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The Hashemite Kingdom of Jordan

Ministry of Water and Irrigation

Water Quality Improvement and Conservation Project

Industrial Audit:

Arab Brewery Company

Harza Environmental Services, Inc.

Development Alternatives, Inc.

USAID

The Technical Assistance Team Includes:

Development Alternatives, Inc.
Science Applications International Corp.
Harza Environmental Services, Inc.
Development Associates, Inc.

United States Agency for International Development
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PA-ABY-044

AUDIT REPORT
ARAB BREWERY COMPANY
JORDAN

Submitted to:
United States Agency
For International Development

Submitted by:
Development Alternatives, Inc.

Prepared for:
Amman Chamber of Industry, Jordan
Ministry of Water and Irrigation, Jordan

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PREFACE/ACKNOWLEDGMENTS

This report is the result of a 4-week study/audit/evaluation of the Arab Brewery Company, Jordan. The purpose of the study was to evaluate and identify potential pollution prevention/waste minimization and water conservation techniques which are appropriate. The executive summary on the following pages outlines the consultants findings and actions during the study/audit/evaluation.

Several individuals on the Water Quality Improvement and Conservation Project contributed to this report. Dr. Usama Mudallal of the Amman Chamber of Industry (Chamber); Engineer Rania Abdul Khaleq of the Ministry of Water and Irrigation (MWI); Eng. Marwan Al Tal, of the Water Authority of Jordan (WAJ); and Dr. Omar Jabay and Dr. Riyad Musa of the Royal Scientific Society of Amman; plant managerial and technical staff including Mr. Mohammad Saleh Ali, Brewery Manager and Mr. Mukhalis Haddad, Production Manager, who shared their knowledge with Mr.Krishna Mayenkar, P.E., of Harza Consulting Engineers and Scientists (Harza), Chicago, USA. These technical staff worked under the direction of Dr. Shawn R. Niaki, P.E., Pollution Prevention Program Director, of Harza, who heads the WQIC component under which the study/audit/evaluation was housed. It is from their combined expertise that this report was possible.

Special appreciation is given to Dr. Mohammed Bani Hani, Secretary General of MWI; Eng. Koussai Quteishat, Secretary General of WAJ; Mr. Khaldun Abuhassan, Chairman of the Chamber; Mr. Walid Al-Khathib, Director General of the Chamber; Dr. Muwaffaq Saqqar of MWI, Project Coordinator; Dr. Raja Gadoun, Director of the WAJ Laboratories; Eng. Randa Dufaha of theWAJ Laboratories; the members of the PP/WM working group from WAJ including Eng. Abdul Wahab Matar, Eng. Nabeel Hejazin, Eng. Mohamad Lafi; and to Development Alternatives, Inc., as represented by Edwin D. Stains, Chief of Party; for their cooperation and confidence.

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ABBREVIATIONS

Organizations

ABC	Arab Brewery Company
CHAMBER	Amman Chamber of Industry
DAI	Development Alternatives, Inc.
FAO	Food and Agricultural Organization
MWI	Ministry of Water and Irrigation
RSS	Royal Scientific Society
USAID	United States Agency for International Development
WAJ	Water Authority of Jordan
WQICP	Water Quality Improvement and Conservation Project

General terms

IWDPP	Industrial Wastewater Discharge Prevention Program
PP/WM	Pollution Prevention/Waste Minimization

Technical Terms

BOD_5	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
TSS	Total Suspended Solids
TDS	Total Dissolved Solids
WWTP	Wastewater Treatment Plant
mg/l	Milligrams per liter

EXECUTIVE SUMMARY

Development Alternatives, Inc. (DAI) under Contract No. 278-0288-00-C-4026-00 with the United States Agency for International Development (USAID) is performing an Industrial Wastewater Discharge Prevention Program (IWDPP) in Amman, Jordan. This Program is one of four components of the Water Quality Improvement and Conservation Project (WQICP) funded by USAID. This program is being performed by DAI with full coordination between the Ministry of Water and Irrigation (MWI) and the Amman Chamber of Industry (Chamber). Harza Consulting Engineers and Scientist (Harza), Chicago, United States (U.S.), was retained by DAI to lead the IWDPP. The Royal Scientific Society (RSS) of Amman, Jordan was selected as a local consultant to assist Harza with the IWDPP. This Program includes conducting the PP/WM audits, feasibility studies, and designing demonstration facilities at selected industrial facilities.

Based on a ranking methodology, the PP/WM Committee has selected ten industries with potential needs for PP/WM audits. The purpose of the audits is to assist the industries in the Amman-Zarqa Basin in assessing pollution problems and developing alternative solutions to achieve desired levels of PP/WM, water conservation, and wastewater treatment appropriate for the selected industry. One of these industries is the Brewery Industry. The Harza/RSS team conducted an audit of Arab Brewery Company, representing the first step of the IWDPP. This report summarizes the results of the audit.

FACILITY AND PROCESS DESCRIPTIONS

The ABC is located in the old industrial area near Zarqa, along the Zarqa River. The ABC initially opened in 1964, closed, and then resumed production in 1971. The ABC is an operating unit of General Investment Co. Ltd. which owns and operates several other breweries and Distilleries. The ABC produces beer under a license from the German brewery Henninger. The total beer production capacity is 20 m^3/day, but current production rates are only 15-20 percent of capacity. The brewery, as we understood, produces the Henninger beer to respond to market demand which is currently only 10 percent of the total beer consumed in Jordan. Because of this low market demand, beer production is relatively low.

The ABC facility is located in Zarqa adjacent to the AMSTEL brewery facility, another operating unit of General Investment Co. Ltd. The facility includes raw material storage, production facilities, product storage, and an abandoned wastewater treatment plant. All the water needs for ABC are satisfied by groundwater (1,000 to 1,500 m^3/month) obtained from an on-site groundwater supply well. This water satisfies the production needs for beer, soft drinks and non-alcoholic beer.

The ABC facility operations can be grouped in two general categories:

- Beer Production Operations
- Ancillary Operations

CURRENT ENVIRONMENTAL AND MAINTENANCE PROGRAMS

The environmental and waste recycling programs at ABC include the following:

- Spent malt and husk produced during the brewing process are 100 percent recovered and sold to farmers.
- Settled yeast from the fermentation tanks is collected and reused. The excess yeast is reused and recycled at other distilleries owned and operated by ABC.
- All solid wastes generated at the facility are sold or disposed off-site at a permitted facility.
- The CIP cleaning systems help conserve chemicals and reduce their discharge to the As Samra Wastewater Treatment Plant.

ENVIRONMENTAL REGULATIONS AND GUIDELINES

Jordan currently has no comprehensive law to control water, air and soil pollution. However, industrial waste water discharges are regulated by the Jordanian Standard 202, adopted in 181 by the Department of Standards and Specifications and revised in 1990. Standard 202 regulates industrial wastewater discharges to rivers, wadis, groundwater, the sea, and reuse for irrigation.

Drinking water quality is regulated by Jordanian Standard 286. Moreover, it is a common practice to use the Food and Agriculture Organization (FAO) guidelines as a reference.

AUDIT

The facility audit was conducted on March 12 and 14, 1995. The audit team, accompanied by two ABC representatives, toured and inspected the facility. An audit questionnaire was used to address the specific details of the process used at the ABC facility. To further discuss water use and process details, an additional site visit was conducted on March 16, 1995.

AUDIT FINDINGS

Water Usage and Balance

Fresh water used as process water in the ABC facility is obtained from groundwater pumped from an onsite private supply well. Water used for domestic purposes is supplied by the WAJ. The estimated total water consumption per month at ABC is approximately 1,000 to 1,500 m^3. The following summarizes typical water use:

- Beer (9 percent);
- Equipment Cleaning (56 percent);

- Floor Cleaning (6 percent);
- Boiler Makeup Water (4 percent); and
- Miscellaneous purposes (25 percent).

A schematic detailing the overall water balance for ABC is provided on Figure ES-1 and is summarized in Table ES-1.

Wastewater Sources

The main wastewater sources are:

- Equipment Cleaning (6.2 m^3);
- Pasteurization (0.8 m^3);
- Floor Drainage (0.7 m^3); and
- Regenerant Wastes (0.54 m^3)

Water and wastewater discharges are not routinely monitored for quantity and quality by the ABC. WAJ, however, routinely monitors AMSTEL brewery effluent and occasionally monitors ABC effluent. Wastewater sources are summarized in Table ES-2.

Wastewater Discharges

The ABC has an activated sludge biological treatment facility to treat industrial wastewater. However, the treatment facility is abandoned in place. Therefore, the facility industrial wastewater is discharged directly to the sewer and is ultimately sent to the As Samra Wastewater Treatment Plant.

Storm Water

All storm water is discharged to a nearby Wadi through natural grade.

Solid Waste

olid wastes generated at the ABC include broken glass, paper and cardboard cartons, chemical ottles, plastic bags and domestic solid waste. Most of the solid waste is sold for reuse. owever, domestic solid waste is disposed at a local landfill. Additionally, the trub generated om the process, with its high organic loading, is discharged directly to the sewer.

ir Emissions

he anticipated emissions from the beer making process are particulate and volatile organic mpounds (VOCs). At the ABC facility, the audit team did not observe any emissions. owever, due to low production, particulate emissions from malt handling, sulfur and nitrogen ides exhaust gases from the boiler, and VOCs from vented steam and hot washwater handling are expected to be very minimal.

CONCLUSIONS

Several PP/WM and water conservation opportunities exist at the ABC facility. By implementing the following PP/WM measures, total water consumption can be reduce from 11.04 m^3 per m^3 of beer produced to 6.2 m^3 per m^3 of beer produced, resulting in a 42 percent reduction. Figure ES-2 presents the proposed water usage plan and is summarized in Table ES-3. PP/WM and water conservation opportunities exist in the following areas:

- CIP System Operation for Brewing and Fermentation Equipment;
- Fermenting and Lagering Operations;
- Beer Manufacturing Schedules;
- Filter Cleaning Operations;
- Trub Discharge Disposal;
- Floor Washing Procedures; and
- General Process Optimization for Brewing, Fermentation and Packaging Operations, Equipment Cleaning, and Ion Exchange Regeneration.

Water savings should result from many of the PP/WM measures described. In addition, water conservation can be achieved through implementation of:

- Insulation of Cooling System Piping and Valves;
- Installation of an Air Cooling System; and
- Filtering and Recycling 100 percent of Pasteurization Water Overflow.

Implementation of PP/WM and water conservation measures could reduce the overall pollution load by 50 percent and the hydraulic load by 42 percent.

Other PP/WM and water conservation opportunities may exist which may require new process applications or modifications and which may be relatively more difficult to implement. However, PP/WM and water conservation opportunities not included in this report should not be eliminated from consideration, as their feasibility can only be determined through more intensive studies and evaluations.

It is very important to note that as beer production becomes continuous rather than intermittent, the amount of water required, or wastewater generated per m^3 of beer produced continues to decline. If the market demand increases and if ABC increases its production to meet the higher demand, the relative water usage and wastewater generation will reduce.

RECOMMENDATIONS

1. Install devices to monitor water use and discharge from all cleaning operations including equipment and floor cleaning. Generate an accurate measurement and balance of facility water use.

2. Design and implement a wastewater sampling and monitoring program to cover all wastewater sources identified in this report. Initially, quarterly sampling frequency should provide the ABC management a fair idea of pollutant loads in different wastewater streams.

3. Study and implement a beer production schedule such that maximum number of batches are produced at each event thereby reducing washing frequency and pollutant discharge. This will also result in production cost saving.

4. Combine fermentation and lagering operations.

5. Optimize CIP systems by lowering washing frequency and using the last rinse water for the initial rinse of the next cleaning operation.

6. Recycle and reuse pasteurizing wastewater flow after filtering and water softening.

7. Explore installing an air cooling system to replace the existing wet evaporative cooling system.

Establish and implement rigorous equipment washdown and floor cleaning procedures to reduce water consumption.

Improve cleaning methods by carefully studying current procedures, washing time, solution concentration, water temperature, intensity of application etc. Applying appropriate combination of these elements to different equipment can reduce water use. Establish cleaning protocols and procedures for water conservation.

Optimize the regeneration process and explore the use of alternative technologies and new resins.

Improve housekeeping and implement a spill prevention control and countermeasures program. Use dry vacuum techniques instead of washing spills into the drain.

Insulate all cooling pipes to avoid frosting and eliminate the use of water to defrost pipes.

Reactivate the biological treatment facility to treat industrial wastewater prior to discharge to the city sewer system. Any on-site pretreatment provided by industries will assist in reducing organic loads discharged to the As Samra treatment plant thereby minimizing shock loads, if any, and providing room to accept more domestic wastes.

14. Develop an environmental management program to include:

- Establishing an environmental department with dedicated personnel and sufficient resources;

- Writing an environmental policy complete with missions, visions, goals, policies and a future work plan. PP/WM and water conservation goals need to be established to achieve the PP/WM program, in line with the MWI and Chamber goals; and

- Developing of training and incentive programs for all the ABC personnel.

15. Consider the following PP/WM items for feasibility level studies:

- Optimize the CIP Systems;
- Combine Fermenting/Lagering Processes;
- Recycle and Reuse Pasteurization Water Overflow; and
- Optimize Filter Cleaning Processes.

Table ES-1
OVERALL WATER BALANCE ACROSS BREWERY[1]

Arab Brewery Company

Water In (m^3)[2]		Water Out (m^3)[2]	
Well Water Pumped	11.04	Beer	1.0
		Spent Malt	0.2
		Trub Discharge	0.1
		CIP Discharges Brewery Cooler Fermentation	 1.1 0.2 1.4
		Regenerant Wastes	0.54
		Bottle/Can Wash	1.4
		Pasteurization	0.8
		Filter Cleaning (including steam)	0.9
		Floor Cleaning	0.7
		Equipment Cleaning	1.0
		Keg Wash (steam)	0.2
		Evaporative Losses Cooling Water Brew Kettle	 0.4 0.1
		Pipe Defrosting	1.0
Total	11.04		11.04

1 Domestic water is supplied by WAJ and is discharged to the city sewer system. The daily water usage is about 2.0 m^3.

2 Water balance is based upon one cubic meter of beer produced.

Table ES-2
WASTEWATER SOURCES AND GENERATION RATES[1]

Arab Brewery Company

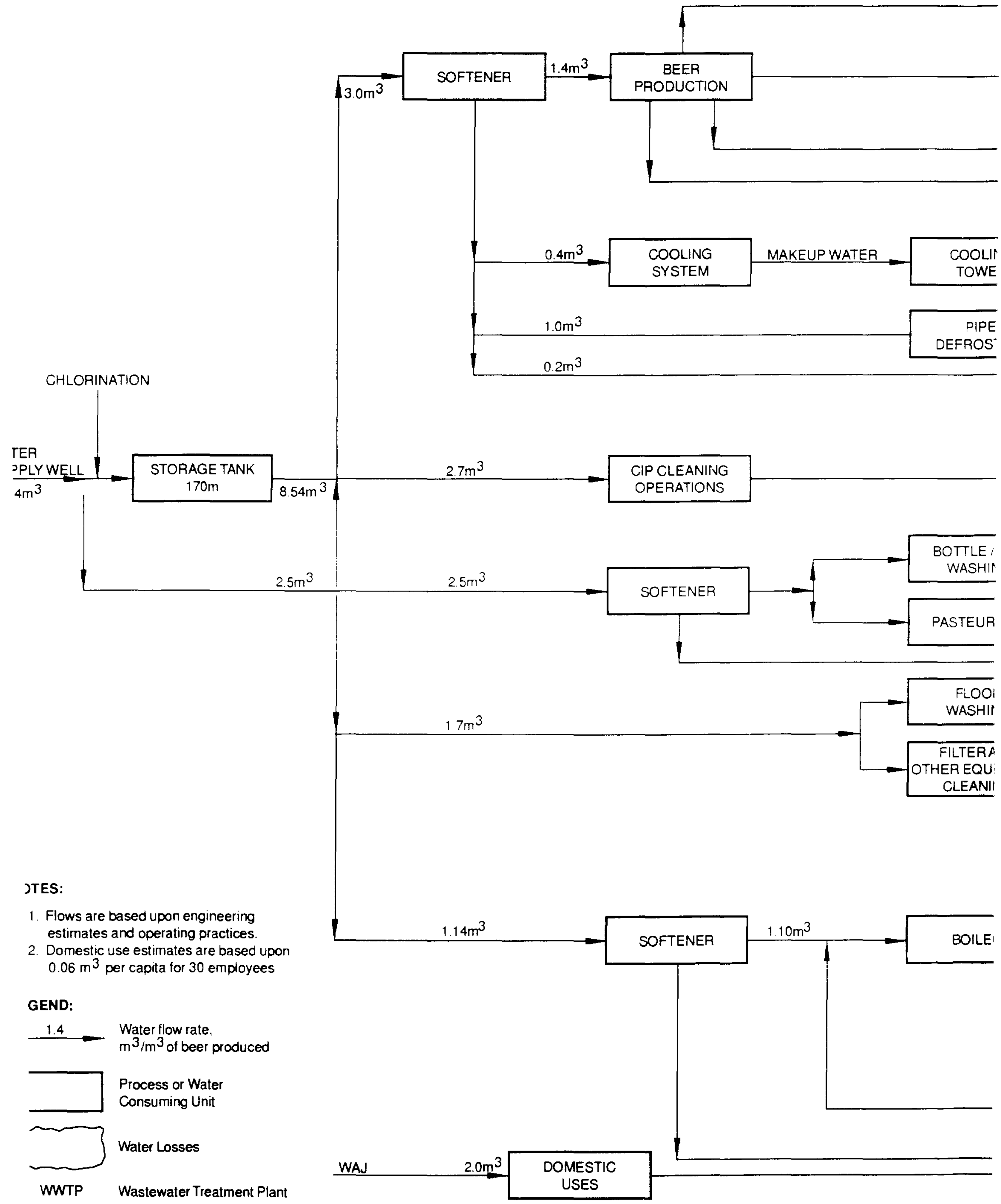
Wastewater Source	Rate (m^3)
Brewing operations	
CIP Cleaning	1.1
Regenerant Wastewater	0.2
Trub Separator Discharge	0.1
Fermentation/Lagering/Finishing	
Wort Cooler CIP Cleaning	0.2
Fermentor CIP Cleaning	1.4
Packaging Operations	
Bottle Washing	1.4
Pasteurization	0.8
Keg Washing	0.2
Filter Cleaning	0.2
Water Softening Regenerant	
Boiler Feed Water	0.3
Wash Water	0.04
General Housekeeping	
Floor Washing	0.7
Equipment/Piping Cleaning	1.7
Pipe Defrosting Water	1.0
TOTAL	9.34

1 Wastewater generation rates are based upon one cubic meter of beer produced.

Table ES-3
PROPOSED WATER REDUCTION/RECYCLE/REUSE

Arab Brewery Company

Water Consumer	Water Use (m^3)		
	Current	Projected	Savings
Beer	1.0	1.0	0.0
Spent Malt	0.2	0.2	0.0
Trub Discharge	0.1	0.1	0.0
CIP Water Use			
Brewhouse	1.1	0.3	0.8
Fermentation	1.4	0.5	0.9
Wort Cooler	0.2	0.2	0.0
Regenerant Waste	0.54	0.34	0.2
Bottle Wash	1.4	1.25	0.15
Pasteurization	0.8	0.0	0.8
Filter Cleaning	0.9	0.8	0.1
Equipment Cleaning	1.0	0.8	0.2
Floor Cleaning	0.7	0.4	0.3
Keg Wash	0.2	0.2	0.0
Cooling Water	0.4	0.0	0.4
Pipe Defrosting	1.0	0.0	1.0
Brew Kettle Steam Loss	0.1	0.1	0.0
TOTAL	11.04	6.19	4.85



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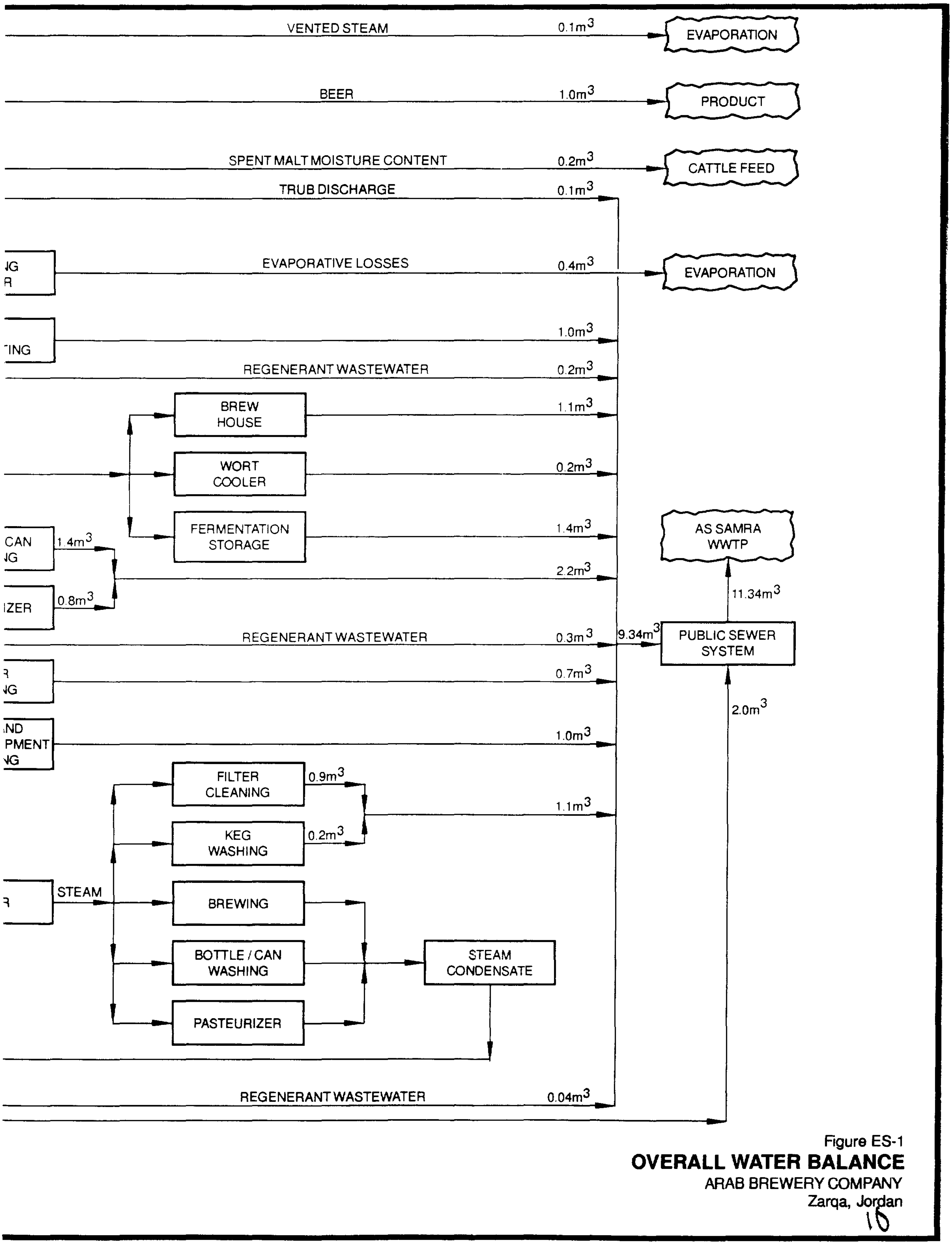
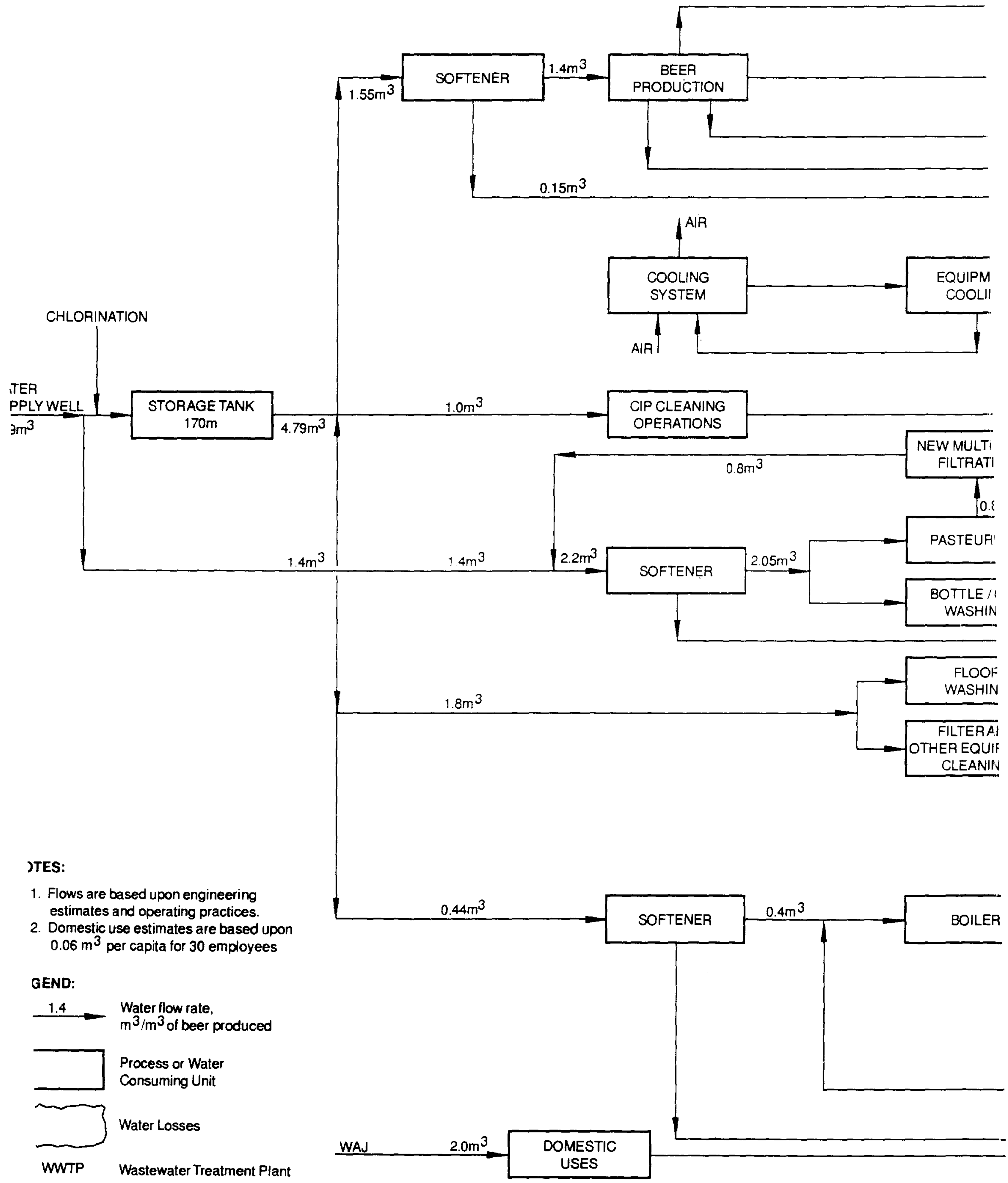


Figure ES-1
OVERALL WATER BALANCE
ARAB BREWERY COMPANY
Zarqa, Jordan



TES:

1. Flows are based upon engineering estimates and operating practices.
2. Domestic use estimates are based upon 0.06 m^3 per capita for 30 employees

GEND:

1.4 →	Water flow rate, m^3/m^3 of beer produced
(box)	Process or Water Consuming Unit
(wavy outline)	Water Losses
WWTP	Wastewater Treatment Plant

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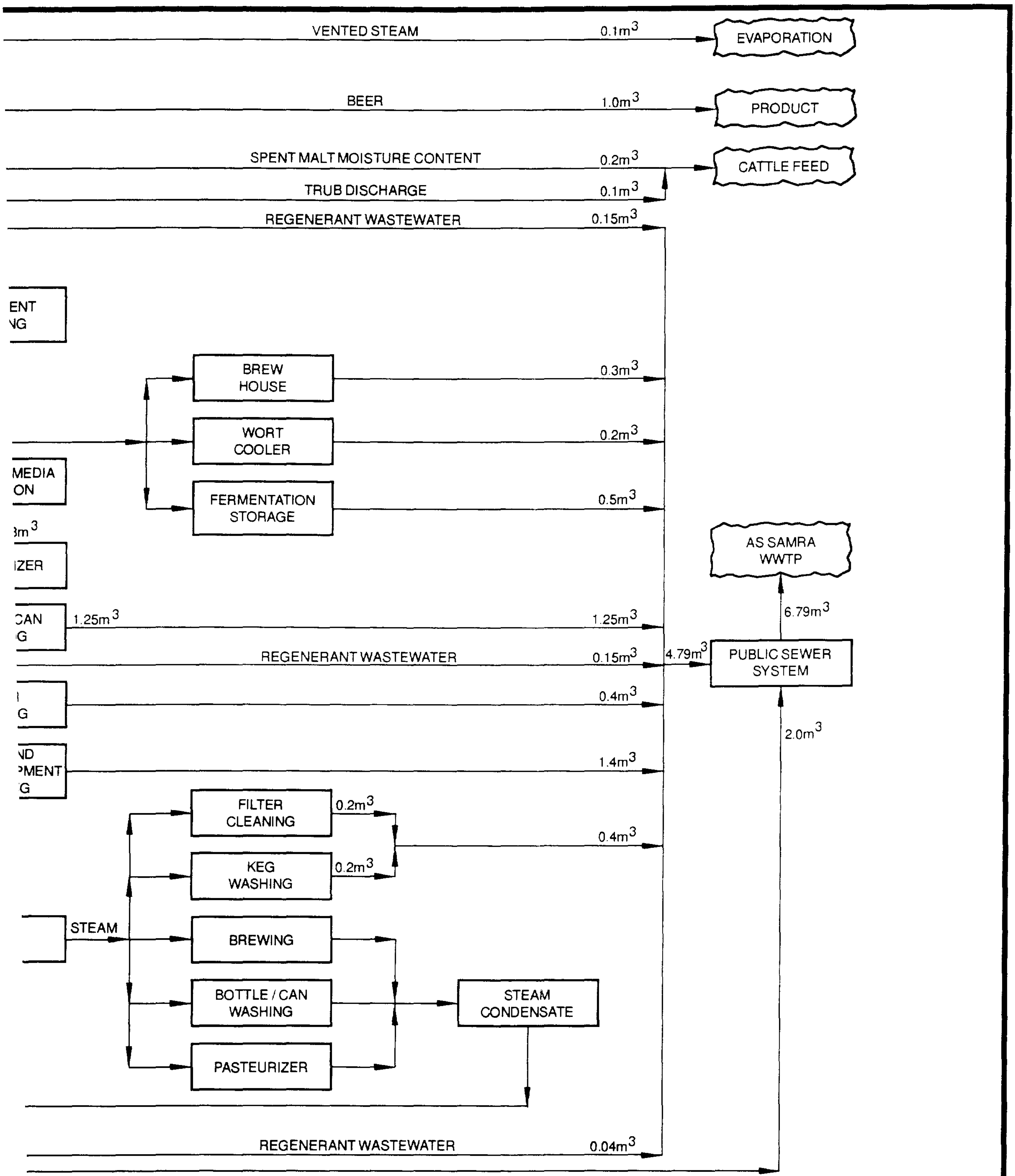


Figure ES-2
CONCEPTUAL WATER BALANCE
ARAB BREWERY COMPANY
Zarqa, Jordan

1.0 INTRODUCTION

This report presents the findings of an audit for pollution prevention, waste minimization (PP/WM) and water conservation for the brewery industry in Jordan using the Arab Brewery Company (ABC) as the basis. The report includes project background information and objectives, brief process and facility descriptions, audit process details, potential for PP/WM and water conservation, conclusions, recommendations, and follow-up actions.

1.1 Background

Development Alternatives, Inc. (DAI) under Contract No. 278-0288-00-C-4026-00 with the United States Agency for International Development (USAID) is performing an Industrial Wastewater Discharge Prevention Program (IWDPP) in Amman, Jordan. This Program is one of four components of the Water Quality Improvement and Conservation Project (WQICP) funded by USAID. This program is being performed by DAI with full coordination between the Ministry of Water and Irrigation (MWI) and the Amman Chamber of Industry (Chamber). Harza Consulting Engineers and Scientist (Harza), Chicago, United States (U.S.), was retained by DAI to lead the IWDPP. The Royal Scientific Society (RSS) of Amman, Jordan was selected as a local consultant to assist Harza with the IWDPP. This Program includes conducting the PP/WM audits, feasibility studies, and designing demonstration facilities at selected industrial facilities.

The PP/WM techniques are defined as any techniques to prevent or reduce waste generation by source reduction or recycling activities. These activities must reduce either the volumes or the concentrations of pollutants generated prior to treatment, storage, or disposal of the waste.

Based on a ranking methodology, the PP/WM Committee has selected ten industries with potential needs for PP/WM audits. The purpose of the audits is to assist the industries in the Amman-Zarqa Basin in assessing pollution problems and developing alternative solutions to achieve desired levels of PP/WM, water conservation, and wastewater treatment appropriate for the selected industry. One of these industries is the Brewery Industry. The Harza/RSS team conducted an audit of the ABC, representing the first step of the IWDPP. This report summarizes the results of the audit.

1.2 Objectives

The objective of conducting a PP/WM audit of the ABC facility was to understand the water, wastewater, and associated waste management practices currently employed at the facility and to identify opportunity for PP/WM and water conservation that may exist at the facility.

The findings of the audit were used to develop recommendations and follow-up actions to assist the ABC in assessing the extent of pollution. Suggested practices and process modifications to achieve additional PP/WM and water conservation are provided.

1.3 The Report

This report contains a description of the brewery process, audit findings, opportunities for PP/WM and water conservation derived from the audit finding. Recommendations and follow-up actions necessary to assess the extent of pollution and to implement PP/WM and water conservation measures at the ABC facility are also included.

Appendices attached to this report include support information obtained during the audit and additional information provided by the industry. Appendix A contains the audit questionnaire used to obtain the necessary information about the facility. Appendix B is a collection of support documentation provided by ABC. A copy of Harza's Background Material Report, including references, is included as Appendix C. Applicable Jordanian regulatory standards for water quality are included as Appendix D. Success stories for PP/WM and water conservation at brewery industries are included as Appendix E. Appendix F includes photos taken of the facility during the audit.

This audit report provides the information required to conduct a PP/WM and water conservation feasibility study of the brewery industry in Jordan, using ABC as the basis. The findings of the PP/WM and water conservation audit conducted for the ABC facility are presented herein.

2.0 PROCESS AND FACILITY DESCRIPTION

2.1 General

The ABC is located in the old industrial area near Zarqa, along the Zarqa River. The ABC initially opened in 1964, closed, and then resumed production in 1971. The ABC is an operating unit of General Investment Co. Ltd. which owns and operates several other breweries and Distilleries. The ABC produces beer under a license from the German brewery Henninger. The total beer production capacity is 20 m^3/day, but current production rates are only 15-20 percent of capacity. The brewery, as we understood, produces the Henninger beer to respond to market demand which is currently only 10 percent of the total beer consumed in Jordan. Because of this low market demand, beer production is relatively low.

2.2 Facility Description

The ABC facility is located in Zarqa adjacent to the AMSTEL brewery facility, another operating unit of General Investment Co. Ltd. The facility includes raw material storage, production facilities, product storage, and an abandoned wastewater treatment plant. All the water needs for ABC are satisfied by groundwater (1,000 to 1,500 m^3/month) obtained from an on-site groundwater supply well. This water satisfies the production needs for beer, soft drinks and non-alcoholic beer.

The wastewater generated is pumped directly into the city sewage system and ultimately discharged to the As Samra Wastewater Treatment Plant. Effluent characteristics for the ABC facility is included in Table 1. Due to the limited nature of ABC brewery effluent data, WAJ reported AMSTEL Brewery wastewater effluent characteristic data for 1993 are included in Table 2 for reference purposes. For comparison purposes, the ABC and AMSTEL wastewater effluent characteristics are included in Table 3. Data for AMSTEL effluent was not used a basis for recommendations included herein.

The ABC facility operations can be grouped in two general categories:

- Beer Production Operations; and
- Ancillary Operations.

Descriptions for each of these operating areas are provided below.

2.3 Beer Production Operations

Beer production at ABC consists of several unit operations and processes. They include:

- Brewhouse Operations;
- Fermenting and Conditioning Processes; and
- Packaging Operations.

A schematic illustrating ABC operations is included in Figure 1. Each of these unit operations and processes are described below:

2.3.1 Brewhouse Operations

Brewing (boiling) is the first step of beer production. Brewing of malt results in the production of a slightly sweet liquid known as "wort" which, when fermented with yeast, produces beer. The brewing process consists of the following unit operations:

- Malt Cleaning
- Malt Milling (with addition of water);
- Mashing (at 78°C) with addition of water;
- Filtration (water is added to filtered wort);
- Brewing;
- Trub Separation; and
- Cooling.

Each of these processes are briefly discussed below.

Malt Cleaning. The raw barley is cleaned via sieving and transferred to the milling machine. Separated husk material is sold to farmers with spent malt.

Malt Milling. Milling reduces the particle size distribution of the malt to a specified gradation. The malt used is typically barley. About 1.5 tons of barley is used per batch in the brewing operation.

Mashing. The milled malt is transferred to mash tub where hot and cold brew water is added systematically to maintain the water temperature within the mash tub at 50°C, and to maintain the malt to water ratio at 1:3. Brew water is the fresh stock water which is used to prepare wort and later beer.

This mixture is then transferred to the brew kettle for cooking. About 4 to 5 m^3 of brew water is added in the mash tub per batch. The milled malt is cooked with steam and converted into a semi-liquid product called mash by enzymes introduced into the malt. The mashing process converts starchy materials into sugars at 78°C.

Mash Filtration. The mash is transferred to another kettle, called lauter tun, which is a false bottom vat. The liquid passes through the bottom screens and solids are retained on the screens.

The filtered liquid is then transferred back to the brew kettle. The solids in the filtration kettle are sparged with about 5 m^3 of hot water to extract as much of the fermentable sugars as possible. However, the net volume of wort is not allowed to exceed 10 m^3 per brewed batch. Any excess water is allowed to vaporize in the brew kettle.

Spent malt solids are stored and ultimately sold to farmers as cattle feed.

Brewing. The wort is transported back into the brew kettle where it is heated to boiling using in direct contact steam. During the boiling process, hop extract is added to impart the characteristic aroma of beer. The pH of the wort is adjusted at this stage to between 5.0 to 5.5 using sulfuric acid.

Trub Separation. After brewing, the hot wort is injected into a vessel, in which whirlpool action separates the sediments and solids containing proteins from the wort. The separated solids are periodically discharged directly to the sewer.

Cooling. The boiled wort is cooled in two stages using fresh stock water (used later for brewing) and alcohol water. The stock water, while cooling hot wort to 24°C, is heated in a counter current heat exchanger which recovers otherwise wasted heat.

Alcohol water allows wort to be further cooled to 0°C in a closed-loop cooling system. Alcohol water is continually circulated through chiller units. Fresh alcohol is added to the system to maintain the desired strength.

The entire brewing process takes approximately 11 hours per batch. The cooled wort is then fermented as discussed below to produce beer.

2.3.2 Fermenting and Conditioning Processes

Fermenting and conditioning processes include processes to age the wort to produce a beer product ready for bottling or kegging. These processes include:

- Fermenting (yeast is added);
- Lagering; and
- Filtration and Carbonation.

Fermenting. The cooled wort is mixed with a selected yeast and transferred to closed fermentation tanks (fermentors). The ABC has six (6) fermentors, each with a 20 m^3 capacity. Each fermentor accepts two batches of 20 m^3 wort for fermentation. Heat is released in the process as fermentation proceeds. The temperature is controlled by attemperators inserted in the fermentors.

Carbon dioxide (CO_2) is also produced during the fermentation process. The CO_2 rises to the top of the fermentors, bringing with it foreign substances, which are removed. The released carbon dioxide is collected and stored under pressure for subsequent use in the beer carbonation process.

Fermentation is complete after seven to ten days, when the sugar concentration is reduced to 2 percent. At this point, most of the yeast has settled to the bottom of the fermentor by gravity and is stored for reuse in subsequent fermentation batches. The excess yeast is sent to other distilleries owned by the same management for recycle and reuse. The fermented liquid is unmatured beer.

Lagering. The beer is allowed to mature, or lager, after fermentation by being cooled to 0^0C in storage tanks for 6 to 7 days. The maturation process mellows the beer, that is, improves its palatability. During storage, the beer is gradually clarified by adding selected beer stabilizers. The ABC has eight (8) storage tanks, each with 20 m^3 storage capacity.

Filtration and Carbonation. After storage, the beer is filtered and carbonated. In the filtration process, the beer is pumped through a plate and frame filter and then stored in three (3) vertical tanks. Carbon dioxide gas at 0^oC is then injected into the beer as necessary for carbonation.

2.3.3 Packaging Operations

Packaging operations include:

- Bottles/Cans Washing;
- Bottle Can Filling;
- Keg Washing and Filling;
- Pasteurization;
- Labeling; and
- Storing.

Each of these operations is described below.

Bottle/Can Washing. The brewery has separate machines for washing and filling of bottles, cans and kegs, as well as separate quality control and packaging operations. The labeling for bottles and cans, however, is done using a common machine.

Bottle/can washing requires a large amount of water and creates a significant waste load. Automatic machines are operated for bottle/can washing which perform the following operations:

- Feed the bottles/cans to the washing equipment;
- Pre-rinse the bottles/cans;
- Immerse the bottles in a series of alkaline baths (typically water and caustic soda) for soaking, label removal, washing and sterilization; and
- Post-rinse the bottles.

Cans are not washed with alkaline solutions and therefore do not require post-rinse.

Bottle/Can Filling. A conveyor line takes the washed bottles/cans to a filling machine. The bottles/cans are manually inspected to remove any defective containers before an automatic machine fills and caps the usable bottles.

Keg Washing and Filling. The kegs are washed manually with steam and water, then filled separately in a unit dedicated for this purpose.

Pasteurizing. Beer is pasteurized to prevent any residual yeast or harmful bacteria growth in the packaged beer prior to consumption. Pasteurization requires heating beer to 60°C. Pasteurization is performed after packaging by immersing the bottled/canned beer in gradually hotter warm-water baths. This gradual heating is required to avoid cracking the glass bottles. Kegs are pasteurized in a separate water tank.

2.4 Ancillary Operations

Ancillary operations are support operations and activities carried out throughout the brewery facility. Ancillary operations include equipment cleaning and sterilizing, steam and hot water production, cooling, housekeeping, and wastewater treatment. These operations are described below.

Equipment Cleaning and Sterilization. All equipment that comes into contact with the product must be cleaned and sterilized. At the ABC facility, all equipment is completely washed, cleaned and sterilized using hot water or steam, caustic soda and disinfectants after each brewing batch.

The ABC has three mechanical cleaning-in-place (CIP) systems; one dedicated to brewing equipment, one dedicated to the fermentation equipment and a third dedicated to the wort cooling system. Caustic soda, phosphate and disinfectants are used in the CIP systems. Chemical solutions are prepared and circulated within the system and reused continuously. When the solution strength reduces below the desired strength, additional raw chemicals are added to the stock solutions. These systems reduce chemical usage and wastewater generation.

However, before and after CIP application, tanks are rinsed with hot water which is discharged to the sewer. The hot water cleaning also helps sterilize the equipment. The brewhouse equipment and wort cooling system are washed and rinsed with hot water while fermenting equipment is washed and rinsed using cold water. All rinse water is discharged directly to the sewer. The typical equipment cleaning sequence for each CIP system is presented below:

<u>Brewhouse Equipment and Wort Cooling System Cleaning</u>:

- Rinse
- Caustic Wash
- Rinse

As a final step, the brewhouse equipment and wort cooling system are washed by passing 4 m^3 of water through the entire system before it is discharged to the sewer.

Fermentation System Cleaning:

- Rinse
- Caustic Wash
- Rinse
- Phosphate Wash
- Rinse
- Hydrogen Peroxide (disinfectant) wash
- Final Rinse

Steam and Hot Water Production. At ABC, hot water is used for mash preparation and filtration (sparging) operations, brewing, cooling equipment cleaning, and sterilization. Indirect steam heating is used for heating brew kettle and pasteurization water baths. The ABC facility operates a package boiler, fired using fuel oil, to produce hot water and steam. The hot brew water used for mash preparation and sparging is generated during the wort cooling process as described in Section 2.3.1. Hot water used for equipment cleaning is supplied by the boiler.

The steam used to heat brew kettle and pasteurization water baths is condensed and returned to the boiler. Boiler makeup water is pre-treated through a water softener unit. Sodium chloride is used to regenerate the softener. The regenerant waste is discharged to the sewer.

Wastewater Treatment. The ABC has an activated sludge biological treatment facility to treat industrial wastewater. However, the on-site wastewater treatment facility is abandoned in-place. Therefore, the industrial wastewater is discharged directly to the sewer and is ultimately sent to the As Samra Wastewater Treatment Plant.

Technical information on the design, operation and maintenance of the wastewater treatment plant was not available to the audit team. However, based on the information provided by Mr. Mukhlais, the wastewater treatment plant consists of a concrete tank (150 m^3 capacity) used for biodegradation and sludge sedimentation processes. There are two air compressors, in a separate room, which supply air to the bioreactor.

Domestic wastewater is discharged directly to the city sewer system.

Housekeeping. Floors, walls and equipment are cleaned with cold and hot water, as required, after each brewing batch. All housekeeping wastewater is discharged directly to the sewer.

2.5 Raw Material Usage

The ABC's annual raw material consumption is presented in Table 4. Due to annual low production levels, the overall chemical usage is minimal.

2.6 Current Environmental and Maintenance Programs

The environmental and waste recycling programs at ABC include the following:

- Spent malt and husk produced during the brewing process are 100 percent recovered and sold to farmers.

- Settled yeast from the fermentation tanks is collected and reused. The excess yeast is reused and recycled at other distilleries owned and operated by ABC management.

- All solid wastes generated at the facility are sold or disposed off-site at a permitted facility. These include:

Broken glass	- Sold for reuse
Paper boards/cartons	- Sold for reuse
Chemical bottles	- Sold for reuse
Plastic bags	- Sold for reuse
Domestic solid waste	- To off-site landfill

- As previously discussed, the CIP systems help conserve chemicals and reduce the overall discharge to the As Samra Wastewater Treatment Plant.

2.7 Environmental Regulations and Guidelines

Jordan currently has no comprehensive law to control water, air and soil pollution. However, industrial waste water discharges are regulated by the Jordanian Standard 202, adopted in 181 by the Department of Standards and Specifications and revised in 1990. Standard 202 regulates industrial wastewater discharges to rivers, wadis, groundwater, the sea, and reuse for irrigation. Drinking water quality is regulated by Jordanian Standard 286. Moreover, it is a common practice to use the Food and Agriculture Organization (FAO) guidelines as a reference. Appendix D contains further discussion and summary tables for these regulations and guidelines.

Also included in Appendix D are regulations governing the discharge of industrial and commercial wastewater connected into the sanitary sewer system.

3.0 AUDIT PROCESS

The objective of the audit was to identify the potential for PP/WM, wastewater treatment, and opportunities for water conservation appropriate for ABC. The following subtasks were undertaken to complete the audit report.

- Audit Coordination;
- PP/WM Background Material Preparation;
- Pre-Inspection Meeting;
- Audit;
- Post-Inspection Meeting; and
- Audit Evaluation Report.

Activities conducted under each of the subtasks are briefly described below.

3.1 Audit Coordination

The Chamber informed ABC about the intent and schedule of the audit. An audit questionnaire specifically developed for this PP/WM project (Appendix A) was included with the request that ABC complete the questionnaire prior to the audit. The ABC was also requested to furnish an overall flow balance and a process description. Available information obtained from ABC (Appendix B) was furnished to the audit team during the audit and included the following:

- Facility layout; and
- Water usage and discharge from each unit operation.

No process description and water flow balance were provided prior to the audit.

3.2 PP/WM Background Material Preparation

The objective for preparing the Background Material Report was to identify the currently available techniques and "state-of-the-art" technologies being practiced for PP/WM and water conservation for breweries in the U.S. and elsewhere in the world. This objective was achieved by performing a comprehensive literature review.

The literature review included the following sources: PP/WM related articles, conference proceedings, books on pollution types and control, and journal articles. In addition to the literature review, in-house technical expertise at Harza contributed to the content of this report. Based on the facility operation information that was made available to the audit team and the information gathered through the available literature, Harza prepared the Background Material Report (Appendix C). This report includes general information on the brewery industry as well as specific information on the process used by ABC.

Harza also prepared a report which included appropriate reference material during the literature search. This report was submitted separately, and contains process and waste management practices used in similar facilities, primarily in the U.S.

3.3 Pre-Inspection Meeting

The pre-inspection meeting was held at the ABC offices on March 12, 1995. The intent of this meeting was to inform ABC staff about the objective of the audit and also for ABC staff to present process details as they relate to fresh water utilization, wastewater generation, treatment and disposal, water recycling and reuse, and overall water management at the facility. The audit team explained to ABC the purpose of the audit. The ABC staff gave a brief description of the brewery processes, raw materials, and products.

3.4 Audit

The facility audit was conducted on March 12 and 14, 1995 and again on March 16, 1995. The initial audit team consisted of the following personnel:

Eng. Rania Abdul Khaleq	Ministry of Water and Irrigation
Eng. Marwan K. Tal	Water Authority of Jordan
Dr. Shawn Niaki	Program Director, DAI (Harza)
Mr. Krishna Mayenkar	Lead American Consultant (Harza)
Dr. Riyad Musa	Local Consultant, RSS
Dr. Omar Jabay	Local Consultant, RSS

Representatives from the ABC facility were:

Mohammad Saleh Ali	Brewery Manager
Mukhlais Haddad	Production Manager

The ABC designated Mr. Mukhlais Haddad to assist the audit team in touring and inspecting the facility.

On the first day, the audit team toured the entire facility. Mr. Haddad explained all processes and operations from malt milling to brewing, fermentation, and final packaging. None of the units except for mashing and brewing were operating. The facility tour, however, provided the audit team with an overall process description and operational insight.

Upon completion of the facility tour, Mr. Haddad and Mr. Mayenkar continued discussion on overall water usage and wastewater management practices currently employed. Some of the specific details, however, remained unanswered.

Dr. Omar Jabay visited the facility again on March 14 and 16, 1995. During both visits, Dr. Jabay discussed water usage for different operations, the cleaning operation sequence for different equipment and also air emissions and solid waste management practices at the facility. Mr. Haddad provided the requested information, to the extent possible, based on the established operational practices. Because most of the water usages are not metered or monitored and most operations are automatic, it was difficult to estimate water consumption for specific operations.

3.5 Post-Inspection Meeting

During the post-inspection meeting, ABC staff and audit team members reviewed the general facility operations and discussed the preliminary impressions regarding PP/WM and water conservation opportunities at the brewery. The facility staff were very responsive to the audit team's requests and agreed to help provide additional data, as necessary.

The information and waste management analyses in the subsequent sections of this report are based on the knowledge gained through audit activities and support provided by ABC staff.

4.0 AUDIT FINDINGS

The information obtained during the facility audit was compiled and thoroughly reviewed. Personnel interviews and discussions with ABC staff, site observations, and the technical data supplied by ABC, all led to the following audit findings:

4.1 Overall Water Usage and Balance

Fresh water used as process water in the ABC facility is obtained from groundwater pumped from an on-site supply well. Water used for domestic purposes is supplied by the WAJ. The estimated water consumption per month at ABC is approximately 1,000 to 1,500 m^3, which represents a rate much lower than capacity due to low market demand.

The facility uses fresh water for two purposes; primarily as a raw material to produce beer and secondly for equipment and facility cleaning purposes. Other areas which require water are steam production, product pasteurization, softener regeneration, cooling and pipe defrosting. The current water usage and water balance at ABC is illustrated on Figure 2 and summarized in Table 5. Approximately 11.04 m^3 of fresh water is used to produce one cubic meter of beer.

The following summarizes typical water use:

- Beer (9 percent);
- Equipment Cleaning (56 percent);
- Floor Cleaning (6 percent);
- Boiler Makeup Water (4 percent); and
- Miscellaneous purposes (25 percent).

Equipment cleaning includes process and process support equipment associated with brewing, fermentation, filtration and packaging operations. Miscellaneous water uses include softener regeneration, cooling water makeup, pipe defrosting, and pasteurization.

As one may note from the process description, the total time required to produce beer from the first step of milling is several days. The wastewater generated from each unit operation or equipment is, therefore, discharged to the sewer at varying times as particular operations are completed. For example, after brewing operation, cooled wort is fermented for about 7 days. However, while all brewing vats and milling equipment are cleaned and sterilized for a new batch, the processed wort is fermented. Similarly, when the fermented wort (now called beer) is transferred to storage for about 7 days, the fermentors are cleaned and sanitized. Thus, the wastewater from equipment cleaning and floor cleaning is generated at a staggered schedule for each batch of beer. Since the beer production is not continuous, the wastewater is generated intermittently. Throughout this report, the wastewater generation rate is therefore referred t per cubic meter of beer produced.

The water use and wastewater sources discussed in this report refer only to the beer production process and do not address non-alcoholic beer or soft drink production. However, we believe that some of the recommended management techniques could be applicable to other productions.

4.2 Wastewater Sources and Discharges

Wastewater generation at the ABC facility is unique due to the intermittent nature of the operation. Wastewater is generated after each unit operation due to equipment and floor cleaning. At the ABC facility, wastewaters are generated from the following operations:

- Brewing;
- Fermentation/Lagering/Finishing;
- Packaging;
- Water Softening;
- General Housekeeping;
- Domestic Water Use; and
- Other Water Uses.

The volume of wastewater generated from each of these unit operations is illustrated on Figure 2 and is summarized in Table 6. Each wastewater source is discussed in detail below:

4.2.1 Brewing

Wastewater generated from brewing operations results primarily from equipment cleaning. After each batch of brewing, all equipment including the milling machine, mash tub, brew kettle, filter vessel, wort cooler and piping, and pumps are thoroughly cleaned using the CIP sequence previously described in Section 2.0. Approximately 1.1 m^3 of wastewater is generated during the brewing operation per m^3 of beer produced.

In addition, the water softener used specifically to produce brew water is estimated to generate about 0.2 m^3 of regenerant wastewater per m^3 of beer produced. Approximately 0.1 m^3 of water is lost as steam escaping through brew kettle and filter vessels. Occasionally, the steam is intentionally released to control the volume of beer produced per batch.

In summary, 1.3 m^3 of wastewater is generated and 0.1 m^3 of steam is exhausted from brewing operations per m^3 of beer produced.

4.2.2 Trub Separator Discharge

Trub is the waste generated from brewing malt, consisting mostly of insoluble proteins. Trub is separated from wort prior to passing it through the cooler and is discharged directly to the sewer. It has been reported that beer production results in an average trub generation of 1.16 kg/m^3 of beer produced. We estimated that trub slurry discharged per m^3 of beer would be about 0.1 m^3 as a 1.0 percent solution. Although the volume of trub discharged is small, the organic load exerted by the trub is extremely high. It is reported that trub can exert biochemical oxygen demand (BOD_5) as high as 50,000 mg/l and can contain suspended solids as high as 3 percent.

4.2.3 Fermentation/Lagering/Finishing

Fermentors, storage vessels and the filter press are cleaned thoroughly after each use using the CIP sequence described in Section 2.0. Approximately 2.7 m^3 of wastewater is generated through CIP cleaning operations in the brewhouse (1.1 m^3), wort cooler (0.2 m^3) and fermentation storage (1.4 m^3) per m^3 of beer produced. Wastewater from the brewing equipment and wort cooler cleaning is warm, while fermenting equipment cleaning wastewater is cold.

4.2.4 Packaging

Large volumes of wastewaters are generated from packaging operations. The major sources are bottle/can/keg washing, cleaning and pasteurization. During pasteurization, although the water is heated under controlled conditions using indirect steam heating, cold water and hot water are frequently added to baths to adjust temperature through direct mixing. As a result, a significant quantity of water is wasted from overflow.

The amount of wastewater generated from washing and pasteurizing operations is about 2.4 m^3 per m^3 of beer produced (1.4 m^3 for bottle washing, 0.8 m^3 for pasteurization and 0.2 m^3 for keg washing, in the form of steam).

4.2.5 Water Softening

Water obtained from the groundwater supply well is demineralized prior to its use for washing, pasteurization, cooling tower makeup, boiler feed water makeup and brew water. The ABC operates three demineralization systems; one for brew water, one for boiler feed water and one for wash water.

Water use associated with the brew water softener is accounted for under brewing operations. The other two demineralization systems which provide most of the utility water are considered here. They process about 3.34 m^3 of water per m^3 of beer produced and generate about 0.34 m^3 of regenerant wastewater. These are typical values for similar units based on Harza's past experience with these operations. Neither wastewater volume nor regeneration information was made available to the audit team during the audit.

4.2.6 General Housekeeping

From a hygienic point of view, brewery floors, and the outside of equipment and piping are routinely cleaned. We estimate that approximately 0.7 m^3 of water is used for floor washing and approximately 1.0 m^3 of water is used for equipment, piping and other surface cleaning per m^3 of beer produced.

4.2.7 Domestic Water Use

The ABC facility currently has a total staff of about 30 personnel. The total domestic water consumption is estimated to be approximately 2.0 m^3/day. The domestic wastewater is discharged separately to the city sanitary sewer system. Comparing this value with the typical industrial domestic water use of 0.06 m^3 per capita per day, the reported water consumption appears to be within a reasonable and acceptable range.

4.2.8 Other Water Uses

Approximately 0.5 m^3 of plant water is lost to evaporation through the cooling tower and brew kettle. Brew kettle steam losses are manually controlled to maintain the wort volume per batch.

About 1.0 m^3 of water is used to defrost cooling system pipes which develops frost on the surfaces due to moisture condensation.

4.3 Storm Water

All storm water is discharged to a nearby Wadi through natural grade. Since most of the area is either covered by buildings or paved surfaces, storm water is expected to primarily contain suspended solids. The audit team did not observe noticeable liquid or solid spills or leaks during the audit visit.

4.4 Solid Waste

It appears that most solid wastes generated from operations at ABC are recycled and/or reused as discussed in Section 2.0.

However, trub, with its high organic loading, is discharged to the sewer directly from the trub separator.

4.5 Air Emissions

The anticipated emissions from the beer making process are particulates and volatile organic compounds (VOCs). At the ABC facility, the audit team did not observe any emissions. However, due to low production, particulate emissions from malt handling, sulfur and nitrogen oxides exhaust gases from the boiler, and VOCs from vented steam and hot washwater handling are expected to be very minimal.

4.6 Data Gaps

There are two general areas of data gaps identified during the audit. They are:

- Lack of water and waste quantity information; and
- Lack of water and waste quality information.

This data is basic to developing the most cost-effective waste minimization and water conservation measures. Specific data gaps noted are as follows:

- Water utilization rates and total water quantities used for all applications and processes included in Table 5;

- Total effluent quality data and individual wastewater source quality data for monitoring, controlling and improving operations. Specific composite wastewater sources that need to be monitored are:

  - Brewhouse CIP Effluent;
  - Fermentor CIP Effluent;
  - Lagering Tanks Cleaning Discharge;
  - Regenerant Wastewater Effluent;
  - Filter Cleaning Wastewater; and
  - ABC Final Effluent.

- Trub discharge from the trub separator and its quality. The primary pollutants which need to be monitored are:

  - pH;
  - Biochemical Oxygen Demand (BOD_5);
  - Chemical Oxygen Demand (COD);
  - Total Suspended Solids (TSS); and
  - Total Dissolved Solids (TDS).

5.0 Pollution Prevention/Waste Minimization Potential

The terms pollution prevention and waste minimization are sometimes used interchangeably, but each term has a different meaning. Pollution prevention means to prevent pollution from occurring in the first place. It costs 10 to 100 times more to treat pollution once it is created than to avoid generating it. By employing waste minimization techniques, less pollution will be created, thus reducing the cost of treating such pollution.

5.1 Pollution Prevention/Waste Minimization - Water

There are five distinct areas which contribute to the major organic pollution load in brewery wastewaters. They are:

- CIP System Wastewater from Brewing;
- CIP System Wastewater from Fermentation/Lagering;
- Filter Washwater;
- Trub Discharge; and
- Floor Drainage.

The regenerant wastes contribute dissolved solids but not organics. Other wastes consisting of wash waters, pasteurizing water, equipment cleaning etc. contribute hydraulically but they are weak in organics and dissolved solids. With the above waste classification, it is obvious that the maximum waste minimization can be attained by controlling waste generated through CIP cleaning, filter wash, trub discharge, floor drainage and regeneration of demineralizers.

Opportunities for PP/WM at ABC are as follows:

5.1.1 CIP System Wastewater

At present, the brewing equipment, fermentation equipment and wort cooler are cleaned using CIP systems after each batch of beer production. However, our discussions with ABC staff revealed that the brewhouse equipment can be used for six successive batches without CIP cleaning. Therefore, the wastewater generated from CIP systems could be reduced by approximately 80 percent in volume and likely 50 percent in organic load, due to possible build up of organic crust in the equipment if the cleaning frequency is reduced.

The ABC staff should, therefore, optimize the cleaning and washing requirements without adversely affecting beer quality. Since hygienic considerations are extremely important, reduction in the cleaning frequency should be thoroughly evaluated prior to implementation.

We are assuming that it is possible to reduce the brewhouse pollution load at least by 30 percent by preparing three (3) batches without CIP cleaning and not affecting the beer quality. In the fermentation process, we understand that ABC is considering combining lagering and fermentation steps. This process modification would reduce storage vessel washing and reduce the hydraulic and pollution load generated. We strongly encourage such process modification to reduce the hydraulic and pollution load discharge from CIP cleaning operations.

5.1.2 Filter Washing Wastewater

Wash water generated from filter washing can be reduced by optimizing filter washing operations. Areas for potential PP/WM include:

- Increase the Filtration Cycle; and
- Store and Refilter the Filter Washing Wastewater.

The filtration cycle can be increased by increasing the amount of beer filtered before washing and cleaning the filter. The filter washing wastewater can be stored and re-filtered before the next batch of beer is processed by removing any yeast and settleable material collected in the washwater. This involves treating the wastewater using existing filters to reduce the BOD_5 and TSS load before discharge to the sewer. Existing unused storage tanks can be used to store the filter washwater. Additional sump, pump and piping will be required.

5.1.3 Trub Discharge

Instead of discharging trub directly to the sewer, it can be stored and mixed with spent malt and husk and sold to farmers. Although the trub discharge is small in volume, trub can exert a high BOD_5 load to the As Samra Wastewater Treatment Plant.

A modest investment in a storage tank, pump and piping can also result in reducing the organic load discharge to the As Samra Wastewater Treatment Plant.

5.1.4 Regenerant Wastes

Regenerant waste volumes and loads are directly proportional to the water treated through demineralizers. By conserving water, as discussed in Section 6.0, and installing alternative technologies and equipment discussed below, the regenerant wastewater from packaging and brewing areas can be reduced by more than 40 percent.

The ABC can explore installing new ion exchange resins as well as new technologies and new regeneration systems described below.

Electrodeionization. The system is a combination of ion-exchange (IX) and electrodialysis and is often used as a replacement for IX. The system contains an IX resin with an electric field applied across it to remove ions on a continuous basis and is capable of producing high purity water. The system has an advantage over IX by elimination of the use of regeneration chemicals (sodium hydroxide and hydrochloric acid). US Filter located in Rockford, Illinois (U.S.) is now marketing a new electrodeionization process called IONPURE.

New IX Resins and Regenerating Chemicals. A series of ion-exchange resins have been developed to improve demineralization, improve performance and reduce chemical use in IX modules. The resins are characterized by excellent physical strength as well as high capacity and regeneration efficiency. These resins could potentially reduce chemical usage and TDS loading. With these resins, the current practice of using HCI and NaOH for regeneration can be substituted with more environmentally friendly chemicals like acetic acid and ammonium hydroxide. Sybron Chemicals of Birmingham, New Jersey (U.S.) has developed such resins.

New IX System. New compact IX systems have been introduced into the market which require less chemicals and generate less regenerant wastewater. ECOTECH, Schaumburg, Illinois (U.S.) has developed such a system. The ABC should explore the feasibility of installing such as a system.

5.1.5 Floor Drainage

Dry malt, yeast, husk, and other organic material can be recovered by sweeping up floors and using a dry vacuum system where possible before washing floors with water. In addition, as discussed in Section 6.0, floor drainage can be minimized by good housekeeping and controlled washing and cleaning operations.

5.1.6 Wastewater Treatment Plant

Although wastewater treatment is considered to be an end-of-pipe treatment and does not, by definition, fall under the PP/WM category, we recommend that the ABC explore reactivating the abandoned wastewater treatment plant.

We strongly believe that all industries who have invested in a wastewater treatment plant should use these facilities to their fullest capacity to reduce the pollution load discharge.

In summary, the following PP/WM measures are recommended for wastewater management:

- Maximize the number of brew and fermentation batches before CIP cleaning (i.e. reduce CIP cleaning frequency);
- Store and treat filter wash water to recover yeast to reduce organic loading;
- Combine trub discharge with spent malt for cattle feed;

- Reduce regenerant wastewater by recycling, conservation and installing new technologies;

- Use a dry vacuum system for floor cleaning and minimize water usage by improved housekeeping and controlled washing operations; and

- Eliminate the cause of spillage and leaks by planned maintenance and operating procedures.

5.3 Pollution Prevention/Waste Minimization - Solid Wastes

All process wastes generated at ABC, except filter cake, are recycled and reused. The municipal solid waste and filter cake are disposed offsite at a local landfill.

We recommend that the trub slurry, which is currently discharged to the sewer, be combined with spent malt and husk and sold to farmers.

5.4 Pollution Prevention/Waste Minimization - Air Emissions

At this time, due to very limited and intermittent production, PP/WM opportunities for air discharges are not being considered.

6.0 Water Conservation Potential

In the following discussion, potential water conservation opportunities for ABC are presented. Comparing 9.34 m^3 of wastewater discharged per m^3 of beer produced at ABC with an average reported figure for beer industry of 6.9 m^3 per m^3 of beer produced, it appears that there is a room for improvement and water saving and conservation.

The water conservation opportunities that we have identified are as follows:

- Process Optimization;
- Reduce CIP Cleaning Frequency;
- Combine Fermentation and Lagering in the Same Tank;
- Recovery and Reuse Pasteurization Water;
- Change from Water Cooling to Air Cooling;
- Install Equipment/Piping Insulation to Eliminate Defrosting;
- Use Procedural and Controlled Equipment and Floor Cleaning;
- Store and Utilize the Last Rinse Water as a First Rinse for the Subsequent Cleaning of Brewhouse and Fermentation Equipment;
- Increase the Water Softener Performance using New IX Resins or Technologies.

The anticipated reduction in water usage is 4.85 m^3 per cubic meter of beer produced as shown in Table 7. The projected fresh water use is 6.19 m^3 per cubic meter of beer produced (i.e. 42 percent reduction from the current water usage of 11.04 m^3 per m^3 of beer).

The suggested water conservation opportunities are briefly described below.

6.1 Process Optimization

We believe that by improving process control and instrumentation, and carefully monitoring the actual water requirement and actual water usage, water consumption can be reduced. Such opportunities exist for:

- Bottle/Can Washing;
- Filter Cleaning; and
- Water Softening.

We have assumed 10 percent probable water savings for the above three operations. Process optimization can be achieved through the following:

- Proper monitoring of process variables including temperature, pressure, feed and effluent water quality and resins;
- Proper application of optimum operating conditions;
- Process water usage control by installing flow-control valves, and timers;
- Monitoring water flow rates in and out of each process unit to ensure controlled

water consumption; and

- Monitoring water quality in processes such as ion exchange, in which regeneration must take place when quality falls below a specified standard. This can avoid using regeneration water before it is actually required.

In addition to the above, a properly instituted maintenance program encompassing preventative maintenance can conserve energy and water.

6.2 CIP Cleaning Frequency Reduction

The CIP cleaning frequency can be reduced. Instead of cleaning equipment after each batch, brewing equipment can be cleaned after every third batch, while maintaining product quality. In addition, the last rinse water can be stored and used as a first rinse for the subsequent cleaning operation.

With the combination of these two measures, the anticipated water saving could be as much as 70 percent.

6.3 Fermentation/Lagering Operation Modification

Fermenting and maturing beer in the same vessel will reduce the wash water requirements by about 40 percent. Using the last rinse water for the first rinse for the next cleaning cycle, will reduce the water requirement by an additional 30 percent.

With the combination of the two measures, the anticipated water savings could be as much as 65 percent.

6.4 Recovery and Reuse of Pasteurizing Water

We recommend that 100 percent of the pasteurizing overflow water be collected, and reused after filtration and softening for bottle/can washing operations. It is clean water unnecessarily wasted.

6.5 Insulate Piping and Equipment

The bare pipes used to convey chilled alcohol water cause condensation of atmospheric moisture on the pipe surfaces which subsequently is converted into frost. Fresh water is used to defrost the pipes.

All pipe and equipment used in the wort cooling system and subjected to defrosting can be insulated to increase the cooling efficiency as well as to eliminate the necessity for pipe defrosting and result in a 100 percent reduction in pipe defrosting water use.

6.6 Procedural and Controlled Equipment and Floor Cleaning

Cleaning practices, unless properly established, monitored and managed can result in wasting hundreds and thousands of m^3 of water every year due to complete lack of controls, non-awareness of water commodity and no incentives to conserve water. The following water conservation measures, if taken, could assist ABC in reducing cleaning water volume.

- Sweep up dried materials instead of flushing to the drain;
- Eliminate the causes of oil spillage, such as leaking pipes and accidental loading, transfer, and storage area spills;
- Use dry vacuum techniques to clean up material spills instead of washing them down the drain;
- Use timer controlled valves for controlling washwater. This will help reduce the amount of water used for each washing;
- Utilize water saving equipment as much as possible. Different types of water saving equipment include:

  Flow Regulation Devices. When these devices are inserted into a water line, they restrict flow to a constant rate.

  Flow Shut-off Devices. The most useful devices are finger operated shut-off valves, or guns, with nozzles on the ends of cleanup hoses. When finger pressure is released, water flow stops.

  Nozzles. Nozzles use less water than drilled pipe sprays. For faster, more efficient cleaning, a "Vee" type nozzle is preferred.

  Overflow Preventors. These devices are employed to prevent overflowing of containers, tanks, or reservoirs, thus minimizing spills.

- Perform washdowns on an as-needed basis; and
- Improve housekeeping by developing and implementing strict operating protocols.

We believe by establishing procedures and schedules for equipment cleaning and floor washing and using dry vacuum system the water requirement can be reduced by 20 to 40 percent.

6.7 Replacing Evaporative Cooling with Air Cooling System

The ABC should explore the use of an air cooling system where water is cooled using an indirect contact heat exchanger and air as a cooling medium. This will eliminate 100 percent evaporative cooling water loss.

6.8 Storing and Utilization of the Last Rinse Water

The final rinse water from CIP cleaning operations is currently discharged directly to the sewer. This water is considered to be relatively clean and can be reused as the initial rinse water for the next CIP wash. By collecting for reuse the combined discharge from the Brewhouse, Fermentation and Wort Cooling Systems, water use for CIP cleaning operations may be reduced by approximately 10 to 20 percent.

6.9 Conceptual Water Balance

PP/WM and water conservation solutions integrated into a single program will offer the greatest water savings. Using the current estimates for ABC water usage (Figure 2), a proposed conceptual water management plan was developed (Figure 3). This scenario includes the following PP/WM and water conservation measures:

- Process Optimization:
- Modify CIP Cleaning System for Brewing Equipment;
- Combine Fermentation and Lagering Operations and Optimize CIP Cleaning System;
- Insulate Wort Cooling and Chiller Piping;
- Recycle and Reuse Pasteurization Water Overflow;
- Replace Wet Evaporative Cooling System with Air Cooling; and
- Use Water Saving Equipment to Minimize Equipment Washdown, Floor Cleaning, and Leakage Losses.

A summary of the projected water usage and savings for individual water sources for this scenario is presented in Table 7. As can be seen from the table, implementing the above PP/WM and water conservation measures can potentially reduce fresh water requirements to 6.19 m^3/m^3 of beer produced (42 percent reduction).

This conceptual water balance illustrates a scenario which we believe is feasible. However, it should be noted that this water balance is not the only possibility. Other PP/WM and water conservation opportunities may exist which may require new process applications or modifications and which may be relatively more difficult to implement. However, PP/WM and water conservation opportunities not included in this scenario should not be eliminated from consideration, as their feasibility can only be determined through more intensive studies and evaluations.

It is very important to note that as beer production becomes continuous rather than intermittent, the amount of water required, or wastewater generated per m^3 of beer produced continues to decline. If the market demand increases and if ABC increases its production to meet the higher demand, the relative water usage and wastewater generation will reduce.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Water plays a critical role in the beer making process. A major use of water in this process is equipment cleaning. Beer consumes only 9 percent of the total process water consumption while equipment cleaning consumes 56 percent of the total water used in beer making operations.

7.1 Conclusions

Based on the audit findings, the following conclusions are made:

1. The main wastewater sources are:

   - Equipment Cleaning (6.2 m^3);
   - Pasteurization (0.8 m^3);
   - Floor Drainage (0.7 m^3); and
   - Regenerant Wastes (0.54 m^3)

2. The reported figures for brewery wastewater generated per m^3 of beer produced range from 5.5 to 8.3 m^3 with an average of 6.9 m^3. Since the ABC facility generates 9.34 m^3 wastewater per m^3 of beer produced, PP/WM opportunities exist in the following areas:

   - CIP System Operation for Brewing and Fermentation Equipment;
   - Fermentation and Lagering Operations;
   - Beer Manufacturing Schedules;
   - Filter Cleaning Operations;
   - Trub Discharge Disposal;
   - Floor Washing Procedures; and
   - General Process Optimization for Brewing, Fermentation and Packaging Operations, Equipment Cleaning, and Ion Exchange Regeneration.

   With PP/WM and water conservation, wastewater generation can be reduced to 6.19 m^3 per m^3 of beer, which is in a more acceptable range.

3. Water saving should result from many of the PP/WM measures described. In addition, water conservation can be achieved through implementation of:

   - Insulation of Cooling System Piping and Valves;
   - Installation of an Air Cooling System; and
   - Filtering and Recycling 100 percent of Pasteurization Water Overflow.

4. The ABC recycles most process solid wastes except trub and filter cake. The trub could alternatively be disposed with the spent malt instead of discharging it to sewer.

5. Air emissions do not appear to be a problem due to infrequent operations of the facility.

6. Water and wastewater discharges are not monitored.

7. Implementation of PP/WM and conservation measures could reduce the overall pollution load by 50 percent and the hydraulic load by 42 percent.

7.2 Recommendations

Based upon the above conclusions, the following recommendations are made:

1. Install devices to monitor water use and discharge from all cleaning operations including equipment and floor cleaning. Generate an accurate measurement and balance of facility water use.

2. Design and implement a wastewater sampling and monitoring program to cover all wastewater sources identified in this report. Initially, quarterly sampling frequency should provide the ABC management a fair idea of pollutant loads in different wastewater streams.

3. Study and implement a beer production schedule such that maximum number of batches are produced at each event thereby reducing washing frequency and pollutant discharge. This will also result in production cost saving.

4. Combine fermentation and lagering operations.

5. Optimize CIP systems by lowering washing frequency and using the last rinse water for the initial rinse of the next cleaning operation.

6. Recycle and reuse pasteurizing wastewater flow after filtering and water softening.

7. Explore installing an air cooling system to replace the existing wet evaporative cooling system.

8. Establish and implement rigorous equipment washdown and floor cleaning procedures to reduce water consumption.

9. Improve cleaning methods by carefully studying current procedures, washing time, solution concentration, water temperature, intensity of application etc. Applying appropriate combination of these elements to different equipment can reduce water use. Establish cleaning protocols and procedures for water conservation.

10. Optimize the regeneration process and explore the use of alternative technologies and systems.

11. Improve housekeeping and implement a spill prevention control and countermeasures program. Use dry vacuum techniques instead of washing spills into the drain.

12. Insulate all cooling pipes to avoid frosting and eliminate the use of water to defrost pipes.

13. Reactivating the biological treatment facility to treat industrial wastewater prior to discharge to the city sewer system. Any on-site pretreatment provided by industries will assist in reducing organic loads discharged to the As Samra treatment plant thereby minimizing shock loads, if any, and providing room to accept more domestic wastes.

14. Develop an environmental management program to include:

    - Establishing an environmental department with dedicated personnel and sufficient resources;

    - Writing an environmental policy complete with missions, visions, goals, policies and a future work plan. PP/WM and water conservation goals need to be established to achieve the PP/WM program, in line with the MWI and Chamber goals; and

    - Developing of training and incentive programs for all the ABC personnel.

15. Consider the following PP/WM items for feasibility level studies:

    - Optimize the CIP Systems;
    - Combine Fermenting/Lagering Processes;
    - Recycle and Reuse Pasteurization Water Overflow; and
    - Optimize Filter Cleaning Processes.

7.3 Success stories

Both large and small breweries are attempting to implement PP/WM and water conservation programs. For example, at the largest Coors Brewery located in Colorado (U.S.) reduced wastewater generation to 3.5 m^3 per m^3 of beer produced while the industry average varied in the range of 5.5 to 8.3 m^3 of wastewater per m^3 of beer produced. This is an excellent example to demonstrate that PP/WM programs, if seriously implemented, could result in significant water and cost savings.

Another PP/WM example is included in Appendix E. The case study presents experience gained while conducting a PP/WM audit to identify short term process water reduction opportunities and long term effluent treatment and disposal options. The study concluded that the initial rinse from the fermentation tanks, storage vessels and yeast recovery tanks accounted for over 90 percent of the COD load in the fermentation area and 10 percent of the entire facility wastewater discharge originated from the hot liquor tank overflow and lauter turns. It was found that the

COD discharge could be reduced by at least 75 percent by passing the rinse through a yeast press. Recommendations were made to reduce the overall facility wastewater pollution load by approximately 20 percent in volume, 30 percent COD load and 15 percent Suspended Solids. The capital costs to implement the recommended PP/WM measures was found to be relatively small compared to facility capital expenditure budget.

8.0 FOLLOW-UP ACTIONS

This section contains our recommendations to ABC concerning follow-up actions required to meet the PP/WM and water conservation objective. Although PP/WM is generally given priority over water conservation in most countries, due to the limited water resources in Jordan, PP/WM and water conservation measures should be given equal importance. With this philosophy, the following actions are recommended in order of their priority.

1. Develop and implement a plan to monitor all wastewater flows by installing flow measuring devices and establishing sample collection procedures and protocols. All flows should be monitored on a quarterly basis. Discharge rates should be recorded daily.

2. Install flow monitoring devices at all key locations to monitor fresh water use.

3. Study, evaluate and implement options recommended for PP/WM and water conservation. Set priority to items recommended for feasibility level studies.

4. Utilize water conservation equipment as much as possible, such as flow regulating devices, automatic shut-off valves, nozzles and overflow preventors.

5. Insulate all cooling piping, valves and equipment and use of water for pipe defrosting.

6. Develop protocols and procedures for equipment and floor washing and strictly adhere to them.

7. Develop a PP/WM and water conservation policy as part of the ABC management operating philosophy and distribute it to all personnel.

8. Implement PP/WM and water conservation through established goals and objectives.

9. Train employees top identify PP/WM and water conservation opportunities that relate to their job.

10. Designate a PP/WM and water conservation coordinator to implement the program.

11. Publicize success stories and reward employees that identify cost effective PP/WM opportunities.

12. Illustrate management efficiency by implementation of the above actions. Reinforce PP/WM policy through continued education at work and company functions.

13. Perform periodic assessment of the PP/WM and water conservation program by key management personnel, the coordinator and independent experts.

Table 1
REPORTED ABC EFFLUENT CHARACTERISTICS[1]

Arab Brewery Company

Parameter	Concentration (mg/l)[2]
Biochemical Oxygen Demand	262.2
Chemical Oxygen Demand	490.3
Total Suspended Solids	95.7
pH (su)	8.5

1 Data obtained from the 1992 COWI/RSS Report.
2 Except as noted.

Table 2
REPORTED AMSTEL BREWERY EFFLUENT CHARACTERISTICS[1]

Arab Brewery Company

Sample Date	Effluent Concentrations (mg/l)[2]				
	Biochemical Oxygen Demand	Total Dissolved Solids	Total Suspended Solids	Chemical Oxygen Demand	pH (su)
11-01-93	1,000	914	35	2,138	9.4
21-04-93	75	418	165	177	7.7
10-05-93	344	908	72	466	6.5
07-06-93	40	434	17	108	7.2
08-07-93	59	442	32	436	8.2
21-08-93	14	468	20	23	7.3
01-09-93	266	598	100	380	7.2
14-10-93	243	460	46	429	7.8
07-12-93	28	412	122	82	8.3
20-12-93	145	406	162	352	7.7

1 Data obtained from WAJ.
2 Except as noted.
3 Data provided for information purposes only.

Table 3
COMPARISON OF ABC AND AMSTEL EFFLUENT CHARACTERISTICS

Arab Brewery Company

Parameter	Concentrations (mg/l)[1]	
	ABC[2]	AMSTEL[3,4]
Biochemical Oxygen Demand	262.6	10 - 17,875
Chemical Oxygen Demand	490.3	16 - 83,679
Total Suspended Solids	95.7	6 - 124,804
pH (su)	8.5	4.2 - 10.7

1 Except as noted.

2 Data obtained from the 1992 COWI/RSS Report.

3 Data collected between 1990 and 1994 by WAJ.

4 All high concentration and low pH values were obtained on November 7, 1990. It is possible that there may have been some operational problems on that day.

Table 4
SUMMARY OF RAW MATERIAL USE[1]

Arab Brewery Company

Material	Annual Consumption
Hops Extract	12 kg
Yeast Slurry	300 liters
Filter Aid	600 kg
Beer Stability Compounds	60 kg
Sulfuric Acid	100 kg
Hydrochloric Acid	Not Available
Caustic Soda	3 ton/year
Acid base Phosphate	20 l/year
Disinfectant	25 l/year
Labeling Glue	150g/1000 bottles/cans

1 Based on 400 m^3 of beer produced annually.

Table 5
OVERALL WATER BALANCE ACROSS BREWERY[1]

Arab Brewery Company

Water In (m^3)[2]		Water Out (m^3)[2]	
Well Water Pumped	11.04	Beer	1.0
		Spent Malt	0.2
		Trub Discharge	0.1
		CIP Discharges Brewery Cooler Fermentation	 1.1 0.2 1.4
		Regenerant Wastes	0.54
		Bottle/Can Wash	1.4
		Pasteurization	0.8
		Filter Cleaning (including steam)	0.9
		Floor Cleaning	0.7
		Equipment Cleaning	1.0
		Keg Wash (steam)	0.2
		Evaporative Losses Cooling Water Brew Kettle	 0.4 0.1
		Pipe Defrosting	1.0
Total	11.04		11.04

1 Domestic water is supplied by WAJ and is discharged to the city sewer system. The daily water usage is about 2.0 m^3.

2 Water balance is based on one cubic meter of beer produced.

Table 6
WASTEWATER SOURCES AND GENERATION RATES[1]

Arab Brewery Company

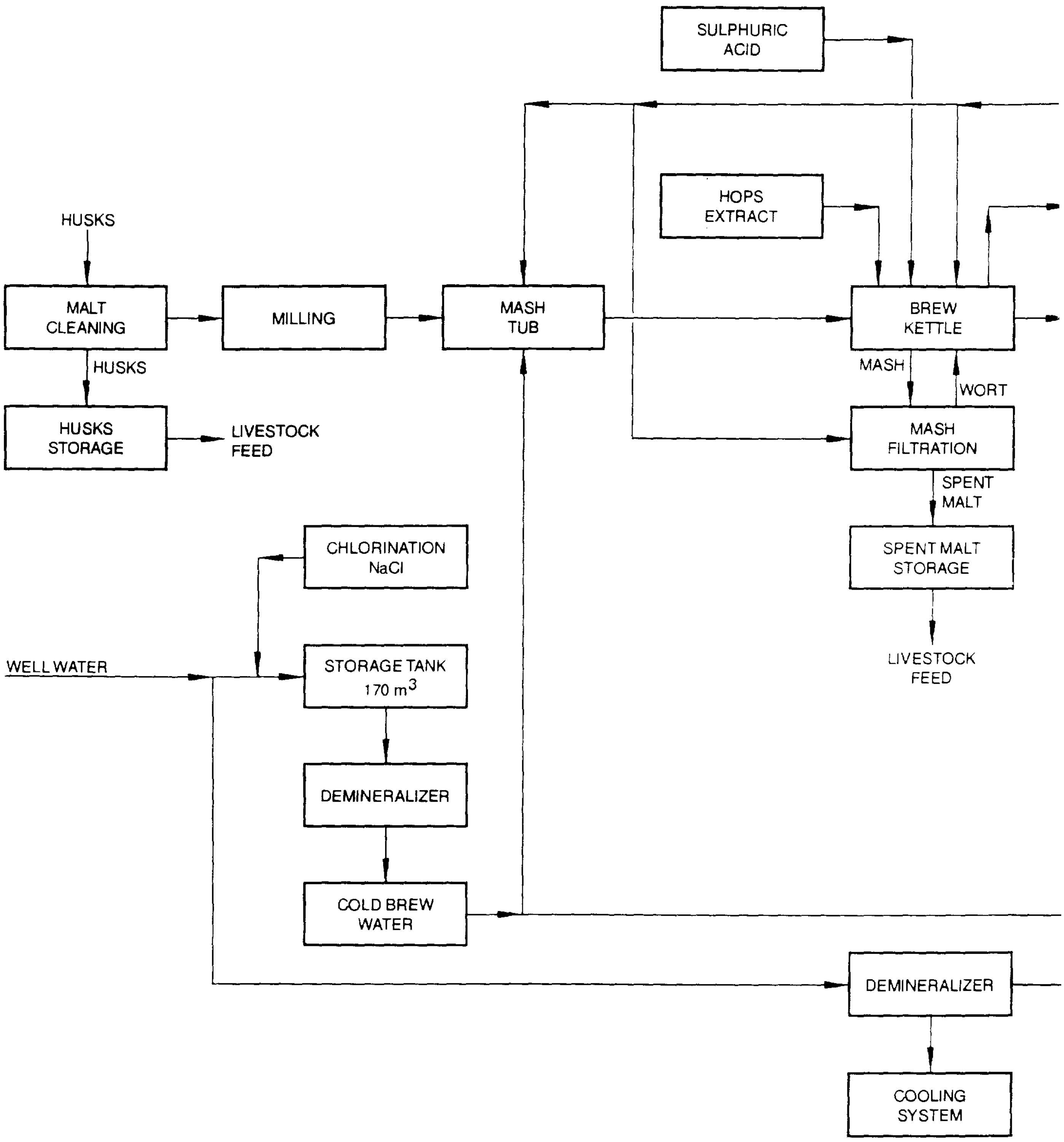
Wastewater Source	Rate (m^3)
Brewing operations	
CIP Cleaning	1.1
Regenerant Wastewater	0.2
Trub Separator Discharge	0.1
Fermentation/Lagering/Finishing	
Wort Cooler CIP Cleaning	0.2
Fermentor CIP Cleaning	1.4
Packaging Operations	
Bottle Washing	1.4
Pasteurization	0.8
Keg Washing	0.2
Filter Cleaning	0.2
Water Softening Regenerant	
Boiler Feed Water	0.3
Wash Water	0.04
General Housekeeping	
Floor Washing	0.7
Equipment/Piping Cleaning	1.7
Pipe Defrosting Water	1.0
TOTAL	9.34

1 Wastewater generation rates are based upon one cubic meter of beer produced.

Table 7
PROPOSED WATER REDUCTION/RECYCLE/REUSE

Arab Brewery Company

Water Consumer	Water Use (m^3)		
	Current	Projected	Savings
Beer	1.0	1.0	0.0
Spent Malt	0.2	0.2	0.0
Trub Discharge	0.1	0.1	0.0
CIP Water Use			
Brewhouse	1.1	0.3	0.8
Fermentation	1.4	0.5	0.9
Wort Cooler	0.2	0.2	0.0
Regenerant Waste	0.54	0.34	0.2
Bottle Wash	1.4	1.25	0.15
Pasteurization	0.8	0.0	0.8
Filter Cleaning	0.9	0.8	0.1
Equipment Cleaning	1.0	0.8	0.2
Floor Cleaning	0.7	0.4	0.3
Keg Wash	0.2	0.2	0.0
Cooling Water	0.4	0.0	0.4
Pipe Defrosting	1.0	0.0	1.0
Brew Kettle Steam Loss	0.1	0.1	0.0
TOTAL	11.04	6.19	4.85



* BBT - BRITE BEER TANK

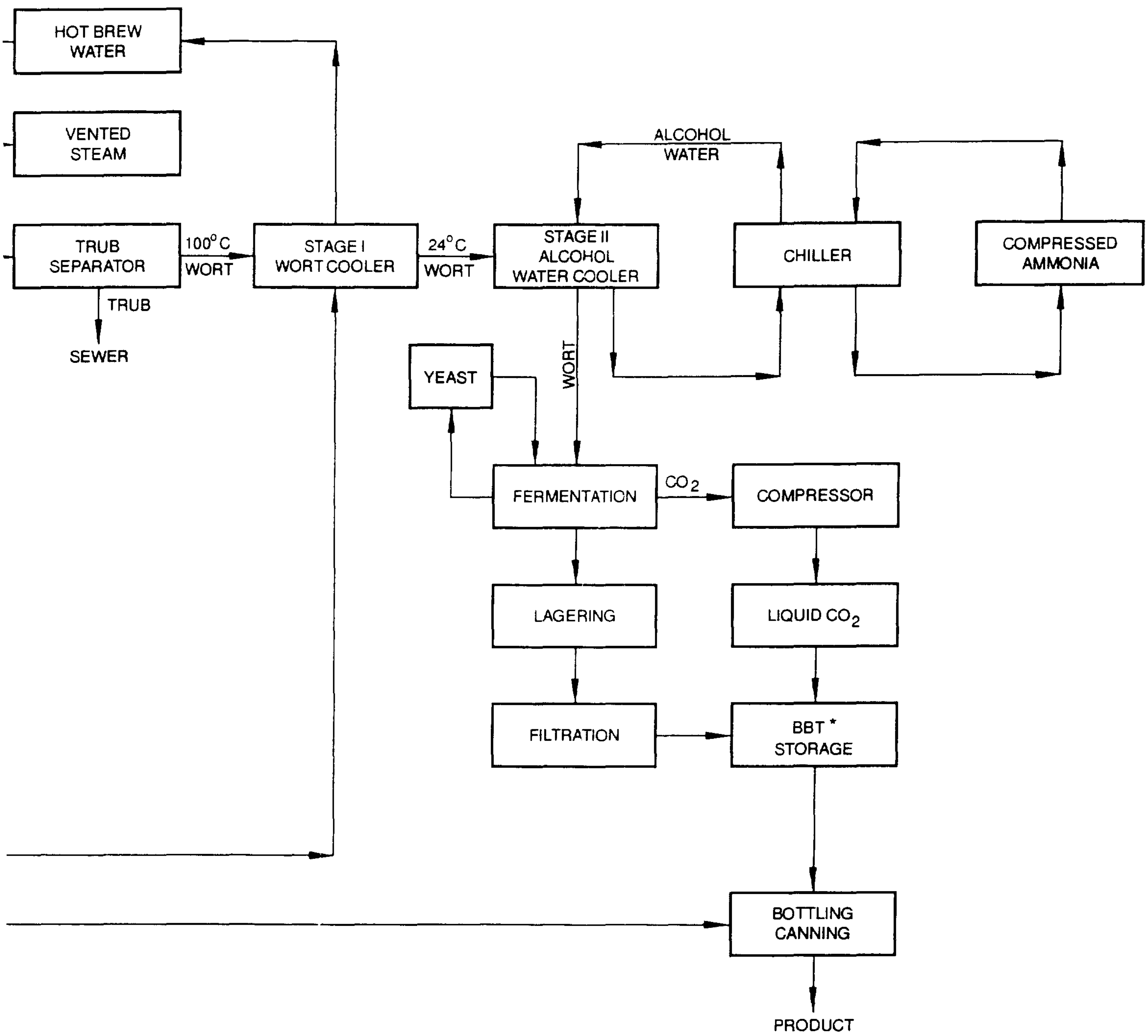
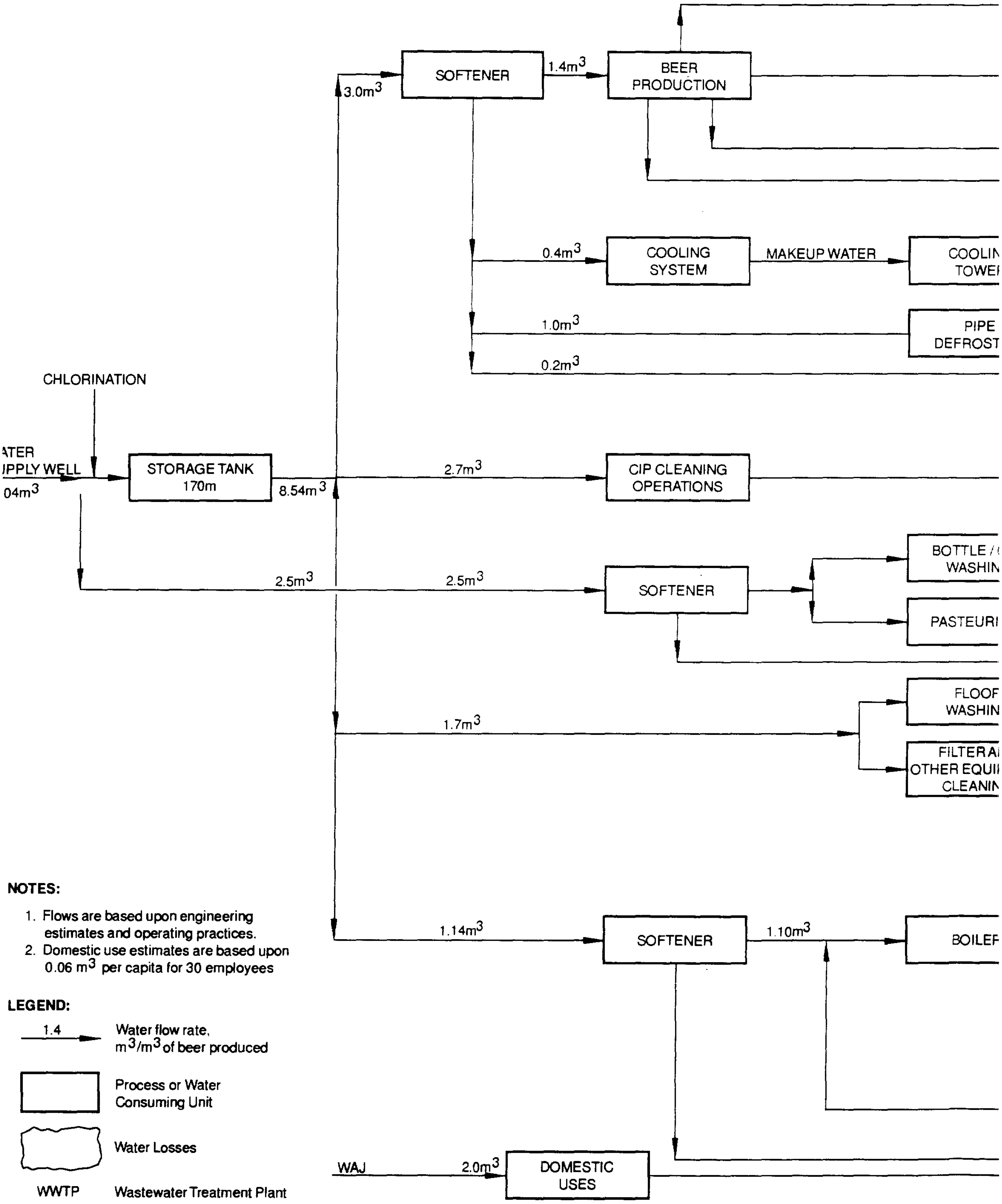


Figure 1
BEER MANUFACTURING PROCESS
ARAB BREWERY COMPANY
Zarqa, Jordan



NOTES:

1. Flows are based upon engineering estimates and operating practices.
2. Domestic use estimates are based upon 0.06 m^3 per capita for 30 employees

LEGEND:

1.4 → Water flow rate, m^3/m^3 of beer produced

[box] Process or Water Consuming Unit

[irregular outline] Water Losses

WWTP Wastewater Treatment Plant

HARZA *Consulting Engineers and Scientists*

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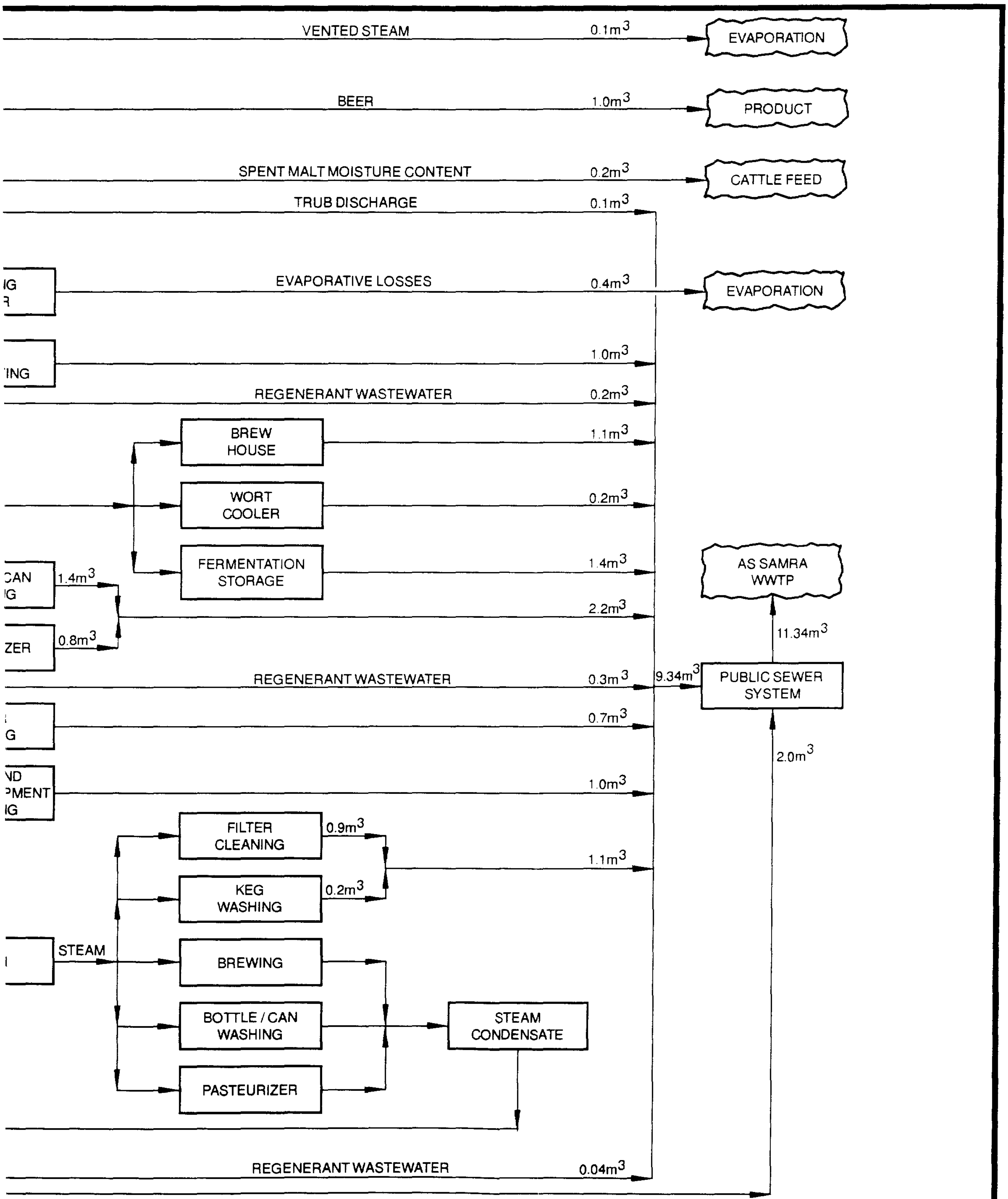
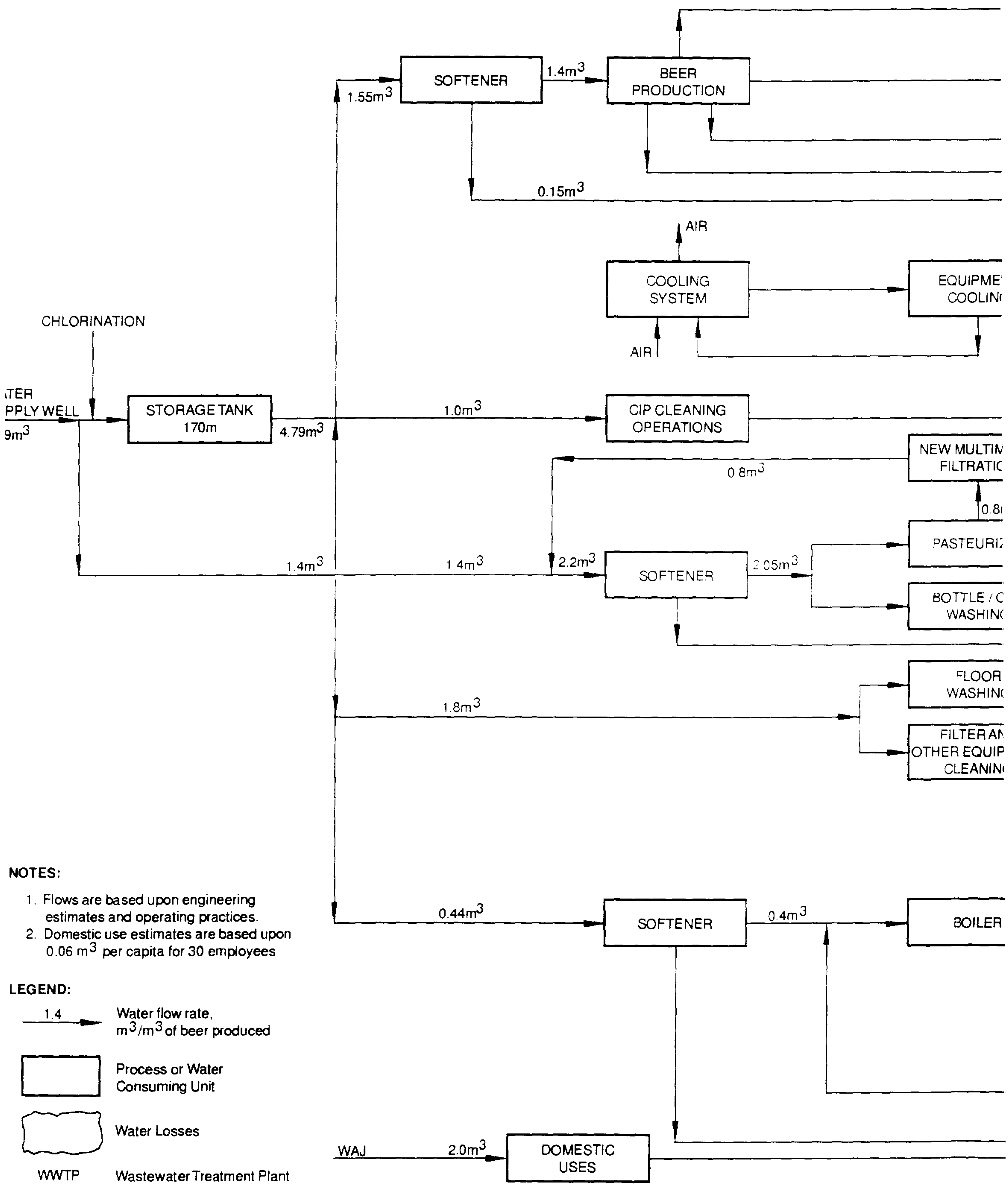


Figure 2
OVERALL WATER BALANCE
ARAB BREWERY COMPANY
Zarqa, Jordan



NOTES:

1. Flows are based upon engineering estimates and operating practices.
2. Domestic use estimates are based upon 0.06 m^3 per capita for 30 employees

LEGEND:

1.4 →	Water flow rate, m^3/m^3 of beer produced
(box)	Process or Water Consuming Unit
(irregular outline)	Water Losses
WWTP	Wastewater Treatment Plant

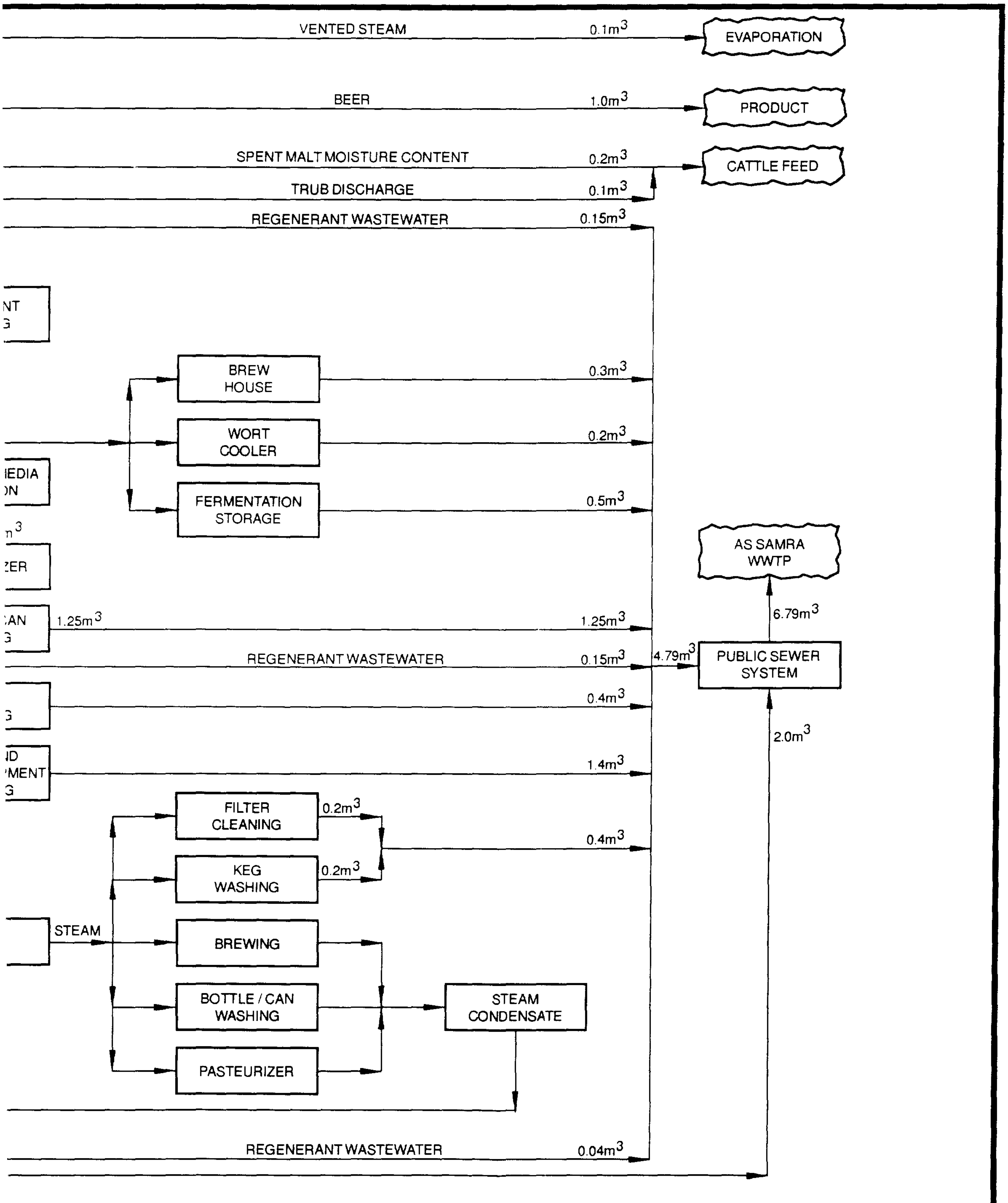


Figure 3
CONCEPTUAL WATER BALANCE
ARAB BREWERY COMPANY
Zarqa, Jordan

WQICP WASTE MINIMIZATION AUDIT

Facility Name: ARAB BREWERY Auditor/Firm: SAIC and R.S.S

Date: ______

ATTACHMENT A
AUDIT QUESTIONAIRE

SITE DESCRIPTION

Facility Name: ARAB Brewery

Area: ZERKA

Address: ZERKA - P.O.Box 59

Telephone: 989(09) - 981421

Major Products: Soft drinks with brand
Beer Henninger

Production Rate: 4000 HL/Year Beer + 90 000 Crate/Year soft dr

SIC Codes:

Major Sources of Wastewater Discharges:
Brew house + cooling + Ferm. cellers + Bottling line and mixing Room for soft drink

Major Processes: Beer = Milling → Mashing → Boiling → Hopping
Cooling → Fermenting → Lagering → Filtration
and Bottling

Soft Drink = Mixing → Filtration → Carbonation → cooling and Bottling

Facility/Equipment Age: Brew house = 1964
Utilities = 1964 - 1985
Bottling line 1980
Canning line 1982
Filter 1982

٢٧

WQICP WASTE MINIMIZATION AUDIT

Facility Name: ARAB BREWERY Auditor/Firm: SAIC and RSS

Date: ________

PROCESS INFORMATION

Operation Type: -- Continuous -- Discrete
-- Batch or Semi-Batch -- Other________

Document	Complete? (Y/N)	Current? (Y/N)	Document Number
Process Flow Diagram	Yes		
Material/Energy Balance	Yes		
Design			
Operating			
Flow/Amount Measurements	Yes		
Stream	No		
Analyses/Assays	For Product		
Stream			
Plant Layout	Yes		
Process Description	Yes		
Operating Manuals	Yes		
Equipment List/Age	Yes		
Equipment Specifications	Yes		
Piping & Instrument Diagrams	No		
Plot and Elevation Plan(s)	Yes		
Environmental Audit Report	No		
Permit/Permit applications	Yes		
Raw Material Inventory Records	Yes		
Product Inventory Records	Yes		
Management method practiced for each wastewater stream	One Point		
Wastewater treatment facilities	No		
Waste management practice	No		
Ancillary facilities	No		
Annual cost for management of the wastewater discharge	No		
Photographic records			

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U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-267 548

State of the Art Wastewater Management in the Beverage Industry

Industrial Environmental Research Lab.-Cincinnati, Corvallis, OR

Feb 77

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 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.

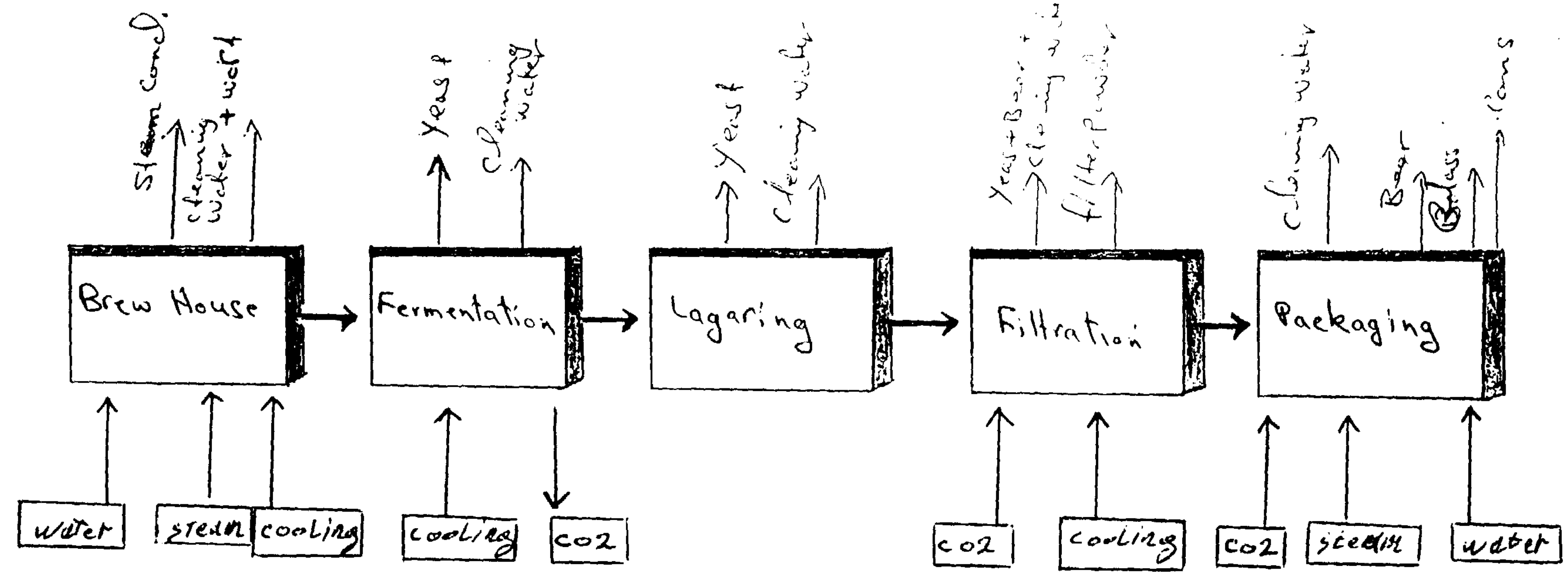
Wastewater Treatment

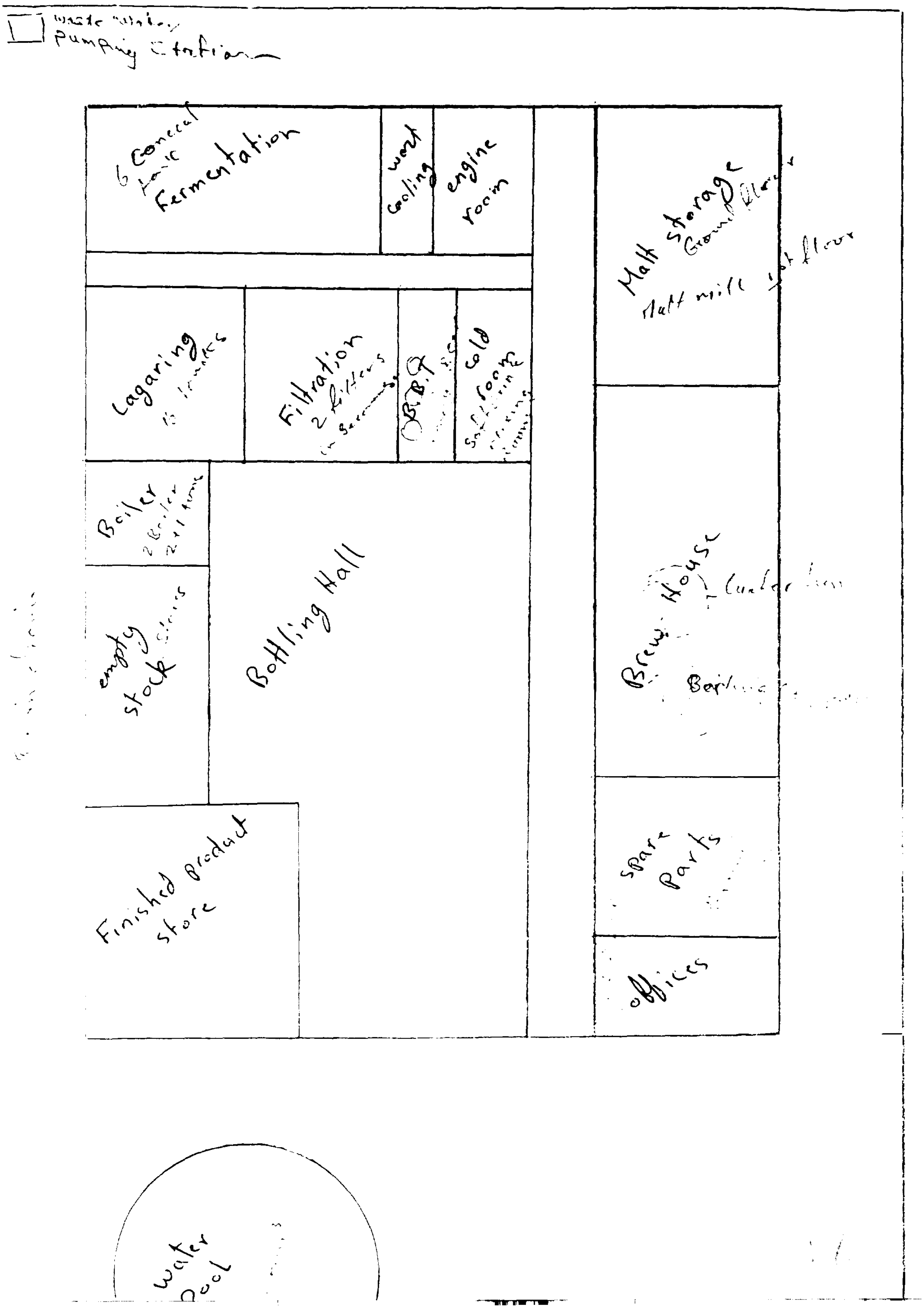
Presently, virtually all breweries discharge their effluent to a municipal treatment system and this will most likely be the predominant practice in the future. Only two U.S. breweries own and operate their wastewater treatment facilities.

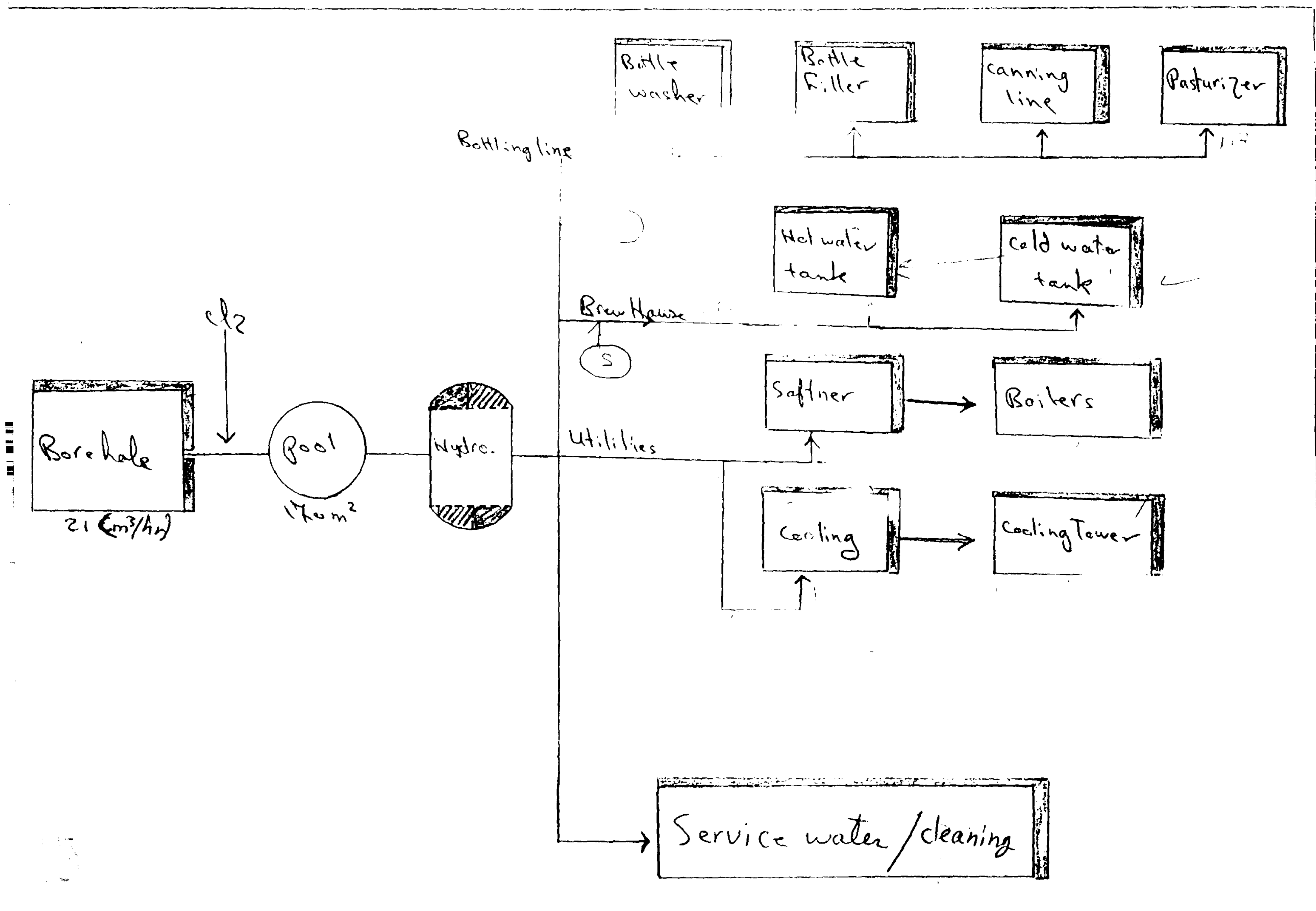
Several advantages exist for a brewery that can dispose of its wastewater in a municipal plant. Brewing wastes are readily biodegradable; therefore, they can be treated by municipal plants which are traditionally biological. Also, the mixing with domestic sewage adds sufficient nutrients that are lacking 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.

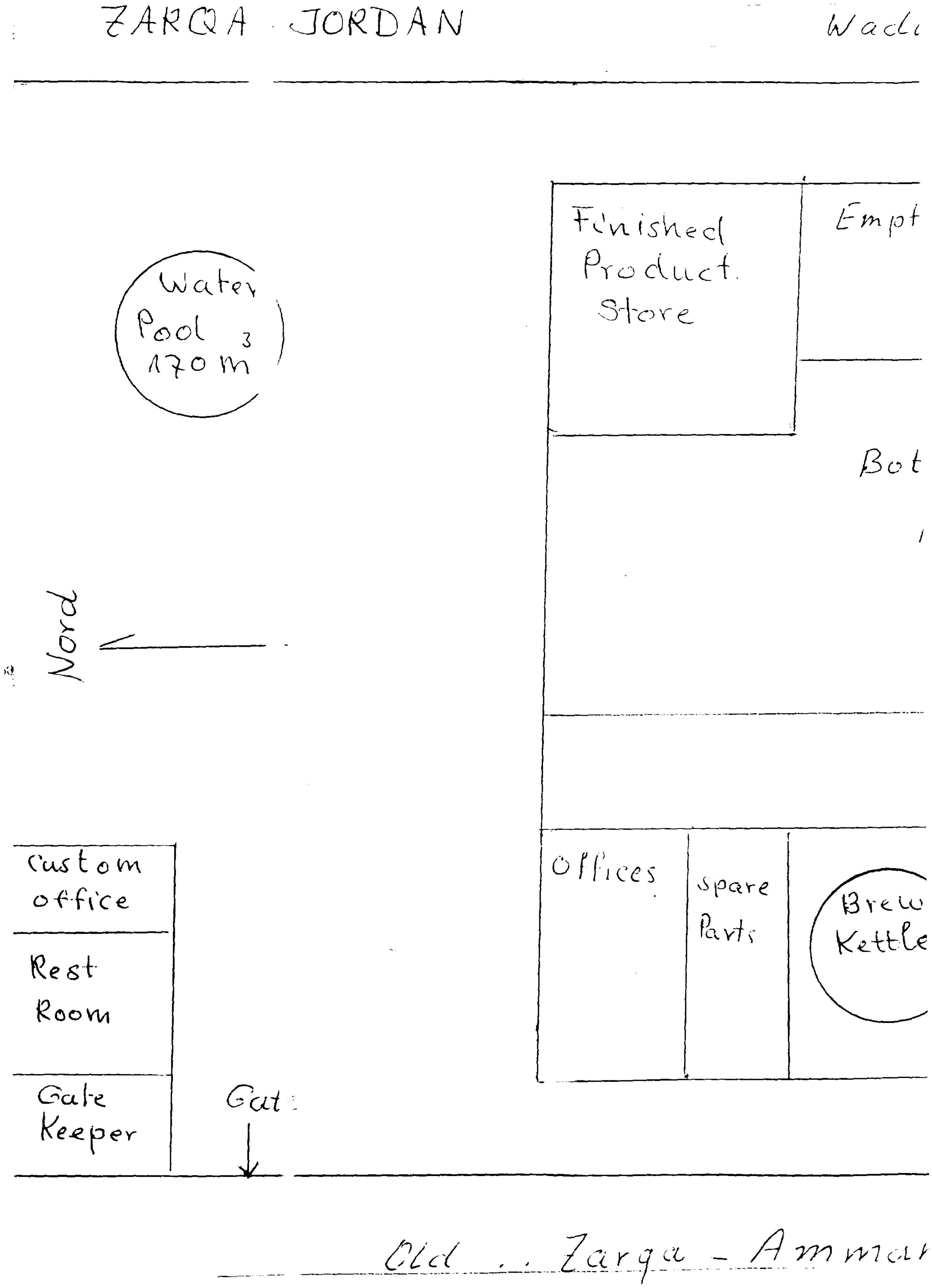
A few municipal waste treatment plants receive considerable volumes of brewery wastes. Table 11 gives descriptions and performances of three of these plants.

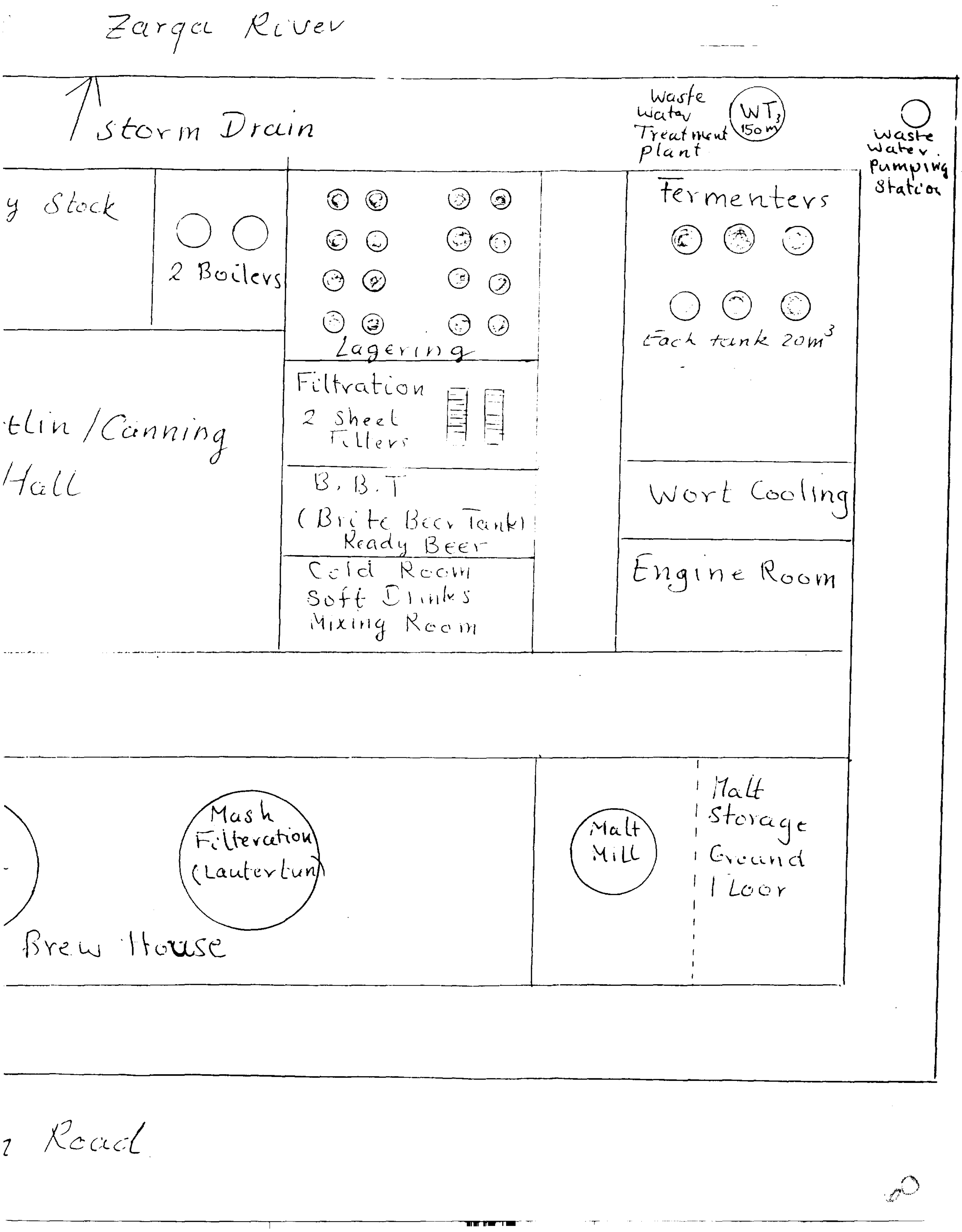

Brew House
Fermentation
Lagaring
Filtration
Packaging
Steam cond.
cleaning water + wort
Yeast
Cleaning water
Yeast
Cleaning water
filter powder
cleaning water
Beer
Cans
water
steam
cooling
cooling
co2
co2
cooling
co2
steam
water


Fermentation
wort cooling
engine room
Malt storage
Lagaring
Filtration
2 filters
BBT
cold room
Boiler
Bottling Hall
Brew House
empty stock
Finished product store
spare Parts
offices
water Pool


Bottle washer
Bottle filler
canning line
Pasturizer
Bottling line
Hot water tank
Cold water tank
Cl2
Brew House
S
Saftner
Boilers
Borehole
Pool
Hydro.
Utilities
21 (m3/hr)
170 m2
Cooling
Cooling Tower
Service water / cleaning

ARAB BE-R BREWERY COMPANY
ZARQA JORDAN





Zarqa River
Storm Drain
Waste Water Treatment plant
WT 150 m3
Waste Water Pumping Station
y Stock
2 Boilers
Lagering
Fermenters
Each tank 20m3
Filtration
2 Sheet Filters
tlin/Canning Hall
B.B.T
(Brite Beer Tank) Ready Beer
Wort Cooling
Cold Room
Soft Drinks Mixing Room
Engine Room
Mash Filteration (Lautertun)
Brew House
Malt Mill
Malt Storage Ground Floor
Road

REPORT NO. 3114-95-2b-29
UNITED STATES AGENCY
FOR INTERNATIONAL DEVELOPMENT
CONTRACT NO. 278-0288-00-C-4026-00
Amman Chamber of Industry, Jordan
Ministry of Water and Irrigation, Jordan

BACKGROUND REPORT

BREWERY INDUSTRY
ARAB BREWERY COMPANY, JORDAN

WATER QUALITY IMPROVEMENT AND CONSERVATION PROJECT

Industrial Wastewater Discharge
Prevention Program

velopment Alternatives, Inc., Washington D.C. U.S.A.
rza Consulting Engineers and Scientists, Chicago, U.S.A.
yal Scientific Society, Amman, Jordan

March 1995

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BREWERY INDUSTRY
BACKGROUND MATERIALS

INDUSTRIAL WASTEWATER DISCHARGE PREVENTION PROGRAM
WATER QUALITY IMPROVEMENT AND CONSERVATION PROJECT

Amman, Jordan

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

FIGURES

1.0 INTRODUCTION

This document presents the materials collected as background information for a pollution prevention, waste minimization, and water conservation audit of the Arab Brewery Company, Limited (ABC).

1.1 Background

Development Alternatives, Inc. (DAI), under a contract with the United States Agency for International Development (USAID) is performing an Industrial Wastewater Discharge Prevention Program (IWDPP) in Amman, Jordan. The IWDPP is one of the four components of the Water Quality Improvement and Conservation project, funded by the USAID. The IWDPP is being performed by DAI with full coordination between the Ministry of Water and Irrigation and the Amman Chamber of Industry. The IWDPP includes conducting audits, performing feasibility studies, and designing for demonstration activities at selected industrial facilities.

Pollution prevention and waste minimization (PP/WM) techniques are defined as any techniques to prevent or reduce waste generation by source reduction or recycling activities. These activities must reduce either the volumes or the concentrations of pollutants generated prior to treatment, storage, or disposal of the waste.

Based on a ranking methodology, the PP/WM Committee has selected ten industries with potential needs for PP/WM audits. One of these industries is the "brewery industry." Harza Consulting Engineers and Scientists (Harza), Chicago/USA, has been retained by DAI to lead the PP/WM audit for this industry.

The purpose of these audits is to assist the industries in the Amman-Zarqa Basin to assess pollution problems and the alternative solutions to achieve desired levels of pollution prevention, water conservation, and wastewater treatment under the following subtasks:

- Subtask 1.1 - Audit Coordination;
- Subtask 1.2 - PP/WM Background Materials Preparation;
- Subtask 1.3 - Pre-Investigation Meeting;
- Subtask 1.4 - Audit;
- Subtask 1.5 - Post-Inspection Meeting; and
- Subtask 1.6 - Audit Evaluation Report.

1.2 Objectives

In this document, background information has been assembled by performing a comprehensive literature review. The purpose of the literature review was to identify the available techniques and clean technologies being practiced for water conservation and PP/WM in the brewing industry. The literature review included PP/WM related articles, industry journal articles and conference proceedings, and books on pollution and controls.

Section 2.0 of this report provides an overview of the brewing industry, including a description of typical brewing processes and the wastes generated by them. Section 3.0 details the brewing processes used at the ABC. Section 4.0 describes areas for potential improvement in regards to PP/WM and water conservation. Finally, Section 5.0 lists the primary references consulted during the literature search: copies of the appropriate sections of these references are provided under a separate cover.

2.0 INDUSTRIAL OVERVIEW

Beer is a beverage of low alcoholic content (2-7%) made by the fermentation of starchy grain cereals. Beer production is typically a batch process; it begins with the cooking and brewing of grains in water, continues with fermentation and maturing of the beer, and concludes with packaging of the beer for distribution.

Large amounts of water are used in brewery processes and operations, and large amounts of solid waste and wastewaters are generated. Wastewaters are perhaps the most notorious waste from a brewery, containing very high concentrations of biochemical oxygen demand (BOD), chemical oxygen demand (COD), and suspended solids (SS). Such contaminants, highly concentrated and released in intermittent discharges, can cause disruptive shock loadings at municipal or on-site biological treatment facilities. Solid wastes mostly consist of spent grains and yeasts: these materials have a high nutritional value and can be used as livestock feed. Air emissions are also produced at breweries, but generally are not significant and do not require emission controls except in areas with strict air quality regulations.

This section provides a description of typical brewery processes, water usages, and wastes and emissions.

2.1 Typical Processes

Beer production can be divided into four groups of processes and operations. The first three groups include the principal stages of beer production: brewhouse processes, fermentation and conditioning processes, and packaging processes. The fourth group consists of ancillary, or support, operations performed throughout the brewing facility. The four groups are described in the following subsections. A typical process diagram for beer production is provided as Figure 1.

2.1.1 Brewhouse Processes

The brewhouse is where raw materials (water, grain, malt, sugars, syrups, and hops) are transformed into unfermented beer, also called wort. The processes required for the transformation are: milling, cooking, mashing, filtration, brewing, and cooling. Each of the listed brewhouse processes is described below.

Milling. Milling reduces the particle sizes of the grain and malt to a specified gradation. The grain used is an ungerminated cereal, such as corn, oats, or rice. The malt used is a kilned, germinated cereal; typically barley. Malt is often purchased by a brewery as a kilned, germinated product; some breweries, however, produce their own malt in a steeping and germination process that requires large amounts of water.

Cooking. In this process, the milled grain is mixed with water and treated with live steam or hot water in a grain cooker to solubilize the cereal starches. Milled malt may be added to the grain cooker to prevent the mixture from becoming too viscous. The mixture is cooked for approximately ten minutes.

Mashing. After cooking, the grain mixture is introduced into mashing tubs, or tuns. There, the grain is combined with the rest of the milled malt and with malt adjuncts (cooked grain, sugars, and syrups) to be converted into a semi-liquid mixture; the product is called mash. The conversion from the grain/malt mixture to mash is accomplished by enzymes introduced by the milled malt: the enzymes convert the starches in the grain/malt mixture into dextrin and sugars. The tuns are heated to 75°C and the mixture is stirred to aid the softening and separating of the digestion process. Mashing continues until conversion ceases.

Mash Filtering. The mash is subsequently filtered to separate the insoluble spent grain from the mash liquid, which will be used directly in the beer brewing process. Filtration is accomplished in either a filter press or a lauter tun: filter presses typically occupy less space and achieve better separation than lauter tuns, which are simply false bottom vats. The filtrate is a slightly sweet liquid called wort; the spent grains have resale value, typically as cattle feed. The efficiency of the filtration process can be improved by sparging the spent grain with water at 75°C for complete recovery of all substances in solution.

Brewing. The filtered wort is boiled in a brew kettle for approximately three hours. After the first hour, hops are added to impart beer's characteristic aroma and bitter flavor (hops are dried flower cones from hop plants). Boiling not only extracts the hops' tannin and aroma, but also concentrates the wort to the desired strength, sterilizes it, destroys its enzymes, and coagulates its proteins.

After three hours of brewing, the mixture is transferred to a false-bottomed vessel, called a hop jack, beneath the brew kettle; there, the spent hops are strained from the boiling wort. As in mash filtration, spent hops can be sparged with hot water prior to disposal to recover additional wort.

Cooling. The boiled wort is passed through cooling vessels for two purposes: to cool, thus causing the protein and hop solids to precipitate, and to absorb enough air to facilitate the start of fermentation. The hot wort is first cooled to approximately 65°C in a large, shallow vessel. Some of the resins precipitate in this cooler and form a sludge-like sediment called trub. Trub is often discharged as waste, or is sometimes mixed with spent grain and sold as cattle feed.

The wort is further cooled by running it over horizontal, brine-cooled tubes or through a shell and tube heat exchanger. Wort aeration takes place during this second cooling stage, as well as a slight wort concentration due to evaporation. The air contacting the wort during this stage is carefully controlled and frequently sterilized to prevent contamination by wild yeasts.

2.1.2 Fermenting and Conditioning Processes

Fermenting and conditioning processes include those processes in which wort is fermented and aged to produce a beer product ready for bottling or kegging. These processes typically include starting, fermenting, storing, and filtering and carbonating.

Each of these is described below.

Starting. The starting process is the one in which wort fermentation is initiated: the cooled wort is mixed with selected yeasts, then placed in open-air tubs to begin fermenting.

Fermenting. After starting, the wort/yeast mixture is transferred to closed fermentation tanks, or fermentors. Fermentation transforms the sugars in the wort to carbon dioxide and ethyl alcohol. Heat is released in the process: the initial fermentation temperature is approximately 5°C, but as fermentation proceeds the temperature rises to 15°C. The temperature is controlled by attemperators inserted in the fermentors.

The carbon dioxide rises to the top of the fermentors, bringing with it foreign substances, which are skimmed. In most larger breweries, the released carbon dioxide is collected and is stored under pressure for subsequent use in the beer carbonation process. Excess carbon dioxide can also be liquified and marketed to other industries.

Fermentation is complete after seven to ten days. At this point, most of the yeast has settled to the bottom of the fermentor; settled yeast is removed as a slurry and sent to yeast tanks for recycling and/or sale. The remaining liquid is unmatured beer.

Storing. The beer is allowed to mature, or lager, after fermentation; it is cooled to 0°C and stored in tanks for three to six weeks. The maturation process mellows the beer, that is, improves its palatability.

Initially, the beer contains a suspension of hop resins, insoluble nitrogenous substances, and yeast. During storage, however, the beer is gradually clarified. A haze may appear in the beer upon cooling; the haze can reduced by "chillproofing" the beer with chemical additives, such as polyvinylpyrrolidone.

Filtering and Carbonating. After storage, the beer is filtered and carbonated. To filter it, the beer is pumped through a pulp filter with or without a filtering aid. Carbon dioxide gas at 0°C is then injected into the beer in amounts between 0.36% and 0.45% of the weight of the beer. After carbonation, the beer is sometimes re-filtered through cotton pulp, while maintaining carbonation, to increase the brilliance of the flavor.

2.1.3 Packaging Processes

Packaging includes the processes by which the final beer product is placed in bottles, cans, or kegs. The packaging operations typically include container washing, container filling, and product pasteurizing. Each of these processes is described below for the case of bottle packaging; the packaging operations for cans and kegs are similar.

Bottle Washing. Bottle washing requires a large amount of water and creates a significant waste load. Automatic machines are available for bottle washing; the machines typically perform the following operations:

- Feed the bottles to the washing equipment;
- Pre-rinse the bottles;
- Immerse the bottles in a series of alkaline baths for washing and sterilization; the alkaline solution is typically a water and caustic soda or caustic and sodium gluconate mixture; and
- Post-rinse the bottles.

Bottle Filling. A conveyor line takes the washed bottles to a filling machine. The bottles are manually inspected to remove the defective ones before an automatic machine fills and caps the usable bottles.

Pasteurizing. Beer is pasteurized to prevent any residual yeast or harmful bacteria from developing in the packaged beer prior to consumption. Pasteurization is typically required only for bottled and canned beer; kegged beer is usually refrigerated and therefore does not require pasteurization.

Pasteurization requires heating beer to 60°C. Pasteurization is commonly performed after packaging by immersing the bottled beer in gradually hotter warm-water baths; gradual heating is required to avoid cracking the glass bottles. Pasteurization can alternatively be performed prior to packaging by "flash pasteurization": flash pasteurization is a continuous heat exchange process by which the beer is rapidly brought to at least 60°C and then cooled.

An equally effective alternative to pasteurization is biological purification by membrane filtration. This technique, also called ultrafiltration, produces so-called "bottled draft beer." Several other new procedures, including the addition of antimicrobials, produce the same effect.

2.1.4 Ancillary Operations

As stated previously in Section 2.1, ancillary brewery operations are support processes and activities carried out throughout the brewing facility. Ancillary operations include equipment cleaning and sterilizing, steam and hot water production, cooling, housekeeping, and wastewater treatment. These operations are described below.

Equipment Cleaning and Sterilizing. All equipment that comes into contact with the product must be cleaned and sterilized. Cleaning is typically performed by a mechanical cleaning-in-place (CIP) system built into the process equipment. Conceptually, a CIP system is a system in which a detergent is introduced at the top of an unclean tank by means of a fixed spray ball or a rotating gun, circulated for some time in the tank, and then discharged. Alkaline detergents, such as sodium hydroxide, are commonly used in large breweries; smaller breweries often use "built" detergents, which contain a strong alkaline agent, a wetting agent, dispersing agent, rinsing agent, and possibly a sequestering agent. "Built" detergents are more expensive, but are safer to handle than sodium hydroxide.

After being cleaned, the equipment is sterilized by use of wet heat (hot water or steam) or a sanitizing agent. Though more expensive than sanitizing agents, wet heat is a convenient sterilization method since it is safe to the product. In order for wet heat to be effective, the temperature of the surface to be sanitized must be raised to 80°C: this heating requires nearly 100°C water or steam.

Chlorine, because it is effective and inexpensive, is a commonly used sanitizing agent. The effective form of chlorine is hypochlorous acid, which is most bactericidal between pH 4 to 6. Most brewers use chlorine at pH 8: though less effective as a bactericide, it is less corrosive to stainless steel at the higher pH. Alternative sanitizing agents are quats, iodophors, and acid-ionics.

Steam and Hot Water Production. Steam and hot water are required for a number of brewery processes, including cooking, mashing, sparging, pasteurizing, and cleaning and sterilization. Steam and hot water are typically produced using a boiler, which may be fired from sources including oil, coal, or natural gas.

Cooling. Cooling is required to reduce the temperature of the wort after brewing, to control the temperature in the fermentors, and to cool the beer prior to storage. A typical cooling system consists of a water circuit including heat exchangers, cooling towers, and a make-up water connection to a water source.

Housekeeping. Floor, wall, and equipment are typically washed with hot water and degreasing agents.

Wastewater Treatment. Brewery effluent contains very high concentrations of SS, BOD, and phosphates, and therefore untreated effluent typically should not be discharged to a body of water. Most breweries in metropolitan areas can discharge their effluent to municipal wastewater collection and treatment systems; in areas without municipal systems or in cases where it is economically feasible, on-site treatment systems can be used.

Municipal treatment systems typically employ conventional biological processes, such as activated sludge. On-site treatment systems are more likely than municipal systems to employ anaerobic treatment processes; a number of anaerobic systems are effective for treating brewery wastewaters. Further discussion of wastewater treatment systems is provided in Section 4.0.

2.2 Water Usage

Though water is used either directly or indirectly in all four groups of brewery processes, the greatest volumes of water are used in the brewhouse, packaging, and ancillary operations. A brief description of water usage is provided below for each of these processes.

2.2.1 Brewhouse Process Water

All six brewhouse processes consume water: milling, cooking, mashing, mash filtering (including grain sparging), brewing (including hops sparging), and cooling.

Of these processes, hot water and/or steam is required for:

- Cooking;
- Mashing;
- Mash Filtering; and
- Brewing.

Cold or unheated water is required for:

- Milling;
- Mashing
- Mash Filtering; and
- Cooling.

2.2.2 Packaging Water

Within the packaging process, water is used for container rinsing, washing and sterilization, and product pasteurization.

2.2.3 Ancillary Operations

Ancillary operations consume water primarily as boiler feed water, cooling system water, and equipment cleaning and sterilizing water. Water is also used for general housekeeping and sanitation.

2.3 Wastes and Emissions

The following subsections list the wastewaters, solid wastes, and air emissions generated at a typical brewery, along with their primary sources. Methods of waste treatment and disposal are discussed in Section 4.0.

2.3.1 Wastewater

As stated in Section 2.0, wastewaters are typically the waste of greatest concern in a brewery: approximately 8.5 cubic meters are produced for every cubic meter of beer produced (m^3/m^3 beer). The wastewaters typically have very high BOD, COD, SS. Wastewater is generated primarily in the following processes; typical volumes are given when known:

- Brewing (1.20 m^3/m^3 beer);
- Cooling (1.40 m^3/m^3 beer);
- Fermenting (0.30 m^3/m^3 beer);

- Filtering (0.70 m^3/m^3 beer);
- Storing (0.40 m^3/m^3 beer);
- Packaging; and
- Housekeeping (0.70 m^3/m^3 beer).

Typical wastewater BOD and SS strengths are as follows:

Source	BOD_5 (mg/l)	SS (mg/l)
Trub (from Cooling)	50,000	28,000
Miscellaneous Filtrate	15,000	20,000
Filtered Yeast	150,000	800
Clarification Precipitates (from Storing)	60,000	100
Tank Rinsate	200-7,000	100-2,000
Cleaning Solutions	1,000	100
Waste Beer	90,000	4,000

Typical wastewater contaminants are as follows:

Contaminant	BOD_5 (kg/m3 beer)	BOD_5 (%)	SS (kg/m3 beer)	SS (%)
Yeast	3.71	30	2.55	30
Trub	3.21	26	1.24	14
Hops	0.39	3	0.77	9
Grain Filtrate	0.85	7	0.50	6
Drain & Rinse Effluent	2.09	17	0.85	10
Final Filter Effluent	0.50	4	1.58	19
Packaging	1.2	10	0.66	8
Miscellaneous	0.42	3	0.35	4
TOTAL	12.4	100	8.50	100

2.3.2 Solid Wastes and Sludges

The main sources of brewery solid wastes and sludges are the following:

- Spent grains from the mash filter;
- Spent hops from the hop jack;
- Trub from the wort cooler;
- Residual trub filter cake from the trub filter;
- Excess yeast from the fermentor;
- Yeast filter cake from the filters; and
- Sludges from wastewater treatment.

2.3.3 Air Emissions

The major emissions from beer making are particulates and volatile organic compounds (VOCs), primarily ethanol, from spent grain drying and particulates from grain handling. VOCs from fermentation are negligible, since the fermentors are typically closed to allow carbon dioxide collection. Other brewery processes, such as wort brewing and malt drying, are minor sources of volatile organics, ethanol, and related compounds.

Depending on the fuel source, exhaust gasses from the facility boilers may potentially contain nitrogen oxides (NO_x), carbon monoxide (CO), trace sulfur dioxide (SO_2), and particulate matter.

3.0 THE BREWING INDUSTRY IN JORDAN

The ABC is located in the old industrial area near Zarqa, along the Zarqa River and close to the Jordan Brewery Company. The ABC was originally opened in 1964, closed, and then restarted in 1971.

The ABC produces beer under a license from the German brewery Henninger. The total beer production capacity is 15 m^3/day, though current production rates are only 15-20% of capacity, or approximately 2.5 m^3/day. The working time is eight hours per day, six days a week.

3.1 Brewing Processes

The primary beer production processes at ABC, shown schematically in Figure 2, include the following:

Brewhouse Processes

- Milling of malt (with addition of water);
- Mashing (at 70°C);
- Filtration (water is added to filtered wort); and
- Boiling.

Fermenting and Conditioning Processes

- Fermenting (yeast is added);
- Lagering; and
- Filtering.

Packaging Processes

- Filling of bottles and cans;
- Pasteurizing;
- Labelling; and
- Storing.

3.2 Raw Materials and Water Usage

The available estimates of ABC's raw material and water consumption rates are given in the following sections.

3.2.1 Raw Materials

ABC's 1990 yearly consumption of chemicals and fuel oil are as given in the following table; no consumption estimates were available for beer-making ingredients:

Material	Yearly Usage
Caustic (Sodium Hydroxide)	3 tons
Detergents	1 ton
Disinfectants	50 kg
Fuel Oil	108,000 tons

3.2.2 Water

Water for ABC is supplied from a private well. Some water is deionized in an on-site ion exchanger; some soft water is also produced. Although the water consumption is not metered, it is estimated by ABC as 5,600 m^3/year, or 19 m^3/day with a production of approximately 2.5 m^3 beer/day. The water is consumed in the following ways:

- Approximately 50-75% of the water is used for cleaning the facility and its equipment;
- Approximately 15% of the water is leaving the factory in bottles and cans as beer;
- Large volumes of water are used for washing bottles;
- Some water is used for pasteurization; and
- Some water is used for boiler water.

Based on the water consumption rate of 19 m^3/day and the beer production rate of 2.5 m^3/day, water consumption is 7.6 m^3/m^3 beer. Although this figure is in line with United States (US) breweries, application of water conservation technologies has enabled some breweries to reduce this figure significantly.

3.3 Waste Discharges

ABC's main waste discharges are wastewaters and solid wastes. These are described in the following subsections.

3.3.1 Wastewater

All ABC wastewater is collected in a tank and pumped to the municipal sewer system, without pretreatment. The flow is estimated to be 66 m^3/working day. ABC has a biological wastewater treatment plant which is not used, since the quality of treated water reportedly complies with the effluent standards in force.

Total brewery effluent characteristics for ABC and for typical US breweries are given below. It is noted that the ABC BOD_5, COD, and SS values are low compared to US values; the low values may indicate that ABC process wastewater is diluted with pure water. The ABC BOD_5 value in parentheses is considered more reliable. The effluent characteristics are as follows:

Characteristic	ABC	Typical US Brewery	
		Average	Range
BOD_5 (mg/l)	28 (1,500)	1,718	1,622-1,784
COD (mg/l)	72	not available	not available
SS (mg/l)	22	817	723-957
pH	7.9	7.4	6.5-8.0
Temperature (°C)	not available	30	28-32

3.3.2 Solid Waste

It appears that all major solid wastes generated from ope tions at ABC are recycled. The two main solid wastes are wet organic wastes and g. .s. More specifically, the following process wastes are generated and recycled as follows:

Milling Preparation
Spent husks are sold to cattle farms.

Mash Filtering
Spent grains are sold to cattle farms.

(In total, 1,400 tons/year of wet solid waste are sold as animal fodder.)

Packaging
Broken glass is recycled at a glass factory.

4.0 AREAS FOR POTENTIAL IMPROVEMENT

Beyond assembling background information regarding beer brewing production facilities, the primary purpose of this document is to present information gathered from the literature search regarding common techniques as well as the latest advances in water conservation, pollution prevention, and waste minimization.

The subjects can be generally defined as follows:

Water Conservation. Water conservation is the reduction of process, clean-up, and domestic water use requirements of a facility.

Pollution Prevention and Waste Minimization (PP/WM). PP/WM is the reduction of volume or concentration of water, air, and solid waste discharges from a facility. PP/WM can be accomplished by implementing process improvements to actually reduce the amount of wastes generated or by developing a beneficial reuse for the waste and transforming it into a marketable by-product.

The following subsections present water conservation and PP/WM techniques potentially applicable to the ABC. Since the focus of the IWDPP project is on water, PP/WM techniques pertaining to air emissions and solid wastes are given secondary importance in the discussion. The discussion will include as much information on source reduction, in-process recycling, clean technologies, raw material substitution, and preventative maintenance as was possible to obtain through the literature search.

After the description of each water conservation or PP/WM technique, a preliminary assessment of applicability to the Arab Brewery Co. facility is provided. These preliminary assessments, based on currently available information, are provided to highlight areas with suspected potential for improvement that should be further investigated.

It is noted that water conservation techniques often provide PP/WM benefits, and vice versa. For example, reusing spent process water that is normally discharged to sewers provides water conservation, but also provides PP/WM through wastewater reduction.

4.1 Water Conservation

Water conservation can be considered from two different aspects: maximization of water reuse; and reduction of water requirements. Both aspects of water conservation, water reuse and water reduction, are addressed below.

4.1.1 Water Reuse

In-plant reuse of potential waste streams is practiced on a limited basis. Some potential areas for water reuse are described below.

Spent Hop Filtrate. The liquid remaining after spent hops are pressed can be recycled. This high-strength waste is usually discharged to the sewer system or mixed with the spent grains. However, in a few breweries the spent hop filtrate is recycled back into the brewing process, usually right after the wort leaves the brew kettle. In most cases, this can be done without having a detrimental effect on beer quality or taste.

Packaging Wastewater. Packaging wastewater is typically weaker than process and sanitary wastewater, and may be economically treated and reused. A dedicated wastewater treatment system for packaging water may prove to be economically feasible. Biological stabilization and carbon adsorption proved to be the most cost-effective treatment for packaging wastewater, in a study for a U.S. brewery.

Equipment Cleaning Water. As discussed previously, caustic cleaning solutions and several rinses are required to clean process tanks. Reuse of caustic cleaning solutions can reduce water use. Initial rinses contain high levels of SS and BOD, while final rinses are fairly clean. A significant reduction in water use can be achieved by using holding vessels to retain the final rinse of a tank and use it as the initial rinse for the next tank. Use of steam for disinfection instead of hot water can also provide savings in water use, since less quantity is required and additionally it can be condensed, captured, and reused.

Recycling of Wastewater Treatment Plant Water. Two approaches can be considered with regard to recycling treated wastewater. The first is to separate packaging water and weak rinse water from the stronger wastewater streams, and treat this water using carbon adsorption or other appropriate methods. This approach was discussed previously.

The second approach to recycling treated wastewater is to treat brewing and packaging wastewaters (excluding human wastes and cooling tower blowdown) by secondary biological stabilization, followed by activated carbon adsorption. The treated water would be suitable for use in brewhouse clean-up, cooling tower makeup, and miscellaneous uses.

4.1.2 Water Reduction

Water reduction includes all actions that lower the consumption of water required for a given amount of production. These include process optimization, good management practices, cooling system improvements, and cleaning method improvements.

Process Optimization. All processes requiring the use of water may potentially be optimized to achieve adequate product quality with minimum use of water.

Good Management Practices. Good management practices should be practiced to minimize use of water. These practices include the following:

- Generate an accurate measurement and balance of facility water use. The balance should track process waste reduction programs;
- Install flow-control valves and timers on pipes and other equipment to better control process water usage; and

- Implement a rigorous water management system that involves facility personnel, such as employee training in water use per batch of beer.

Cooling Systems Improvements. Cooling system water use can be reduced by the following methods:

- Use a closed loop cooling system, rather than wasting heated water;
- Use an alternate heat transfer liquid, such as propylene glycol and/or a water mix; and
- Recycle treated wastewater as a cooling medium (with additional treatment, as necessary).

Cleaning Method Improvements. Cleaning effectiveness is a function of washing time, temperature, concentration of solution, and intensity of application. Applying appropriate combination of these elements to each type of soil present in different process equipments can reduce water use. Typically, a hot solution is recommended in brewhouse equipment because of hop and protein incrustations. Cold wash water can be applied to clean fermentation and maturation tanks. Water can also be saved by cleaning soiled surfaces immediately after use.

4.2 Pollution Prevention/Waste Minimization

The following sections document state-of-the-art PP/WM techniques identified in the literature: the techniques include waste treatment and by-product recovery. The information focuses primarily on wastewater PP/WM.

4.2.1 Waste Treatment

State-of-the-art treatment processes for wastewater, solid waste, and air emissions are described below. The emphasis is on wastewaters, as solid wastes and air emissions are generally not a concern in the brewing industry.

Wastewater. Brewery wastewater is characteristically high in organics, solids, and volume. The combination of these factors makes disposal to natural water courses unacceptable; therefore, most brewery wastes are sent to a municipal wastewater treatment systems or are treated by on-site systems. Here, due to the high strength, the brewery waste may be only 4-5% of the total influent but 25% of the total BOD loading. Because brewery wastewaters are quite variable as to flow and strength, a municipal treatment system can experience severe shock loads.

Several advantages exist to discharging brewery waste to a municipal wastewater treatment system: first, brewery waste is organic in nature and is biodegradable, and therefore can be readily treated by a typical biological municipal plant; and second, mixing brewery waste with sanitary sewage adds nutrients that are lacking in brewery waste, and also helps to temper the variability of the brewery waste loadings.

Several different technologies for on-site treatment of brewery wastewater are available, including activated sludge, anaerobic processes, sequential batch reactors, and bioaugmentation.

Activated Sludge. Traditional on-site wastewater treatment systems are based on activated sludge processes, typically including the following operations: bar screening, grit removal, primary clarification, aeration, secondary clarification, chlorination, and anaerobic digestion (for treatment process sludges).

Anaerobic Processes. Anaerobic processes for wastewater treatment are increasingly used for treating brewery wastes. The main advantages of anaerobic processes include the following:

- Greater resistance to shock loads than a conventional activated sludge processes;
- Greatly reduced sludge generation; and
- A useable energy by-product in the form of m hane gas.

Two anaerobic processes successfully used to treat brewer waste are Upflow Anaerobic Sludge Blanket (UASB) reactors and Anaerobic Fluidized Bed (AFB) reactors. There are several manufacturers with propriety UASB treatment systems that have extensive experience with the brewing industry.

Bioaugmentation. Bioaugmentation consists of adding special strains of bacteria to indigenous bacteria in biological treatment process, to improve treatment properties. In the case of brewery waste, bioaugmentation can be used to improve the treatment system's resistance to shock loadings, as well as to improve solids settling. This may avoid reseeding biological processes when disrupted by shock loadings, as well as reduce polymer demand and sludge handling costs resulting from poor solids settling.

Sequential Batch Reactors. Sequential Batch Reactors (SBRs) are aerobic biological treatment units operated in a batch treatment mode. Most conventional activated sludge systems are operated in a continuous-flow mode.

The cycle for a typical SBR tank is divided into the following five discrete periods: fill with wastewater, bioreact, settle solids, withdraw clarified supernatant, and idle to await refill. Since treatment and settling are accomplished in the same tank, SBR systems do not need separate final clarifiers and return activated sludge pumps.

The advantage of using SBR tanks to treat brewery wastewater is their tolerance to shock loads of BOD. The performance of several conventional activated sludge systems have been shown to significantly improve after conversion to SBR operation.

Solid Waste. As mentioned previously, organic solid wastes are typically processed and recycled as livestock feed or other types of food products. Broken glass is normally recycled, as are paper and plastic packaging wastes. No treatment is required prior to landfill disposal.

Air Emissions. Brew kettle vapor emissions can be removed by barometric condensation, although this method entails high levels of energy consumption. Another emissions from the brew kettle which may be significant is odor.

NO_x can be reduced either by retrofitting the burners to decrease NO_x generation, or by removing NO_x from off-gases by selective catalytic reduction or selective non-catalytic reduction.

4.2.2 By-Product Recovery

Recovery of waste solids from the different process streams is practiced extensively in the brewing industry and it appears to be the method of reducing waste loads both technically and economically. Grains, hops, trub, yeast, lost beer, and glass bottles and caps are all currently being recovered, as described below.

Spent Grains. Spent grains (barley, rice and/or corn) are recovered by all breweries large and small. The grains are removed 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, in which the grains are pressed and screened to reduce 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.

Following recovery, most small breweries haul the still wet spent grains away for use as cattle feed. Large facilities dry the grains before shipment to cut down on transportation costs. In either case, the grains make an excellent and very valuable cattle feed. A study of wet brewery by-products as livestock feed indicates that an optimum moisture content is 75-80%, and that adequate protein is available in grain-yeast mixtures so no supplements are needed. More recently, spent brewers grain has been used to produce barley bran for human consumption. Some studies indicate that barley bran is twice as effective in reducing cholesterol as oat bran.

Spent Hops. 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, while larger breweries add to the spent grains to be dried. A study has demonstrated that up to 10% 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 increasingly used in the US.

Trub. Trub is the waste from the wort cooling process, consisting mostly of insoluble proteins. Trub is sewered by nearly all small breweries and by many larger ones. The remaining larger breweries add trub to the spent grain to be used as cattle feed. Beer production results in an average trub generation of 1.16 kg/m^3 beer.

Yeast. Yeast is another very important by-product of the brewing industry that can also be used for livestock feed. It is both settled and filtered out of the brewing process after fermentation. Excess yeast is produced at a rate of about 1.3 kg/m^3 beer. Most plants sewer the yeast or haul it away in 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: the addition of steam-killed brewers yeast to spent grains in a 1:6 ratio can increase its nutritional value without causing an undesirable tastes that would cause cattle to reject it.

Lost Beer. 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% of the beer produced, based on a production-weighted average. Most breweries of all sizes dispose of this beer in their sewers, but a few larger ones are recovering the beer and adding it to their spent grains for evaporation.

Glass Bottles and Kegs. Glass bottles and metal kegs often can be refilled. Where refillable bottles and kegs are used, washing becomes a major operation and requires large amounts of water and caustic. In a typical plant, washing (bottles and plant clean-up) requires 1.62 kg of caustic per m^3 of beer produced. Some larger plants recycle caustic, rather than discharging it to the sewer, and achieve significant savings in cost and resources.

5.0 REFERENCES

The following documents were reviewed to prepare this report. The essential components of each are included as an attachment to this report, under separate cover.

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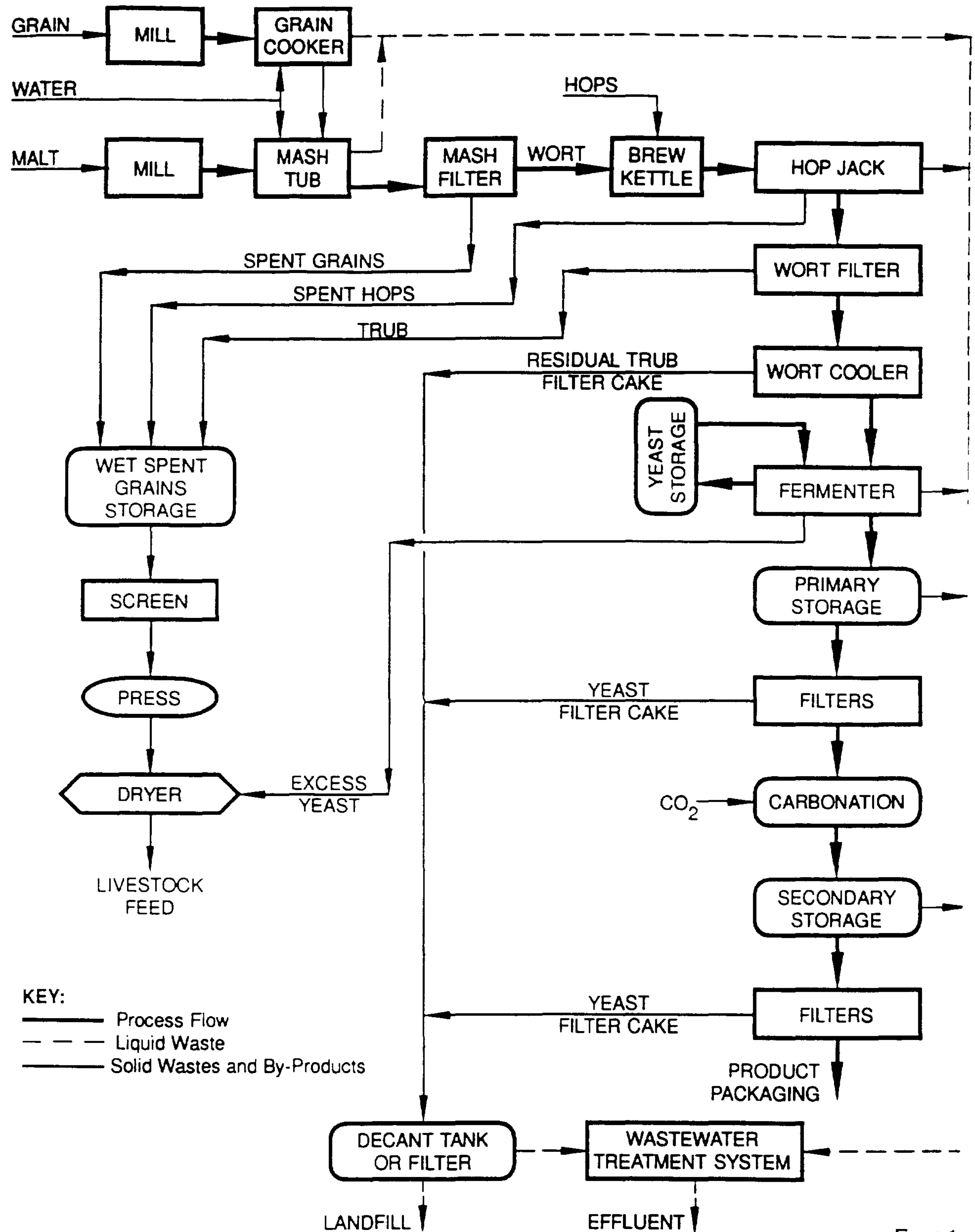

SOURCE: State-of-the-Art Wastewater Management in the Beverage Industry.

Figure 1
TYPICAL PROCESS DIAGRAM FOR BEER PRODUCTION
INDUSTRIAL WASTEWATER DISCHARGE PREVENTION
WATER QUALITY IMPROVEMENT AND CONSERVATION PROJECT
Amman, Jordan

HARZA *Consulting Engineers and Scientists*

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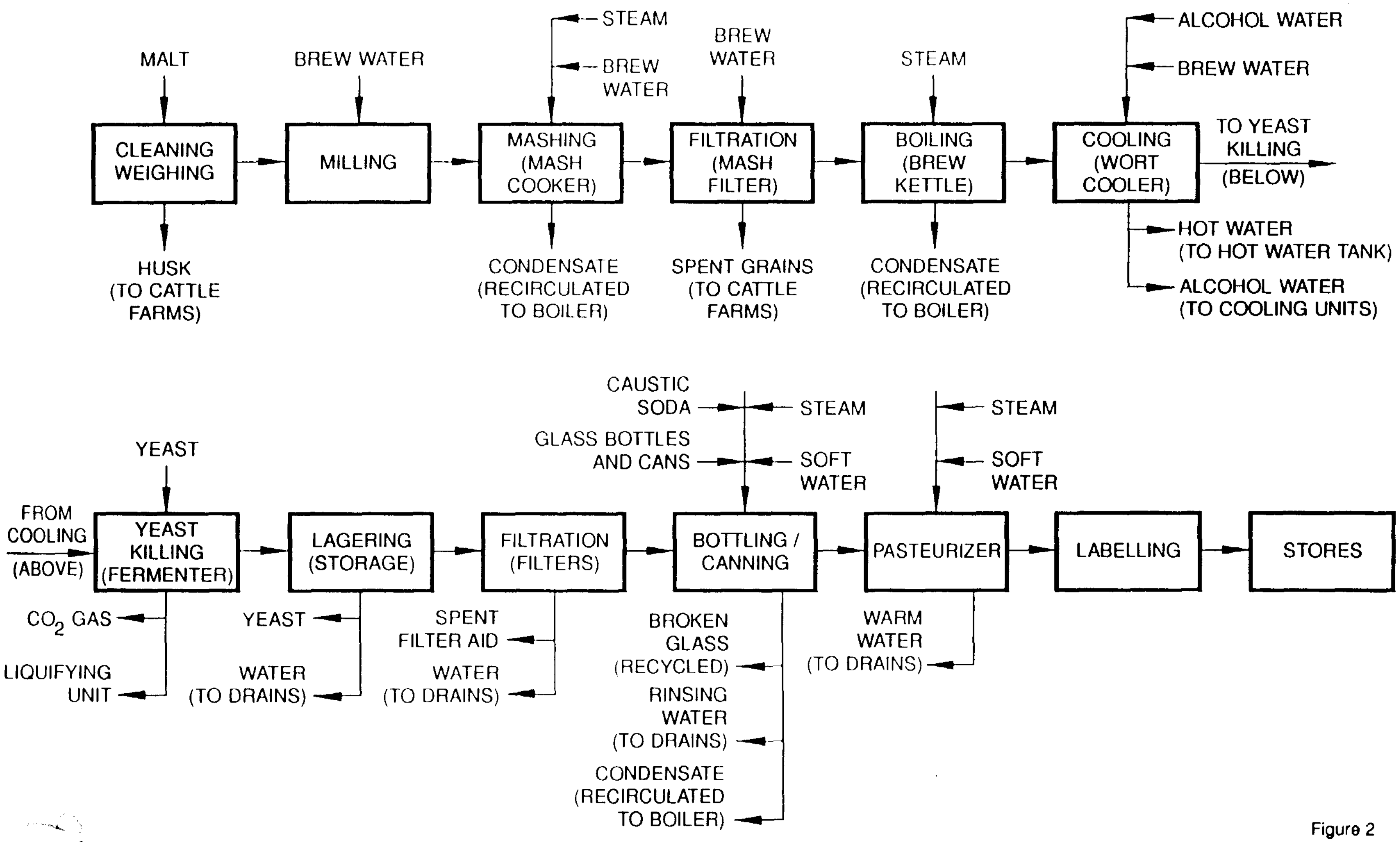

SOURCE: COWI Consult and RSS

Figure 2
ARAB BREWERY COMPANY
PROCESS DIAGRAM FOR BEER PRODUCTION
INDUSTRIAL WASTEWATER DISCHARGE PREVENTION

APPLICABLE REGULATORY CRITERIA

Current Status of Environmental Regulations in Jordan:

In order to assess the Arab Brewery Company (ABC) compliance with applicable Jordanian standards and regulations, it is of importance at this stage to present an overview of Jordan's environmental protection control laws, standards, and regulations. Interestingly, Jordan has no comprehensive law to control water, air, and soil pollution. However, a Jordanian Environment Act (JEA) was drafted two years ago to achieve the principle objectives mentioned in the National Environment Strategy (NES) for Jordan. JEA is currently awaiting approval from the Parliament.

In general, the nature of water pollution standards and regulations in Jordan vary according to sources. Industrial wastewater discharges are regulated by the Jordanian Standard Specification number 202 (Table D-1) adopted in 1981 by the Department of Standards and Specifications (DSS) and revised in 1990. Standard 202 regulates industrial wastewater discharges to rivers, wadis, groundwater, the sea, and reuse for irrigation. This standard covers 37 pollutant parameters and sets maximum allowable concentration limits of pollutants in the discharged industrial wastewater effluents. Moreover, the standard also contains narrative conditions to protect public health, aquatic life, worker health; and groundwater quality. The standard is not associated with a permitting mechanism and therefore is self-implementing.

Drinking water quality is regulated by the Jordanian standard number 286. Tables D-2a - D-2e present quantitative requirements of pertinent characteristics including physical, chemical, radiation, and health related issues. With regards to regulations related to the quality of treated domestic wastewater to be reused in irrigation, Jordan has neither standards nor guidelines. However, it is a common practice to use the Food and Agriculture Organization (FAO) and World Health Organization (WHO) Guidelines as a reference.

Tables D-3 through D-5 are related to the quality of treated domestic wastewater effluents to be reused in irrigating agricultural crops. The remaining Tables D-6 - D-12 present the tolerance and sensitivity of crops to salinity and other specific ions like Sodium, Boron and Chloride. These are adapted from the FAO Guidelines (1985). Treated domestic wastewater is regulated by the Jordanian Standard 893 (Table D-13) adopted in 1994 by DSS. Regarding air pollution, Jordan does not have any existing standards or regulations to control air pollution.

Regulations Applicable to the ABC Discharges:

The ABC Facility generates wastewater from brewhouse operations, fermentation, lagering, finishing, packaging, softener regeneration, floor equipment. washing and domestic. Industrial wastewater discharged into the public sewer system is subjected to Jordanian regulations governing discharge of Industrial and Commercial wastewater into the sanitary sewer system.

Table D -1

Summary of requirements of Jordan Standard 202/1991 for disposal of industrial effluents.

Parameter	Maximum Allowable Limit, (mg/l)+			
	Disposal To			
	Wadis & Rivers	Sea	Groundwater Recharge	Reuse for Irrigation**
5	50M	-	50M	-
	150M	200	150M	-
	1*	5*	1*	1*
	3000(1)	-	1500 (1)	2000 (2)
	50	-	-	100 (3)
u)	6.5-9.0	5.5-9.0	6.5-9.0	6.5-8.4
· (unit)	15	75	15	-
	-	4	-	-
	5	10	Absent	5
ol	0.002	1	0.002	0.002
S	25		15	-
N	12 (4)	-	2 (4)	30
	5	12	5	5
	-	125	-	50
P	15	-	-	-
	500	-	500	350 (3)
	500	-	500	400
	1.5	-	1.5	-
3	-	-	-	500
	-	-	400	-
	-	-	-	-
	-	-	-	-
	-	-	-	9
	5	-	0.3	5
	0.05	0.1	0.05	0.1
	1	-	1	1 (5)
	0.1	0.3	0.05	0.1
	2	0.1	2	0.2
	1	2	1	5
	0.2	0.2	0.2	0.2
	0.2	0.02	0.1	0.2
	0.1	0.1	0.1	1
	0.02	0.02	0.05	0.02
	0.01	0.07	0.02	0.01
	15	-	15	2
	0.1	1	0.1	0.1
	0.001	0.001	0.001	0.001
MPN/100ml		5000	-	-
MPN/100ml	1000(6)	-	1000 (6)	1000 (6)
odes	< 1	-	-	< 1

units are in mg/l except where noted.
nimum value.
pends upon, type and quantity of crops, irrigation methods, soil type, climate & groundwater in the area concerned.
determined.
onthly average.

S allowable limit is subject to the TDS concentration in the water supply and the water basin affectd.
owable limits of wastewater reuse determine the degree of restriction (none, slight to moderate, or severe).
thod of irrigation is determined by wastewater quality being used.
rate concentrations allowed are determined by its concentrations in the affected water basin.
uld reach 3 mg/l.
ometric mean.

Table D -2a

Jordanian Drinking Water Standards
A: Physical characterstics

Parameter	Permissible Limit	Max. allowable conc. in case no better source is available
Taste	aesthetically acceptable	-
Odor	aesthetically acceptable	-
Color	10 units	15 units
Turbidity	1 unit (JCU)	5 units
pH	$6.5 < pH < 9$	-
Temperature	8 - 25 c	-

Table D -2b

Jordanian Drinking Water Standards

B: Chemical Charecterstics

Parameter	Max. Allowable Conc. mg/l
Pb	0.05
Se	0.01
As	0.05
Cr	0.05
CN	0.1
Cd	0.005
Hg	0.001
Sb	0.01
Ag	0.01

Table D -2c

Jordanian Drinking Water Standards
C: Health related

Parameter	Permissible Limit mg/l	Max. allowable conc. in case no better source is avialable	Effects within max. allowable limits
TDS	500	1500	aesthetic
TH(CaCO3)	100	500*	aesthetic
ABS	0.5	1	indicator
Al	0.2	0.3	aesthetic
Fe	0.3	1	aesthetic
Mn	0.1	0.2	aesthetic
Cu	1	1.5	aesthetic
Zn	5	15	aesthetic
Na	200	400	aesthetic
Ni	0.05	0.1	health
Cl	200	500	aesthetic
F	1	1.5	health
SO4	200	500	aesthetic
NO3	45	70	health

Table D -2d

Jordanian Drinking Water Standards
D: Radiation

Parameter	Maximum limit Bq/l
Alpha-emitters (except for Radon)	0.1
Beta-emitters	1

Table D -2e

Jordanian Drinking Water Standards
E: Organic pollutants*

Parameter	Max. Permissible Conc. mg/l
A) Chlorinted	
Hydrocarbons	
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
B) Chlorophenoxys	
2,4-D	0.1
2,4,5-TP	0.01
(Trichlorophenoxy propionic acid)	

* Other organic pollutants should not exceed the max. allowable limit set by WHO.

Table D -3

Guidelines for interpretations of water quality for irrigation (1)

Potential irrigation problems	Units	Degree of restriction on use: None	Slight to moderate	Severe
Salinity (affects crop water availability) (2)				
EC_w (or)	dS/m	< 0.7	0.7 - 3.0	> 3.0
TDS	mg/l	< 450	450 - 2000	> 2000
Infiltration (affects infiltration rate of water into the soil. Evaluate using (EC_w and SAR together) (3)				
SAR = 0-3 and EC_w	=	> 0.7	0.7 - 0.2	< 0.2
= 3-6	=	> 1.2	1.2 - 0.3	< 0.3
= 6-12	=	> 1.9	1.9 - 0.5	< 0.5
= 12-20	=	> 2.9	2.9 - 1.3	< 1.3
= 20-40	=	> 5.0	5.0 - 2.9	< 2.9
Specific ion toxicity (affects sensitive crops)				
Sodium (Na) (4)				
Surface irrigation	SAR	< 3	3 - 9	> 9
Sprinkler irrigation	me/l	< 3	> 3	
Chloride (Cl) (4)				
Surface irrigation	me/l	< 4	4 - 10	> 10
Sprinkler irrigation	me/l	< 3	> 3	
Boron (B) (5)	mg/l	< 0.7	0.7 - 3.0	> 3.0
Trace elements (see table E4)				
Miscellaneous effects (affects susceptible crops)				
Nitrogen (NO3-N) (6)	mg/l	<5	5 - 30	> 30
Bicarbonate (HCO3) (Overhead sprinkling only)	me/l	< 1.5	1.5 - 8.5	> 8.5
pH			Normal range 6.5 - 8.4	

(1) Adapted from University of California Committee of Consultants 1974

(2) ECw means electrical conductivity, a measure of the water salinity, reported in deciSiemens per metre at $25C^0$ (dS/m) or in units millimhos per centimeter (mmho/cm). Both are equivalent. TDS means total dissolved solids, reported in milligrams per liter (mg/L).

(3) SAR means sodium adsorption ratio. SAR is sometimes reported by the symbol RNa. At a given SAR, infiltration rate increase as water salinity increases. Evaluate the potential infiltration problem by SAR as modified by ECw.

(4) For surface irrigation, most tree crops and woody plants are sensitive to sodium and chloride; use the values shown. Most annual crops are not sensitive. With overhead sprinkle irrigation and low humidity (<30 percent), sodium and chloride may be absorbed through the leaves of sensitive crops.

(5) For borm tolerances, see Tables 16 and 17.

(6) NO3-N means nitrate nitrogen reported in terms of elemental nitrogen (NH4-N and Organic-N should be included when wastewater is being tested).

Assumptions in the Guidelines

The water quality guidelines in Table 1 are intended to cover the wide range of conditions encountered in irrigated agriculture. Several basic assumptions have been used to define their range of usability. If the water is used under greatly different conditions, the guidelines may need to be adjusted. Wide deveations from the assumptions might result in wrong judgements on the usability of a particular water supply, especially if it is a borderline case. Where sufficient experience, field trials, research or observations are available, the guidelines may be modified to fit local conditions more closely.

The basic assumptions in the guidelines are:

Yield Potential: Full production capability of all crops, without the use of special practices, is assumed when the guidelines indicate no restrictions on use. A "restriction on use" indicates that there many be a limitation in choice of crop, or special management may be needed to maintain full production capability. A "restriction on use" does not indicate that the water is unsuitable for use.

Site Conditions: Soil texture ranges from sandy-loam to clay-loam with good internal drainage. The climate is semi-arid to arid and rainfall is low. Rainfall does not play a significant role in meeting crop water demand or leaching requirement. (In a monsoon climate or areas where precipitation is high for part or all of the year, the guideline restrictions are too severe. Under the higher rainfall situations, infiltrated water from rainfall is effective in meeting all or part of the leaching requirement.) Drainage is assumed to be good, with no uncontrolled shallow water table present within 2 metres of the surface.

Methods and Timing of Irrigations: Normal surface or sprinkler irrigation methods are used. Water s applied infrequently, as needed, and the crop utilizes a considerable portion of the available stored soil-water (50 percent or more) before the next irrigation. At least 15 percent of the applied water percolates below the root zone (leaching fraction [LF] ≥ 15 percent). The guidelines are too restrictive for specialized irrigation methods, such as localized drip irrigation, which results in near daily or frequent irrigations, but are applicable for subsurface irrigation if surface applied leaching satisfies the leaching requirements.

Water Uptake by Crops: Different crops have different water uptake patterns, but all take water from wherever it is most readily available within the rooting depth. On average about 40 percent is assumed to be taken from the upper quarter of the rooting depth, 30 percent quarter, 20 percent from the third quarter, and 10 percent from the lowest quarter. Each irrigation leaches the upper root zone and maintains it at a relatively low salinity. Salinity increases with depth and is greatest in the lower part of the root zone. The average salinity of the soil-water is three times that of the applied water and is representative of the average root zone salinity to which the crop responds. These conditions result from a leaching fraction of 15-20 percent and irrigations that are timed to keep the crop adequately watered at all times.

Salts leached from the upper root zone accumulate to some extent in the lower part but a salt balance is achieved as salts are moved below the root zone by sufficient leaching. The higher salinity in the lower root zone becomes less important if adequate moisture is maintained in the upper, "more active" part of the root zone and long-term leaching is accomplished.

Restriction on Use: The "Restriction on Use" shown in Table 1 is divided into three degrees of severity: none, slight to moderate, and severe. The divisions are somewhat arbitrary since change occurs gradually and there is no clear-cut breaking point. A change of 10 to 20 percent above or below a guideline value has little significance if considered in proper perspective with other factors affecting yield. Field studies, research trials and observations have led to these divisions, but management skill of the water user can alter them. Values shown are applicable under normal field conditions prevailing in most irrigated areas in the arid and semi-arid regions of the world.

Table D -4

Recommended maximum concentrations of trace elements in irrigation water (1)

Element	Recommended maximum concentration(2) (mg/L)	Remarks
Al (aluminium)	5.0	Can cause non-productivity in acid soils (pH < 5.5), but more alkaline soils at pH > 7.0 will precipitate the ion and eliminate any toxicity.
As (arsenic)	0.10	Toxicity to plants varies widely, ranging from 12 mg/L for Sudan grass to less than 0.05 mg/L for rice.
Be (beryllium)	0.10	Toxicity to plants varies widly, raning from 5 mg/L for kale to 0.5 mg/L for bush beans.
Cd (cadmium)	0.01	Toxic to beans beets and turnips at concentrations as low as 0.1 mg/L in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans
Co (cobalt)	0.05	Toxic to tomato plants at 0.1 mg/L in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Cr (chromium)	0.10	Not generally recognized as an essential growth element. Conservative limits recommended due to lack of knowledge on its toxicity to plants.
Cu (copper)	0.20	Toxic to a number of plants at 0.1-1.0 mg/L in nutrient solutions.
F (fluoride)	1.0	Inactivated by neutral and alkaline soils.
Fe (iron)	5.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment and buildings.
Li (lithium)	2.5	Tolerated by most crops to 5 mg/L, mobile in soil. Toxic to citrus at low concentrations (<0.075 mg/L). Acts similarly to boron.
Mn (manganeses)	0.20	Toxic to a number of crops at a few-tenths to a few mg/L, but usually only in acid soils.
Mo (molybdenum)	0.01	Not toxic to plants at normal concentrations in siol and water. Can be toxic to livestock if forage is grown in siols with high concentrations of available molybdenum
Ni (nickel)	0.20	Toxic to a number of plants at 0.5-1.0mg/L; reduced toxicity at neutral or alkaline pH.
Pd (lead)	5.0	Can inhibit plant cell growth at very high concentrations.
Se (selenium)	0.02	Toxic to plants at concentrations as low as 0.025 mg/L and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. An essential element to animals but in very low concentrations.
Sn (tin)		
Ti (titanium)		Effectively excluded by plants; specific tolerance unknown.
W (tungsten)		
V (vanadium)	0.1	Toxic to many plants at relatively low concentrations.
Zn (zinc)	2.0	Toxic to many plants at widely varying concentrations, reduced toxicity at pH > 6.0 and in fine textured or organic soils.

1- Adapted from National Academy of Sciences (1972) and Pratt (1972).

2- The maximum concentration is based on a water application rate which is consistent with good irrigation practices (10000 m3/ha per years). If the water application rate greatly exceeds this, the maximum concentrations should be adjusted downward accordingly. No adjustment should be made for application rates lease than 10 000 m3/ha per year. The values given are for water used on a continuous basis at one site.

Source: FAO Guidelines, R.S. Ayers & D.w. Westcot (1985).

Table D -5

Recommended microbiological quality guidelines for wastewater use in agriculture (a)

Category	Reuse conditions	Exposed group	Intestinal nematodes (b) (arithmetic mean no. of eggs per litre (c))	Faecal coliforms (geometric mean no. per 100ml) (c)	Wastewater treatment expected to achieve the required microbiological quality
A	Irrigation of crops likely to be eaten uncooked. sports fields, public parks, (d)	Workers, Consumer, public	<1	< 1000 (d)	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, Pasture and trees (e)	Workers	<1	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent helminth and faecal coliform removal
C	Localized irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation.

(a) In specific cases, local epidemiological, sociocultural and environmental factors should be taken into account, and the guidelines modified accordingly.

(b) Ascaris and Trichuris species and hookworms

(c) During the irrigation period.

(d) A more stringent guideline (< 200 faecal coliforms per 100 ml) is appropriate for public lawns, such as hotel lawns. With which the public may come into direct contact

(e) In the case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.

Source: Scientific group on health aspects of use of treated wastewater for agricultural and aquaculture-W H O Geneva 18-23 Nov. 1987

Table D -6

Chloride tolerance of some fruit crop cultivars and rootstocks.(a)

Crop	Rootstock or cultivar	Maximum permissible Cl in water without leaf injury (b),(c) (mg/L)
	<u>Rootstocks</u>	
Avocado (Persea americana)	West indian	180
	Guatemalan	145
	Mexican	110
Citrus (Citrus spp.)	Sunki mandarin, grapefruit Cleopatra mandarin, Rangpur lime	600
	Sampson tangelo, rough lemon, sour orange, Ponkan mandarin	355
	Citrumelo 4475, trifolate orange, Cuban shaddock, Calamondin, Sweet orange, Savage citrange, Rusk citrange, Troyer citrange	250
Grape (Vitis spp.)	Salt Creek, 1613-3	960
	Dog ridge	710
Stone fruit (Prunus spp.)	Marianna	600
	Lovell, Shalil	250
	Yunnan	180
	<u>Cultivars</u>	
Berries (Rubus spp.)	Boysenberry	250
	Olallie blackberry	250
	Indian Summer raspberry	110
Grape (vitis spp.)	Thompson seedless, Perlette	460
	Cardinal, black rose	250
Strawberry (Fragaria spp.)	Lassen	180
	Shasta	110

(a) Data are adapted from Haas (13)

(b) For some crops, the concentrations given may exceed the overall salinity tolerance of that crop and cause some yield reduction before chloride ion toxicities. Values given are for the maximum concentration in the irrigation water. The values were derived from saturation extract data (ECe) by the following relationship : saturation extraction concentration = 1.5 water concentration.

(c) The maximum permissible values apply only to surface irrigated crops. Sprinkler irrigation may cause excessive leaf burn at values far below these, (see Table 3-10).

Source : FAO Guidelines, R.S. Ayers & D.W. Westcot (1985).

Table D -7

GUIDLINES FOR INTERPRETING LABORATORY DATA ON WATER SUITABILITY FOR GRAPES

Potential Irrigation Problem	Unita	Degree of Restriction on Use		
		None	Slight to Moderate	Severe2
Salinity [3] *(affects water availability to crops)*				
ECw	dS/m	< 1	1.0 - 2.7	> 2.7
Toxicity *(Specific ions which affect growth of crop)*				
Sodium (Na^+)[4]	me/l	< 20	-	-
Chloride (Cl^-)[4]	me/l	< 4	4 - 15	> 15
Boron (B)	mg/l	< 1	1 - 3	> 3
Miscellaneous				
Bicarbonate (HCO_3^-)[5]	me/l	< 1.5	1.5 - 7.5	> 7.5
Nitrate-nitrogen (NO_3-N)	mg/l	< 5	5 - 30	> 30

1. Adapted from Neja et al. 1978.
2. Special management practices and favorable soil conditions are required for successful production.
3. Assumes that rainfall and extra water applied owing to inefficiencies of normal irrigation will supply the crop need plus about 15 percent extra for salinity control.
4. With overhead sprinkler irrigation, sodium or chloride in excess of 3 me/l under extreme drying conditions may result in excessive leaf absorption, leaf burn and crop damage. If overhead sprinklers are used for cooling by frequent on-off cycling, damage may occur even at lower concentrations.
5. Bicarbonate (HCO3) in water applied by overhead sprinklers may cause white deposits on fruit and leaves which reduces market acceptability, but is not toxic to the plant.

Table D -8

PELATIVE SALT TOLERANCE OF VARIOUS CROPS AT GERMINATION[1]

Crop		50 percent Emergence reduction (ECe in dS/m)
Barley	*(Hordeum vulgare)*	16 - 24
Cotton	*(Gossypium hirsutum)*	15.5
Sugarbeet	*(Beta vulgaris)*	6 - 12.5
Sorghum	*(Sorghum bicolor)*	13
Safflower	*(Carthomus tinctorius)*	12.3
Wheat	*(Triticum aestivum)*	14 - 16
Beet, red	*(Beta vulgaris)*	13.8
Alfalfa	*(Medicago sativa)*	8.2 - 13.4
Tomato	*(Lycopersicon Lycopersicum)*	7.6
Rice	*(Oryza sativa)*	18
Cabbage	*(Brassica oleracea capitata)*	13
Muskmelon	*(Cucumis melo)*	10.4
Maize	*(Zea mays)*	21 - 24
Lettuce	*(Lactuca sativa)*	11.4
Onion	*(Allium cepa)*	5.6 - 7.5
Bean	*(Phaseolus vulgaris)*	8.0

Table D -9

Relative boron tolerance of agricultural crops (1), (2)

Very Sensitive (<0.5 mg/L)

Lemon	*Citrus Limon*
Blackberry	*Rubus spp.*

Sensitive (0.5-0.75 mg/L)

Avocado	*Persea americana*
Grapefruit	*Citrus X paradisi*
Orange	*Citrus sinensis*
Apricot	*Prunus armeniaca*
Peach	*Prunus persica*
Cherry	*Prunus avium*
Plum	*Prunus domestica*
Persimmon	*Diospyros Kaki*
Fig, Kadota	*Ficus carica*
Grape	*Vitis vinifera*
Walnut	*Juglans regia*
Pecan	*Carya illnoiensis*
Cowpea	*Vigna unguiculata*
Onion	*Allium cepa*

Sensitive (o.75-1.0 mg/L)

Garlic	*Allium sativum*
Sweet potato	*Ipomoea batatas*
Wheat	*Triticum eastivum*
Barley	*Hordeum vulgare*
Sunflower	*Helianthus anraius*
Bean, mung	*Vigna radiata*
Sesame	*Sesamum indicum*
Lupine	*Lupinus hartwegii*
Strawberry	*Fragaria spp.*
Artichoke, Jerusalem	*Helianthus tuberosus*
Bean, Kidney	*Phaseolus vulgaris*
Bean, lima	*Phaseolus lunatus*
Groundnut/Peanut	*Arachis hypogaea*

Moderately Sensitive (1.0-2.0 mg/L

Pepper, red	*Capsicum crucum*
Pea	*Pisum sativa*
Carrot	*Daucus carota*
Radish	*Raphanus sativus*
Potato	*Solanum tuberosum*
Cucumber	*Cucumis sativus*

Moderately Tolerant (2.0-4.0 mg/L)

Lettuce	*Lactuca sativa*
Cabbage	*Brassica oleracea capitat*
Celery	*Apium graveolens*
Turnip	*Brassica rapa*
Bluegrass, Kentucky	*Poa pratensis*
Oats	*Avena sativa*
Maize	*Zea mays*
Artichoke	*Cynara scolymus*
Tobacco	*Nicotiana tabacum*
Mustard	*Brassica juncea*
Clover, sweet	*Melilotus indica*
Squash	*Cucurbita pepo*
Muskmelon	*Cucumis melo*

Tolerant (4.0-6.0 mg/L)

Sorghum	*Sorghum bicolor*
Tomato	*Lycopersicon Lycopersi*
Alfalfa	*Medicago sativa*
Vetch, purple	*Vicia benghalensis*
Parsley	*Petroselinum crispum*
Beet, red	*Beta vulgaris*
Sugarbeet	*Beta vulgaris*

Very Tolerant (6.0-15.0 mg/L)

Cotton	*Gossypium hirsutum*
Asparagus	*Asparagus officinalis*

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(1) Data taken from Maas (1984)

(2) Maximum concentrations tolerated in soil-water without yield or vegetative growth reductions. Boron to vary depending upon climate, soil conditions and crop varieties. Maximum concentrations in the irrigatic are approximately equal to these values or slightly less.

Source: FAO Guidelines, R.S. Ayers & D.W. Westcot (1985).

Table D -10

Relative tolerance of selected crops to exchangeable sodium (1).

Sensitive (2)	Semi-tolerant(2)	Tolerant(2)
Avocado	Carrot	Alfalfa
(Persea americana)	*(Daucus carota)*	*(Medicago sativa)*
Deciduous Fruits	Clover, Ladino	Barley
Nuts	*(Trifolium repens)*	*(Hordeum vulgare)*
Bean, green	Dallisgrass	Beet, garden
(Phaseolus vulgaris)	*(Paspalum dilatatum)*	*(Beta vulgaris)*
Cotton *(at germination)*	Fescue, tall	Beet, sugar
(Gossypium hirsutum)	*(Festuca arundinacea)*	*(Beta vulgaris)*
Maize	Lettuce	Bermuda grass
(Zea mays)	*(Lactuca sativa)*	*(Cynodon dactylon)*
Peas	Bajara	Cotton
(Pisum sativum)	*(Pennisetum typhoides)*	*(cossypium hirsutum)*
Grapefruit	Sugarcane	Paragrass
(Citrus paradisi)	*(Saccharum officinarum)*	*(Brachicria mutica)*
Orange	Berseem	Rhodes grass
(Citrus sinensis)	*(Trifolium alexandrinum)*	*(Chloris gayana)*
Peach	Benji	Wheatgrass, crested
(Prunus persica)	*(Melilotus parviflora)*	*(Agropyron cristatum)*
Tangerine	Raya	Wheatgrass, fairway
(Citrus reticulata)	*(Brassica juncea)*	*(Agropyron cristatum)*
Mung	Oat	Wheatgrass, fairway tall
(Phaseolus aurus)	*(Avena sativa)*	*(Agropyron slongatum)*
Mash	Onion	Karnal grass
(Phaseolus mungo)	*(Allium cepa)*	*(Diplachra fusca)*
Lentil	Radish	
(Lens culinaris)	*(Raphanus sativus)*	
Groundnut *(peanut)*	Rice	
(Arachis hypogaea)	*(Oryza sativus)*	
Cram	Rye	
(Cicer arietirum)	*(Secale cereale)*	
Cowpeas	Ryegrass, Italian	
(Vigna sinensis)	*(Lolium multiflorum)*	
	Sorghum	
	(Sorghum vulgare)	
	Spinach	
	(Spinacia oleracea)	
	Tomato	
	(Lycopersicon esculentum)	
	Vetch	
	(Vicia sativa)	
	Wheat	
	(Triticum vulgare)	

Adapted from data of FAO-Unesco (1973); Pearson (1960); and Abrol (1982).
Source: FAO Guidelines, R.S. Ayers & D.W. Westcot (1985).

Table D -11

LABORATORY DETERMINATIONS NEEDED TO EVALUATE COMMON IRRIGATION WATER QUALITY PROBLEMS

Water parameter	Symbol	Unit[1]	Usual range in irrigation water	
SALINITY				
Salt Content				
Electrical Conductivity	EC_w	dS/m	0 - 3	dS /m
(or)				
Total Dissolved Solids	TDS	mg/l	0 - 2000	mg/l
Cations and Anions				
Calcium	Ca^{++}	me/l	0 - 20	me/l
Magnesium	Mg^{++}	me/l	0 - 5	me/l
Sodium	Na^{+}	me/l	0 - 40	me/l
Carbonate	CO_3^{--}	me/l	0 - .1	me/l
Bicarbonate	HCO_3^{-}	me/l	0 - 10	me/l
Chloride	Cl^{-}	me/l	0 - 30	me/l
Sulphate	SO_4^{--}	me/l	0 - 20	me/l
NUTRIENTS[2]				
Nitrate - Nitrogen	NO_3 - N	mg/l	0 - 10	mg/l
Ammonium - Nitrogen	NH_4 - N	mg/l	0 - 5	mg/l
Phosphate - Phosphorus	PO_4 - P	mg/l	0 - 2	mg/l
Potassium	K^{+}	mg/l	0 - 2	mg/l
MISCELIANEOUS				
Boron	B	mg/l	0 - 2	mg/l
Acid / Basicity	pH	1 - 14	6.0 - 8.5	
Sodium Adsorption Ratio[3]	SAR	$(me/l)^{1,2}$	0 - 15	

1. dS/m = desiSiemen/meter in S.I. units (equivalent to 1 mmho / cm - 1 millimmho / centimeter)
   mg/l = milligram per litre ~ parts per million (ppm).
   me/l = milliequivalent per litre (mg/l ÷ equivalent weight = me/l); in SI units, 1 me/l = 1 millimol / litre adjusted for electron charge.
2. NO3-N means the laboratory will analyse for NO3 but will report the NO3 in terms of chemically equivalent nitrogen. Similarly, for NH4-N, the laboratory will analyse for NH4 but report in terms of chemically equivalent elemental nitrogen. The total nitrogen available to the plant will be the sum of the equivalen elemental nitrogen.
   The same reporting method is used for phosphorus.
3. SAR is calculated from the Na, Ca and Mg reported in me/l.

Table D -12

Crop tolerence and yield potential of selected crops as influenced by irrigation water salinity (ECw) or soil salinity (ECe)

	Yield potential (2)									
	100%		90%		75%		50%		0% maximum(3)	
	ECe	ECw	ECe	ECw	ECe	ECw	ECe	ECw	ECe	ECw
Field crops										
Barley *(Hordeum Vulgare)* (4)	8.0	5.3	10	6.7	13	8.7	18	12	28	19
Cotton *(Gossypium hirsutum)*	7.7	5.1	9.6	6.4	13	8.4	17	12	27	18
Sugarbeet *(Beta vulgaris)* (5)	7.0	4.7	8.7	5.8	11	7.5	15	10	24	16
Sorghum *(Sorghum bicolor)*	6.8	4.5	7.4	5.0	8.4	5.6	9.9	6.7	13	8.7
Wheat *(Triticum aestivum)* (4), (6)	6.0	4.0	7.4	4.9	9.5	6.3	13	8.7	20	13
Wheat durum *(Triticum turgidum)*	5.7	3.8	7.6	5.0	10	6.9	15	10	24	16
Soyabean *(Glycine max)*	5.0	3.3	5.5	3.7	6.3	4.2	7.5	5.0	10	6.7
Cowpea *(Vigna unguiculata)*	4.9	3.3	5.7	3.8	7.0	4.7	9.1	6.0	13	8.8
Groundnut *(peanut)* *(Arachis hypogaea)*	3.2	2.1	3.5	2.4	4.1	2.7	4.9	3.3	6.6	4.4
Rice *(paddy)* *(Oriza sativa)*	3.0	2.0	3.8	2.6	5.1	3.4	7.2	4.8	11	7.6
Sugarcane (Saccharum officinarum)	1.7	1.1	3.4	2.3	5.9	4.0	10	6.8	19	12
Corn *(maize)* *(Zea mays)*	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10	6.7
Flax *(Linum usitatissimum)*	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10	6.7
Broadbean *(Vicia faba)*	1.5	1.1	2.6	1.8	4.2	2.0	6.8	4.5	12	8.0
Bean *(phaseolus vulgaris)*	1.0	0.7	1.5	1.0	2.3	1.5	3.6	2.4	6.3	4.2
Vegetable crops										
Squash zucchini *(courgette)* *(Cucurbita pepo melopepo)*	4.7	3.1	5.8	3.8	7.4	4.9	10	6.7	15	10
Beet, red *(Beta vulgaris)*(5)	4.0	2.7	5.1	3.4	6.8	4.5	9.6	6.4	15	10
Squash, scallop *(Cucurbita pepo melopepo)*	3.2	2.1	3.8	2.6	4.8	3.2	6.3	4.2	9.4	6.3
Broccoli *(Brassica oleracea botrytis)*	2.8	1.9	3.9	2.6	5.5	3.7	8.2	5.5	14	9.1
Tomato *(Laycopersicon esculentum)*	2.5	1.7	3.5	2.3	5.0	3.4	7.6	5.0	13	8.4
Cucumber *(Cucumis sativus)*	2.5	1.7	3.3	2.2	4.4	2.9	6.3	4.2	10	6.8
Spinach *(Spinacia olerucea)*	2.0	1.3	3.3	2.2	[illegible]	3.5	8.6	5.7	15	10
Celery *(Apium graveolens)*	1.8	1.2	3.4	2.3	5.8	3.9	9.9	6.6	18	12
Cabbage *(Brassica oleracca capitata)*	1.8	1.2	2.8	1.9	4.4	2.9	7.0	4.6	12	8.1
Potato *(Solanum tuberosum)*	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10	6.7
Corn, sweet *(maize)* *(Zea mays)*	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10	6.7
Sweet potato *(Impomoea batatas)*	1.5	1.0	2.4	1.6	3.8	2.5	6.0	4.0	11	7.1
Pepper *(Capsicum annuum)*	1.5	1.0	2.2	1.5	3.3	2.2	5.1	3.4	8.6	5.8
Lettuce *(Lactuca sativa)*	1.3	0.9	2.1	1.4	3.2	2.1	5.1	3.4	9.0	6.0
Radish *(Raphanus sativus)*	1.2	0.8	2.0	1.3	3.1	2.1	5.0	3.4	8.9	5.9
Onion *(Allium cepa)*	1.2	0.8	1.8	1.2	2.8	1.8	4.3	2.9	7.4	5.0
Carrot *(Daucus carota)*	1.0	0.7	1.7	1.1	2.8	1.9	4.6	3.0	8.1	5.4
Bean *(Phaseolus vulgaris)*	1.0	0.7	1.5	1.0	2.3	1.5	3.6	2.4	6.3	4.2
Turnip *(Phaseolus vulgaris)*	0.9	0.6	2.0	1.3	3.7	2.5	6.5	4.3	12	8.0
Forage crops										
Wheatgrass, tall *(Agropyron elongatum)*	7.5	5.0	9.9	6.6	13	9.0	19	13	31	21
Wheatgrass, fairway crested *(Agropyron cristatum)*	7.5	5.0	9.0	6.0	11	7.4	15	9.8	22	15
Bermuda grass *(Cynodon dactylon)* (7)	6.9	4.6	8.5	5.6	11	7.2	15	9.8	23	15
Barley *(forage)* *(Hordeum vulgare)* (4)	6.0	4.0	7.4	4.9	9.5	6.4	13	8.7	20	13
Ryegrass. perennial *(Lolium perenne)*	5.6	3.7	6.9	4.6	8.9	5.9	12	8.1	19	13
Trefoil, narrowleaf birdsfoot (8) *(Lotus corniculatus tenuifolium)*	5.0	3.3	6.0	4.0	7.5	5.0	10	6.7	15	10

Table D - 12 Continued

	Yield potential									
	100%		90%		75%		50%		0%maximum (3)	
	ECe	ECw	ECe	ECw	ECe	ECw	ECe	ECw	Ece	ECw
Harding grass *(Phalaris tuberosa)*	4.6	3.1	5.9	3.9	7.9	5.3	11	7.4	18	12
Fescue, tall *(Festuca elatior)*	3.9	2.6	5.5	3.6	7.8	5.2	12	7.8	20	13
_Wheatgrass, standard crested *(Agropyron sibiricum)*	3.5	2.3	6.0	4.0	9.8	6.5	16	11	28	19
Vetch, common *(Vicia angustifolia)*	3.0	2.0	3.9	2.6	5.3	3.5	7.6	5.0	12	8.1
Sudan grass *(Sorghum sudanense)*	2.8	1.9	5.1	3.4	8.6	5.7	14	9.6	26	17
Wildrye, beardless *(Elymus truicoides)*	2.7	1.8	4.4	2.9	6.9	4.6	11	7.4	19	13
Cowpea *(forage)* *(Vigna unguiculata)*	2.5	1.7	3.4	2.3	4.8	3.2	7.1	4.8	12	7.8
Trefoil, big *(Lotus uliginosus)*	2.3	1.5	2.8	1.9	3.6	2.4	4.9	3.3	7.6	5.0
Sesbania *(Sesbania exaltata)*	2.3	1.5	3.7	2.5	5.9	3.9	9.4	6.3	17	11
Sphaerophysa *(Sphaerophysa salsula)*	2.2	1.5	3.6	2.4	5.8	3.8	9.3	6.2	16	11
Alfalfa *(Medicago sativa)*	2.0	1.3	3.4	2.2	5.4	3.6	8.8	5.9	16	10
Lovegrass *(Eragrostis sp.)* (9)	2.0	1.3	3.2	2.1	5.0	3.3	8.0	5.3	14	9.3
Corn *(forage) (maize) (Zea mays)*	1.8	1.2	3.2	2.1	5.2	3.5	8.6	5.7	15	10
Clover, berseem *(Trifolium alexandrinum)*	1.5	1.0	3.2	2.2	5.9	3.9	10	6.8	19	13
Orchard grass *(Dactylis glomerata)*	1.5	1.0	3.1	2.1	5.5	3.7	9.6	6.4	18	12
Foxtail, meadow *(Alopecurus pratensis)*	1.5	1.0	2.5	1.7	4.1	2.7	6.7	4.5	12	7.9
Clover, red *(Trifolium pratense)*	1.5	1.0	2.3	1.6	3.6	2.4	5.7	3.8	9.8	6.6
Clover, alsika *(Trifolium hybridum)*	1.5	1.0	2.3	1.6	3.6	2.4	5.7	3.8	9.8	6.6
Clover, ladino *(Trifolium repens)*	1.5	1.0	2.3	1.6	3.6	2.4	5.7	3.8	9.8	6.6
Clover, strawberry *(Trifolium fragiferum)*	1.5	1.0	2.3	1.6	3.6	2.4	5.7	3.8	9.8	6.6
_Fruit crops (10)										
Date palm *(Phoenix dactylifera)*	4.0	2.7	6.8	4.5	11	7.3	18	12	32	21
Grapefruit *(Citrus paradisi)* (11)	1.8	1.2	2.4	1.6	3.4	2.2	4.9	3.3	8.0	5.4
Orange *(Citrus sinensis)*	1.7	1.1	2.3	1.6	3.3	2.2	4.8	3.2	8.0	5.3
Peach *(Prunus persica)*	1.7	1.1	2.2	1.5	2.9	1.9	4.1	2.7	6.5	4.3
Apricot *(Prunus armeniaca)* (11)	1.6	1.1	2.0	1.3	2.6	1.8	3.7	2.5	5.8	3.8
Grape *(Vitus sp.)* (11)	1.5	1.0	2.5	1.7	4.1	2.7	6.7	4.5	12	7.9
Almond *(Prunus dulcis)* (11)	1.5	1.0	2.0	1.4	2.8	1.9	4.1	2.8	6.8	4.5
Plum, prune *(Prunus domestica)* (11)	1.5	1.0	2.1	1.4	2.9	1.9	4.3	2.9	7.1	4.7
Blackberry *(Rubus sp.)*	1.5	1.0	2.0	1.3	2.6	1.8	3.8	2.5	6.0	4.0
Boysenberry *(Rubus ursinus)*	1.5	1.0	2.0	1.3	2.6	1.8	3.8	2.5	6.0	4.0
Strawberry *(Fragaria sp.)*	1.0	0.7	1.3	0.9	1.8	1.2	2.5	1.7	4.0	2.7

(1) Adapted from Maas and Hoffman (1977) and Maas (1984). These data should only serve as a guide to relative tolerances among crops. Absolute tolerances vary depending upon climate, soil conditions and cultural practices. In gypsiferous soils, plants will tolerate about 2ds/m higher soil salinity (ECe) than indicated but the water salinity (ECw) will remain the same as shown in this table.

(2) ECe means average root zone salinity as measured by electrical conductivity of the saturation extract of the soil, reported in decisiemens per meter (ds/m) at 25C. ECw means electrical conductivity of the irrigation water in deci Siemens per meter (ds/m). The relationship between soil salinity and water salinity (ECe=1.5 ECw) assumes a 15-20 leaching fraction and a 40-30-20-10% water use pattern for the upper to lower quarters of the root zone.

(3) The zero yield potential or maximum ECe indicates the theoretical soil salinity (ECe) at which crop growth ceases.

(4) Barley and wheat are less tolerant during germination and seedling stage : ECe should not exceed 4 - 5 dS/m in the upper soil during this period.

(5) Beets are more sensitive during germination : ECe should not exceed 3 ds/m in the seedling area for garden beets and sugar beets.

(6) Semi-dwarf, short cultivars may be less tolerant.

(7) Tolerance given is an average of several varieties : Suwannce and Coastal Bermuda grass are about 20% more tolerant, while common and Greenfield Bermuda grass are about 20% less tolerant.

(8) Broadleaf Birdsfoot Trefoil seems less tolerant than Narrowleaf Birdsfoot Trefoil.

(9) Tolerance given is an average for boer. Wilman, Sand and Weeping Lovegrass ; Lehman Lovegrass seems about 50% more tolerant.

(10) These data are applicable when rootstocks are used that do not accumulate Na^+ and Cl^- rapidly or when these ions do not predominate in the soil.

(11) Tolerance evaluation is based on tree growth and not on yeild.

Source: FAO Guidelines, R.S. Ayers & D.W. Westcot (1985).

Table D-13
Summary of requirements of Jordanian Standard 893/1994 for treated domestic wastewater.

Parameter	Maximum allowable limit (mg/L)*	
	Disposed to wadis, rivers, surface water bodies, and groundwater recharge	Reuse for irrigation
	6.5-9	6.5-9
erature change (C)	<3	-
	31	-
	3000	2000 (1)
	50(3) / 200(4)	100 (1)
	50(3) / 50(4)	-
	150(3) / 150(4)	-
	30	-
	15	15
	6	-
	0.5 (5)	-
	0.5	-
IPN/100mL	< 1000	< 1000 (6)
l nematodes	< 1	< 1 (6)

; are in mg/L except where noted.
ıds on degree of restriction (none, slight to moderate, or severe).
ıds on method of irrigation.
:ntional wastewater treatment plants.
stabilization ponds.
; a minimum limit of residual chlorine and it should be linked with total faecal coliform count.
ınd WHO guidelines and their amendments should be taken into consideration.

Table D-14

Summary of Jordanian Regulations Governing Discharge of Industrial and Commercial Wastewater Into the Sanitary Sewer System.*

Parameter	Unit	Maximum Allowable Limit
pH	Su	5.5-9.5
BOD	mg/l	800
COD	mg/l	2100
TSS	mg/l	1100
P	mg/l	50
FOG	mg/l	50
MBAS	mg/l	26
Phenol	mg/l	10
Cr**	mg/l	5
Cu**	mg/l	4.5
Zn**	mg/l	15
Sn	mg/l	10
Be	mg/l	5
Ni**	mg/l	4
Cd**	mg/l	1
As	mg/l	5
Ba	mg/l	10
Pb**	mg/l	0.6
Mn	mg/l	10
Ag**	mg/l	1
B	mg/l	5
Hg**	mg/l	0.5
Fe	mg/l	50
S (as H_2S)	mg/l	10
Temp	°C	65
Chlorinated Solvents	mg/l	0

* Published in the Official Gazette, September 17, 1988

** The total concentration of all the double asterisked materials should not exceed 10 mg/l

It is not permitted to dispose any liquids or materials which have cyanides in a concentration which can produce 1 mg/l HCN or more

It is not permitted to dispose any radioactive material without written approval from WAJ.

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Wastewater Minimisation and Effluent Disposal at a Brewe

By Colin Watson

ABSTRACT

The case study presents experience gained whilst conducting a water and wastewater audit for a brewery in order to identify short-term options for in-process waste reduction and to assess the brewery's long-term effluent treatment and disposal options. Sampling and flow monitoring of the main effluent streams were carried out to ascertain current flows and pollution loads. Discharges from individual process units were sampled manually to aid identification of the major sources of high pollution loads. Within each unit operation, water re-use and waste treatment/reduction alternatives were looked at to help formulate a cost effective waste management plan. Long-term effluent treatment and disposal options were then considered for the whole brewery site. By estimating the expected reductions in effluent flow and pollution loads, costs were calculated to show the benefits that would be gained by instigating water re-use and waste reduction measures.

SINTÉSIS

Este estudio presenta la experiencia ganada mientras se conduj auditoria de agua y aguas servidas de una cervecería para identific ciones a corto plazo para reduccion de desperdicios de proceso y evaluar las opciones a largo plazo de la cervecería para el tratamien efluente y manejo de desperdicios. Se llevo a cabo muestreo y co de flujos de las vias principales de efluente para determinar nivele tuales de flujo y polución. Se utilizo muestreo manual de descar procesos individuales para ayudar a identificar las fuentes principal cargas altas de polucion.

Dentro de cada unidad de operacion se evaluo alternativas de re de agua y tratamiento/reduccion de desperdicios para ayudar a form un plan para el manejo de estos puntos que sea eficiente en relaci su costo.

Luego se consideran opciones a largo plazo para tratamiento y posicion de desperdicions para la cerveceria entera. Estimando la ducciones de efluente y carga de polucion se calculo los costos ; demonstrar los beneficios que se tendria al instigar re-uso de agu medidas para reduccion de desperdicios.

INTRODUCTION

The following case study describes a typical effluent audit/reduction study carried out at a brewery by ASHACT Ltd.

BACKGROUND

The modern brewery produces beer in bottles, kegs and bulk tankers. Considerable volumes of effluent containing high chemical oxygen demand (COD) and suspended solids (SS) concentrations are produced as a result of washing of vessels and associated equipment between batches. Effluent flows and pollution loads have increased significantly with production increases, resulting in consent limits for discharge to the public sewer being exceeded on a regular basis.

The water company had recently indicated that the brewery flows could continue to be accepted to sewer and the normal trade effluent charging system would be applied whereby charges varied according to variations in flow and pollution loads.

The current trade effluent charges amount to several hundreds of thousands of pounds per annum. After considering the likely implications of the increase in effluent charges, the company decided to appoint ASHACT Ltd, a firm of consultants, to carry out a study to investigate the possible ways of minimising efflu disposal costs. The audit team considered that the cost of efflu disposal at the brewery could be minimised in two ways:

- reduction in volume, COD and/or SS load of the efflu produced at source; and
- reduction in the COD and/or SS load of the effluent c charged to sewer by pretreatment.

Mr Watson graduated from Heriot-Watt University, Edinburgh, Scotland with a first class Honours Degree in Chemical Engineering. He joined Pilkington Glass Ltd and worked in the float glass production department and as a technologist in the development department.

He left the company in 1990 and joined ASHACT Ltd, a consultancy specialising in process and environmental management. Mr Watson, now a chartered chemical engineer, is responsible for many of ASHACT's projects including environmental auditing, waste minimisation, discharge sampling and monitoring programmes, contaminated land assessments and pollution abatement equipment evaluation. Recent projects have spanned a broad range of industries including brewing, papermaking, food processing and chemical manufacturing.

PREASSESSMENT

Two ASHACT staff were allocated to carry out the requir investigations, assisted as necessary by one of the brewery's tec nologists. With the help of the brewery's engineering staff, notch weirs were installed in manholes where all the various fluents combined so that the flow could be monitor continuously using ultrasonic level/flow meters and associat data loggers. Flow-proportional daily composite samples we collected using automatic samplers. The brewery's own labor tory was able to carry out the required effluent analyses.

In order to put the brewery operations in perspective from waste management viewpoint, a preliminary check on efflue and pollution loads discharged per cubic metre of beer produce was carried out based on past records of water usage and produ data together with some limited information on combined effl ent strength. These are shown in Table 1 below.

It was concluded that, in general, the brewery operated wit a very low degree of water wastage with most of the useful b products or wastes already being recycled or recovered for of site disposal. These aspects had been considered at an early stag in the design of the brewery and had clearly paid dividends i

Table 1
Effluent Contributions from Beer Production

	Actual	Typical Brewery	Old Brewery
Effluent Flow (m^3/m^3 beer)	2.1	7.0	18.0
COD Load (kg/m^3 beer)	7.1	4.5	15.0

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ducing effluent volumes and pollution loads discharged. Nevertheless, it was considered that there was still scope for further waste saving measures to be implemented.

-other factor in favour of this brewery is that most of the : transported in road tankers rather than bottles or kegs, b of which give rise to more effluent being produced.

The study team started off the effluent audit/waste reduction programme by becoming familiar with all the various production stages. This was done by walking around the plant with the brewery technologist and collecting relevant information from departmental records.

Schematic flow diagrams were drafted to illustrate the various unit operations that contributed to effluent discharges. An example for the kegging hall is shown in Figure 1. Once all the unit operations had been identified and described, the audit team proceeded to gather data on water usage, effluent output and waste recovery.

QUANTIFICATION OF WATER USAGE AND EFFLUENT PRODUCED

The principal process outputs of concern were the effluent discharges arising from production operations. It was also noted that minor domestic sewage contributions discharged to the same drainage network as the brewery process effluent. The audit team then proceeded to quantify these outputs.

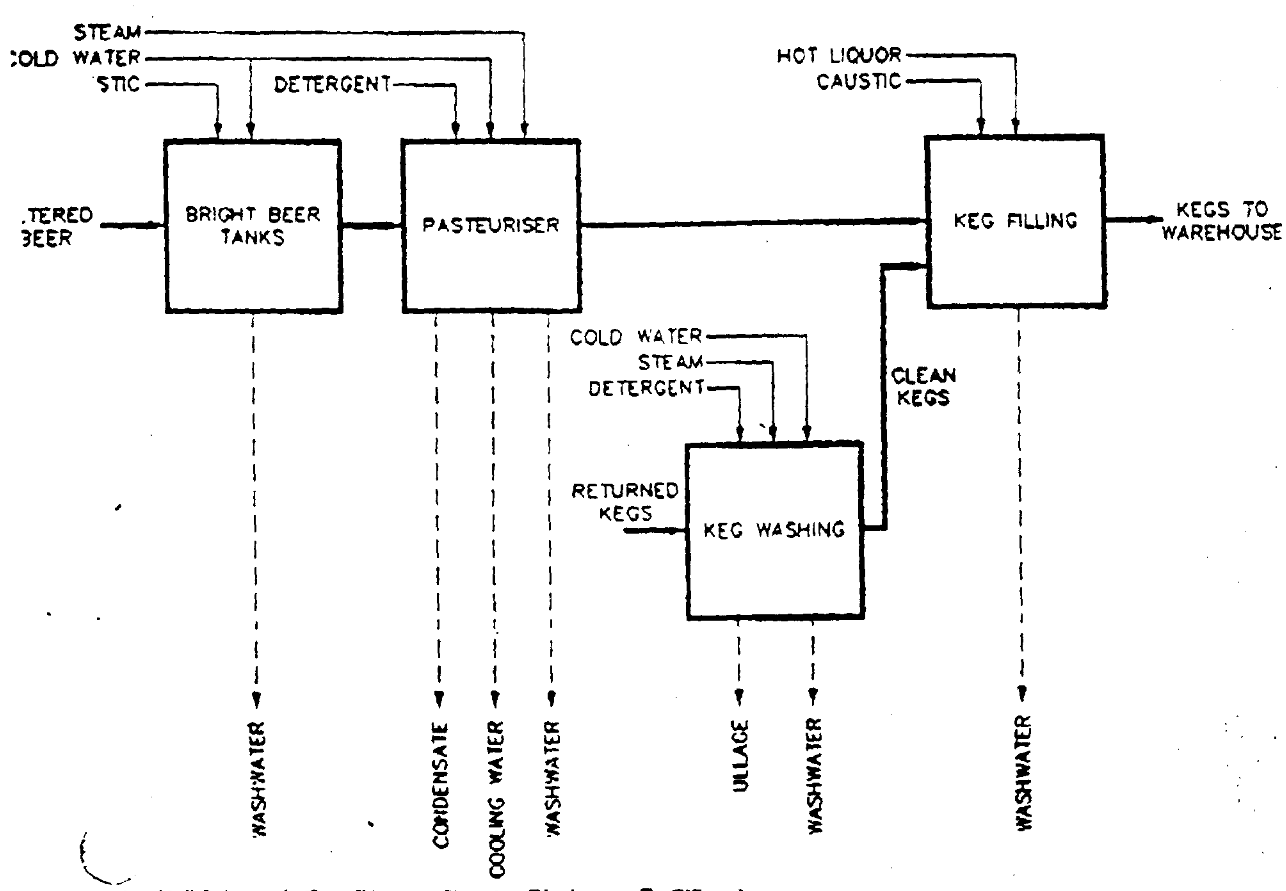
The total effluent flow recorded during a two-week monitoring period averaged 1,400 m^3/d. It was noted, however, from the flow patterns during each day that discharges were extremely variable with a peak flow rate of up to 80 m^3/h. On the basis of th a number of other assumptions, the audit team estimate the maximum flow on any one day could reach 2,100 m^3/d

An estimate of domestic water usage and hence domestic age discharges to the trade effluent drainage system were made; this was determined as only 5 m^3/d (75 employees litres per head per day).

Each effluent source was quantified in terms of volume pollution load. This involved sampling and flow measureme individual discharges around the brewery. Since the volume composition of some of these discharges varied considerably the type of beer produced, the survey was undertaken over eral weeks to allow a realistic assessment of the situation t made.

The material balance with respect to overall effluent gen tion compared to the sum of the point sources showed a markably good agreement; the average daily combined pollu loads amounting to around 10% above the individual sources sessed.

On studying the volumetric data collated, and comparing to the water usage records it appeared that around 7% of water was unaccounted for (after making allowances for wate the product). It was observed that no allowance for evaporat had been included in the water balance and that, fr ASHACT's previous experience of brewery operations, eva ration alone could account for up to 5% of total water usage. T allowance therefore effectively closed the small difference tween water input and output indicated.



. Kegging Hall Schematic Flow Diagram Showing Discharges To Effluent.

EVALUATION OF EFFLUENT REDUCTION MEASURES

In the light of a comprehensive examination of the waste producing areas, it was possible to identify the major sources of effluent at the brewery. To assist the investigations into reduction possibilities, reference was made to available information (including database) sources, as well as ASHACT's own experience of undertaking similar projects. The various sections of the brewery were studied in turn as follows.

Brewhouse

The two principal discharges in the brewhouse were the drain from the Lautertuns and a hot liquor tank (70-80°C water) overflow. Together these contributed over 10% of the total effluent flow from the brewery.

[redacted] and that this should be possible without detriment to brewing standards. This would reduce raw water costs, eliminate effluent charges previously incurred by this discharge, reduce energy requirements and eliminate existing shock load discharges from this source which should remove any need for flow/load balancing of the total site effluent flow.

Since the hot liquor tank overflow was clean and hot, continual reuse was the obvious possibility. Unfortunately this proved to be impossible owing to the spasmodic production of this water. As the tank was very large however, it was considered that all its inherent balancing capacity could be utilised if the supply for reuse was taken from the base of the tank rather than from part way down the tank.

Reuse of this water would be preferable in a process that consumed hot water at approximately the same rate as the hot liquor production. The only process in the brewery that utilised this quantity of hot water was the pasteurising machine. However, all of this flow was not hot water since a temperature gradient had to be maintained within the pasteuriser to ensure that bottles were not warmed up or cooled down too rapidly.

It was considered that the hot liquor should be injected directly into the pasteuriser to replace the heating of cold water to 60°C. In addition, the hot water could be blended with the supply of cold water that already existed to give the required temperature profile throughout the pasteuriser. It was estimated that such a system would enable at least half of the excess hot water to be reused each day.

Fermentation Area

The majority of effluent produced in this area of the brewery originated from the CIP systems, the discharges from which contained a high COD load due principally to the high yeast content. With the exception of the initial rinse from pre-fermentation stage gauging vessels, the initial rinses from other tanks—fermentation tanks, storage vessels and yeast recovery vessels—all exceeded 5,000 mg/l COD and together accounted for over 90% of the COD load produced in the fermentation area. Proposals for reducing/treating these discharges were developed as follows.

Possibilities for reducing the pollution load from the gauging vessel CIP effluent were limited as no yeast was present that could be filtered out. However, reuse of the relatively clean final rinse as the initial rinse for the next CIP wash would reduce the effluent flow to drain by a total of 20 m³/d from 6 vessels. It was also noted that the caustic wash from the brewhouse which occurred usually every week was discharged to drain from these gauging vessels every weekend and that this, together with the acid wash from Wort Kettle discharged via a fermentation tank, had a major effect on the combined wastewater pH giving values frequently outside the allowable pH range for discharge to the public sewer of 6–10. Tests showed that if the acid and causti discharges were run to drain together, the neutralising effect c the acid on the caustic was negligible owing to the different vol umes, strengths and buffering capacities involved. Rather tha install a localised acid dosing/pH control system to neutralise th predominant caustic load, it was envisaged that closing up th system by providing additional holding tank capacity would b suitable. This could be achieved using a similar arrangement t the existing closed CIP units in order to standardise on equip ment; it would reduce effluent flows to drain, raw water cost and also chemical-cleaning costs.

The load produced by the initial rinse of the fermentatio tanks was found to be 198 kg COD/d and 120 kg SS/d whicl could be reduced by at least 75% by passing the rinse through : yeast press. It was considered that the final CIP rinse could als be reused as the initial rinse, reducing effluent flow by 20 m³/d As referred to above, acid washes from the brewhouse were bein discharged from the fermentation tanks; on occasions, these de pressed the pH to 3. Containment and recirculation via a nev CIP unit were considered to be the most suitable and practicabl control measure.

The initial rinse in the storage tank CIP sequence was foun to contain 60 kg COD/d and 8 kg SS/d. It was estimated tha passing these rinses through a yeast press would reduce overal loads from this source to 18 kg COD/d and 2 kg SS/d. Also, reus of the final rinse as the initial rinse of the next sequence woul reduce effluent flows by 5 m³/d.

Discharges from yeast recovery plant centrifuge cleaning wer difficult to arrange at the time of the waste audit and reductio investigations. However, from visual observations the initial rins clearly contained a significant quantity of yeast and so it was rec ommended that such wastes should also be passed to a yeast filte press. Similarly, recovery of the final rinse and reuse as a sub sequent initial rinse was proposed. It was also suggested that th initial rinses from yeast storage vessels should be filtered throug a yeast press. The brewery had already purchased a new yeas press to filter yeast liquors which at the time were stored unti press capacity became available. This proposal was expected t reduce storage requirements, allowing a small amount of bee recovery (press filtrate) and elimination of the frequent storag tank overflow.

Therefore, instead of treating each of the fermentation cell discharges separately which would be uneconomic, the audi team considered that the proposed filter-press installation for th yeast recovery area should be arranged to filter the initial rinse from fermentation tanks, storage vessels and yeast recover equipment. This would not only prevent the majority of yea from flowing to drain but would enable its recovery for resale t a food manufacturer. In addition, any other liquor containin yeast that had to be dumped to drain, such as the initial dro from the storage tanks when the yeast storage vessels were ful could be filtered and the yeast and beer recovered. The expecte increase in flow to the proposed filter press was estimated to b well within the unit's design capacity.

Treatment Cellar

A number of waste saving options were recommended for th area. The principal measures proposed related to the bottling an kegging areas. The possibilities of utilising the hot liquor tan overflow for the pasteuriser supply have already been highlighte in the brewhouse section above. The audit team felt that th water flowing out of the pasteuriser could be used as an initi rinse in the bottle washer.

The existing bottle washer system used 7 m³/h fresh deionise water. It was proposed that the final sparge pipes should continu

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Table 2
Summary of Existing and Proposed Reduced Waste Contributions

Unit Operation	Waste Description	Existing Composition			Recommendation	Predicted Composition		
		m³/d	kg COD/d	kg SS/d		m³/d	kg COD/d	kg SS/d
Lauter Tun	Final run to Drain	40	1000	35	Reuse	0	0	0
Hot Liquor Tank	Overflow	120	—	—	50% reuse as make-up for pasteuriser	60	0	0
Gauging Vessels	CIP wash	20	—	—	Reuse rinsewater	0	0	0
Fermenting Vessels	CIP wash	60	198	120	Reuse and yeast separation	40	50	30
Storage Tanks	CIP wash	15	60	8	Reuse of rinsewaters/pressing of initial rinse	10	18	2
Yeast Storage and recovery	CIP wash	2	15	1	Yeast recovery	2	2	0
Pasteuriser	Process water	75	—	—	Reuse in bottlewasher	0	0	0
Total		332	1273	164		112	70	32

to be supplied with deionised water but that the pasteuriser water be used to supply the remainder and also for continual replenishment of the water in the final rinse tank. Mains water would be provided as a standby supply in the event for any reason that the pasteuriser water ceased.

In the kegging area, dumping of returned beer to drain was occurring periodically giving a very significant rise in COD load during the dumping periods. It was indicated to the company that separate disposal, possibility directly to land, should be seriously considered as often adopted by other breweries.

nary

Table 2 shows the existing and proposed reduced effluent contributions for the unit operations highlighted.

The predicted reductions on the total effluent discharges were approximately 20% volume, 30% COD load and 15% SS load. This indicated a 25% reduction in trade effluent charges resulting from implementation of the flow/load reduction proposals. This corresponded to reduced average waste quantities per cubic metre of beer produced of 1.6 m³, 6.0 kg COD and 1.8 kg SS.

The audit team appreciated that in addition to savings in trade effluent charges, there would be other cost benefits which were difficult to quantify during the time-frame of the project but which included costs associated with raw water, energy and product.

PRETREATMENT PRIOR TO SEWER DISCHARGE

The strategy of reducing pollution at source reduced the design flows and loads on which to size and cost the effluent pretreatment facilities. Land for the pretreatment plant was limited and therefore only compact processes were investigated. The possible stages considered were:

- screening;
- balancing;
- pH control;
- settlement or flotation with and without chemical addition;
- anaerobic processes;
- aerobic processes including activated sludge, trickling filters and submerged biofilters;
- final settlement; and
- combinations of these.

Capital cost estimates were drawn up following outline design of each option. These were based upon budget price quotations from mechanical and electrical equipment manufacturers and suppliers. Civil engineering costs were estimated by applying ac tual rates for items currently being constructed as part o ASHACT projects; other items were estimated by taking of quantities for major items, including excavation, concrete, rein forcing steel and formwork and applying published rates.

An economic evaluation of the capital and operating costs c each alternative compared to savings in trade effluent charge including discounted cash flow analyses was undertaken. The op erating costs included allowances for chemicals, electricity, was water, steam, labour and maintenance.

The evaluation identified the best option for the brewery as a on-site pretreatment plant based on pH control, balancing an pure oxygen activated sludge treatment in order to reduce trad effluent charges payable to the water company. This process ha the additional attraction of reduced risk of developing filamen tous, poorly settling sludges compared with conventional air a tivated sludge systems treating brewery, or similar wastes, havir a high soluble carbohydrate content.

CONCLUSION

The results of the effluent audit and reduction studies we formally presented to the brewery's management in the form a technical report. The recommendations made were accept and plans were then made to implement the recommendatio It was recognised that some capital expenditure would be r quired to implement the proposed effluent reduction programr and that this aspect was best costed by their own engineeri staff. However, since the capital sums involved would be re tively small compared to the brewery's capital expenditu budget for the current year, and related to progressive impro ments in the brewery production operations, the brewery wo be likely to accept the effluent savings proposals on the basis the significantly reduced trade effluent charge savings alone.

ASHACT have subsequently carried out the detailed proc design for the pretreatment plant.

The audit had provided a sound understanding of all princi sources of effluent arising within the brewery. Furthermore, i brewery technologist assigned to assist the waste audit team b benefited greatly from being involved in the step-by-step a proach adopted by ASHACT. It was considered that the ex rience gained by the brewery would enable company staff to t the lead in any future waste audit programme, particularly assessment of the actual waste reductions achieved follow commissioning of the plant modifications and additions p posed.

ARAB BREWERY COMPANY PHOTOS

AUDIT REPORT
Brewery Industry
Jordan

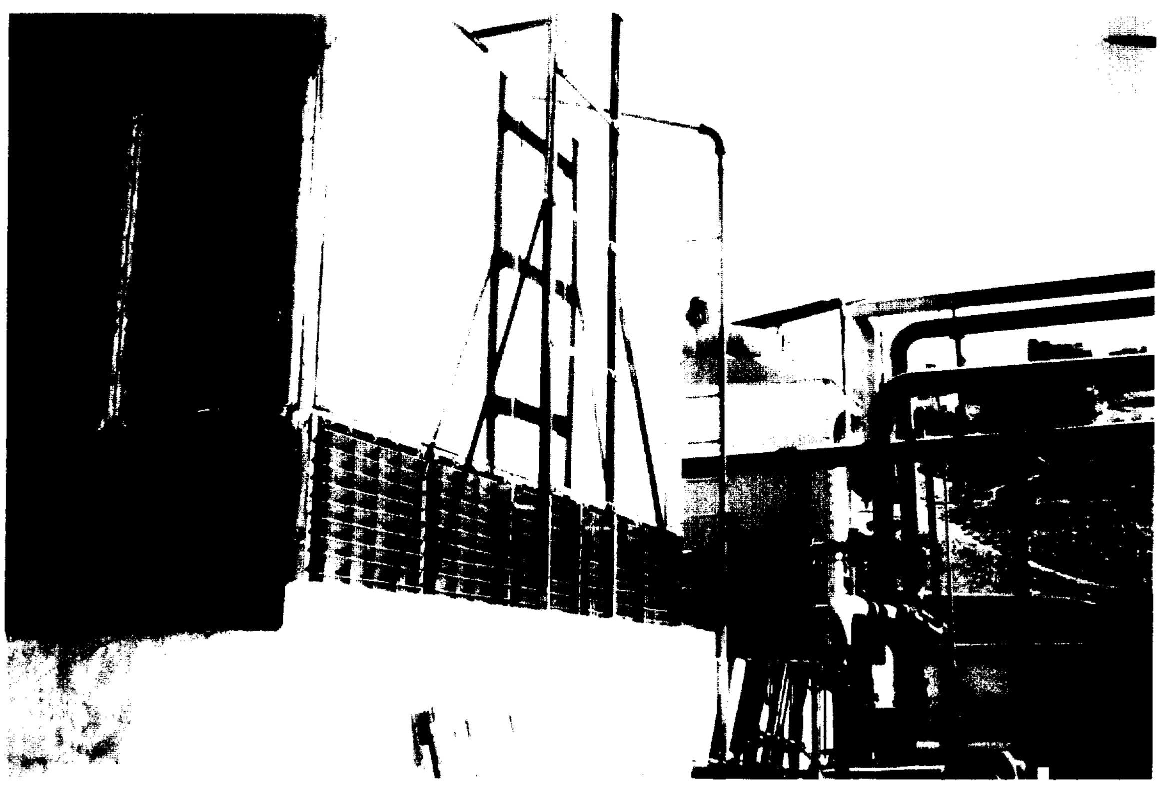
Fermentors

Brewhouse

ARAB BREWERY COMPANY PHOTOS

AUDIT REPORT
Brewery Industry
Jordan

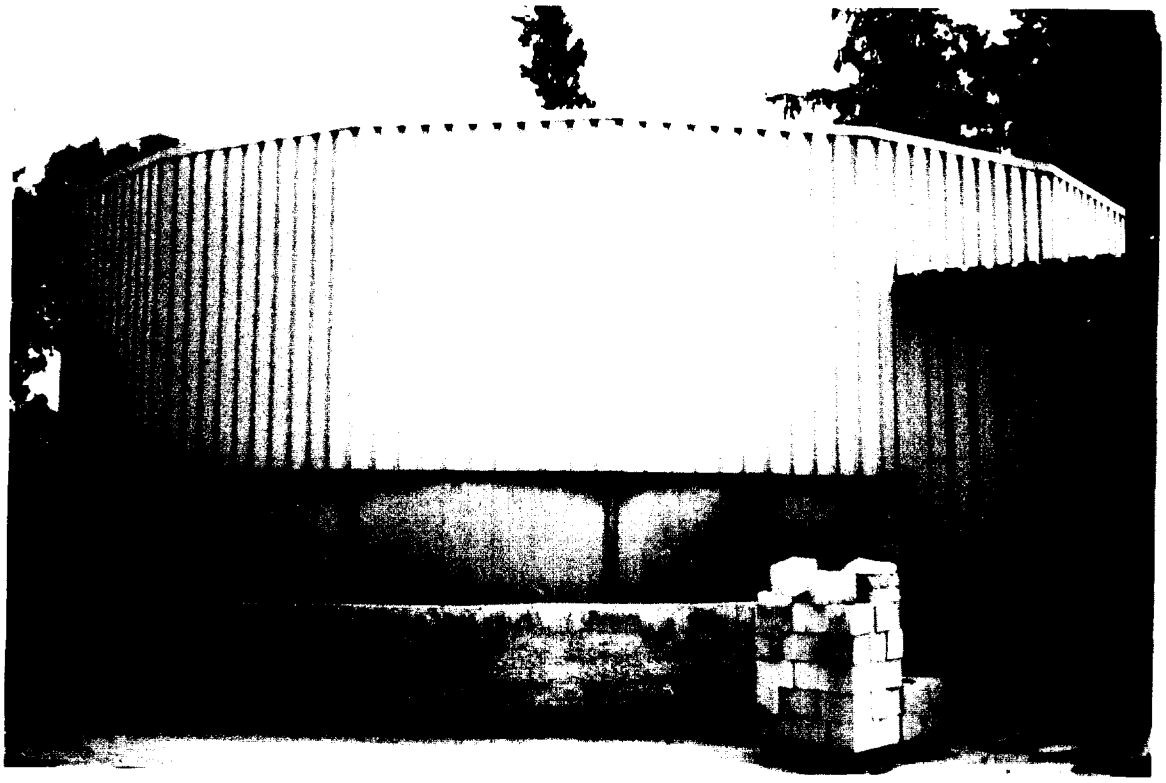
Bottle/Can Washing Operations



Cooling Towers

ARAB BREWERY COMPANY PHOTOS

AUDIT REPORT
Brewery Industry
Jordan



Wastewater Treatment Plant (not in use)