

TABLE 8. TYPICAL CONCENTRATIONS OF WASTES DISCHARGED FROM SPECIFIC BREWERY OPERATIONS (36) [Continued]

Brewing Operation	SS (mg/l)	BOD_5 (mg/l)
KEGS		
Prerinse	100	1,000
MISCELLANEOUS WASTES		
Bottle and can filler drip	--	50,000
Conveyor lube drip	1,000	5,000
Spray tunnel drip	40	3,000
Floor hosedown	--	--

Wastewater Management

The nature of the brewing industry and the resulting wastewater present some special management problems. As previously described, the wastewater is characteristically high in organics, solids, and volume (a large brewery may discharge in excess of 4 million m^3/yr. The combination of these factors makes disposal in natural watercourses unacceptable; therefore, most brewing wastes are sent to municipal treatment systems. Here, due to the strength, the brewery waste may be only 4 percent or 5 percent of the total influent but 25 percent of the total BOD loading. Because brewery wastewaters are quite variable as to flow and strength, a municipal system can experience severe shock loads.

Most beer is produced in large metropolitan areas so a high capacity municipal system is available for wastewater disposal. Recently, there has been a tendency to build new breweries in smaller cities and towns. This situation will require brewery-owned treatment plants or expansion of the existing municipal facilities.

Recycling

In-plant recycling of potential waste streams is practiced on a limited basis. The glass bottle is the most important container used for retail sales and the major portion of these bottles are the refillable type. In fact, a Senate committee has considered a bill to make all beer and soft drink bottles refillable as is the case in Oregon (56). Washing of refillable bottles is a major operation in a brewery and is likely to remain so. The large metal containers (half-barrels, quarter-barrels, etc.) are also recycled and must be washed. This container washing plus plant clean-up requires an average of about 1.62 kg of caustic per m^3 of beer produced (2). Most breweries put the cleaning caustic directly into the sewer, however, 10 percent of the very large production breweries do recycle it. For a brewery producing hundreds of thousands or even millions of barrels per year the cost savings and waste reduction could be very significant.

The liquid remaining after the spent hops are pressed can also be recycled. Customarily, this high strength waste is put in the sewer or, in a few large facilities, it is mixed with the spent grains. However, a few breweries (abour 10 percent) recycle the spent hop liquid back into the brewing process; usually right after the wort leaves the brew kettle (2). One particular article (36) in the literature discusses several alternatives open to a brewery facing increasing sewer surcharges including: no changes, implement a rigid water-conservation program, treat and reuse the packaging wastewaters and treat all brewing and packaging wastewaters by secondary biological stabilization and carbon adsorption. Of these alternatives the authors suggest that treating the packaging wastewater using carbon adsorption is the most economical with increasing surcharges as more municipal plants incorporate secondary treatment. Using this system only the weak packaging wastewaters which are about 50-75 percent more voluminous than the process effluents will be treated and reused within the brewery. This will reduce sewer charges and water costs which can be very large for a brewery.

By-Product Recovery

Recovery of waste solids from different process streams is practiced extensively in the brewing industry and it appears to be the best method of reducing waste loads both technically and economically. Grains, hops, trub, yeast, and lost beer are all currently being recovered (14).

Spent grains (barley, rice and/or corn) are recovered by virtually all breweries large and small. The grains are removed from the brewing process after the starches have been solubilized and then converted to sugars. Most smaller brewers and about half of the larger ones utilize the lauter tun filter, which is a gravity filtration device, to separate the grains from the mash. A disadvantage is that it requires a large amount of water to sluice out the spent grain. Some larger plants employ a plate and frame filter which is showing increased use. The grains are screened and pressed to reduce the moisture content. The press liquor is frequently put in the sewer; however, it has been recycled back into the process or filtered, centrifuged, evaporated and added to the spent grains (17).

Following recovery, most small breweries haul the spent grains away wet for use as cattle feed. Large facilities dry the grains before shipment to cut down on transportation costs. In either case the spent grains make an excellent and very valuable cattle feed. A recent study of livestock feeding of wet brewery by-products indicated that an optimum moisture content is between 75 percent and 80 percent and that adequate protein is available in grain-yeast mixtures so no supplements are needed (30).

Spent hops are separated from the brewing process by a hop jack filter after the wort leaves the brewing kettle. The smallest breweries usually haul wet spent hops away and the largest add them to the spent grains to be dried. A study (30) has demonstrated that up to 10 percent wet spent hops can be added to the spent grains with no deleterious effect on voluntary uptake by cattle. The use of hop extract in the brewing process, which eliminates the hop disposal problem at the brewery, has been on the increase with 17 percent of the plants employing it in 1971 (2).

The spent hop liquor is predominantly sent to the sewer. A few very large plants mix the liquor with the spent grains to be dried or return it to the brewing process as previously discussed.

Trub (mostly insoluble proteins) is sewered by virtually all small breweries and about 40 percent of the large ones. The remaining large breweries add trub to the spent grain to be used as cattle feed. Beer production results in an average of 1.16 kilograms of dry trub per cubic meter of beer produced (2).

Yeast is another very important by-product of the brewing industry that can be used for livestock feed. It is both settled and filtered out of the brewing process after the fermentation. About 1.3 kilograms of excess yeast are generated per m^3 of beer produced (2). Most plants sewer the excess yeast or haul it away in a wet form. A few of the larger breweries add it to the spent grains to be dried or dry it separately. The yeast makes an excellent feed supplement with an approximate composition (dry basis) of (77):

Protein	47%
Carbohydrates	43%
Ash	8%
Fat	2%

The addition of steam killed spent brewers yeast to spent grains in a 1:6 ratio can increase voluntary feed uptake, rate of gain and feed efficiency (30). Lost beer can be another significant by-product of the brewing industry. It results mainly from the racking, transferring and bottling operations. The volume of lost beer is about 6.3 percent of the beer produced based on a production weighted average (2). The vast majority of breweries of all sizes dispose of this beer in their sewers, but a few larger ones are recovering the beer and adding it to the spent grains to be evaporated.

Table 9 shows how extensive by-product recovery and waste recycling schemes can significantly reduce a brewery's raw waste load as demonstrated by Coor's brewery. The by-product recovery consists of utilizing 154,000 kg daily of dried spent grains, spent hops, and the insoluble protein precipitate (trub) from the cooling of the wort. Presently this is being combined with the sprouts and roots from the malting facilities and is pelletized using condensed beer syrup as a binder and 163,000 kg are sold per day as cattle feed under the name "Coors Malt Pellets." Coors is also experimenting with a barley malt protein using materials from the brewing operation which produces a product of 50-55 percent protein and 11 percent fat and is suitable for human consumption. See Tables 10 and 25 for chemical-nutritional analyses of the malt protein and malt pellets respectively. From the fermenting process, the spent or surplus yeast is concentrated to 15-25 percent solids and then spray dried and is sold as an animal feed supplement. By-products in the final stages of development at Coors are a yeast extract with human food possibilities and an animal feed using waste activated sludge (34).

TABLE 9. OVERALL PLANT RAW WASTE CHARACTERISTICS (17)

Parameter	Coors Raw Waste[a]	Brewing Industry Mean Raw Waste[b]
Volume	3.5 m^3/m^3 beer	8.3 m^3/m^3 beer BOD_5
BOD_5	2.90 kg/m^3 (825 mg/l)	11.8 kg/m^3 beer (1622 mg/l)
SS	1.00 kg/m^3 (280 mg/l)	4.8 kg/m^3 beer (772 mg/l)

[a]Based on average at Coors for month of June, 1974

[b]Industrial Waste Survey of the Malt Liquor Industry prepared for EPA, Aug. 1971, by Associated Water and Air Resources Engineers, Inc.

Wastewater Treatment

Presently, virtually all breweries discharge their effluent to a municipal treatment system and this will most likely be the predominant practice in the future. Only two U.S. breweries own and operate their wastewater treatment facilities.

Several advantages exist for a brewery that can dispose of its wastewater in a municipal plant. Brewing wastes are readily biodegradable; therefore, they can be treated by municipal plants which are traditionally biological. Also, the mixing with domestic sewage adds sufficient nutrients that are lacking in straight brewery waste and helps to temper shock loads or periods of low wastewater production such as Sunday. In 1971, 80 percent of the U.S. breweries paid a sewer tax and most charges varied with the load which stimulates the use of the by-product recovery schemes mentioned in the previous paragraphs.

A survey of the brewing industry indicated that the average percentage of a municipal plants total flow due to brewery waste is 4.2 per= cent. The corresponding average BOD_5 loading is about 25 percent (2). Both of these values are averages based on data with considerable scatter. The flow percentage varied from less than 1 percent to 12 percent and the BOD load from less than 1 percent to 70 percent.

A few municipal waste treatment plants receive considerable volumes of brewery wastes. Table 11 gives descriptions and performances of three of these plants.

Table 10. COORS BARLEY MALT PROTEIN (18)

	Percent
Protein	50
Fat	10
Fiber	2
Nitrogen Free Extract	29
Carbohydrates	31
Ash	3
Moisture	6
Amino Acids	
Lysine	3.25
Histidine	1.74
Ammonia	3.06
Arginine	5.60
Asportic Acid	5.62
Threonine	4.10
Serine	3.98
Glutamic Aicd	24.56
Proline	11.56
Gylcine	3.62
Alanine	5.38
Half Cystine	0.99
Valine	4.63
Methionine	1.88
Isoleucine	2.44
Leucine	7.05
Tyrosine	4.05
Phenylalanine	6.45
	100.00

TABLE 11. LOADING AND EFFICIENCY OF CITY TREATMENT PLANTS CONTAINING BREWERY WASTES (4)

City	Flow (m^3/day)	% of Flow Contributed by Brewery	Treatment Plant Influent Strength (mg/l)	Efficiency (%)
Merrimac, NH	12,000 (Design 18,925)	100	BOD_5: 1200-5000 SS: 200-400	90
Frankenmuth, MI	2271-2650	50	BOD_5: 1400-1500	BOD_5: 90-95 SS: 50-85
Belleville, IL	25,170	20	BOD_5: 400-500 SS: 275-350	94

Two U.S. breweries own and operate their waste treatment facilities: Pabst Brewery in Perry, Georgia, and Coors in Golden, Colorado. In 1970, the Pabst Brewery at Perry, Georgia went on line in a rural area about 6 miles from Perry where no municipal treatment facilities were available. The brewery was designated for an initial production capacity of 1.76 million m^3/yr. The receiving stream was unpolluted and had a minimum flow of about 1000 l/sec which dictated an efficient treatment system to maintain the water quality.

Preceeding the treatment plant is an extensive in-plant by-product recovery and waste collection system. The brewery recovers the spent grains, spent hops, trub and yeast using techniques similar to those described in the previous section. Several separate waste collection systems exist at the brewery. All uncontaminated cooling water is collected and put in the storm sewer. Cooling tower and boiler blowdown containing corrosion inhibitors and biocides are discharged directly to the polishing lagoon. Sanitary sewage is collected and treated separately in a packaged extended aeration unit which eliminates the need for chlorinating the brewery's entire effluent. The diatomite filter backwash is decanted to remove solids and then added to the process sewer. The high strength process waste is collected separately, put in holding tanks and metered into the treatment system. The spent caustic cleaning solutions are treated similarly which helps control the pH of the influent.

Figure 3 is a flow diagram for the Pabst treatment facilities and Table 12 gives the design unit loadings. A complete description of the system is given in the literature (37). Table 13 is a summary of the treatment plant's performance.

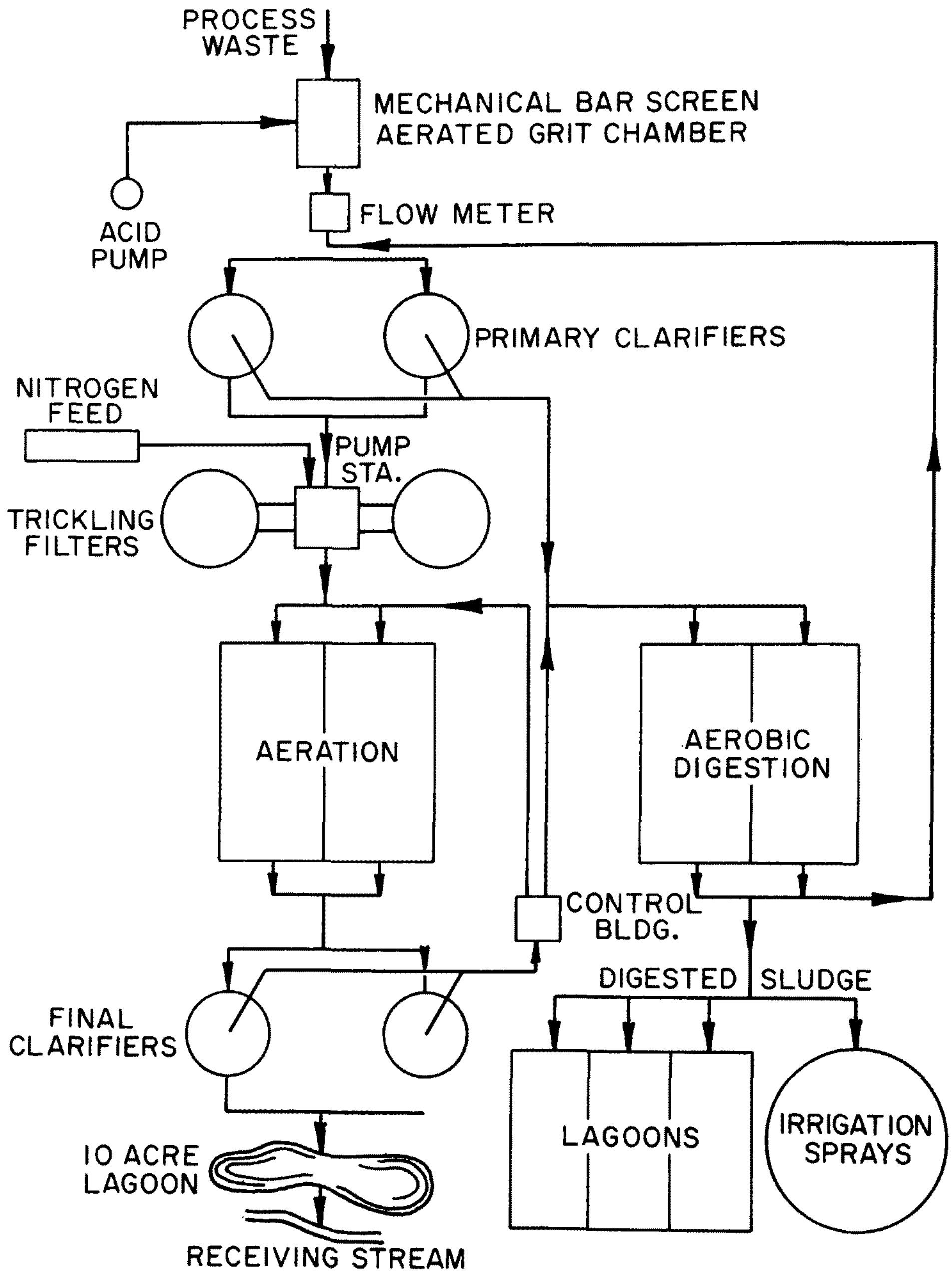


Figure 3. Flow diagram for Pabst waste treatment facility (37).

The Adolph Coors brewery produces 1.23 million m^3 of beer per year. Pollution control efforts began in 1951 with an inplant water conservation program and construction of a waste treatment facility. An extensive by-product recovery program is used to recover the spent grains, hops, trub and yeast. A plate and frame filter is used to filter out the spent grains because it uses subsequently less water than the conventional lauter tub. The spent grain liquor is centrifuged to remove solids and then recycled back into the process. The trub is handled like the spent liquor. The benefits of the water conservation program are shown in Table 9. The treatment scheme as shown in Figure 4, utilizes a high rate activated sludge system. Flow equalization and pH adjustment are used to provide for optimum performance.

Table 14 gives a summary of performance. A complete discussion of the Coors facility is given in the literature (17).

TABLE 12. TREATMENT PLANT DESIGN LOADINGS FOR PABST BREWERY, PERRY, GEORGIA (37)

Treatment	Metric	English
Primary Clarifier		
Surface loading	27.1 m^3/m^2 day	665 gpd/ft^2
Weir loading	72.2 m^3/m day	5820 gpd/ft
Detention	1.9 hours	1.9 hours
Trickling Filters		
BOD_5 loading	4.8 kg/m^3	300 lb/1000 ft^3
Hydraulic loading including recirculation		
Minimum	.68 l/sec m^2	1 gpm/ft^2
Maximum	1.36 l/sec m^2	2 gpm/ft^2
Activated Sludge		
BOD_5 loading	1.60 kg/m^3	100 lb/1000 ft^3
Aeration capacity	1.5 kg O_2/kg BOD_5	1.5 lb O_2/lb BOD_5
Return sludge ratio	50%	50%
BOD_5/MLSS ratio	0.38	0.38
MLSS concentration		
Contact basin	4.9 hours	4.9 hours
Reaeration basin	14.5 hours	14.5 hours
Final Clarifier		
Surface loading	20.7 m^3/m^2 day	509 gpd ft^2
Weir loading	73.9 m^3/m day	5950 gpd/ft
Detention	3.7 hours	3.7 hours

TABLE 12. TREATMENT PLANT DESIGN LOADINGS FOR PABST BREWERY, PERRY, GEORGIA (37) [Continued]

Treatment	Metric	English
Polishing Lagoon		
BOD_5 loading	60.5 kg/day/ha	50 lbs/day/acre
Detention	15 days	15 days
Aerobic Digestion		
Solids retention	10 days	10 days
MLSS concentration	15,000 mg/l	15,000 mg/l
Sludge Spray Disposal		
Liquid loading	2.54 cm depth/appl.	1 in depth/application
Solids loading	0.5 kg/m2/appl.	0.1 lb/ft2/application
Application interval	1 to 7 weeks	1 to 7 weeks

TABLE 13. PERFORMANCE OF PABST BREWERY TREATMENT PLANT (39)

Characteristic	Units	Raw Waste	Effluent	Percent Reduction
Flow	m^3/day	48.45		
	(MGD)	(1.28)		
	m^3/m^3 beer	5.48		
	(gal/bbl)	(1.70)		
BOD_5	kg/day	88405	252	97
	(lb/day)	(18530)	(556)	97
	mg/l	1740	58	97
	kg/m^3 beer	9.55	.27	97
	(lb/bbl beer)	(2.47)	(.07)	97
SS	kg/day	3470	208	94
	(lb/day)	(7650)	(459)	94
	mg/l	716	40	94
	kg/m^3 beer	3.94	0.23	94
	(lb/bbl beer)	(1.02)	(0.06)	94

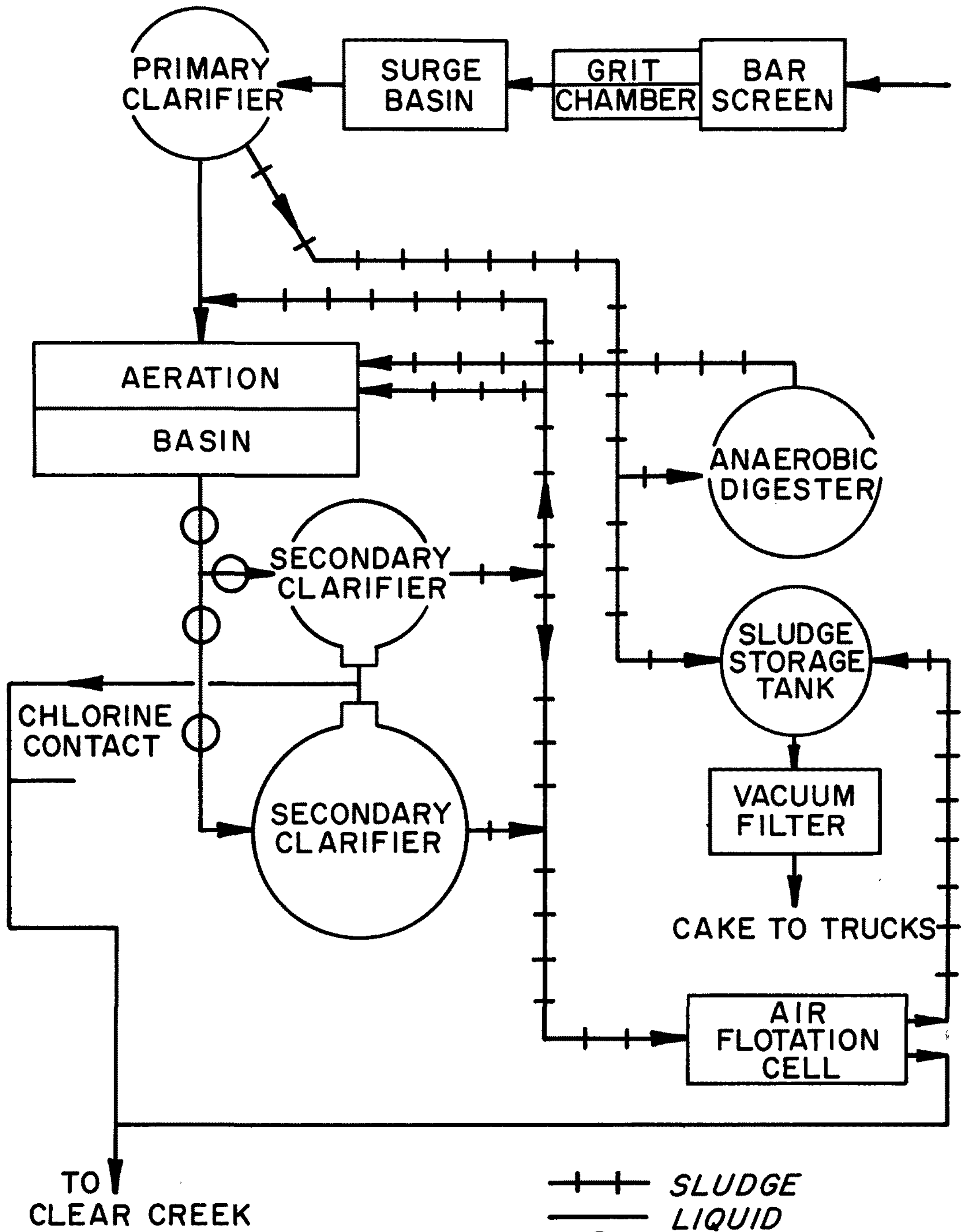


Figure 4. Flow diagram for Coor's waste treatment facility (17).

TABLE 14. COORS RAW WASTE AND EFFLUENT PARAMETERS (17)

Parameter	Raw Waste	Treated Effluent	Percent Removal
Flow	12490 m^3/day (3.3 MGD)	--	--
BOD_5	825 mg/l	34 mg/l	96
Suspended Solids (SS)	280 mg/l	29 mg/l	90

SECTION IV

S.I.C. 2083 THE MALT INDUSTRY

Industry Description

A geographical distribution of operating plants by region is given in Table 15. It is apparent that the North-Central region has the vast majority of the malt plants.

Table 16 presents estimated values of malt shipments for the years 1958-1967. The value of malt shipments relative to the entire beverage industry has decreased over one percent in the period shown.

Table 17 indicates that over the 12 year period shown, (1958-69) there has been a 400-employee decrease in employment in the malt industry and an increase in payroll of 2.9 million dollars.

TABLE 15. DISTRIBUTION OF MALT PLANTS (61)

Regions	Estimated Number of Plants	Percentage of Plants Within Region	Percentage of Plants Within Division
United States (Total)	43		
Northeast Region	6	14.0	
New England Div.	1		16.7
Middle Atlantic Div.	5		83.3
North Central Region	34	79.1	
East North Central Div.	24		70.6
West North Central Div.	10		29.4

TABLE 16. ESTIMATED VALUE OF MALT SHIPMENTS, 1958-1967 (66)

Year	Dollars ($X 10^3$)	Percentage of Total Beverage Industry
1958	195,327	3.6
1959	203,264	3.5
1960	205,484	3.5
1961	207,456	3.4
1962	190,834	3.0
1963	183,515	2.7
1964	215,542	2.9
1965	204,366	2.6
1966	205,539	2.5
1967	216,500	2.4

TABLE 17. EMPLOYMENT AND PAYROLL IN THE MALT INDUSTRY, 1958-69 (66)

Year	Number of Employees ($X 10^3$)	Payroll ($\$x10^6$)
1958	2.4	16.3
1959	2.5	17.2
1960	2.7	19.2
1961	2.5	18.5
1962	2.3	17.1
1963	1.9	15.1
1964	2.1	17.2
1965	1.9	15.8
1966	1.8	15.3
1967	2.0	17.1
1968	2.0	18.1
1969	2.0	19.2

TABLE 18. PROJECTED INDUSTRIAL GROWTH TO 1980 (4)

Year	Malt Liquors (10^9 liters)	Malt (10^9 kg)	Malt (10^9 bu)	Barley (10^9 kg)	Barley (10^9 bu)
1971	14.7	1.678	0.108	2.06	0.095
1972	15.7	1.799	0.117	2.21	0.102
1973	16.9	1.933	0.125	2.36	0.109
1974	18.0	2.054	0.133	2.52	0.116
1975	19.0	2.175	0.141	2.67	0.141
1976	20.4	2.336	0.151	2.84	0.131
1977	21.8	2.497	0.162	3.06	0.141
1978	23.2	2.658	0.172	3.26	0.150
1979	24.6	2.820	0.183	3.45	0.159
1980	26.0	2.981	0.193	3.64	0.168

For the purposes of this study, the malt industry production volumes have been projected according to the projected malt requirements of the malt liquor industry (4). The estimated quantity of barley to be steeped per annum (1971-80) is shown in Table 18. No effort has been made to separate that barley to be steeped by independent versus non-independent maltsters. Since the malt liquor industry uses the vast majority of the malt annually produced, projections based upon the malt liquor industry's requirements are reasonable for estimated malt production.

It is important to note that malting operations are rated based upon the number of bushels of barley processed. A standard barley bushel weighs 21.7 kilograms, whereas, a standard U.S. malt bushel weighs 15.4 kilograms. As shown in Figure 5, a production weighted average of 1.15 bushels of malt are produced per bushel of barley processed.

Production Process (69)

The purpose of malting is to initiate enzymatic reactions that modify the starch and protein in barley to produce fermentable sugars and other substances important in the brewing of beer and similar products. The process is conducted in such a way as to produce the desirable flavor and aroma of malt necessary for satisfactory beer production.

The process of manufacturing malt from barley consists of three steps: steeping, germinating, and kilning. Steeping is performed in large cylindrical tanks in which barley is submerged in cold water for a period of two to three days. During this time the grain absorbs moisture and the dormant embryo in each kernel becomes activated. The water is changed several times during the steeping operation. The disposal of

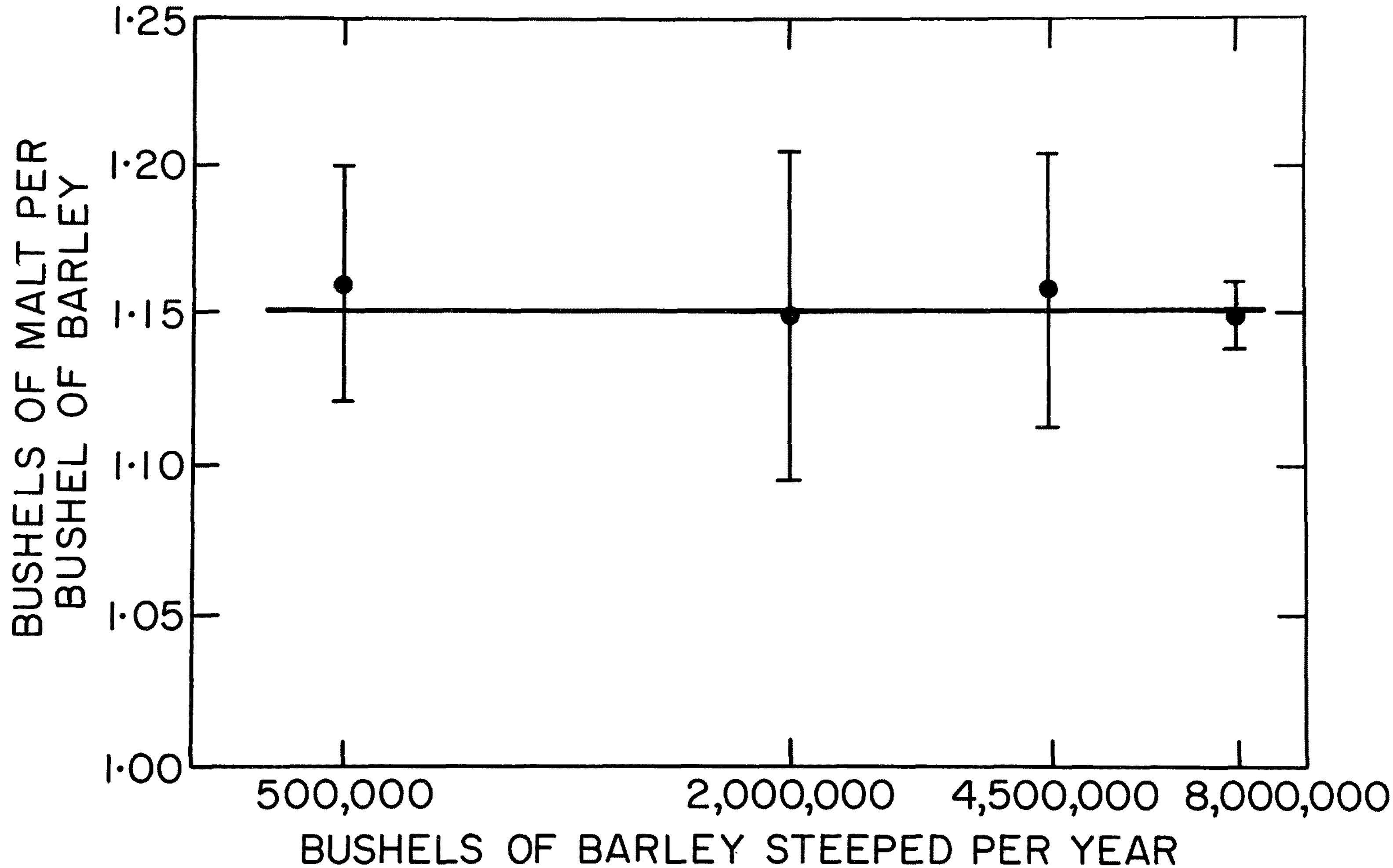


Figure 5. Bushels of malt produced per bushel of barley processed (4).

the water used for steeping constitutes a large portion of the effluent load with the first steep having a BOD_5 as high as 2800 mg/l and a fourth steep BOD_5 of 900 mg/l (54).

After steeping, the barley is transferred to the germination facilities where it remains for a period of five to eight days. During this period some of the starch and protein are solubilized. Germination is usually conducted either in drums or compartmented containers. In both methods, cool, moist air is passed through the germinating barley to control the temperature and moisture within close tolerances.

Following germination, the malt is conveyed to drying floors where it is slowly dried for a period of 2 to 4 days to reduce the moisture to a level satisfactory for storage and to develop the aroma and flavor characteristics of malt. This process is known as kilning. The "typical standard manufacturing process (SMP) for the malt industry is shown in Figure 6. Although there are some variations within various malt houses, this SMP is representative of the typical malting process for the entire industry.

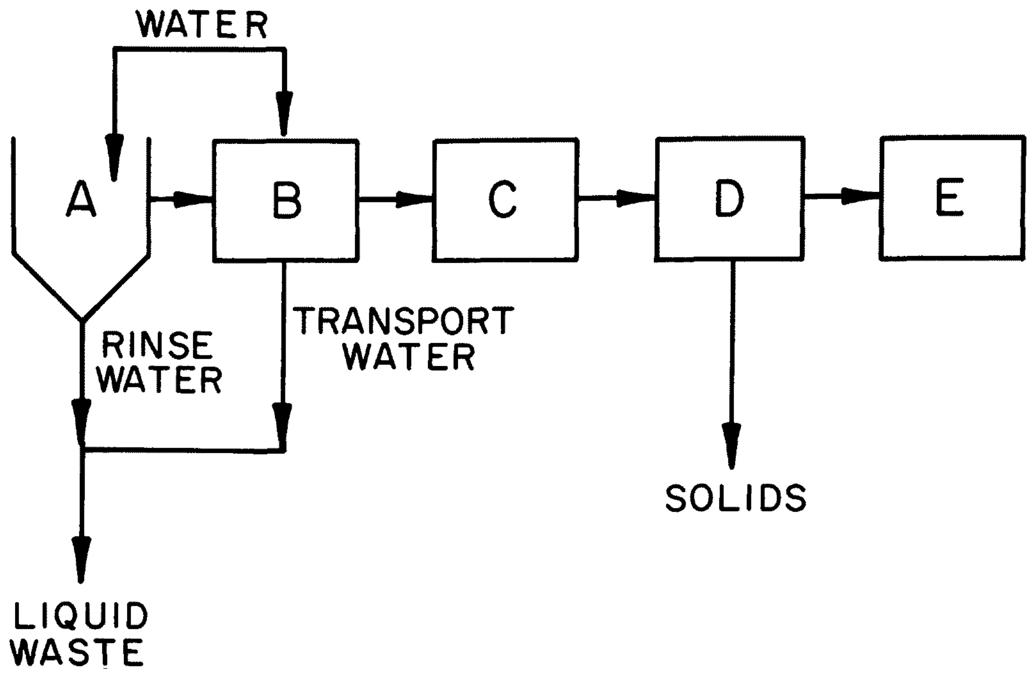
Malt House Waste Characteristics

The typical malt house in terms of production weighted averages in an input-output format is shown in Figure 7. A summary of the malt house effluent characteristics is shown in Table 19. As shown, the concentration of the process effluent suspended solids and BOD is 117 mg/l and 700 mg/l, respectively.

The following tables are included to indicate the variability within the malt industry as delineated by production category (Tables 20-24).

TABLE 19. MALT HOUSE EFFLUENT CHARACTERISTICS (69)

Parameter	Production Weighted Mean	Standard Deviation
Process Effluent Suspended Solids	0.53 kg/m^3 barley 117 mg/l	0.24 kg/m^3 barley 77 mg/l
Process Effluent BOD_5	3.09 mg/m^3 barley 700 mg/l	1.67 mg/m^3 barley 500 mg/l
Process Effluent pH	6.74	--
Process Effluent Temperature	15.1°C	1.1°C
Process Effluent Volume	4.53 m^3/m^3 barley	2.10 m^3/m^3 barley
Cooling Water Effluent Temperature	14.9°C	2.5°C



A *STEEP TANK*

B *GERMINATION COMPARTMENT*

C *KILN*

D *CLEANER*

E *MALT STORAGE*

Figure 6. Malting typical standard manufacturing process (4).

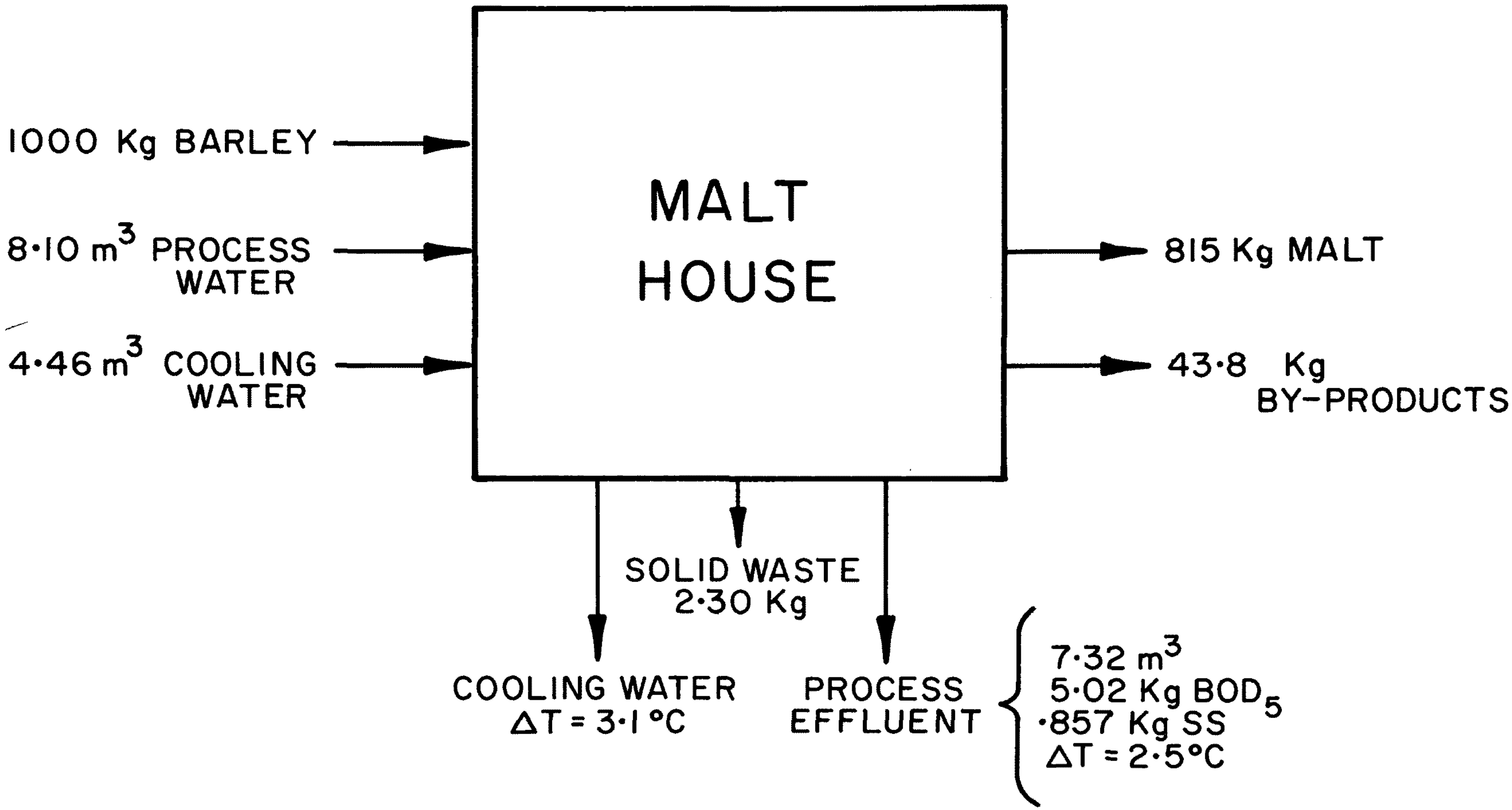


Figure 7. Malt house input-output characteristics (4).

By-Product Recovery

Information regarding by-product recovery in the malt industry is very limited. A literature search revealed one paper on the subject (34). The Adolph Coors Company utilizes 10,000 kg/day of malt sprouts and roots in producing feed. "Coor's Malt Pellets" is the feed in which the sprouts and roots along with spent grains, hops and trub from the brewery process are mixed and bound using condensed beer syrup and/or steam and then pelletized into 0.64 cm pellets. 160,000 kg are produced and sold per day. Table 25 gives the chemical-nutritional analyses for the malt pellets.

TABLE 20. CHARACTERISTICS OF THE STEEPING OPERATION (69)

Barley Steeped[a] (m^3/yr)	Water Usage (m^3/m^3 Steeped)	Effluent Water (m^3/m^3 Steeped)	Effluent BOD_5 (kg/m^3 Steeped)	Effluent Suspended Solids (kg/m^3 Steeped)	pH
18,000	3.13 (1.29)[b]	2.19 (.20)	1.29 (.90)	0.51 (.26)	6.7
70,000	4.29 (1.35)	3.94 (1.39)	5.28 (3.73)	0.64 (.26)	6.8
160,000	3.33 (1.15)	2.94 (1.15)	1.80 (1.03)	0.51 (.39)	6.7
280,000	5.10 (2.46)	4.73 (2.48)	2.83 (1.16)	0.40 (.13)	6.7

[a]Mid points of surveyed production ranges
[b]( ) designates standard deviation

TABLE 21. CHARACTERISTICS OF THE GERMINATION OPERATION (69)

Barley Steeped[a] (m3/yr)	Water Usage (m^3/m^3 Germinated)	Effluent Water (m^3/m^3 Germinated)	Effluent BOD_5 (kg/m^3 Germinated)	Effluent Suspended Solids (kg/m^3 Germinated)	pH
18,000	1.0 (1.3)[b]	1.1 (0.54)	0.77 (0.39)	0.77 (0.90)	6.8
70,000	0.71 (0.67)	0.78 (0.60)	0.51 (0.39)	0.39 (0.39)	7.1
160,000	0.99 (0.77)	1.0 (0.86)	0.39 (0.39)	0.51 (0.39)	6.8
280,000	0.40 (0.19)	0.41 (0.09)	0.39 (0.13)	.026 (0.013)	6.9

[a]Mid points of surveyed production ranges
[b]( ) designates standard deviation

TABLE 22. CHARACTERISTICS OF TOTAL PROCESS WATER (69)

Barley Steeped[a] (m^3/yr)	Water Usage (m^3/m^3 Steeped)	Cooling Water (m^3/m^3 Steeped)	Effluent Water (m^3/m^3 Steeped)	Effluent BOD_5 (kg/m^3 Steeped)	Effluent Suspended Solids (kg/m^3 Steeped	pH
18,000	6.33 (3.28)[b]	3.67 (3.97)	5.68 (3.73)	2.83 (3.73)	0.605 (0.219)	6.7
70,000	6.34 (2.51)	3.63 (3.68)	5.90 (2.47)	5.41 (3.35)	0.721 (0.259)	6.7
160,000	3.56 (1.98)	1.14 (0.92)	3.09 (1.59)	1.93 (1.03)	0.463 (0.386)	6.8
280,000	5.54 (2.27)	3.57 (1.95)	5.09 (2.28)	3.22 (1.29)	0.412 (0.129)	6.7

[a]Mid points of surveyed production ranges
[b]( ) designates standard deviations

TABLE 23. CHARACTERISTICS OF SOLID WASTE (69)

Bushels Steeped[a] (m^3/yr)	Marketable Waste (kg/m^3 Steeped)	Non-Marketable Waste (kg/m^3 Steeped)
18,000	24.5 (6.4)[b]	1.54 (1.54)
70,000	24.5 (7.7)	1.67 (1.93)
160,000	27.0 (3.9)	1.29 (2.06)
280,000	28.3 (6.4)	2.06 (0.26)

[a]Mid points of surveyed production ranges
[b]( ) designates standard deviation

TABLE 24. MALT HOUSE WATER TEMPERATURE CHARACTERISTICS (69)

Production Range (Million bushesl of barley steeped/year[a])	Cooling Water				Process Water			
	≤1	1-3	3-6	≥6	≤1	1-3	3-6	≥6
Influent (C°)								
Low	8.8	3.2	10.8	6.1	9.9	8.5	11.1	8.3
Average	12.6	11.9	12.9	11.7	13.9	12.6	12.8	11.7
High	15.6	17.5	14.2	15.0	17.1	17.7	14.3	15.0
Effluent (°C)								
Low	11.0	9.4	13.3	12.1	10.7	10.9	14.2	11.4
Average	16.2	--	15.0	22.9	15.6	14.0	15.7	15.0
High	20.4	20.1	18.0	33.9	20.0	18.1	16.9	16.0

[a]One bushel = .0352 m^3 = 21.7 kg barley

TABLE 25. COORS MALT PELLETS (34)

Guaranteed Analysis	%	Amino Acids	Weight % of Total Solids
Crude Protein 26% min.	27.5	Valine	1.6
Digestible Protein	22.0	Lysine	0.7
Fat 6% min.	7.0	Isoleucine	1.1
Fiber 14% max.	12.5	Methionine	0.5
Total Dissolved Nitrogen	70.0	Leucine	2.2
Nitrogen Free Extract	42.0	Arginine	1.7
Carbohydrate	54.5	Threonine	1.0
Total Dry Matter	93.5	Phenylalanine	1.9
Calcium	0.31	Histidine	0.8
Phosphorus	0.46		

Waste Abatement and Treatment Practices

A survey (69) indicated that approximately 80 percent of the malt plants discharge their process effluents directly to municipal sewers, whereas most of the remaining plants discharge their process effluent to waterways. Sixty-eight and thirty-two percent of the plants discharge their cooling water to municipal systems and waterways, respectively.

Of those plants discharging to municipal systems, approximately twenty-five percent are pretreating their wastes by means other than equalization. Ten percent are pretreating by equalization only.

In the survey, 11 of 25 plants responded to the question of their contribution to municipal treatment plant loads. Although these plants contributed a production weighted average of 12 percent of the flow, the data ranged from 0.1 to 45 percent. The BOD_5 contribution averaged 22 percent with a range from 0.1 to 75 percent. The load contributed to municipal systems from malt plants is shown by production category in Figure 8.

Of the malt operations surveyed 85 percent or 21 plants are investigating new or modified in-plant procedures to reduce their effluent load. Sixty-seven percent (14 plants) of these 21 plants are now paying a sewer tax. Seventy-nine percent of the 14 responding plants pay a sewer tax which varies according to their load contributed to the municipal system.

Two maltsters operate their own waste treatment facilities; a lagooning operation and a trickling filter, reactor-clarifier operation.

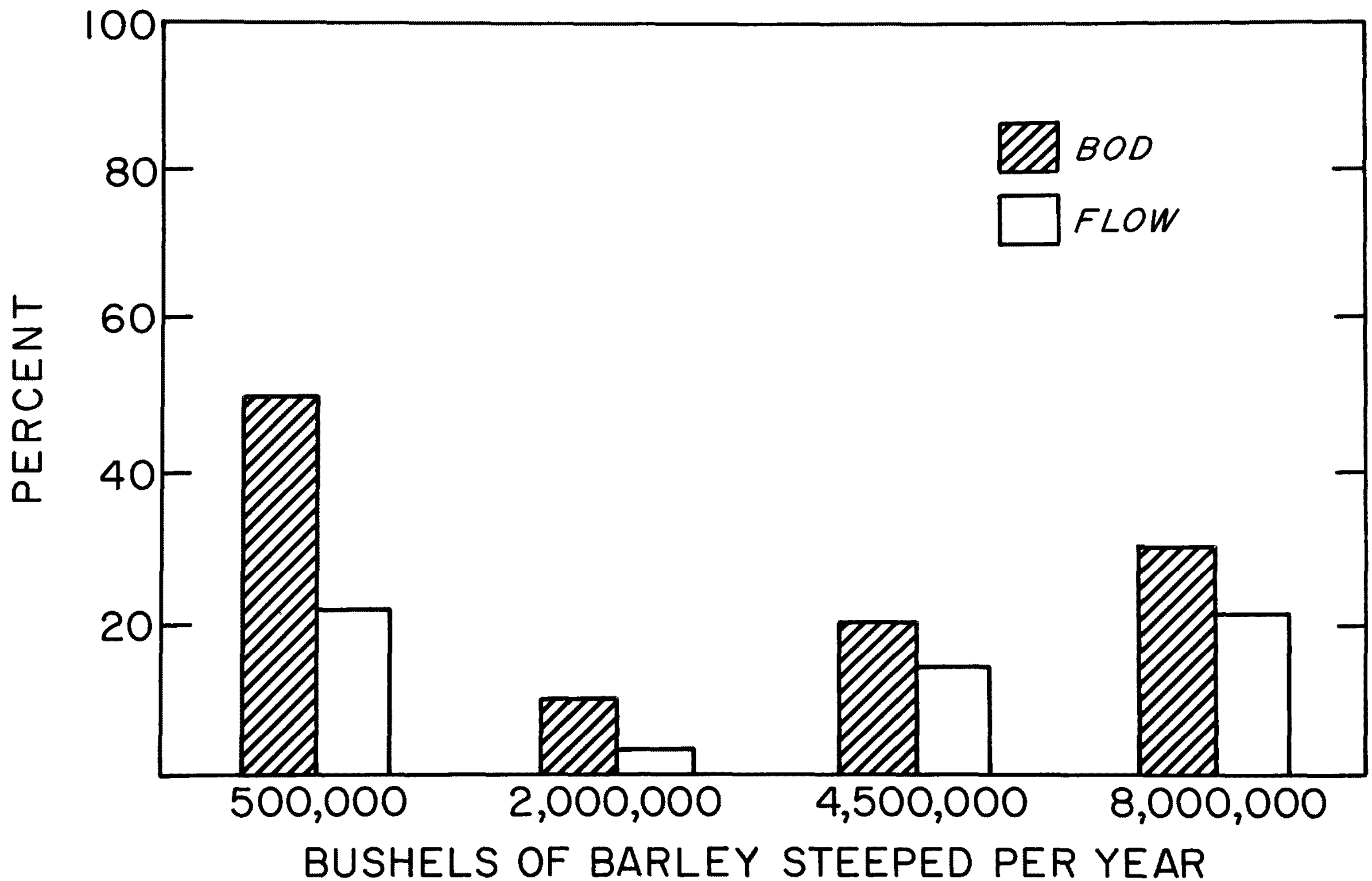


Figure 8. Percentage of municipal plant load due to malt house contribution (4).

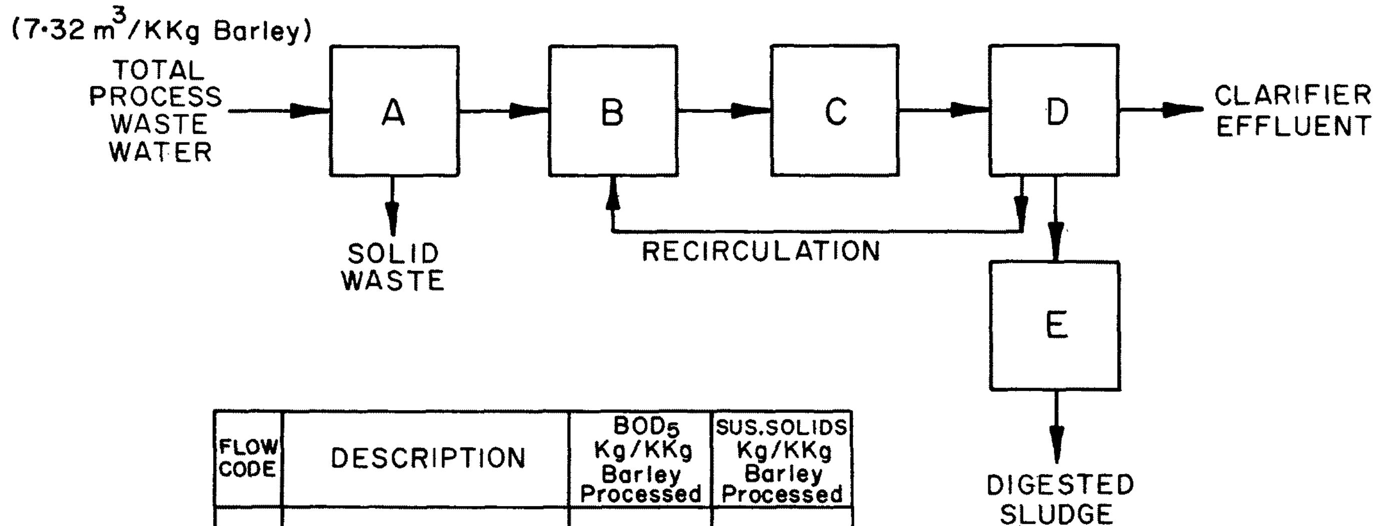
A flow diagram of the trickling filter, reactor-clarifier is shown in Figure 9. As shown, the wastewater flows through a screenhouse to remove suspended solids. The wastewaters flow through two trickling filters and a reactor-clarifier to remove most of the BOD and suspended solids. The reactor-clarifier functions as a mixing basin, an aeration unit and a conventional upflow clarifier in one package unit. The sludge from the reactor-clarifier is pumped to a sludge digestor. This treatment plant typically reduces the influent BOD_5 and suspended solids by 78 and 40 percent, respectively.

For the purposes of this study the malt industry production volumes have been projected according to the projected malt requirements of the malt liquor industry. Modifications in housekeeping and changes within the modes of manufacturing are expected to be similar for the malt and malt liquor industries, therefore, an allowance of 3 percent per annum has been included to account for better housekeeping within the manufacturing process. The projected waste load using the above assumptions are presented in Table 26. The anticipated increase in BOD generated per annum is only expected to require an expansion of existing waste treatment facilities.

Malt wastewaters contain no exotic characteristics and are therefore amenable to conventional biological waste treatment. No special considerations need to be given to wastewater treatment plant design due to effluents from malt operations other than taking into account the flow and strength characteristics.

TABLE 26. PROJECTED INDUSTRIAL GROWTH TO 1980 (4)

Year	Malt (10^6 kg Malt)	Barley (10^6 kg Barley)	Effluent BOD (kg BOD_5/ kkg Barley)	Total BOD_5 (10^6 kg)	Effluent Suspended Solids (kg SS/kkg Barley)	Total Suspended Solids (10^6 kg)
1971	1680	2060	5.02	10.3	.860	1.77
1972	1800	2210	4.87	10.8	.836	1.85
1973	1920	2360	4.72	11.2	.815	1.92
1974	2050	2520	4.58	11.5	.773	1.95
1975	2170	2670	4.43	11.8	.752	2.01
1976	2320	2840	4.30	12.2	.732	2.08
1977	2500	3060	4.18	12.8	.711	2.17
1978	2650	3260	4.05	13.2	.690	2.25
1979	2820	3450	3.93	13.6	.669	2.31
1980	2970	3640	3.80	13.9	.648	2.36



FLOW CODE	DESCRIPTION	BOD_5 Kg/KKg Barley Processed	SUS. SOLIDS Kg/KKg Barley Processed
A	SCREEN HOUSE	5·20	0·640
B	PRIMARY FILTER	3·18	0·512
C	SECONDARY FILTER	1·30	1·910
D	FINAL CLARIFIER EFFLUENT	1·17	0·387
E	DIGESTER	—	—

Figure 9. Malt house effluent treatment facilities (4).

SECTION V

S.I.C. 2084 WINE AND BRANDY

Industry Description

The United States wine industry is one of the top eight in the world, with wine production averaging 1.12 billion liters from 1969-71. Grape brandy production for the same period averaged 54.9 million proof liters. This segment of the industry has declined recently in response to a decreased demand for fortified wines. The value of the wine and brandy shipments in 1974 was estimated at about one billion dollars or about 14 percent of all alcoholic beverages (75).

California produced 1.16 billion liters of wine in 1971 or 84.8 percent of the U.S. total (75). Production varies each year with weather conditions, but California has produced between 81 percent and 85 percent of the U.S. total each year since 1967 (Table 27). In 1972, there were 462 bonded winery premises in the U.S. of which 258 or 56 percent were in California '76). A distribution of U.S. wineries is given in Table 28. Within California the vast majority of the wine is produced in the Central Valley in Fresno, Kern, Madera, Merced, Tulare and Stanislaus Counties. Most of the remainder comes from the coastal counties of Mendocino, Monterey, Napa, San Benito, Sonoma, and Santa Barbara. A small volume of wine is made in the southern part of the state. Essentially all of the U.S. brandy distilleries are located in California and for the most part in the Central Valley.

All the other states combined produced about 208 million liters of wine in 1971. New York made the majority of this or about 8.4 percent of the U.S. total. Most of the New York wine is produced in the Finger Lake region.

TABLE 27. GROSS WINE PRODUCTION, BY STATE, CROP YEARS 1967-1971 (75)

State	1967	Quantity Produced (1,000 liters) 1968	1969	1970	1971
California	634,158	668,105	867,863	801,224	1,161,957
New York	72,108	70,848	81,041	91,120	115,442
Illinois	16,904	16,313	20,341	24,069	32,377
New Jersey	16,014	15,602	15,855	15,855	17,400

TABLE 27. GROSS WINE PRODUCTION, BY STATE, CROP YEARS 1967-1971 (75) (Continued)

State	1967	1968	1969	1970	1971
	Quantity Produced (1,000 liters)				
Virginia	7,366	7,990	8,539	8,883	9.171
Michigan	9,184	7,184	7,964	7,010	6,752
Ohio	3,762	4,996	3,251	5,329	5,594
Washington	7,366	7,941	5,583	4,674	5,235
Georgia	5,204	5,136	3,310	3,100	4,920
U.S. TOTAL	779,945	811,826	1,022,434	968,691	1,396,795
	Percent of U.S. Total				
California	81.3	82.3	84.9	82.7	84.8
New York	9.2	8.7	7.9	9.4	8.4
Illinois	2.2	2.0	2.0	2.5	2.3
New Jersey	2.1	1.9	1.6	1.6	1.3
Virginia	0.9	1.0	0.8	0.9	0.7
Michigan	1.3	0.9	0.8	0.7	0.5
Ohio	0.5	0.6	0.3	0.6	0.4
Washington	0.9	1.0	0.5	0.5	0.4
Georgia	0.7	0.6	0.3	0.3	0.4

Growth trends for the industry are difficult to establish at the present time. In 1967, the per capita consumption in the United States was 3.90 liters per year. By 1972, this figure rose 57.1 percent to 6.12 liters. Also, in the late 1960's and early 1970's an increased number of people began reaching the legal drinking age each year. The per capita disposable income also increased during this same period.

The rise in demand encouraged expansion of the wineries and increased planting of wine grapes. By 1972, 41 percent of wine grape acreage in California was non-bearing (76). In 1973, the Bank of America estimated a market for U.S. wines of 1.97 billion liters by 1980 (6).

The projections for 1980 may still be reached; however, as an example, wine consumption in California for 1973-74 increased only 0.1 percent over 1972-73 giving a decrease in per capita consumption for the first time since 1961-62. From 1954-55 to 1972-73 the average increase in consumption was 6.1 percent annually (9). Wine price increases that occurred mainly in the early 70's along with a very high overall inflation rate in 1973 and 1974 are probable reasons for this rather significant turnaround. Supply caught up with demand in 1973 so prices should stabilize somewhat.

TABLE 28. BONDED WINERY PREMISES - U.S., 1963-72 (76)

Year	California	New York	Ohio	New Jersey	Arkansas	Michigan	Other States	All States
1963	237	46	39	14	13	11	88	448
1964	231	44	35	13	13	10	92	438
1965	233	44	30	13	13	10	92	435
1966	231	42	28	13	13	10	89	426
1967	231	44	26	13	13	10	91	428
1968	234	45	27	13	14	10	89	432
1969	240	42	27	13	13	11	92	438
1970	244	40	28	13	12	12	92	441
1971	245	38	27	13	13	13	97	446
1972	258	39	29	14	12	12	98	462

If the economy stabilizes the wine industry will likely grow substantially in the future as the potential market is still there. A 3-4% annual growth rate seems realistic. The Bureau of Domestic Commerce predicts a compound annual growth rate of 7.6 percent through 1980.

Consumption of fortified wines has declined since 1967 and this trend will probably continue for a number of years. This is significant, since the wastes from the production of these wines and brandy are the most difficult to handle.

Production Methods and Wastewater Sources

Table Wines

The specific methods used by individual wineries to make table wines vary considerably; however, the basic procedures are similar. A discussion of these basic processes will encompass the important wastewater sources. Figures 10 and 11 are general production diagrams for red and white wine, respectively.

The fresh grapes are usually brought to the wineries in trucks or gondolas. They are dumped into a hopper and transported by conveyor to a stemmer crusher. The "Garolla" crusher is used frequently in California. The grapes are stemmed and crushed in one operation in a way to prevent breaking the seeds or severely grinding the stems. The resulting solid waste consists of stems and debris. The crusher, conveyor and hopper are usually washed down periodically and at the end of the day.

Following the crusher, the grapes used to make white wine are pumped to a tank where the free-run juice is allowed to separate from the skins, seeds and any remaining stems. The juice (must) is pumped to a fermenter. All the remaining skins, etc., are sent to the press to remove the juice. The resulting solids are reffered to as pomace. The press juice may be used for blending or making less expensive wines.

The juices and skins used to make red wines are pumped directly from the crusher to the fermentation tank. Wine fermentation is a batch process. Sulfur dioxide is added before the fermentation is started to control undesirable microbial growth. After several hours a yeast culture is added to start the fermentation. Large quantities of heat are produced so the tanks are usually water cooled to control the temperature. Before the fermentation is completed the red wine is drawn off the skins if enough color and tannin have been extracted. The fermentation is completed without the skins. The skins are pressed to extract the remaining juice which can be used for blending or distilling material. The pressed solids or pomace remain. The same general procedures are used to ferment white wines except the skins are not included and the temperature is kept lower. The fermentation tanks must be washed thoroughly after the wine is removed. This washwater will contain the residual wine and solids (yeast cells, some seeds and grape solids). The presses are also washed to remove residual solids.

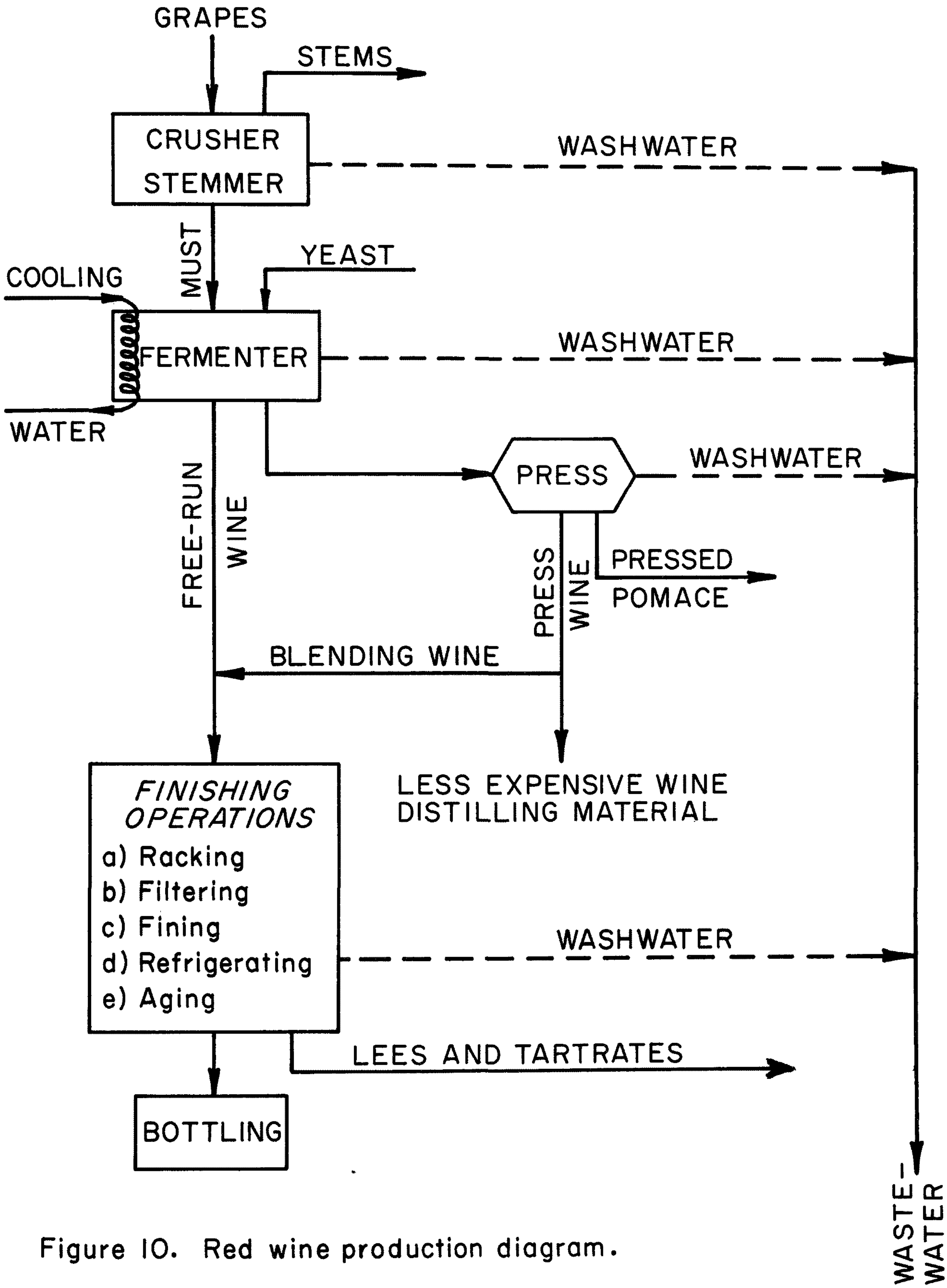


Figure 10. Red wine production diagram.

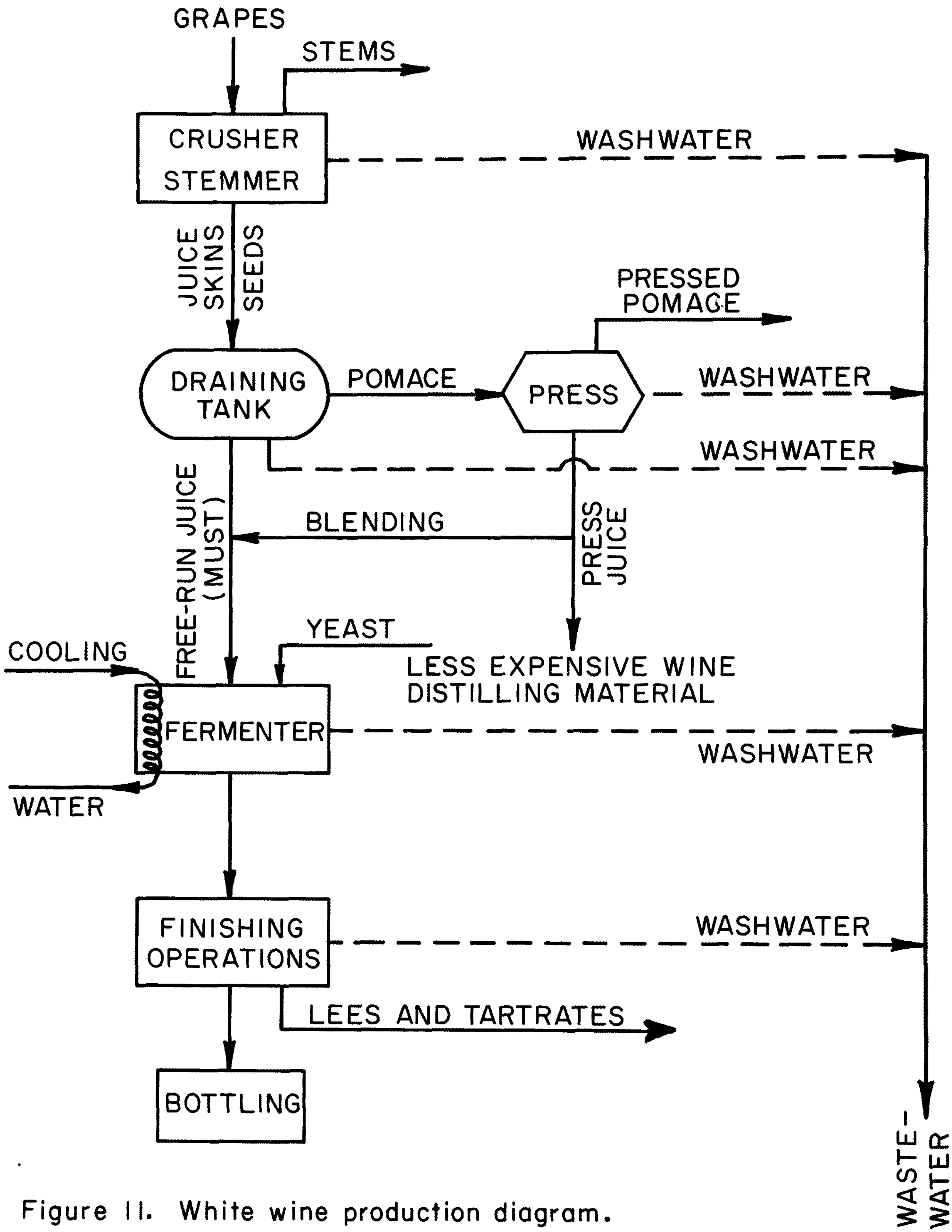


Figure 11. White wine production diagram.

The processes discussed above are started as early as late August in California and are usually completed by mid-November depending upon location.

After the fermentation has slowed the new wine is pumped into storage tanks for clarification and aging. These storage and aging tanks may be made of stainless steel, redwood, concrete, oak and lined steel or iron (23). While in storage, solids in the wine will settle out, so the wine is periodically pulled off of its sediment (racked) and put in another container. This process leaves a residue of lees (yeast cells and grape residue). A winery must dispose of the lees or use them for distilling material. After racking, the remaining wine and lees must be thoroughly washed out of the tanks. Cream of tartar (potassium bitartrate) often precipitates as crystals on the surfaces of the storage and aging container. This can be scraped off or redissolved in hot water and washed out.

Wines are aged for varying lengths of time. Reds are held longer than whites with some reds aged for 10 or more years.

Most of the aged wines are fined or filtered at least once prior to bottling to remove any solid residue remaining in the wine. Asbestos and diatomaceous earth filters are used frequently. The filters and retained solids are dry enough to be easily landfilled. Fining is another method of clarifying the wine with bentonite being the most commonly used fining agent. The substance is added in solution or suspension to give quick-settling coagulums. The fining agent adsorbs suspended material and clarifies the wine as it settles. The material which settles out consists of the agent, tannin, acid, or protein that has reacted with the agent and the settled solids. The wine is then racked to separate it from the settled residue. The remaining solids can be handled like lees.

Bottling is the final wine-handling operation at the winery. Virtually all wineries use automatic filling and corking machines. With these, the wine is transferred directly from the storage containers to the machine and into the bottles. The bottles are automatically corked and labelled. A limited amount of wastewater is generated during this final operation. Virtually all wineries use new bottles so no washing is needed and little rinsing is required; however, the trend may be turning toward returnable bottles (56). If this occurs, the volumes of washwater required will greatly increase. On some bottle lines a detergent is used as a lubricant and ends up in the floor drains. Occasionally some bottles break or wine is spilled during filling, but these wastewater volumes are very small. After bottling is completed the emptied storage tanks and the bottling machine must be flushed clean.

Dessert Wines

Most of the processes used to make dessert wine are the same as those used for table wine. One difference is that during fermentation some fortifying spirit is added to raise the alcohol level to a predetermined amount (more than 14 percent) and to halt the fermentation at the desired sugar level. Extracting sufficient color during this short fermentation has always been difficult. Sometimes a red wine concentrate is added or the must heated to extract color. Aging procedures may also be different. Sometimes dessert wines are fined, filtered and refrigerated several times to speed up the aging process. A few wine makers heat the wine for a specified period at 49° to 60°C. The usual procedure is to hold dessert wine in the wine cellar for about one year while it is stabilized and then put it in oak for another year or two.

Sparkling Wines

Sparkling wines are defined as those which have more than 1.5 atmospheres pressure at 10°C and contain a visible excess of carbon dioxide, approximately 3.9 grams per liter. The different methods of obtaining this excess carbon dioxide are: by fermentation of residual sugar from primary fermentation, from malo-lactic fermentation, from fermentation of sugar added after the process of fermentation, and by the direct addition of carbon dioxide to the wine.

Brandy

Most of the brandy is produced during a period from early September to late October. Brandy production is basically a distillation and aging process as shown in Figure 12. Wine, lees and pomace are used as distillation materials. Wine is used to make beverage brandy, and unmarketable wine, lees, pomace in ash and filter wash are used to make fortifying brandy (1, 5). Nearly all California brandy is produced using continuous column stills. Wine is introduced near the top of the still and steam or indirect heat introduced near the bottom strips the alcohol from the wine. This alcohol containing vapor is condensed to form the spirit. The disposal of the dealcoholized solution (stillage) which comes off the bottom of the still can be the most difficult wastewater problem in the wine industry. The solution is high strength and concentrated though its specific characteristics are dependent on the distilling material used. The stills also require extensive volumes of cooling water which must in turn be disposed of or cooled.

Beverage brandy is removed from the still at 170° proof or less. It is then diluted to the desired alcohol content and put in wood containers for aging.

Wastewater Characteristics

Although many of the waste streams from the individual processes are mixed into a total winery effluent, an idea of what is coming from each process can be very helpful to a waste management program. A limited amount of information has been collected to characterize these individual waste streams, but most of the wastewater is generated during the pressing season which is quite short and is characterized by erratic wastewater flows.

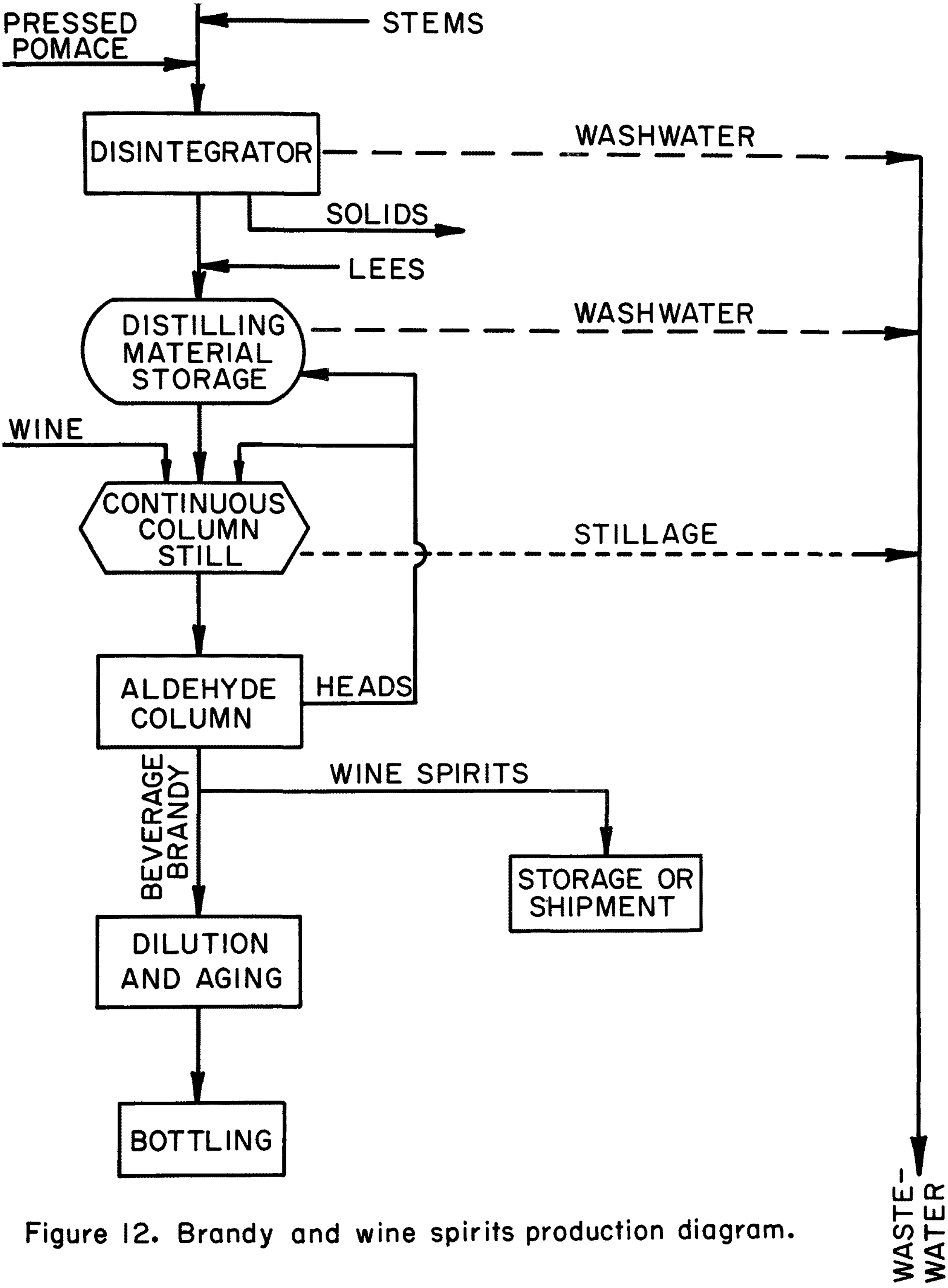


Figure 12. Brandy and wine spirits production diagram.

Table Wine

The stemming and crushing occurs over a one to two month period in the fall. About the only liquid waste is the washwater that is used. This washwater contains mainly juice, some debris and other grape residue. Because this washwater occurs over a short period of the year and just occasionally during the day, monitoring has been limited. The solid waste from the stemmer consists of stems, leaves and debris. These solids may amount to 30-38 kilograms per metric ton of grapes crushed and a few wineries crush over 90,000 metric tons of grapes in a season (1).

Pomace makes up the major waste from the pressing operation. Using a basket press, about 172 kg/metric ton result from the pressing of red wine while 195 kg/metric ton are left from the production of white wine. Values for screw presses are somewhat lower. Other values in the literature for both types of wines run between 125 and 200 kg/metric ton. Skins and seeds are the major constituents of the pomace with seeds making up about 20 to 30 percent on a wet weight basis. Liquid accounts for 56 to 68 percent of dry wine pomace with 7 to 8 percent of the liquid being alcohol. Pomace also contains significant amounts of tartrates; red wine contains about 11 to 16 percent and white wine about 4 to 11 percent on a dry weight basis. The tartrates are a source of substantial BOD if subjected to biological attack. There are two sources of wastewater in the fermentation process; cooling water and wash water. It is difficult to establish a figure for the volume of water required to keep a fermentation tank at a certain temperature because of several variables: the type of wine, size of tank, tank material and weather conditions. The amount of washwater used to process the wine from crushing through fermentation is about 200 liters/metric ton of grapes (1, 5, 27, 31).

During clarification and aging the lees are the primary wastewater problem. The lees (mainly yeast cells) are in the form of a semi-liquid paste. About 17-29 liters are produced per metric ton of grapes processed. Within the lees are 24-84 kg/m^3 of tartrates and 5-13 percent, by volume, alcohol (31). The lees are an extremely strong waste stream.

Filtering and fining the wine yields very little wastewater. Filtering the wine leaves a solid cake of lees that is quite dry. Fining gives a paste like residue similar to lees.

Table 29 gives a summary of characteristics for different wash water streams in two California wineries. Tables 30 and 31 give summaries of effluent characteristics for eastern wineries and non-distilling California wineries.

TABLE 29. CHARACTERISTICS OF WINERY WASTEWATER SOURCES (49)

Characteristic[a]	Units	Crusher Wash[b]	Pomace Conveyor Wash	Fermentation Tank Wash	Press & Area Wash	Storage & Bottle Wash	Storage Tank Floor Wash	Cooling & Refriger- ation Blow- down & Misc.
pH	--	3.85	4.20	4.08	3.80	6.6	7.13	6.65
Suspended Solids	mg/l	3,220	3,050	2,440	1,046	290	108	4
BOD_5	mg/l	27,300	4,650	8,300	1,540	1,130	2,800	373
Portion of Daily Flow	%	2.5	5	10	7.5	50	10	15

[a]Data from Christian Brothers, South St. Helena and Greystone Wineries - 1965-66.
[b]Washdown from Crush, Pomace Conveyor and Press Area occurs during the one hour cleanup period from 4 p.m.-5 p.m.

TABLE 30. WASTEWATER TREATMENT FOR NEW YORK WINERIES(46)

Winery	Flow (m^3/day)	Influent BOD_5 (mg/l)	Influent SS (mg/l)	Treatment System	Percent BOD_5 Removal (yearly avg.)	Year Data Collected
Gold Seal Hammonds Port	900	562	225	Rotating biological contactor with a sand filter	93.5	'74
Widmer Wine Cellars, Naples	600	1010	150	Activated sludge with a sand filter	97	'72
Taylor Wine, Co. Hammonds Port	600	2424	11	Extended aeration	94.5	'68-'73

TABLE 31. WASTEWATER CHARACTERISTICS FOR NON-DISTILLING CALIFORNIA WINERIES (49)

Characteristic	Crushing Season Range	Crushing Season Mean	Non-Crushing Season Range	Non-Crushing Season Mean
pH	3.5-5.5	4.1		4.8
Dissolved oxygen	0	0	0	0
BOD_5	2000-5000	2500	2000-5000	2400
COD	4000-10,000	5000	4000-10,000	4000
Grease	5-30	15	5-50	40
Settleable Solids	25-100	80	2-10	2.5
Suspended Solids	200-800	500	100-400	400
Volatile Suspended Solids	150-700	450	80-350	300
Dissolved Solids	300-600	800	400-800	700
Nitrogen	5-40	20	10-50	40
Phosphorus	5-10	10	10-25	25
Sodium	100-200	150	100	140
Alkalinity ($CaCO_3$)	40-120	115	10-100	50
Chloride	100-250	150	100-250	150
Sulfate	20-75	50	20-75	50
Boron	0-012 0.2	0.1	0.2	0.1

All units are mg/l except pH.

Brandy stillage (still slops) is the primary environmental problem of the California wine industry. One of the largest distilleries may produce up to 2.3 million liters/day during a 1-1/2 month period in the fall (50). The stillage volume and characteristics vary with still practice, still type, and source of the distilling material (wine, pomace or lees). Stillage is very high in COD, BOD, SS and acidity. An average still produces about 20 liters of stillage per wine liter of brandy (45). A still producing 7600 wine liters of brandy per day from conventional material has a population equivalent of over 20,000. Characteristics of the three types of stillage are given in Table 32.

Considerable volumes of cooling water are needed for any distilling operation with condensers requiring the most. Frequently, heat exchangers are used to cool the stillage prior to discharging it to municipal sewers or a land disposal system. Stillage leaves the still at about 66°C and is usually cooled to 43-49°C before discharge (50, 10).

In both cases the cooling water retains its incoming quality except for waste heat.

TABLE 32. WINE STILLAGE CHARACTERISTICS

Component (mg/l except pH or otherwise specified	Wine Stillage (44 Wineries)	Average Values (12) Wine Stillage Detartrated (7 Wineries)	Pomace Stillage (8 Wineries)
Alcohol Content (% by volume before distilling)	6.37	5.82	5.05
pH	3.74	4.34	3.72
Acidity (as $CaCo_3$)	3,700	2,300	3,800
Total Solids	16,700	13,950	29,780
SS	4,470	2,940	18,660
Soluble Solids	12,410	10,900	13,410
Volatile Solids (Total)	13,120	10,420	27,140
Total Ash	2,900	3,490	3,440
Soluble Volatile Solids	8,870	--	9,380
Soluble Ash	2,400	--	2,610
Total BOD_5	12,300	9,825	17,840
Soluble BOD_5	9,660	7,745	11,330
		Average Values (45)	
	Wine Stillage	Lee Stillage	Pomace Stillage
pH	4.7	3.8	6.8
Acidity (as $CaCO_3$)	3,170	9,860	1,220
Total Solids	20,100	68,000	13,180
Volatile Solids (% of TS)	87.4	86.5	77.0
SS	3,120	59,000	--
Extractable Acids (as acetic)	1,900	2,480	380
Total Nitrogen (as N)	271	1,532	330
NH_3-N (as N)	2.8	45.1	4.0
Total Phosphorus (as P)	11,150	4,284	1,310
BOD_5	11,000	20,000	2,400

Wastewater Management

Before actually discussing specific management techniques, there are some waste water disposal problems peculiar to the wine industry that deserve attention. As previously mentioned, the bulk of the wastewater is generated during a short 1-1/2 - 2 month season and, where stillage is involved, the waste is strong. The combination of these two factors make it very difficult for a municipal system to handle winery waste. The same combination makes it very expensive for a winery to set up a conventional treatment system that may operate at capacity for only one-sixth of the year.

The geographical location of the U.S. wine industry also has a great influence on the disposal techniques employed. In the Eastern States the precipitation is distributed throughout the year. This, along with possible freezing temperatures, makes land disposal very difficult. The streams flow year-round which can provide some dilution to a treated effluent; however, there is a fish population that must be protected along with other downstream uses.

In California the period of high effluent flow comes during the latter part of the dry season. Most streams are at low or no flow condition and can accept very little waste load. These same dry weather conditions are ideal for operation of a land disposal system.

Basic water conservation practices are essential for any effluent management program. Within the wine industry these may include automatic barrel cleaning devices, trigger handled spray nozzles, stainless steel tankage and smooth floors.

Recycling

Recycling of waste streams is not practiced extensively nor is it practical for most wastewater in the wine industry due to fresh water cost and availability. The majority of the wine is never pasteurized so care must be taken to prevent contamination throughout processing. Condenser water and fermentation cooling water are currently being recycled at some wineries. The common practice is to cool this water in a cooling tower and recycle it with any make-up water that may be required. Several of these systems are currently being used and eliminate the addition of waste heat to receiving waters. Frequently, the stillage is cooled with heat exchangers before it is sent to a land disposal system or to the sewer. This cooling water can also be handled with a cooling tower.

By-Product Recovery

This aspect of wastewater management has received particular attention recently. Recovery of a by-product can reduce both the strength and volume of the waste stream besides yielding a product of some economic value.

Tartrate recovery in the U.S. wine industry has generally not been economical. Prior to World War II, the tartrates were imported mainly from the wine producing countries of the Mediterranean area. During World War II, the imports were cut off; consequently, tartrate production was increased in this country to help take up the slack. This production fell off again in the post war years and presently has almost ceased. However, some people in the industry feel that the price of tartrates is about high enough to make tartrate production in the U.S. economical again.

Winery wastes are the world's major source of tartrates with pomace and stillage both containing large amounts. Red wine pomace contains about 11.1 - 16.1 percent tartrates on a dry weight basis and white wine 4.2 - 11.1 percent (31). Stillage has a tartrate content (mostly potassium bitartrate) of 1.25 - 7.25 gm/l depending on several factors; the weather during the growing season, variety and maturity of grapes, and distillery practices (1). The lees and argols are available in smaller quantities but are also very good sources. The argols, which occur on the walls and bottom of the storage tanks, are almost pure cream of tartar.

Besides any economic benefit, the removal of tartrates can reduce the BOD of these wastes by 50 to 75 percent (5, 71). Tartrates are highly biodegradable and exert a strong demand on any biological system.

Two methods for recovering tartrate from pomace have been explored or practiced. Hot water extraction has proved to be very satisfactory. In pomace, the tartrates are present as small crystals adhering to the skins. These crystals are readily soluble at temperatures of 60-100°C (31). The process may be continuous or batch. The hot water is passed over the pomace and the solids are filtered or settled out. If the tartrate rich liquid is allowed to cool and stand several days the tartrates will recrystalize.

Cold acid extraction can be used where steam is not available. This process is similar except an acidified cold solution is used to dissolve the cream of tartar. Both of the above processes are easy to set up and require little additional winery equipment, but they do require additional handling of the pomace. Since the crystallization of the cream of tartar is slow it may be more satisfactory to precipitate the tartrate as calcium tartrate. This process is much faster, but it requires chemical addition and very close control.

Recovery of tartrates from stillage is a more difficult problem. One suggested method is to allow the stillage to settle and cool in large tanks, rack off the clarified liquid and then precipitate the tartrates by chemical addition as mentioned above. This process requires large tank volumes and the know-how to control the chemical precipitation. Ion exchange columns have also been tried on stillage. This technique requires further investigation but a preliminary study is given in the literature (33).

The lees are a very rich source of tartrates. Two procedures can be used to recover them. Whether or not they are used for distilling, the lees are allowed to settle and then stand several days while the cream of tartar crystallizes. Finally, the liquid is removed and the crystals washed and dried. The crystallization step can be omitted if chemical precipitation is used.

The argols that form on the walls and floors of wine tanks are almost pure cream of tartar and can be marketed in that form. It is very difficult and time consuming to chip the "winestone" off the tanks so usually it is dissolved by applying a strong solution of sodium hydroxide to the surface. Then the solution can be acidified which will enable the cream of tartar to recrystallize.

All of the techniques mentioned above for tartrate recovery are discussed in greater detail in the literature (1, 31, 32).

The grape pomace itself can and is being recovered as a usable by-product. Ever since grapes have been cultivated, the pomace has been returned to the soil as a conditioner and fertilizer. The past few years it has been in great demand as an orchard fertilizer. A study (27) done in the 1930's found that pomace has about the same ultimate fertilizer value as standard manure. An average analysis is: 1.5 to 2.5 percent nitrogen, 0.5 percent phosphorus and 1.5 to 2.5 percent potassium on a dry weight basis (29). The nitrogen becomes available slowly. As the pomace decomposes it also improves the physical nature of the soil.

The pomace can also be sold as livestock feed. Due to the seed hulls, the crude fiber content is too high for use as the sole feed, so it is mixed or used as a supplement. The analysis of several samples of dehydrated grape pomace meal ranged from 12.05 to 14.88 percent protein, 5.63 to 8.90 percent fat and 17.74 to 34.99 percent fiber (1).

Oil from the grape seeds is another by-product that deserves more attention. Grape-seed oil has been produced in Europe since before World War I and in a plant operated in Fresno, California from before World War I until about 1960. Seeds make up about 20 to 30 percent of the pomace on a wet weight basis and grape seeds contain 11 to 15 percent oil on a dry weight basis (1). One method of recovering the seeds from the pomace is to wash, drain, thresh and sieve to achieve separation. The seeds should then be dried, possibly with gas fired rotary drum driers. The oil that can be obtained using solvent extraction or mechanical pressing has a very high content of linoleic acid which is considered an essential fatty acid for humans (28). Grape seed oil also has a pleasant flavor and is resistent to clouding at cool temperatures which makes it a good salad oil. It is also quite stable when used for frying.

Waste stems are disposed of by spreading them on the fields daily. They are also utilized as a source of fermentable material after grinding (1).

Wastewater Treatment

In order to effectively discuss wastewater treatment, the wine industry should be divided into wineries that distill and those that do not. The addition of stillage to the effluent greatly changes the wastewater characteristics along with the method and degree of treatment required.

Of the wineries that do not distill, there are waste characteristics and treatment differences that exist due to the various locations, climates, processing techniques and grape varieties. These differences have been or will be discussed where they are significant.

Generally, from non-distilling wineries, the wastewater has a BOD_5 of about 800-1300 mg/l, SS of 150-500 mg/l, pH of 5.8 and a flow of 1960 liters per metric ton of grapes crushed (5, 46). (These are just average values and will vary between seasons and parts of the country). These characteristics along with its biodegradability, make the wastewater amenable to most conventional biological treatment schemes. These may consist of biological treatment at the winery or sending the waste to a municipal plant. The large eastern wineries in the Finger Lakes region have their own biological treatment systems. The effluents are discharged to local streams and lakes that have high recreational value so the lakes' quality must be maintained. Several different types of biological systems are currently being used as shown in Table 30. Figure 13 shows the treatment system at Widmer's Wine Cellars in greater detail. Biological systems appear to work well on winery wastewater that does not contain stillage.

Biological systems have also been used at non-distilling California wineries; however, their effluents are usually put back on the land or sent to a municipal plant so the degree of treatment required is less. Aerated lagoons have been used successfully in California providing BOD reductions of 90 to 98 percent with a 30-day retention time.

Wineries that do distill have a much greater waste treatment problem. The stills usually operate for a 1 to 2 month season which can cause acclimation problems for most biological systems. The wastewater is also of high strength; conventional stillage has a BOD5 of about 10,000 mg/l, SS of 4,000 mg/l and pH of 3.7 and these values increase for lees and pomace stillage as shown in Table 32.

For any disposal system the volume of stillage produced should be kept to a minimum by keeping the alcohol content of the distilling material at or above 8 percent (11). The quantity of stillage produced is inversely proportional to alcohol content of the distilling material (Table 33). Also, the cooling water should be kept separate from the stillage.

The effective treatment of stillage using a land disposal system depends on rapid seepage into the soil to prevent odors from developing and insects from breeding, and an effective drying period before reapplication (11). Such a treatment system may consist of an area of land divided into several plots or "checks" about one acre each. The plots should be leveled to prevent ponding and the soil is disced to make it friable.

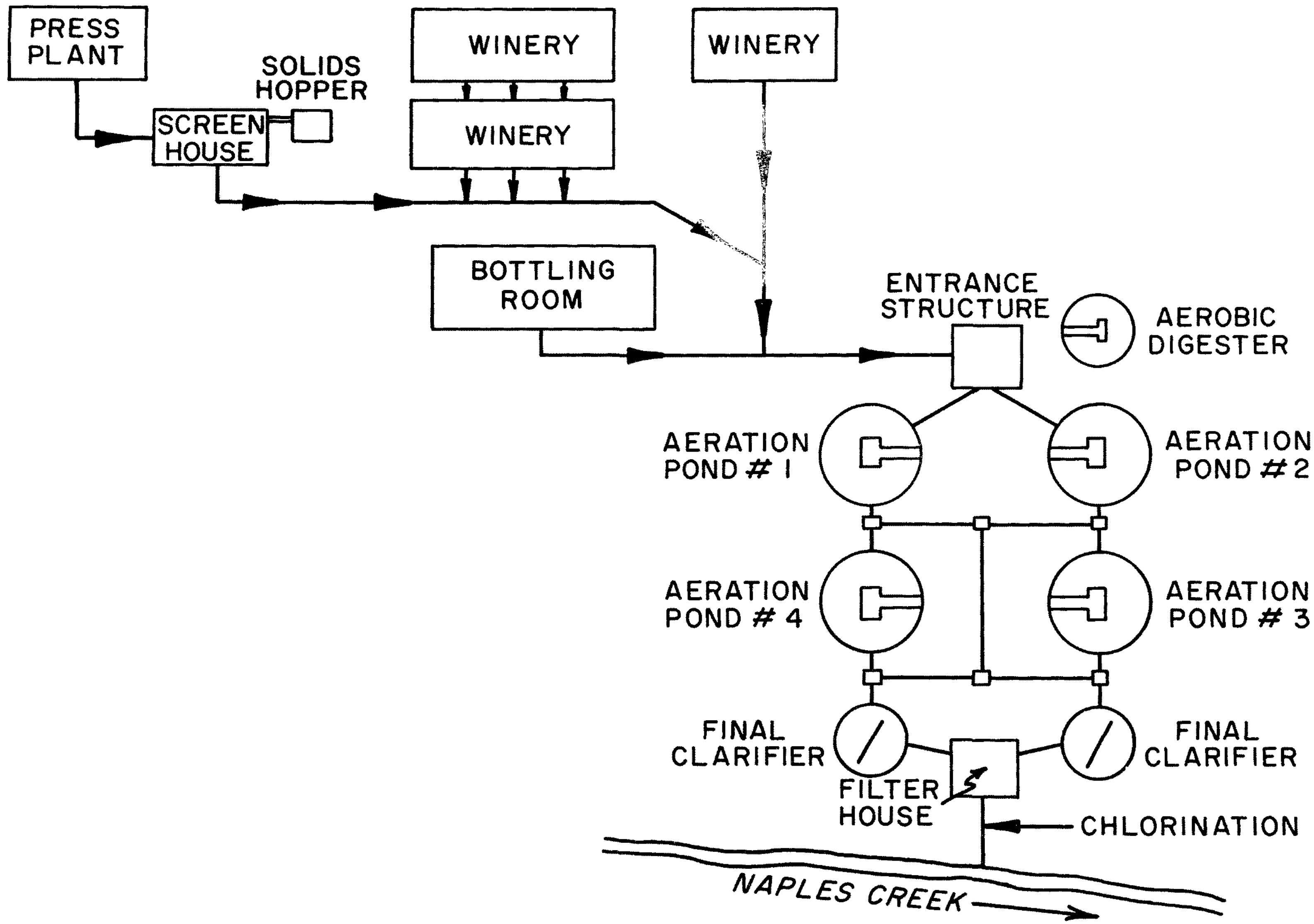


Figure 13. Flow diagram for Widmer's waste treatment facility (74).

The stillage is flowed onto soil to a depth of about 10 cm or a loading of 935 m3/ha and then allowed to dry completely. This drying period takes from 7 to 14 days depending on the type of stillage, soil and weather conditions. When thoroughly dry the solid cake will crack and curl exposing the soil. The dry cake can be disced into the soil and the plot used again. The initial 10 cm liquid depth and adequate drying must be emphasized for successful operation.

Fortunately, virtually all wine distilleries are located in California's central valleys. The climate is hot and dry and the soil is sandy. Under these conditions properly managed systems have been operated successfully for many years.

TABLE 33. RELATION OF VOLUME OF STILLAGE TO ALCOHOL IN DISTILLING MATERIAL

Original 12% D.M., l	Water Added To Original D.M., l	Final D.M., l	Alcohol In Final D.M., %	Brandy Produced, # Proof l	Stillage Produced[a], l
100,000	0	100,000	12	24,000	115,000
100,000	20,000	120,000	10	24,000	138,000
100,000	50,000	150,000	8	24,000	172,500
100,000	100,000	200,000	6	24,000	230,000
100,000	200,000	300,000	4	24,000	345,000
100,000	500,000	600,000	2	24,000	690,000

[a]The number of liters of stillage is approximately 15 percent higher than the number of liters of distilling material. This represents the steam condensate from the still.

Land disposal of stillage has several benefits. It is easily operated with no special skills or education required as compared to most other treatment schemes. When properly managed no untreated wastewater reaches the surface water courses and a crop can be grown on part of the land during the off season to help defray costs. This past year, one California winery planted wheat and barley on part of its disposal field without additional fertilization. The crop was very successful and paid for a major portion of the operating costs.

Along with these benefits a couple of very definite drawbacks exist. The system requires a substantial area of land, 0.74 to 1.5 hectares per 100,000 liters of stillage produced per day. Many wineries are located within cities so the stillage must be piped to a site outside the populated area. The city of Fresno, California currently has a system that sends the wastewater from three wineries 6 miles to a land disposal site (13). Also, even undeveloped land in many parts of California's central valleys is very expensive (more than $400 per hectare) so a substantial capital outlay may be involved.

A second problem is the possibility of polluting the ground water. A current study (79) of soil and water conditions in a land disposal site is being carried out in California. For this study the samples were compared to a control plot receiving only irrigation water. Some results were: a higher microbial biomass in the surface layers of soil receiving stillage, a higher pH only in the upper two feet (this decreased with time when stillage applications were halted), increased soil salinity was not found to be a problem with stillage disposal, and the phosphorus and potassium levels were higher at depths greater than or equal to 1.8 meters (79, 78). Very significant amounts of nitrogen and phosphorus can be removed from the soil by raising a crop during the off-season (70). The study also indicates that the concentration of phosphorus, nitrogen, nitrate, and salt in soil receiving stillage wastes is lower than the standards for potable water at depths of 1.8 to 4.9 meters (79).

The quality of the groundwater should be monitored periodically as increasing pollution would require a re-examination of the treatment method. Despite these problems a conscientiously designed and operated land disposal system appears to be the most practical for wine stillage disposal.

Most attempts to treat winery stillage using conventional biological techniques have been unsuccessful. Virtually all these attempts have been either bench or pilot scale. One of the major problems is the very high suspended solids content of stillage. Aerobic treatment may require that 90 percent of the solids be removed prior to aeration (51). The solids are very difficult to settle in clarifiers, and even when separated, they represent a huge sludge disposal problem. The BOD_5 is also too high for standard aerobic treatment requiring a dilution to 1000-1500 mg/l with a subsequent increase in volume (80). There is inadequate available nitrogen and the pH is low as shown in Table 32. These factors combined with the short season make both aerobic and anaerobic treatment of stillage impractical either operationally or economically.

Anaerobic treatment schemes have been tried several times on winery stillage. One study (80) showed that about 70 percent reduction of BOD_5 and volatile solids could be achieved with loadings of 1.6 to 3.2 kg of volatile matter per day per cubic meter of digester capacity. A recent study (51) done with anaerobic packed beds showed similar removal rates. However, with 70 percent removal the effluent is still of very poor quality and probably would require additional treatment before it could be sent to a municipal treatment plant. Also, anaerobic systems require an acclimation period which could be a problem with such a seasonal waste. Effective operation has traditionally been a problem with these systems. One researcher (51) of stillage treatment states that additional study of anaerobic systems is not recommended.

Aerobic treatment of winery stillage has been investigated recently using pilot scale activated sludge units (51). Effective biological treatment in the aeration tank was found to be dependent on pretreatment for solids removal. Centrifugation proved to be the only method that would effectively remove the solids as they must be concentrated from about 2 percent to 10 percent. With this pretreatment, aerobic treatment was very successful in converting the organic matter; however, the activated sludge settled very slowly and contained substantial unsettleable material. This resulting effluent had unsatisfactorily high levels of COD and SS. Another drawback to aerobic treatment is the large quantities of nitrogen that must be added.

Based on the study mentioned above, a system of aerated lagoons preceeded by solids removal was recommended as the best method of biological treatment when land disposal is not feasible. Final sedimentation would take place in holding ponds with about a one day residence time. The final effluent should be satisfactory for irrigation or disposal in a municipal treatment plant.

Presently, an extended aeration plant in Kelowna, British Columbia, is treating a combination of winery waste including stillage, fruit processing wastes and municipal sewage (22). About 48 percent of the total BOD_5 load and 23 percent of the flow come from the winery. This plant produces an excellent effluent; however, the loadings are low and the plant is currently operating considerably under capacity.

SECTION VI

S.I.C. 2085 DISTILLED LIQUORS EXCEPT BRANDY

Industry Description

The U.S. distilled liquors industry is of considerable size with 64 facilities producing 387 million tax liters of beverage from January to July, 1974. This results in over 3 million m^3 of wastewater assuming 8 liters are discharged for every liter of product. The industry can be divided into rum distilleries that utilize cane molasses as a raw product and grain distilleries that make whiskey, gin, vodka, and cordials. Whiskey constitutes about 75 percent of all distilled liquor production. In 1973, 64 grain distilleries used 938 billion kg of grain of which about 1/3 is considered waste (55). The five rum distilleries operating in Puerto Rico have a waste equivalent of 77 percent of the island's population (2.7 million in 1970) (55). Five distilleries in the United States also make rum but in most cases that is not their sole product. About half of the grain distilleries are located in Kentucky with most of the remainder being in the neighboring states of Illinois, Indiana, Maryland, Pennsylvania and Tennessee.

The Bureau of Domestic Commerce estimates that the distilled spirits industry will grow at a compounded annual rate of 3 percent through 1980 from a $1.6 billion production in 1974 (67).

Production Methods and Wastewater Sources

For the purposes of this discussion the distilled spirits industry will be divided into grain distilleries which make mostly whiskey and those that use cane molasses to make rum. Most grain distilleries use similar processes and procedures to make their product, so a brief outline of these techniques will be discussed with emphasis on waste generation. Figure 14 gives a general process diagram for a grain distillery.

About 1.3 kg of grain are required to produce one proof liter of distilled liquor (3, 55). The common grains used are corn, barley, wheat, oats, rye and sorghum. First, the grains are milled into a meat which breaks the cellulose around each kernel and exposes more starch surface. Then the meal is put into a cooker and 75 to 150 liters of water are added per bushel to form a mash. Four different cookers may be used: atmospheric batch, pressure batch, pressure continuous and pressure semicontinuous. After cooking, the mash is cooled and milled malt is added which converts starches in the mash to sugars by enzyme action. Water is used to cool the cooked mash and to wash the cooker.

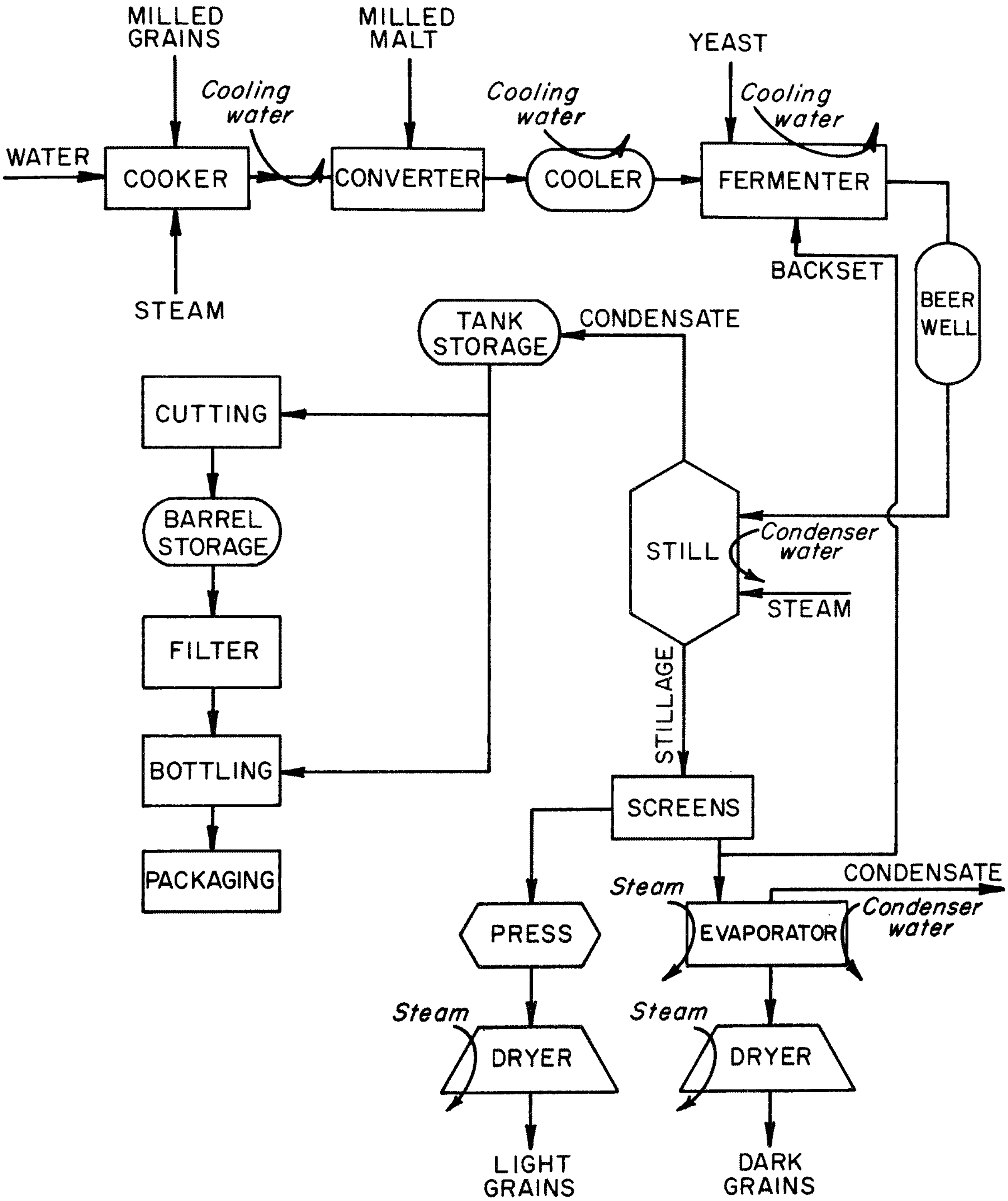


Figure 14. Process diagram for grain distilleries.

After the starches are converted, the mash is further cooled to 18-24°C and pumped to the fermenters. Here yeast and backset (screened stillage) are added and the mash is allowed to ferment until all sugar is converted to alcohol and carbon dioxide (55). Cooling water is used to control the fermentation temperature. Washwater is used for fermenter and yeast tub clean-up and may account for 1 percent of the total waste load. The first rinse which may contain considerable mash and alcohol is frequently discharged to the beer well.

Following fermentation, the "beer" (fermented mash) which contains about 7 percent alcohol by volume is put into a beer well. The beer is held in the well until it is pumped into the still near the top. In the still, which is usually a continuous whiskey separating column, steam strips the alcohol from the beer. This vapor is condensed and used to make the product. The residual mash (stillage), which contains 4-6 percent solids, is discharged at the base of the still (55). Once it has been screened, 15-35 percent of the stillage is recycled back to the fermenter as backset. This recycling reduces the volume of the non-fermentable portion of the grain by 15-35 percent. For each proof gallon of product about 30 liters (8 gallons) of wastewater, which contains 1.8 kg of grain, are discharged from the still.

When making Bourbon whiskey, the first distillation from the beer still is redistilled (doubled) to remove various impurities. The doubler which is usually a steam heated kettle increases the alcohol content of the distillage from 115 proof to 130 proof. The hot liquid plus impurities in the doubler are dumped periodically, usually after each day's distillation. This wastewater is low in volume, high in strength and accounts for 1 to 2 percent of the plant load.

As they come from the still, beverage spirits are colorless and somewhat pungent and therefore must undergo a final process called maturation. Portions are used for producing various grades of liquor by diluting with deionized water. Then, the spirits are put in new, charged white oak barrels and stored until the whiskey attains the desired ripeness and maturity. During this time wood constituents are extracted from the barrel and some of the liquid components are oxidized.

After reaching maturity in the barrels and being filtered, the product is ready for bottling. Sometimes bottling is done at a separate facility. In the bottle area waste can result from occasional breakage, spillage and upkeep, but it is usually less than 1 percent of a distillers total. Table 34 gives a summary of the wastewater sources in a grain distillery.

Rum is made in much the same fashion as whiskey and other grain spirits; however, the general process and wastewater sources will be briefly mentioned. Molasses, which is the primary raw material is pasteurized, diluted with water, and acidified with sulfuric acid. Then nutrients and yeast are added to make up the fermentation mash. The mash is put in a fermentor to undergo a controlled batch fermentation which leaves the mash with an 8-12 percent alcohol content (25). Next, the mash is distilled using a three column system; one to remove all the volatiles and the other two to purify the ethyl alcohol. The still slops are removed from the bottom of the still. Following distillation, the spirits are transferred to holding tanks and then to oak barrels for aging. After a legally defined period of aging the beverage is bottled. Figure 15 is a process diagram for the production of rum.

TABLE 34. DISTRIBUTION OF POLLUTION LOAD OF A DISTILLING PLANT OPERATING AT AN AVERAGE OF 225 METRIC TONS (9000 BUSHELS) OF GRAIN PER DAY FOR FIVE DAYS A WEEK (3)

Source	Volume (m^3/1000 kg)	BOD_5 (kg/1000 kg)	Percent of Total BOD_5
Cooking & Mashing	3.03	.544	12
Fermenting	.151	.036	1
Distilling	.454	.036	1
Feed Recovery	4.09	4.52[a]	79
Rectifying & Bottling	.151	.181	4
Power House	.151	.072	2
Domestic	.454	.054	1
TOTAL	8.48	5.44	100

[a] Includes BOD_5 from barometric waters

Wastewater Characteristics

As a result of the stillage produced, grain distilleries have potentially a very strong, high volume effluent. Several factors can significantly affect the quality of this wastewater. Complete or partial recovery of spent grains is essential to reducing the waste load. The extent of water conservation reuse and inplant residue recycling is also quite important along with the type of processing used at the distillery.

Generally, all of the individual waste streams are combined and disposed as one total effluent. This effluent contains non-recoverable grain particles, organic acids, aldehydes, esters and alcohols making both the BOD and solids levels unacceptable for disposal in a natural water source. The temperature of the effluent is around 41°C which could make it a source of thermal pollution (57). Tables 34-37 list a few of the characteristics of a distillery's total effluent.

For by-product recovery and water reuse, the characteristics of the individual process effluents are important. The dry house effluent accounts for about 80 percent of the total distillery organic load and 70-75 per

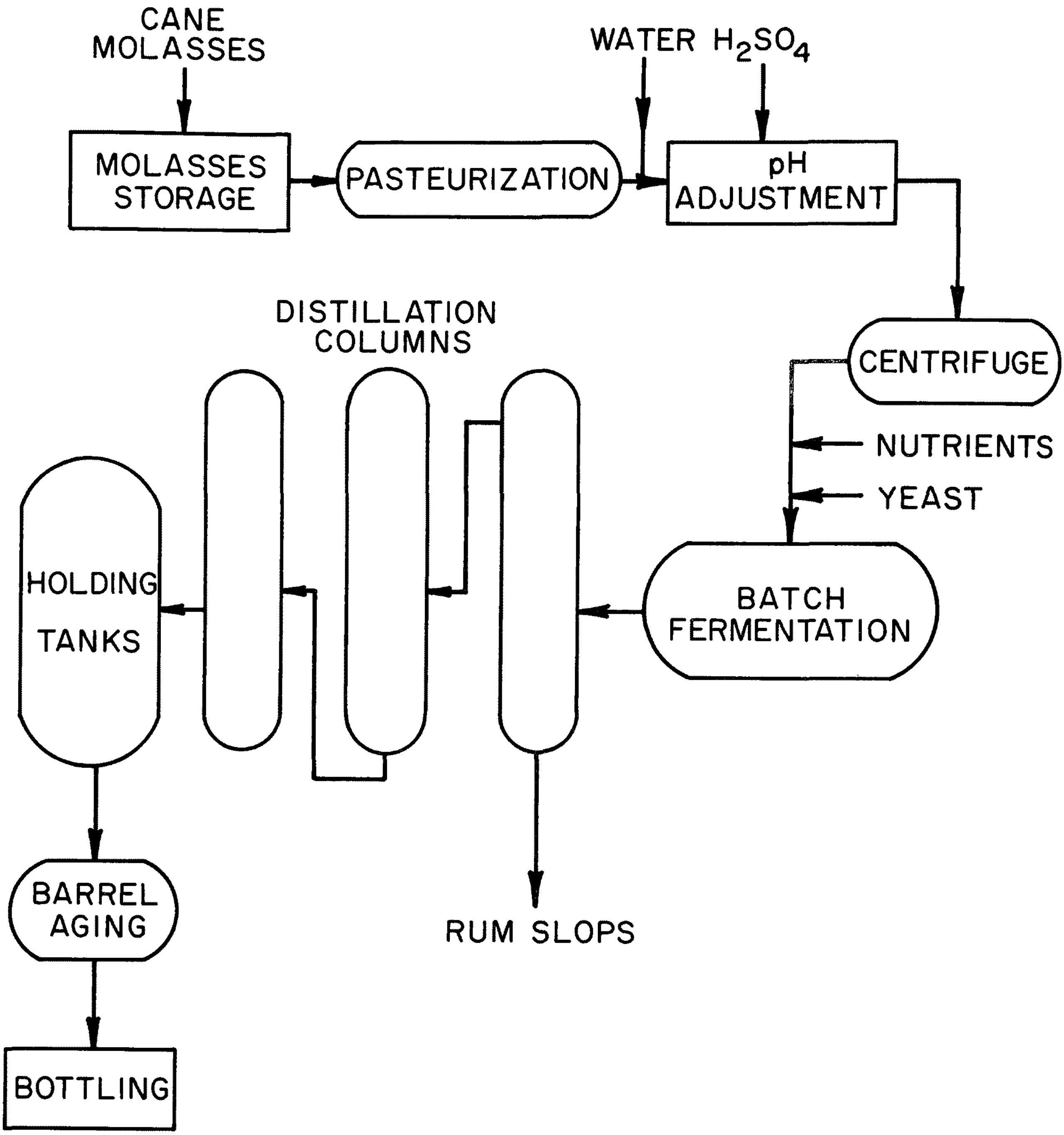


Figure 15. Process diagram for rum distilleries.

cent of the liquid volume. Within the dry house, the sterile evaporator condensate makes up about 80 percent of the effluent. The liquid content of the stillage, which is received in the dry house, is affected by the beer gallonage, the percent of backset and the method of heating the stills. The beer gallonage is the gallons of water added per bushel of grain to make up the mash. This volume can be kept down around 28-36 gallons per bushel. The strength of the condensate can vary significantly with differences in design and operation of the evaporators.

Tables 35-37 give a summary of the different wastewater sources and the associated effluent volumes and loads.

TABLE 35. AVERAGE WASTEWATER CHARACTERISTICS - GRAIN DISTILLERY (8)

Parameter[a]	With Cooling Water	Without Cooling Water
BOD_5 (mg/l)	266	486
Suspended Solids (mg/l)	177	148
Settleable Solids (%)	0.13	0.15
Total Solids (mg/l)	772	827
Temperature (°C)	42	62

[a]Distillery processes about 138 metric tons (5500 bushels)/day

TABLE 36. AVERAGE WASTEWATER CHARACTERISTICS BY PROCESS AREA-GRAIN DISTILLERY (44)

Parameter[a]	Avg. Flow (m^3/day)	Avg. BOD_5 (kg/day)	Avg. SS (kg/day)
Bottling Area	114	82	27
Cooker Building	400	252	363
Fermenters	28	27	10
Distillation & Feed House	570	411	481
Warehouse & Power Plant	16	2	3
Other & Sanitary	100	85	103
TOTAL	1228	859	987

[a]Distillery processes about 312 metric tons (12,500 bushels)/day

TABLE 37. DISTILLERY AND DRYHOUSE WASTES FROM A TYPICAL PLANT (3) (75 Metric Tons (3000 Bushels) Capacity)

Type of Waste	Volume (m^3/1000 kg)	Total Solids mg/l	Total Solids kg/1000 kg	BOD_5 mg/l	BOD_5 kg/1000 kg	BOD_5 % of Total	pH	Temp. (°C)
Evaporator Condensate	2.27	130	.29	600	1.4	42	3.9	52
Washes	1.06	1050	1.1	1000	1.1	33	6.0	21
Cooling Tower Overflow	1.20	1100	1.4	550	.64	20	8.0	46
Doubler	.152	240	.036	1000	.16	5	5.0	77
TOTAL	4.68	590	2.8	690	3.2	100	5.0	43

Like grain distilleries rum distilleries must dispose of stillage which has a very high pollution potential. The volume and strength of the stillage are affected by the variable sugar and ash contents of the molasses plus the acidification of the molasses-water mixture needed to obtain an optimal pH level for fermentation.

The total plant effluent from a rum distillery is doninated by the presence of the stillage which gives it a high temperature and strength and a dark brown color. Tables 38 and 39 give a summary of the effluent characteristics.

Of the individual waste streams, the slops discharge constitutes 66 percent of the waste flow, over 98 percent of the BOD_5 and COD, over 90 percent of the solids and essentially all the nitrogen and phosphorus. Table 40 gives a listing of individual process effluent characteristics.

Wastewater Management

Both grain and rum distilleries must dispose of an effluent that is high in organics and solids. The effluent strength must be drastically reduced by in-plant recovery and treatment techniques before it can be safely discharged to a natural water body. Even discharge to a municipal sewer will require significant waste load reductions.

Recycling

Within a distillery, few process areas exist where recycle technology can be applied. As previously discussed, grain distilleries recycle about 18-35 percent of the screened stillage (backset) back to the fermenter. This practice concentrates the non-fermentable portion of the grains by a corresponding amount.

TABLE 38. TYPICAL ANALYSIS OF RAW WASTE FROM RUM PRODUCTION (25)

Parameter	Level
pH	4.7
BOD_5	20-35 g/l
COD	100-130 g/l
Sugar	1.6% (by volume)
Volatile Solids	50-75 g/l
Ash	16-40 g/l
Volatile Acids	700 mg/l (as acetic)
Alkalinity	1000 mg/l (as $CaCO_3$)

TABLE 39. TYPICAL ANALYSIS OF RAW WASTE FROM RUM PRODUCTION (53)

Parameter	Level
COD	70-100 g/l
BOD_5	20-60 g/l
Total Suspended Solids	3-10 g/l
Total Dissolved Solids	75-85 g/l
Total Nitrogen	0.8-1.5 g/l
Total Phosphorus	60-100 mg/l
Sulfate	3-5 g/l
pH	4.0-4.7
Color	100,000 units
Temperature	80-90°C

TABLE 40. WASTEWATER GENERATION IN RUM PRODUCTION (53)

Waste Parameter or Constituent	Total Facility Waste Generation per Proof Gallon	Percent Contribution by Type of Waste Stream: Slops Streams	Barrel Washings	Boiler/Cooling Water & Fermentation Washdown	Water Treatment & Analytical Lab. Wastewaters
Volume	55.6 l (14.7 gal)	66%	5%	26%	3%
COD	3.0 kg (6.6 lb)	98%	1%	1%	--
BOD_5	1.0 kg (2.3 lb)	99%	--	1%	--
Total Solids	4.2 kg (9.2 lb)	91%	--	9%	--
Total Dissolved Solids	3.9 kg (8.6 lb)	91%	--	9%	--
Total Suspended Solids	0.25 kg (0.56 lb)	97%	--	3%	--
Total Kjehldahl Nitrogen	0.06 kg (0.14 lb)	100%	--	--	--
Total Phosphate	0.003 kg (0.007 lb)	100%	--	--	--

Recycle of cooling waters is practiced extensively by both grain and rum distilleries. A distiller will not recycle its cooling water if a large source such as a river is readily available; however, when the supply of water is limited, some type of recycling process is required. Cooling towers and spray ponds are the predominant cooling devices used. The towers are ideal when the available land area is limited. Figure 16 shows the results of a sampling of distilleries taken in 1971 in regard to cooling water recycle.

By-Product Recovery

The recovery of spent grains by grain distilleries is their most important pollution abatement practice. The grains have been recovered at some distilleries since the turn of the century and in 1973 over 360,000 metric tons were reclaimed. Although the grain recovery operation substantially reduces a distillery's waste load, spent grains are still responsible for 80-85 percent of the remaining load.

The stillage leaves the still at around 5-7 percent solids. Some small distilleries haul the grains away in this wet form for livestock feed with a few plants providing coarse screening. Generally the destination of these wet, spent grains is close to the distiller as transportation costs can become prohibitive.

Most large distilleries operate a "dry house" where the water is removed from the stillage. First, the stillage is screened to remove the coarse solids which are then processed. The screened stillage ("thin" stillage) may then be centrifuged to remove some of the smaller solids. Next the thin stillage is sent to a multiple-effect evaporator and concentrated to a syrup of 25-30 percent solids which is dried in drum driers. The evaporator condensate accounts for 40-50 percent of the plant's total waste load. The dried grain contains, fat, fiber, protein, non-fermentable carbohydrates and a small amount of minerals which make it an excellent livestock and poultry feed. Figure 17 is a diagram of dry house operations.

One grain drying system currently in use (26) employs a recompression evaporator to replace the triple-effect evaporator. This unit is saving $75,000 to $100,000 in annual operating costs while handling 378,000 liters of stillage per day, six days a week. First, the stillage is centrifuged and then the concentrate is sent to the recompression evaporator where it is concentrated from 2.5 percent to 31 percent solids. This unit operates at relatively low temperatures; therefore, the high nutritive value of the stillage is maintained. A plate evaporator and dispersion dryer complete the process.

At rum distilleries the nature of the raw material and the resulting stillage make by-product recovery far less attractive. Most of the solids in rum stillage are soluble and therefore difficult to dry. Only 30 percent of the solids in grain stillage are soluble. Presently, recovery of rum stillage is not practiced on a commercial scale.

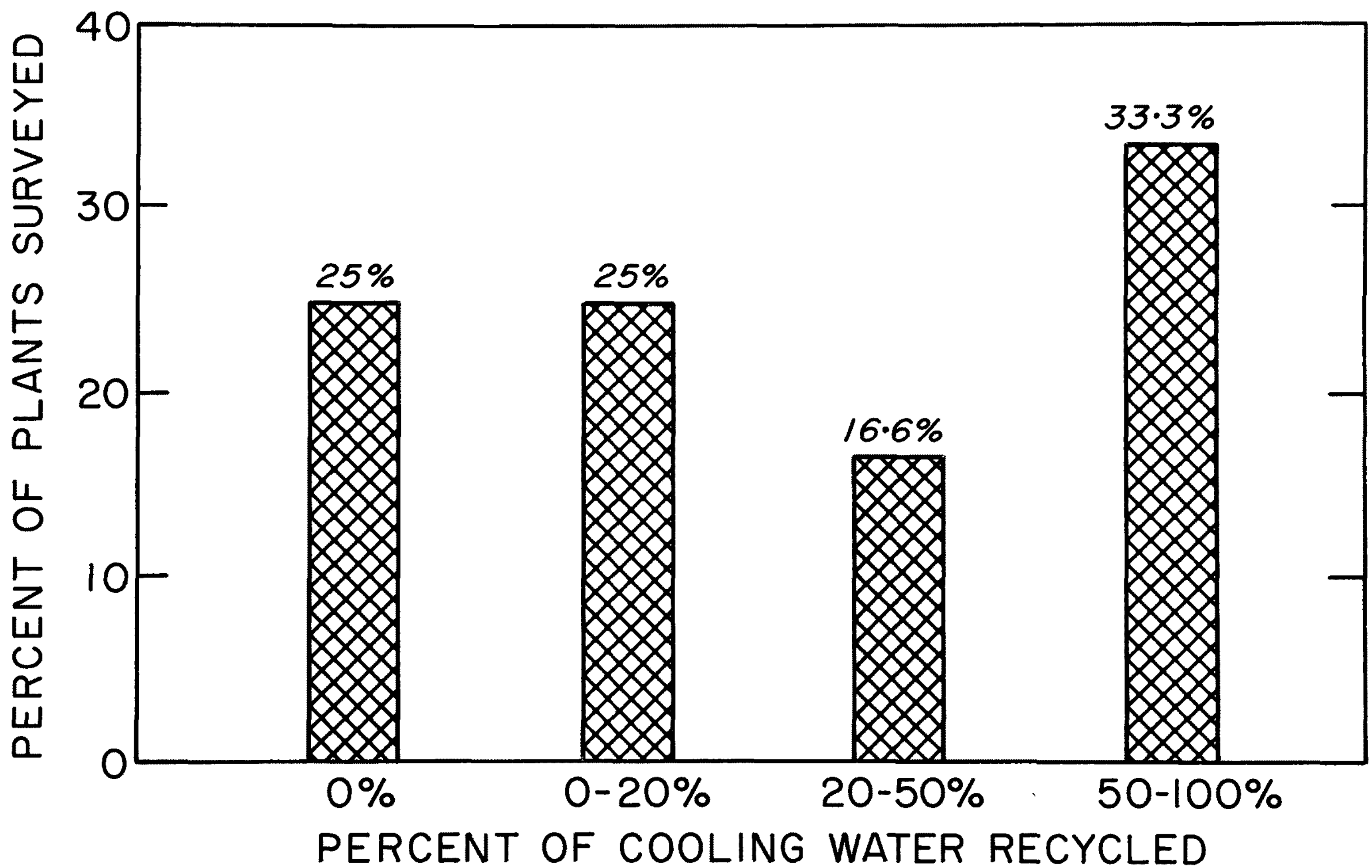


Figure 16. Percent of plants surveyed practicing various degrees of cooling water recycle (3).

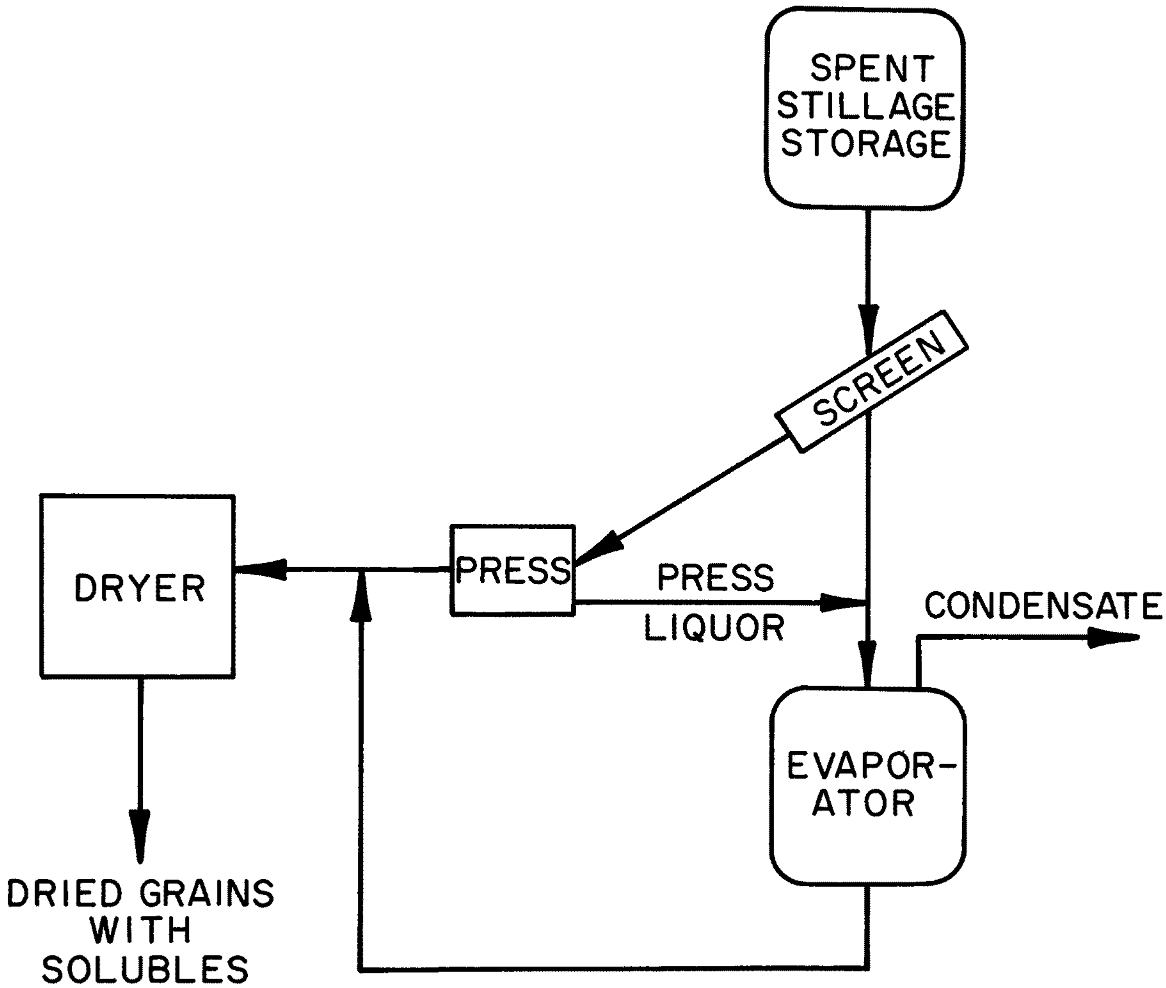


Figure 17. Dry house operations.

During the mid 60's a pilot plant was built in India to dry rum stillage and recover the potassium salts as a by-product. India has a great need for potash fertilizers. The plant used a filter press and a quadruple-effect evaporator to drive off most of the liquid. Then, the concentrated stillage was incinerated and the potash-rich ash collected. The potassium salts are leached out of the ash and recrystallized. At that time the process was reported to be economically sound (7).

Wastewater Treatment

As previously discussed, distillery wastewaters are organic in nature and highly biodegradable. This makes them potentially very harmful to natural streams and amenable to biological treatment systems. The effluent strength and degree of treatment required are dependent on by-product recovery techniques, the amount of water reuse, waste stream segregation, and processing techniques.

In 1970 about 50 percent of the grain distilleries questioned in a survey had waste treatment plants, but that percentage has certainly increased. Most of the remaining plants discharge their effluents into municipal sewers with just a few putting their wastes directly into large bodies of water. Being readily biodegradable, distillery wastes require no special facilities when discharged to a municipal plant. Of the distillery owned treatment plants, most utilize conventional biological treatment methods. Three existing plants are described here as examples (19).

Plant 1

This treatment system consists of three lagoons in series receiving a total waste flow of 136,000 liters per day. The first lagoon is about 2 meters deep and provides primary treatment. Most of the solids are settled out and digested under anaerobic conditions. This lagoon achieves 85 percent BOD_5 removal at a loading of 90 kg BOD_5/hectare - with an 89 day detention period. The second lagoon is also 2 meters deep and provides secondary treatment under aerobic conditions. This lagoon achieves 65 percent BOD_5 removal at a loading of 20 kg BOD_5/hectare-day with a detention time of 75 days. The third pond is 0.9 meters deep and provides tertiary treatment, mostly nitrogen and phosphorus removal. It achieves 57 percent BOD_5 removal at a loading of 3.6 kg BOD_5/hectare-day with a detention time of 49 days. The whole system provides 95 percent BOD_5 removal. This treatment scheme yields a good effluent with minimal operation and maintenance; however, it does require substantial land area that may not be available to many distilleries.

Plant 2

This distillery-owned treatment plant consists of a primary aeration pond, a two stage trickling filter and two oxidation ponds. The total distillery flow is 378,000 liters per day. The BOD_5 of the effluent as it leaves the distillery averages around 800 mg/l. The primary aeration pond has two 5 H.P. aerators which supply sufficient oxygen but do not keep the solids in suspension. It has a detention time of 5.85 days and a surface loading of 2500 kg/hectare. This unit's BOD_5 removal efficiency varies from 45 percent in winter to 70 percent in summer.

The two trickling filters are operated in series with an average hydraulic loading of 0.68 l/sec/m^2 (1 gpm/ft^2). The filters are 4.66 meters square, 6.7 meters deep and filled with PVC media. The first oxidation pond has a detention period of 7.5 days and a surface area of 0.19 hectares. A 5 HP aerator is provided at the entrance of the pond. In series with the first oxidation pond is a second with a surface area of 0.19 hectares and a detention period of 6 days. The final effluent BOD_5 for the system averages 30 mg/l (19). This type of system requires considerably less land area than Plant 1, but operation is more complex and costs are higher.

Plant 3

The American Distilling Company, successfully treats its wastewaters using parallel operation of three activated sludge units and bio-disc treatment (57). In a full-scale U.S. Environmental Protection Agency supported demonstration project the activated sludge system with a total design flow of 2000 m^3 per day consistently removed over 90 percent of the BOD_5 with widely varying operating conditions. The bio-disc system, after the flow was reduced to 170 cubic meters per day from the design flow of 450 m^3, attained a BOD_5 removal efficiency of 90 percent. Series operation of the bio-disc and activated sludge treatment did not improve efficiency.

Pilot scale anaerobic digestion has also been used to treat grain distillery wastes (43). Results have been quite good, but it is more attractive when the influent waste load is abnormally higher than common grain distillery effluent.

Rum distilleries located in Puerto Rico do not treat their wastewaters prior to disposal. Like those from a grain distillery, rum distillery effluents are readily biodegradable but they are also much stronger. A major portion of the organics in grain distillery effluent are in the insoluble form and are easily removed. This is not the case with rum distillery effluents. The large organic content and the resulting high oxygen demand make economical oxygen transfer in an anaerobic system very difficult. For this reason most research to date has concentrated on anaerobic treatment.

Both bench and pilot scale anaerobic digestion systems have been tried on rum stillage (25, 53, 7, 52, 48). A very interesting aspect of these investigations is the importance of feed dilution. One study (25) showed a 70 percent COD removal with a loading of 5.9 kg COD/m^3-day and a detention time of 16 days treating full strength stillage. Using diluted waste (65 percent of full strength) 71 percent COD removal was achieved with an organic loading of 7.7 kg COD/m^3-day at a detention time of 8.4 days. This higher loading with the diluted waste can be attributed to the high volatile acids and low pH that develop when the raw waste is fed to the digestor. The sulfide ion was found to inhibit digestor operation so its concentration must be controlled. Gas scrubbing with ferric chloride and recirculation through the reactor relieves this inhibition and lowers the volatile acid concentration.

Pilot scale anaerobic contact units have also been used to treat rum stillage. This is just a variation of the anaerobic digestor involving sludge recycle and a lower liquid detention time. One Environmental Protection Agency study (53) showed that the unit could produce an effluent of 30,000 mg/l COD from an influent of 70,000-100,000 mg/l with detention times greater than 40 days.

Both of these anaerobic units produce methane on such a scale that it is economical to recover as a by-product. About 25 volumes of gas are produced for every volume of wastewater treated and 60 percent of this is methane. The anaerobic contact study indicated that methane recovery in a plant-scale installation could reduce unit treatment costs by one-third at a design capacity of 189 m^3/day and two-thirds at 1136 m^3/day.

Although they do reduce COD significantly, these anaerobic units produce an effluent that is still very strong and unacceptable for disposal even to a municipal sewer. Most likely, a combination of anaerobic, aerobic and solids separation processes or some type of land disposal like that used for wine stillage will be required to produce a satisfactory effluent. Much more research is needed in this area as rum distillery effluents continue to be one of the most serious water pollution problems in the beverage industry.

SECTION VII

S.I.C. 2086 BOTTLED AND CANNED SOFT DRINKS INDUSTRY

Industry Description

The soft drink industry (SDI) had 2943 plants in 1971 (18). About half of these are small, employing fewer than twenty people. The bulk of the product comes from medium-sized and large plants owned by major companies offering nationally advertised products, or from medium-sized plants bottling the same products under franchise agreements. The product is sold in stores in a variety of containers ranging in size from 0.18 liters (six ounces) to 1.9 liters (half-gallons). Vending machines are in common use in gasoline stations and canteens. Restaurants and bars used bottled or canned products to some extent, but there is a strong trend toward the use of dispensing equipment. Some small plants or companies serve a local market through direct home delivery. Small locally-owned plants produce a variety of flavors, while larger companies with many plants (and franchise agreements) have tended toward the production of a single product. In recent years, however, the larger companies have developed fuller lines of flavors with several advertised brand names

A number of recent developments in the industry have had a marked impact on industry practices and on wastewater production and disposal. First, there is the introduction of non-returnable or one-way containers. From the wastewater standpoint, bottle washing was and is the major contributor of waste. A plant packing only one-way containers eliminates the major source of water-borne waste. Some plants packing both returnable and one-way bottles pass the one-way bottles through the wash cycle because of the automatic features of their packing machines, and because new bottles or cans contain cardboard dust or other soil from manufacturing and packing. This affects water use, but no significant amounts of waste substances are added to the total wastewater streams. Some plants use an air wash for new containers.

Public acceptance of canned soft drinks is commonplace. Family-sized packages (32 ounces) are not offered in cans. The so-called "fruit juice drinks" are sold in 42 ounce cans in food stores, but the fruit juice drinks are not manufactured in soft-drink packing plants. Most recently, the leading brands of juice drinks have been introduced in the standard individual soft drink can size (12 ounces) as have "iced-tea" beverages.

The Food and Drug Administration is pushing for nutritional labeling of foods and beverage products (42). Such labeling could affect the market acceptance of beverage products. If juice drinks or other products displace soft drinks from the market, one can expect that the soft drink packers will take on the new types of products in the future. One of the major juice drink brand names is owned by a major national soft drink company. A food company brand name iced-tea beverage is being packed and is now available on the market.

The recent public awareness of environmental quality has resulted in some national pressure against one-way containers and in state laws banning one-way containers (56). Success of the bottle bill in Oregon along with a recent Maryland Supreme Court decision allowing local jurisdiction in requiring refundable containers would indicate that the trend of using "throw away" containers is reversing. In fact, a Texas soft drink bottler has urged the industry to end its opposition to returnable bottles (73).

Another important development was the introduction and growth in popularity of the sugar-free or low-calorie soft drink. Since sugar is the major BOD substance in a soft drink packing plant waste, the waste strength should be markedly less in a plant packing only the low-calorie products. Industry-wide there has been a tendency for the low-calorie products to be packed in one way containers. The banning of cyclamates hit the industry hard, but since then new cyclamate free recipes have been developed. The dietetic products are being heavily advertised and have captured the same market attention as the cyclamate-sweetened products.

Over the past decade or so the soft drink industry has grown about five times faster than the population, at a rate of about 6.5 percent a year. There is evidence that this growth rate is leveling off (18). This can be seen as inevitable with population growth and per capita consumption of soft drinks leveling off. At present, per capita consumption is about 83 liters per year. There has been a very definite trend toward the loss of small plants and thus an increase in the average size of plants in the industry as discussed later. Another possible development that could profoundly affect the character of the national industry is the regulation or banning by the Federal Trade Commission of territorial or area-exclusive franchises, which are the present practice (41). Such banning action would presumably result in the swamping of smaller, poorly capitalized franchise packers by larger franchise packers.

Soft drinks are more than 90 percent water (by volume). The water quality requirements for this so-called product water are stringent, essentially potable water requirements (68). Potable quality water is also needed for washing process equipment and final rinsing of bottles (if practiced). Because product delivery costs are such a large part of total costs, and because of water needs, soft drink packing plants tend to be located in or close to the urban market and almost all plants have municipal water supplies and discharge their wastewaters to municipal sewer systems.

Bottled and Canned Soft Drinks - The Product

Soft drinks are manufactured beverages consisting of sugar, syrup, flavors, acid, and water saturated with carbon dioxide. Some soft drinks are noncarbonated, but these are a small part of the total production.

Flavors (also called extracts in the bottling trade) are mixtures of flavorings extracted from fruits, roots, and other plant tissues. They also contain essential oils or aromatic chemicals in solution.

Acidulents used are the acids citric: tartaric, phosphoric and lactic. The final pH of a soft drink is 2.5 for cola and about 3.0 for fruit flavors. Root beer and similar flavors have a pH of about 4.0. A typical recipe for pH 2.0 beverage is 780 mg of 50 percent citric acid in 100 liters of beverage. A 60° Brix syrup contains 0.77 kg/liter sugar, 0.52 kg/liter water, total weight being 1.29 kg/liter. A typical soft drink contains in one liter about 3 volumes (S.T.P.) of carbon dioxide equal in weight to 6.2 mg. The 100 ml of syrup contain 0.88 ml of flavoring and 38 ml water.

The typical soft drink formula or recipe is:

Syrup	100 ml
Acid	3.8 ml
Carbon dioxide	6.2 ml
Water	890 ml
TOTAL	1.0 liter

Most bottling plants do not blend their own syrups but receive them in barrels or smaller containers, the contents of which are transferred to holding or mixing tanks as required.

Some franchised bottles receive complete syrups from the licensor. There are some independent syrup makers whose specialty is flavored syrups.

The largest companies refine raw sugar to the syrup stage and use this product for blending syrup.

Several of the large franchisors produce their own extracts; however, most flavoring syrups in use are produced from the blending of purchased materials - sugar, essences, juice concentrates or extracts.

Standard Manufacturing Process

Compared to the other industries in the Beverage Industry, the manufacture of bottled and canned soft drinks is a relatively simple process. Developments in the past two decades have made it largely automatic, requiring a minimum of manufacturing personnel. However, the ramifications of the business and the low price per unit sale combine to require a high degree of efficiency and close control of costs.

The standard manufacturing process is shown in Figure 18. The three principal sources of waste materials are:

1. Preparation of flavoring materials
2. Carbonated water
3. Bottles

While some beverage bottlers produce the flavors used from basic ingredients, blending them according to formula, most purchase those materials from specialists in flavor manufacture. They are received as extracts and usually require the addition of acidulant, color, or other ingredients which, with sugar syrups, make up the flavored base used in the finished beverage.

Simple syrup is produced by dissolving sugar in water and used as a major component of the flavoring base. After filtration of the simple syrup, the flavoring material is added according to formula to make the flavored syrup. The syrup is transferred to the filling machine by pipeline from the mixing vessel or storage tank.

The syrup-making process is omitted in some plants where the finished flavored syrup is made by proprietary formula at a central point and delivered to the bottler in barrels ready for use in the filling operation.

The component carbonated water involves water treatment depending on the characteristics of the feed water and the process water requirements. After treatment the water is cooled to approximately 2-4°C for better adsorption of the carbon dioxide. In the carbonating apparatus, the prepared refrigerated water is saturated with the carbonic gas under pressure and agitation. In some cases, a modification of the foregoing process is practiced, and that involves premixing of flavor syrup with the purified water in bulk and then subjecting it to the carbonation process.

Bottle washing is an important process in the soft drinks industry in that it adds waste load. Various types of automatic machines are available for use in the essential bottle washing operation. These machines must wash, clean, sterilize, and rinse clear all bottles. This operation generally consists of four steps:

a. Feeding of bottles to the machine

b. Pre-rinsing

c. Immersion of bottles into a series of alkaline baths for washing, cleaning and sterilization. In actual practice, only caustic soda or caustic and sodium gluconate are used. Trisodium phosphate is not commonly used nor are detergents, per se.

d. Final rinsing

After cleansing, an endless conveyor line takes the bottles to the filling machine. Inspections of the bottles are carried out before and after washing to remove the unusables and the defective ones.

Bottle washing is not practiced in about 50 percent of the plants where either washed and sterilized bottles are delivered to them by manufacturers or non-returnable (one-way) containers are used.

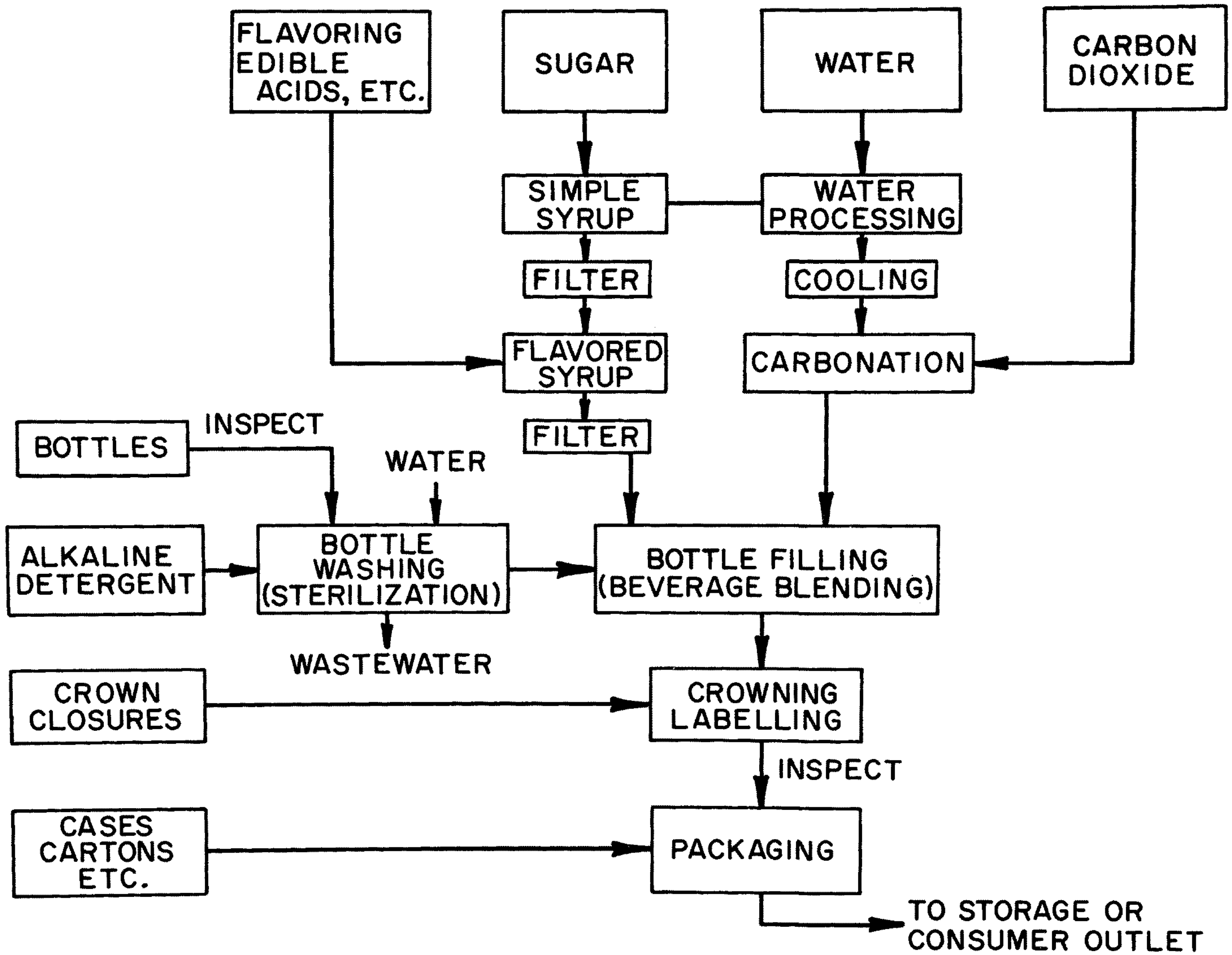


Figure 18. Flow diagram of standard manufacturing process-bottled and canned soft drinks (18).

The filling operation is carried out automatically. First, flavored syrup is added to the bottle in predetermined quantity and then it is filled with carbonated water. The metal plastic-lined crown is then placed on the bottle, being held firmly over the mouth by crimping on the locking ring at the top of the bottle. Because the syrup portion is heavier than the water, the contents must be mixed. This is done by end-over-end mixing on a machine to which the bottles are delivered by chain conveyor and from which they continue to the labeler. Labeling (if practiced) and casing are the two major finishing operations before packaging.

Water Uses and Wastewater Characteristics

In the production of soft drinks, water is used not only in the finished product but also for the following purposes:

(a) Washing containers (if practiced)
(b) Cleaning production equipment
(c) Cooling refrigeration and air compressors
(d) Plant clean-up
(e) Truck washing (if bottling plant distributes own product)
(f) Sanitary purposes
(g) Low pressure heating boilers
(h) Air conditioning

The possible sources of wastes from the manufacture of soft drinks are also as shown in the above paragraph. In addition, in-plant water treatment will involve processes by chemical coagulation, settling, carbon and sand filtration, chlorination, deaeration and others depending upon local water quality and plant demands. Ion exchange units are sometimes used. In-plant water treatment will produce waste effluents and sludges from backwashing of filter units and from removal of settled materials following chemical coagulation. The character and quantity of wastes arising from treating water will depend on the quality of the local water supply and the type of treatment units employed.

Wastewater from the bottle washing machine results from continuous discharges from the pre-rinse and final rinse, and from intermittent dumping of the cleaning solution. Various materials such as left-over drink, straws, discarded cigarette butts, soil, mold, and other miscellaneous substances are removed from dirty bottles by the pre-rinse operation of the bottle washing machine. The wastewater leaving the pre-rinse, especially in the case of modern machines, may be passed through a medium to coarse sieve or water strainer to prevent discharge to the sewer of large quantities of suspended matter. Solids recovered through screening of the wastewater from bottle washing are deposited in the plant's garbage disposal system. Some bottling plants reuse part of the final rinse as pre-rinse water which reduces spent water volumes leaving the bottle washer. Other wastes are those which occur intermittently as a result of cleaning of the syrup mixing tank, syrup feed storage tanks, and syrup filters; spillage at the syrup tank and filler; and poor housekeeping. About 10-15 percent of the products (nationwide) use artificial sweeteners which do not cause BOD.

The results of a study conducted on three bottling plants by the Taft Sanitary Engineering Center of U.S. Public Health Service (47) are given in Table 41. Plant C in the Taft Center study was obsolete at the time of the study and went out of business shortly after the study was published. From the results it can be seen that the pH of the wastes are high, ranging from 10.0 to 11.4. The BOD_5 varied from 380 to 660 mg/l and suspended solids varied from 160 to 240 mg/l.

A summary of the raw waste load is given in Table 42. The wastewater volumes per m^3 of processed drink in plants A and B are much higher than in D. This is due to the improvement of technology through the 1960's. Inspection of the BOD values will reveal that there is a large variation. It was found from the literature that the higher values are due to bottle washing operations and to paper labels on the containers. It was verified by the researchers of the Taft Sanitary Engineering Center, by measurements of left over liquid from a representative number of soft drink bottles, that waste from the bottle washing machine constituted the major source of BOD load. Of the three plants studied, Plant C discharged the greatest amount of BOD_5 per unit of production. This was due to additional operations concerning inplant mixing and blending of syrups, and the presence in the wastewater of greater quantities of materials associated with label removal from bottles. Both Plants A and B received simple flavored stock syrups for plant use and processed relatively small numbers of paper-labeled bottles.

TABLE 41. WASTE ANALYSIS OF THE EFFLUENTS FROM SOFT DRINK BOTTLING PLANTS

Plant	BOD_5 mg/l	SS mg/l	Alkalinity Pheno.	Alkalinity Total	Range of pH
A	380	170	230	390	10.1-11.4
B	660	160	100	250	10.0-11.2
C	250	340	110	220	10.4-11.2
D[a]	260	--	--	--	4.0-8.5

[a]Plant D is a typical value for a medium or large-sized modern plant operating under franchise from a major national company

TABLE 42. WASTE LOADS DISCHARGED FROM SOFT DRINK BOTTLING PLANTS PER CUBIC METER FINISHED PRODUCT

Plant	Wastewater m^3/m^3	BOD_5 kg/m^3	SS kg/m^3
A	5.07	1.92	0.88
B	3.53	2.32	0.57
C	12.8	3.15	4.33
D[a]	2.65	0.58	--

[a]Plant D is a typical value for a medium or large-sized modern plant operating under franchise from a major national company.

Based on 1960 technology, Table 42 shows a range of 1.9-3.2 kg BOD_5 per m^3 of product, but a figure of 0.6 kg BOD_5 per m^3 is shown for a typical modern medium-sized franchise bottler. By using total annual production and number of plants from the association's 1969 Sales Survey (40) and the data of Table 43, an average of BOD_5 waste load can be calculated. Table 43 contains a mixture of modern and older plants and the calculated waste loads for the minimum waste strength of 250 mg BOD_5/l and for the maximum of 500 mg BOD_5/l are 0.97 and 1.95 kg BOD_5/m^3 of beverage, respectively.

TABLE 43. SOFT DRINK PROCESS EFFLUENT BOD_5 (18)

Plant	Kilograms per Day[a]		10^3 Kilograms per Year of 250 Days	
	Min	Max	Min	Max
A	34	68	8.5	17
B	66	131	16	33
C	7.2	14	1.8	3.6
D	33	66	8.2	16
E	14	27	3.4	6.8
F	10	20	2.6	5.2
G	9.5	18	2.4	4.8
H	35	70	8.7	17

TABLE 43. SOFT DRINK PROCESS EFFLUENT BOD_5 (18) (Continued)

Plant	Kilograms per Day[a] Min	Max	10^3 Kilograms per Year of 250 Days Min	Max
I	5.4	11	1.4	2.7
J	19	36	4.6	9.3
K	9.5	18	2.4	4.8
L	37	73	9.2	18
M	4.5	9.1	1.1	2.3
N	11	23	2.8	5.7
O	8.6	18	2.2	4.3
P	19	36	4.6	9.3
Q	23	45	5.7	11

[a]Based on BOD_5 max/min, 500/250 mg/l using 1970 figures

Table 44 presents wastewater volume data from the industry survey in relation to production capacity and total water use. There is extreme variability in the ratio of wastewater volume to total water used (or to product water). With non-returnable containers in use, the wastewater can be as low as 10 percent of the total water used (90 percent of water used goes into the product). This plant does not even wash trucks, but passes the product to distributors who pick it up at the plant. In the case of the largest plant the wastewater produced includes an unknown amount of wastewater arising in a complete syrup manufacturing process in the same facility. Table 45 presents a critical check on data obtained in the soft drink industry survey, and it shows clearly that there is a marked inconsistency in the data for the two smallest plants.

It was found that all respondents except for two tended to underestimate wastewater volume, but the error is gross in the case of the two smallest plants. In the case of the smallest plant (#13) water use seems very high for production capacity, and product water estimated from water use and wastewater volume is also high in relation to production.

Due to practices in this industry such as the use of non-returnable containers and better housekeeping procedures, the waste volume and the waste load are reduced considerably. The waste loads from this industry do not pose a significant problem when compared to the other industries of the beverage category.

It is noteworthy that some plants use only non-returnable containers. These use forced air for cleaning containers. The wastewater volume in these operations is minimal. The only wastewater source is washdown of equipment and floors and backwash of water treating equipment and occasional spillage and breakage. Truck washing is not practiced in such plants because the products are marketed through distributors. The solid waste problem is also at a minimum because glass enters the premises in the final deliverable carton. The gallon jugs or other containers for extracts or complete syrup are resold and they do not constitute solid waste problems.

TABLE 44. ANNUAL PRODUCTION VS. WATER USE IN THIRTEEN SOFT DRINK PLANTS[a] (18)

10^3 Cubic Meters Beverage Per Year	Total Water Intake (10^3/m3)	Total Waste Water[b] ($10^3/m^3$)	Type Container	Waste Water (m^3/m^3) Beverage	Ratio of Wastewater Total Water Use %
50	212	170	1/2 RC 1/2 cans	3.4	80
15	42	20	NRC	1.3	48
10	50	22	NRC	2.2	44
9.1	95	76	RC	8.4	80
9.1	95	66	RC	7.2	69
6.2	45	34	RC	5.5	76
3.0	25	14	NRC	4.7	56
2.2	19	15	NRC	6.8	79
2.0	36	33	62% RC	16	92
1.4	13	95	RC	6.8	73
.57	12	9.5	85% RC	17	79
.57	7.6	7.1	RC	12	93
.24	11	1.1	RC	4.6	10

[a] Based on 1970 production--250 days/year.
[b] Includes cooling water
[c] RC = returnable bottles, NRC = non-returnable bottles or cans

TABLE 45. CRITICAL ANALYSIS OF SOFT DRINK INDUSTRY SURVEY DATA (18)

Plant	Product Water Estimated From Case Production (10^3 m^3)	Product Water Estimated As Difference Between Water Use and Waste-Water (10^3 m^3)	Ratio (Factor or Error)
1	45	42	0.93
2	14	23	1.6
3	9.2	28	3.0
4	8.2	19	2.3
5	8.2	32	3.9
6	5.7	11	1.9
7	2.8	11	3.9
8	1.9	3.8	2.0
9	1.8	3.2	1.8
10	.53	2.4	4.5
11	.53	.49	0.92
12	.23	8.8	38
13	.1	3.8	34

It has been estimated that 80 percent of the total water intake becomes wastewater when all the containers are washed. Where non-returnable containers are in use, only 50 percent or less of the water intake becomes wastewater, and the remainder ends up as product. A plant using entirely one-way containers and bottling only a single flavor or switching flavors only infrequently and not washing trucks could have a total wastewater as little as 10 percent of the product water used. The strengths of wastewaters from plants using returnable and one-way containers are in the range of 380-660 mg/l and 200-250 mg/l BOD_5, respectively (18).

Treatment Processes for Soft Drink Industry Wastes

In the survey (18) of SDI companies and interviews with managers and technical staff, none reported disposing of waste other than via a municipal sewer system. SDI wastewater is amenable to disposal via municipal systems containing, as it does, cleaning compounds, caustic soda, sugar, organic acids and salts from water treatment. Where phosphoric acid is used as acidulant in the soft drink recipe, phosphate is also included. In BOD terms, more than ninety-seven percent of the waste load can be attributed to materials washed out of reused bottles (47). Caustic material also originates almost solely from bottle washing. Strong caustic washing compounds may also be used for plant clean-up and truck washing. For the present mix of plant operations in the SDI as a whole, an average of 5.3 m^3 of wastewater per m^3 of beverage and a waste load of 1.2 kg BOD_5 per m^3 beverage are generated.

SECTION VIII

S.I.C. 2087 FLAVORINGS AND EXTRACTS

Industry Description

For 1971, the total value of shipments in the flavorings and extracts industry (FEI) was estimated at $1,475 million (64). While employment in the FEI in 1960 was about 9,500, in 1970 it was about 13,000, a figure which indicates an increase of less than 4 percent per year.

The value of the product for 1960 was $548 million. There was a 9 percent increase in the ten years following, making the 1970 value of the product $1,350 million (65). A 9 percent growth rate is predicted for the decade 1970-1980.

There is a trend towards a decreasing number of plants as shown in Table 46 with 502 establishments in 1958 and 401 in 1967. The geographic distribution of FEI plants in 1967 is shown in Table 47. A discrepancy exists in the total number of plants as reported by the different sources in Tables 46 and 47.

Note the concentration in the industrial Northeast and E. North Central regions. Employment comparisons indicate that if the average number of employees in a small plant can be taken as twelve, the average employment in a large plant is about eighty.

The Product

Natural and imitation flavorings are used in almost all manufactured food products including: bakery goods, meat, fish, and salad products, ice cream, candy and confections, and liquors and soft drinks. Sources of these materials are roots, seeds, leaves, stems, blossoms, exudates, and barks of herbs, shrubs, and trees. The industry tends to be highly proprietary.

Production methods or unit processes include milling, comminution, maceration, digestion (using heat), fermentation, percolation, extraction, concentration by freezing and evaporation, and distillation. Alcohol is added to retain volatiles during concentration by freezing.

TABLE 46. DECLINE IN NUMBER OF PLANTS (62)

Year	Number of Plants
1958	502
1963	492
1967	401

TABLE 47. GEOGRAPHIC DISTRIBUTION OF PLANTS (63)

Region	Number of Plants Total	Number of Plants >20 Employees
Northeast	170	43
South Atlantic and E. So. Central	51	14
E. No. Central	90	26
W. No. Central	30	5
Mountain	5	0
Pacific	51	14
All U.S.A.	431	110

Yields of non-citrus natural fruit flavors are about one liter of 30° Brix concentrate from 3 kg of fruit. The composition of fruit flavoring is a mixture of fruit extract, concentrated juice, and condensed volatiles from the vacuum distillation--the so-called essence.

Botanical flavors are classified from bitter to sweet to aromatic in six grades.

Distillation (the middle fraction) is employed to purify or improve alcoholic extracts prepared from macerations, digestions, and percolations. These alcoholic solutions may be freed from terpenes by dilution with water.

Oleoresins are the extracts of botanicals by means of low boiling solvents such as ethylene dichloride solvent which is recovered by condensation. Spice oils are prepared this way to preserve volatile flavor components.

Essential oils may be prepared by these unit processes:

1. Expression - (e.g., from citrus peel)

2. Steam distillation of plant tissues

3. Enfleurage - flowers steeping in fat or oil

4. Solvent extraction - especially from flowers with petroleum ether accompanied by solvent recovery

5. Adsorption - air or gas passed over delicate blossoms and adsorbed on charcoal

The basic reference text (38) lists about 300 plants as sources of flavorings. Thousands of individual compounds have been isolated and identified as compounds of flavor and many synthetics are used as additives in imitation flavorings.

The use of flavoring and other additives to food is controlled by a 1958 law (59). In reflection of the requirements of that law, a technical committee of the industry association prepared the so-called list of substances "generally regarded as safe" (GRAS), which includes natural substances (like essential oils and other extracts), and pure substances both naturally occurring and synthetic.

The first list (23) includes about 1100 substances of which about 600 are of natural origin. The second list (24) adds 125 more substances almost all of which are pure substances available as synthetics. It is not possible to determine how many of the approximately 600 natural substances are available as synthetics and consequently are produced in the organic chemicals industry (as opposed to SIC 2087), but there is no doubt of a trend toward growth of the list as synthetic organic chemical technology grows.

Components of essential oils are esters, alcohols, aldehydes, ketones, and hydrocarbons including cyclics and terpenes. Glucosides and alkaloids are also flavor ingredients.

Imitiation flavors which play a large part in processed foods are blends of aromatic chemicals, essential oils, and other substances devised to imitate natural flavors or are extracts which are flavors by themselves.

Modern analytical techniques have permitted the separation and identification of extract components resulting in more fidelity of imitation.

Natural flavorings are added in amounts ranging from 5 percent to 25 percent to improve the imitation. Preference is shown by manufacturers for these imitations because of better stability. Fortification of natural flavorings (extracts) with aromatic chemicals can increase their strength without impairing their quality.

Standard Manufacturing Process

Because of the variety of products and their proprietary nature it is difficult to classify the industry with regard to manufacturing processes and wastewater production. However, rough classification is given below:

1. Citrus oils, extracts, concentrates and other flavoring products

2. Non-citrus fruit flavors and syrups - (natural and imitation)

3. Essential oils and extracts of spices and botanicals

4. Blended syrups and flavors not involving production of basic ingredients

A typical process for a non-citrus fruit flavoring is as follows:

1. Expression of fruit, collecting juice

2. Alcohol steep of presscake and recovery of extract

3. Distillation of juice or alcohol extract of both, collecting first condensate as an essence. The essence may be fractionally distilled

4. Vacuum distillation of juice or produce concentrate

5. Removal of alcohol from steep by distillation to effect separation of residue as concentrate - possible clarification of extracts

6. Blending of the products of steps four and five with one or more of the products of step three to make the flavoring

Manufacture of several of the more common flavors and extracts are discussed below.

Vanilla Extract

Vanilla beans are finely cut up and macerated cold with three successive portions of 35 percent ethyl alcohol. The resulting extracts are combined to make a fine vanilla extract. Other solvents may be used, and the extraction carried further, but the product becomes coarser and less desirable as a fine flavor. Imitation vanilla flavor has largely replaced the natural flavoring extraction in the market.

Chocolate and Cocoa

The fermented cocoa beans are received at the manufacturing centers after drying. The beans are then heated in rotary roasters between 104 and 121 degrees Celsius which develops the true chocolate flavor and aroma and removes unpleasant tannins and volatile matter. The roaster beans are quickly cooled to prevent over-roasting, cracked in a conical mill, are dehusked by a winnowing air stream, and are degerminated. The product is known as "cocoa nibs." To work up the cocoa product into chocolate, the modern method is to grind the sugar in a closed circuit disintegrator and the nibs in a separate water-cooled two stage disc mill with closed circuit removal of fines. The two are then mixed making a fine and uniform product. For cocoa, the roasted and ground beans are subjected to pressure in hydraulic presses to remove some of the fat content. Some of the products so produced find their way into syrups and flavorings used in the beverage and food industries, but chocolate and cocoa per se are food products.

Citrus Oils

Citrus oils are used in many products other than foods. The method of manufacture is unique because the oil is abundant and almost all of it is contained in an outer layer of the peel, the flavedo (0.4 mm of the outer layer of the peel). Citrus juices contain some oil as do the seeds. The seed oil is not used much in food flavorings.

Cold pressed citrus oils (60) are currently recovered in the U.S. by three methods: (1) removal of oil from the peel after juice extraction; (2) simultaneous extraction of juice and oil emulsion from the whole fruit; and (3) abrasion of the oil-bearing flavedo from the whole fruit. As of 1962 most oils were being produced by the first method (Figure 19).

In the second method a machine consisting of two heavy rotating cylinders of stainless steel simultaneously extracts juice and shaves off the flavedo. One of the cylinders revolves against a perforated grid that presses out the juice after the cut fruit has been flattened by passage through the rollers. A peel shaver removes the thin flavedo after juice extraction just before the peel is discharged from the unit. The resulting flavedo is finely shredded, slurried with water and the oil separated as in the primary method. No water sprays are used in this method and loss of water-soluble fractions is minimal.

The third method involves removal of the oil-bearing flavedo by passing whole fruit through a tunnel of horizontal, carborundum-covered rolls. A water spray removes the oil and peel debris during the passage of the fruit through the tunnel. A screening of this slurry is followed by the standard centrifugation method of the previously detailed methods. The highest yields of oil are obtained by this method. (There are other types of abrasers or graters that can be used in this process.)

Cold pressed citrus oils may be concentrated to reduce their limonene content by vacuum distillation. The resulting products, known as "fold oils," are mainly in beverages because of good storage stability.

Natural Citrus Base for Non-Carbonated Drinks

Often called a beverage concentrate, this product consists of a mixture of natural juice or juices and sugar syrup, acidified with citric or

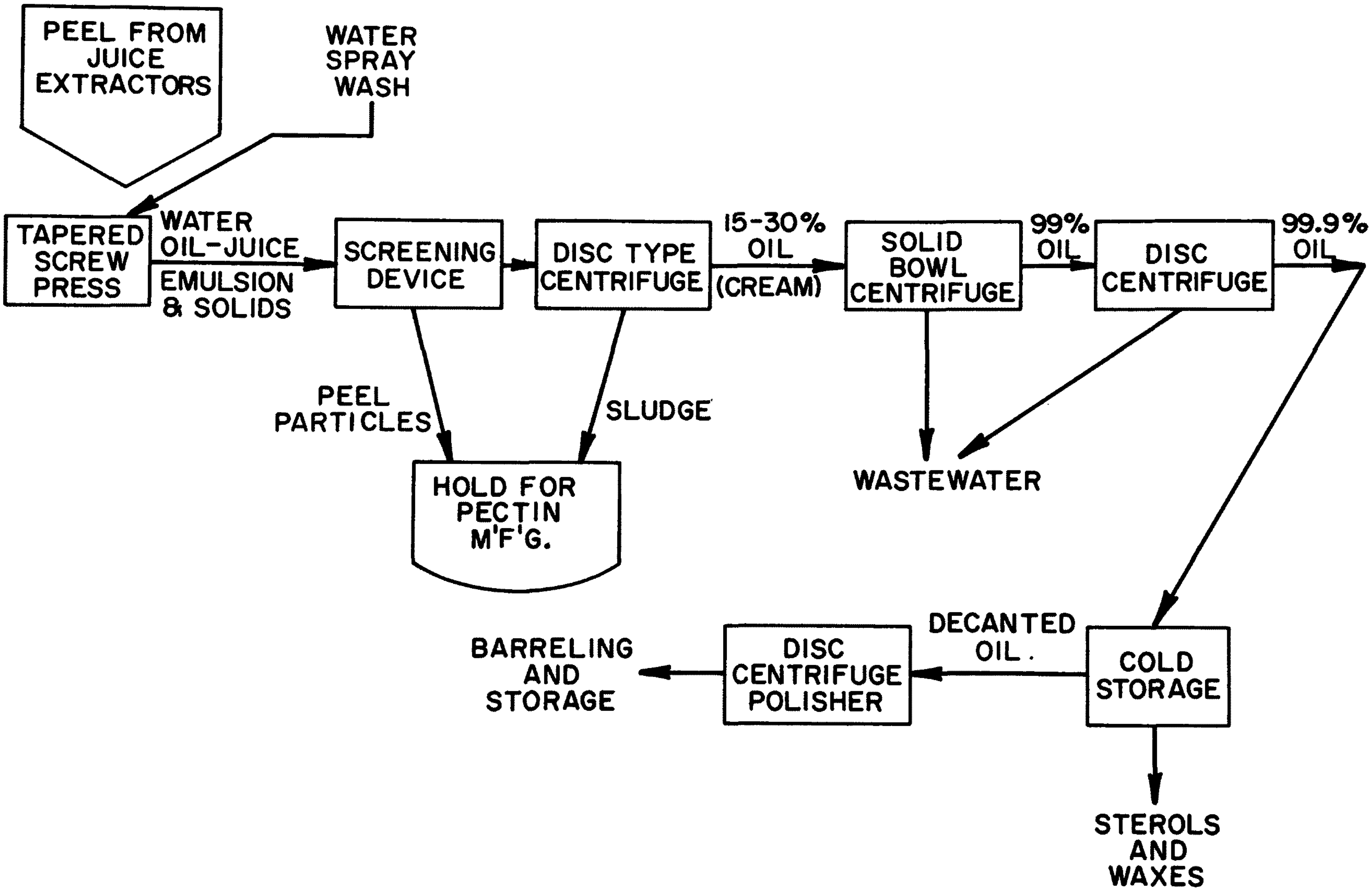


Figure 19. Cold pressed citrus oils production process (20).

tartaric acid, flavored with citrus oils, and colored with certified food colors. Deaeration, followed by flash pasteurization, canning, and cooling are operations necessary for the finished product. Beverages are prepared generally using one part concentrate plus five parts of water.

Bottlers Base for Carbonated Drinks

Bottlers base is made from a juice concentrate by pasteurizing initially to stabilize the juice "cloud" essential for appearance in the final carbonated drink and to inhibit pectic enzymes (Figure 20). The product is canned hot, sealed, and cooled, then stored at 13-16°C for preserving flavor and color. One liter of base makes from 100 to 200 liters of beverage.

Almost all citrus-flavored soft drinks today are made from so-called imitation flavors containing a concentrated juice-essential oil mixture with synthetic additives.

Water Use in the Industry

Table 48 shows the distribution of water use in FEI.

TABLE 48. WATER USE AS A FUNCTION OF PLANT SIZE, 1967 (20)

Plant Water Use (mgy)	<1	1-9	10-19	20-99	>100	TOTAL
Nominal Size of the Class (mgy)	0.7	5.0	15.0	55.0	150	
Number of Plants	300	81	22	22	6	431
Water Use Total (mgy)	210	404	330	1,210	900	3,054

A comparison of Tables 47 and 48 shows that small plants (with less than 20 employees) (321) are about equal in number to plants using less than 3.78 million liters per year of water (300).

Total water use in FEI establishments using more than 20 million gallons per year (mgy) has been estimated to be on the order of 1,100 mgy according to Water Use in Manufacturing (63). In order to match that figure, it would be necessary to take smaller nominal values for the plant size classes, since the nominal sizes used above lead to an estimate of total water use in plants using more than 20 mgy of 2,110 mgy (the sum of 1,210 and 900 in Table 48).

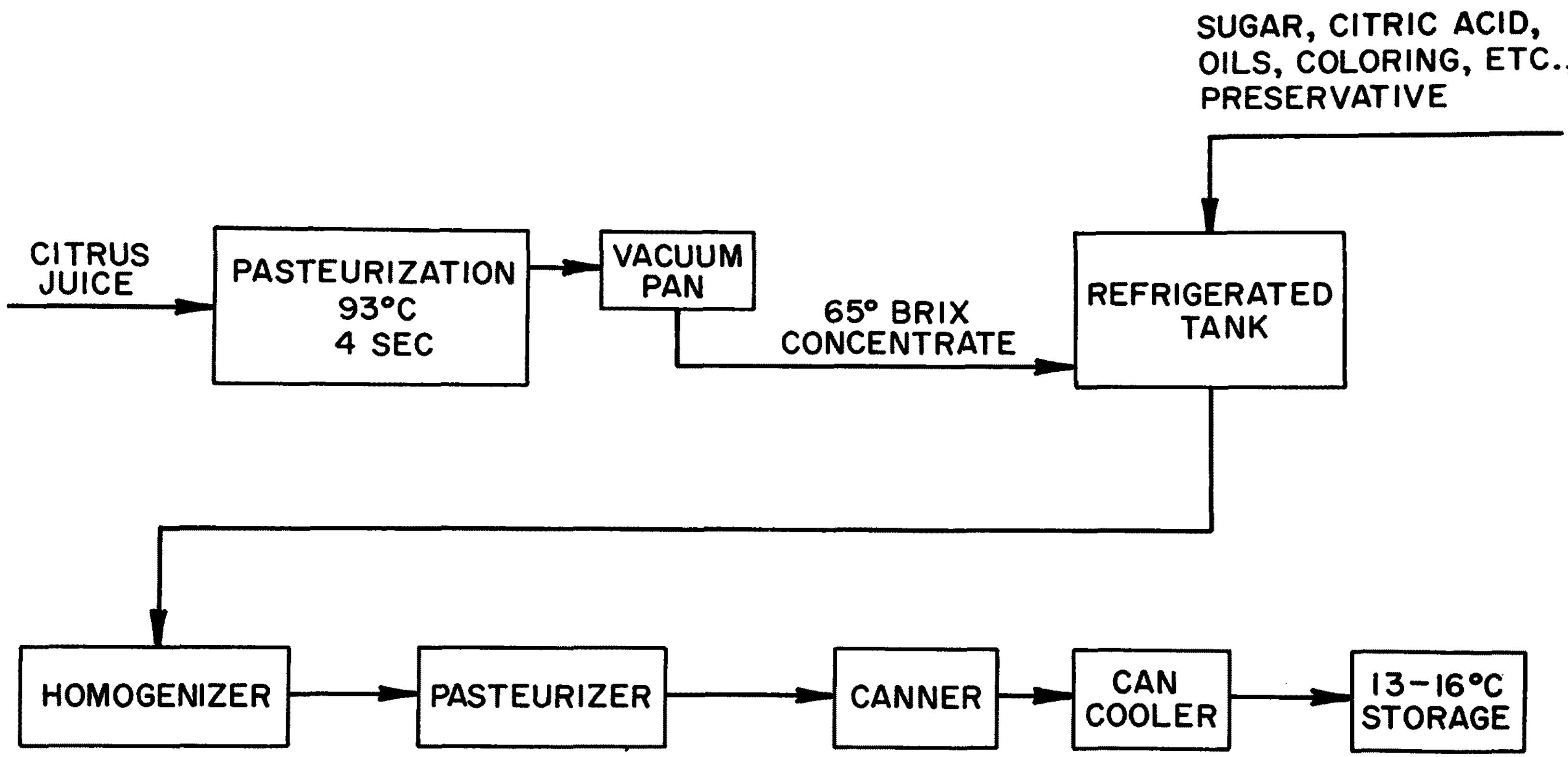


Figure 20. Beverage base for carbonated drinks production process (20).

Table 49 presents a classification of FEI plants by number of employees according to Water Use in Manufacturing (63). Some pairs of adjacent classes are combined to give larger classes containing numbers of plants corresponding roughly to the water-use classes.

In a recent industrial wastewater survey of Cleveland (15), seven FEI establishments were surveyed. (All were soft drink syrup blenders). The number of employees ranged from 1 to 100 and water use ranged from 60 to 109,000 gpd (15,000-27,250,000 gallons per year). The ratio of water use to employees ranged from 0.02 to 1.9 mgy/employee.

TABLE 49. A COMPARISON OF PLANT EMPLOYMENT AND WATER USE (63)

Number of Employees	1-4	5-9	10-19	20-49	50-99	100-249	250-490	500-999
Number of Plants	198	68	55	61	23	22	3	1
(Total 431)	266		116		23	22	4	
Nominal # of Employees	5		25		75	175	400	
Corresponding Water-Use Class (mgy)	0.7		5.0		15.0	55.0	150.0	
mgy/employee	0.14		0.20		0.20	0.31	0.38	

Waste and Wastewater Characteristics

The waste streams of extract producers and/or syrup blenders apparently have never been seriously analyzed as most characteristics are unknown. However, a wastewater sample was analyzed from FEI plants in a Cleveland Industrial Wastewater Survey (15) yielding wastewater characteristics as shown in Table 50.

TABLE 50. WASTEWATER CHARACTERISTICS--CLEVELAND SAMPLE, 1970 (15)

Parameter	Value
pH	6.3
Temperature	22°C
BOD_5	280 mg/l

TABLE 50. WASTEWATER CHARACTERISTICS--CLEVELAND SAMPLE, 1970 (15) (Continued)

Parameter	Value
COD	1,294 mg/l
Total Solids	1,349 mg/l
Suspended Solids	64 mg/l
Volatile Suspended Solids	60 mg/l
Volatile Solids	1,241 mg/l
Nitrogen	3.0 mg/l
Phosphorus	1.0 mg/l

The data may well be typical for a syrup blending plant. However, it would be unwise to assume they are typical for the basic FEI manufacturing processes like extraction and essence distillation. Such wastes probably resemble fruit and vegetable processing wastes more closely.

Efficient spray balls used in tank washing aid in maintaining lower volumes of wastewater. Other sources of wastewater are filter backwash and steeping kettle wash from extraction processes as for vanilla and boiler blowdown and bottom drainage from steam distillation processes.

Some segments of the industry are associated as subsidiary components of other, more major, industrial facilities - e.g., food manufacturing and organic chemical manufacturing. Citrus oils are produced mainly in citrus fruit processing plants covered by SIC 2033. The small amount of waste associated with the production of citrus oils and other flavorings is combined with the major waste stream for disposal. The production of chocolate flavorings is associated with the manufacture of chocolate and cocoa and produces, of itself, only insignificant wastes relative to the main products. Many manufacturers of syrups simply blend flavoring ingredients with sugar and other syrups, conducting no manufacturing of the flavoring ingredients themselves.

Solid wastes from the making of extracts are moderate in most cases, the major exception being the production of citrus oils and other citrus flavor products. The citrus processing industry is geared to handle much of its own wastes as many of these wastes are sources of useful by-products such as animal feeds and soil mulches.

With the exception of citrus flavoring products, the universal practice on wastewater is discharge to municipal sewer systems. Some citrus flavoring manufacturers treat the wastewaters in privately-owned activated sludge systems.

Wastewater Disposal

A survey (20) of the industry and interviews with technical people revealed only one small plant which did not discharge wastewater to municipal sewers. The 1967 Water Use in Manufacturing indicated that about half the wastewater discharged by plants polled was discharged to water courses with or without treatment. The survey results found no way to resolve this contradiction, but it may be that virtually all FEI plants have come to be served by municipal sewers since 1967, or it may be that the plants indicating direct discharge to water courses in the poll were citrus fruit processing plants producing FEI products as a sideline to the main manufacturing processes in SIC 2033 and 2037.

SECTION IX

ECONOMICS

The economics of certain waste treatment schemes for the entire beverage industry are summarized in Table 51. The following summary consists of economic estimates made in the Environmental Protection Agency effluent guidelines document dealing with miscellaneous foods and beverages (21). The waste treatment systems available to the different segments of the beverage industry are very diverse, but the costs for only two basic systems are given due to the very limited amount of cost data available. The costs are given for aerated lagoons and activated sludge systems which in some cases may not be practical methods of treatment but are listed as examples.

As explained in the Development Document those costs are intended to serve only as a guide in which the following assumptions were made in developing the figures.

1. All costs are reported in August 1972 dollars. All engineering cost estimates were made in December 1974 costs and converted to August 1972 dollars by the Construction Cost Index of the Engineering News Record.

2. Annual interest rate for capital is taken to be eight percent.

3. All investment cost is depreciated over a period of 20 years except rolling stock which is depreciated over ten years.

4. Salvage value is taken as zero at the end of the depreciation period.

5. Depreciation is attributed by the straight line method.

6. Total yearly cost = (investment cost/2) (0.08) + yearly depreciation cost + operating cost.

7. Power costs = \$0.04/kw-hr.

8. Excavation and fill is estimated at \$3.92/m^3 (\$3.00/cu yd) for December 1974.

9. Personnel costs for operation is \$5.00/hr plus 50 percent fringe benefits, administration, and other overhead.

TABLE 51. ECONOMICS OF BEVERAGE INDUSTRY TREATMENT SYSTEMS (21)

Industry	Treatment Scheme	Cost (10^3 dollars) Investment	Total Yearly (Capital & Operating)	Estimated % Removal BOD5	SS
Breweries					
New Large: 1500 m^3 (12800 bbl.)/day	A.L.[a]	2355	1056	97.4	90
	A.S.[b]	3731	1030	97.4	90
Old Large: 2600 m^3 (22,000 bbl.)/day	A.L.	7125	3328	97	98.5
	A.S.	11377	3107	97	89.5
All Other: 470 m^3 (4000 bbl.)/day	A.L.	1344	530	96.4	89.1
	A.S.	1507	440	96.4	89.1
Malt: 350 metric tons (16,000 bu.)/day	A.L.	1200	573	95.2	83.1
	A.S.	709	176	95.2	83.1
Wineries					
Without Stills: 180 metric tons grapes/day	A.L.	413	172	97.8	90.1
	A.S.	414	116	97.8	90.1
With Stills: 700 metric tons grapes/day	Land Spreading	382	52	100	100
Grain Distilleries					
With Stillage Recovery: 375 metric tons (15,000 bu)/day	A.L.	1231	603	95.7	92.3
	A.S.	1230	289	95.7	92.3
Without Stills: 50 metric tons (2000 bu)/day	A.L.	134	28	85.7	75
Molasses Distilleries: 30,000 Proof Gallons/day	Evaporation:				
	With A.L.[c]	2646	800	99.9	99.8
	With A.S.[d]	2644	698	99.9	99.6
Soft Drinks					
Canners: 309 m^3 (81,500 gal.)/day	A.L.	205	66	94.9	76
	A.S.	339	49	94.9	76
Bottlers: 136 m^3 (35,000 gal.)/day	A.L.	244	79	89.4	63
	A.S.	290	66	89.4	63
Beverage Bases: 379 m^3 (0.1 MG)/day	A.L.	290	115	95.8	40
	A.S.	721	123	95.8	40

TABLE 51. ECONOMICS OF BEVERAGE INDUSTRY TREATMENT SYSTEMS (21) (Continued)

Footnotes:

[a]Aerated lagoon
[b]Activated sludge
[c]Evaporation with aerated lagoon treatment of the condensate
[d]Evaporation with activated sludge treatment of the condensate

10. All capital construction work is performed by an outside contractor using normal profit margins.

11. When between 10 and 20 aeration units are purchased, a discount of 5.0 percent is obtained. When more than 20 units are purchased, the discount is 7.5 percent.

12. The December 1974 cost of steel is $0.20/kg ($0.45/lb).

13. The December 1974 cost of concrete is $134/m^3$ ($175/cu yd).

14. The December 1974 cost of contracted truck hauling of liquid sludge or wastewater is $5.28/1000 liters ($20.00/1000 gal).

Table 52 contains a sample breakdown of the costs using an aerated lagoon system for new large breweries.

TABLE 52. ITEMIZED COST SUMMARY FOR AERATED LAGOON SYSTEM - NEW LARGE BREWERIES (21)

Treatment Modules: Designed for 97.4 percent BOD_5 reduction
- Screening and Grit Chamber
- Equalization Basin
- Acid Neutralization
- Nitrogen Addition
- Aerated Lagoon System

Investment Costs:	
1. Construction	$1,879,640
2. Land	26,410
3. Engineering	187,960
4. Contingency	187,960
5. PVC Liner	73,770
TOTAL	$2,355,740

TABLE 52. ITEMIZED COST SUMMARY FOR AERATED LAGOON SYSTEM - NEW LARGE BREWERIES (21) (Continued)

Yearly Operating Costs:	
1. Labor	24,990
2. Power	678,780
3. Chemicals	74,190
4. Maintenance and Supplies	61,690
5. PVC Liner	5,200
TOTAL	844,830
Total Yearly Costs	
1. Yearly Operating Cost	844,830
2. Yearly Investment Cost Recovery	94,230
3. Depreciation	116,740
TOTAL	1,055,530

The costs presented in Table 51 may not be applicable in some cases, since many of the industries discharge to municipal treatment such as the case for "Old Large Breweries." Because of the urban location of these breweries, adequate land is not available for a treatment system.

Municipal wastewater rates vary widely as reported by Dupre (16) and Maystre and Geyer (35) and are generally based on BOD_5 and suspended solids loads. Estimated surcharge costs for two hypothetical industries comparable to the beverage industry has been calculated (21). For BOD_5 and SS concentrations of 800 mg/l and one industry having a flow of 2830 m^3 per month and the other having a flow of 28,320 m^3 per month; the surcharges for the smaller ranged from $8/mo to $269/mo and for the larger the range was calculated to be from $78/mo to $2,690/mo.

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GLOSSARY

Argols - Crystalline coating of almost pure cream of tartar on the walls and bottom of wine storage tanks.

Backset - Screened or "thin" stillage that is returned from the base of the whiskey separating column to the fermenter, as used in the distilled spirits industry.

Barrel - As used in the Malt Beverage Industry, a barrel contains 117 liters (31 gallons).

Brandy - A distillage of wine produced at 189° or less proof.

(a) Neutral Brandy is that produced at 171° to 189° proof.

(b) Beverage Brandy - is that distilled at 170° or less proof, usually 165 to 169°.

°Brix - A measure of percent sugar in solution.

Bushel - The weight of the grain contained in a bushel varies by industry as follows:

(a) Barley = 21.7 kg (47.7 lb)

(b) Malt = 15.4 kg (33.9 lb)

(c) Distillers Grain = 25 kg (55 lb)

Distillation - A process of evaporation and recondensation used for separating liquids into various fractions according to their boiling points or boiling ranges.

Fermentation - The production of alcohol and carbon dioxide from fermentable carbohydrates by the action of yeast.

Hops - The dried conelike fruit which is boiled with wort to impart additional flavor and aroma to beer.

Lees - The yeast, pulp, and tartrate sediment resulting from fermentation and finishing operations in the wine industry.

Malting - The germination of barley to develop enzymes.

Mashtun - Vessel in which the conversion of grain starches into maltose sugar takes place.

Mashing - The process involving cooking, gelatinization of starch, and conversion, changing starch into grain, sugars.

Must - The juice, skin, and seeds from crushed grapes.

Plate and Frame Filter - A filtering device consisting of a "screen" fastened inside a metal frame.

Pomace - The skin, pulp, and seed solids present after separation from a liquid such as juice or oil.

Proof - Alcoholic content of a liquid at 16°C, stated as twice the percentage of alcohol by volume (United States definition).

Proof Gallon (Liter) - A standard U.S. gallon (liter) containing 50 percent alcohol.

Racking - The decanting of liquid from settled residues, as used in the wine and malt beverage industries.

Sparkling Wine - A grape wine which has more than 1.5 atmospheres of pressure at 10°C and less than 14 percent alcohol by volume.

Spent Beer - Residual nutrients separated from harvested yeast by centrifugal separation.

Stillage - The de-alcoholized residue discharged from the base of the still column.

Table Wine - A grape wine having an alcoholic content not in excess of 14 percent by volume.

Tax Gallon (Liter) - A standard U.S. gallon (liter).

Trub - Insoluble materials which collect in the brew kettle.

Wine Gallon (Liter) - A measure of actual volume.

Wort - A mixture of maltose and water.

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(Please read Instructions on the reverse before completing)

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16. ABSTRACT

The general purpose of this paper is to investigate, through the literature, the water pollution impact caused by the wastes from the beverage industry and the methods available to combat the associated problems. The size of each industry is discussed along with production processes, wastewater sources and effluent characteristics. Wastewater management techniques are described in terms of in-plant recycling, by-product recovery and end-of-pipe treatment along with the economics of treatment.

The malt liquor, malting, soft drink, and flavoring industries primarily dispose of their effluents in municipal sewers. In-plant recycling and by-product recovery techniques have been developed in these industries to reduce their raw waste load. The wine and brandy and distilled spirits industries in many cases must treat their own effluent so they have developed wastewater management systems including industry-owned treatment plants that yield good effluents. The technology to adequately treat rum distillery wastewater has not been demonstrated.

The information basis for this paper was a literature search, an effluent guidelines report done for EPA, limited site visits, personal communications and an unpublished report conducted for EPA that included questionnaire surveys of the industries.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
*Waste Treatment, Operating Costs *Industrial Wastes, *By-Products,	*Beverage Wastes, Economics, Beverage Industry, Treatment Costs	13/B

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