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Industrial Audit:

Vegetable Oil Refining Industry, Universal Modern Industries Co., Ltd.

Science Applications International Corp.

Development Alternatives, Inc.

USAID

The Technical Assistance Team Includes:

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

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VEGETABLE OIL REFINING INDUSTRY AUDIT REPORT JORDAN

Submitted to:

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Submitted by:

Development Alternatives, Inc.

Prepared for:

Amman Chamber of Industry, Jordan
Ministry of Water and Irrigation, Jordan

Prepared by:

Science Applications International Corp. (SAIC)
Falls Church, VA, USA
and
Harza Consulting Engineers and Scientists
Chicago, IL, USA

in association with:

Royal Scientific Society (RSS)
Amman, Jordan

PREFACE/ACKNOWLEDGMENTS

This report is the result of a 4-week study/audit/evaluation of the Universal Modern Industries Co., LTD's Vegetable Oil Refining Industry in 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. Waleed Hussein, 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 Eng. Fawzi G. Saman, Manager and Eng. Adul Azziz, Operation Section Head, shared their knowledge with Mrs. Mary Veal Walron., of Science Applications International Corporation (SAIC), Falls Church, Virginia, 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.

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EXECUTIVE SUMMARY

Under Contract No. 278-0288-00-C-4026-00 with the United States Agency for International Development (USAID), Development Alternatives, Inc. (DAI) is performing an Industrial Wastewater Discharge Prevention (IWDP) Program in Amman, Jordan. The IWDP Program is one of the four components of the Water Quality Improvement and Conservation (WQIC) project funded by USAID. The Program is being performed by DAI with full coordination between the Jordanian Ministry of Water and Irrigation (MWI) and the Amman Chamber of Industry (Chamber). Harza Consulting Engineers and Scientists (Harza), Chicago, Illinois, USA, and Science Applications International Corporation (SAIC), Falls Church, Virginia, USA, have been retained as the subcontractors to lead the audits. The Royal Scientific Society (RSS) of Jordan was selected as the local consultant to assist the lead consultants in the audit site visits and report preparation.

This program includes conducting the Pollution Prevention/Wast Minimization (PP/WM) audits, Feasibility Studies (FS), and design demonstration units at selected industrial facilities. Based on a ranking methodology, the PP/WM Committee selected ten industries with potential needs for PP/WM audits. One of these industries is the vegetable oil refining industry. The SAIC/RSS team conducted an audit of the Universal Modern Industries Company, Limited (UMIC), representing the vegetable oil refining industry, as the first step of the IWDP Program. This report summarizes the results of the audit.

AUDIT

The facility audit was conducted on January 7 and 14, 1995. The UMIC Manager and Head of the Operation Section and the audit team toured and inspected the facility. A follow-up visit was conducted on January 14, 1995 to collect additional information and to collect wastewater samples.

AUDIT FINDINGS

The findings presented below on water use and waste disposal practices at the UMIC facility are based on information collected during the facility audit through interviews and discussions with UMIC employees, observations made during the site visit, and data provided by UMIC both before and after the site visit.

Vegetable Oil Refining Processes at UMIC

The UMIC facility refines four oils: refined, bleached, and deodorized (RBD) palm oil, RBD palmoline, semi-degummed corn oil and semi-degummed soya oil. The current production rate is 170 to 180 tons per day (T/day). The UMIC facility operates two different types of refining processes, chemical refining and physical refining. Process operations consists of:

- Crude oil transfer to storage tanks;
- Chemical refining operations: degumming and neutralization, bleaching, and

deodorization;
- Physical refining by steam stripping;
- Cooling and filtering; and
- Packaging.

Additionally, the UMIC facility operates two separate cooling water systems, a central steam boiler system, and a water softener unit.

Water Usage and Balance

The UMIC facility receives its water from the Zarqa Free Zone groundwater wells. Most, approximately 72 percent, of the water the facility uses is first treated using an ion-exchange unit. The four largest consumptions of water at the facility are for:

- Steam for refining and producing vacuum, and cooling water for the barometric condensers, 41 m^3/day;
- Washing the oil in the neutralization operation, 24 m^3/day;
- Boiler blowdown, 20 m^3/day; and
- Cooling the heat exchangers, 20 m^3/day.

Other water uses that total approximately 42 m^3/day include floor and equipment cleaning, live and closed-loop steam heating, laboratory tests, chemical solutions, spill clean-up, and sanitary.

The UMIC facility uses approximately 147 m^3/day of groundwater, most of which is treated with a water softener before being used for steam generation, process washwater, and cooling purposes. In general, water use at the facility is not excessive (1.2 m^3/T of refined oil); however, opportunities for conservation do exist.

With the addition of the physical refining operation, the quantity of cooling water has increased. This is overloading the cooling tower so that the facility is removing the cooling water and refilling the cooling system with fresh water. The daily average blowdown is estimated at 4.2 m^3/day, but may be much higher since the facility hauls in fresh water and hauls away the contaminated cooling water. The frequency of hauling, the number of tanker trucks, or the quantity hauled is unknown.

Wastewater Discharges

The major wastewaters generated at the facility are:

- Neutralization washwater, 24 m^3/day;
- Boiler blowdown, 20 m^3/day;
- Floor and equipment washwater, 10 m^3/day;
- Steam condensate from tanker truck heating, 8.4 m^3/day; and
- [redacted]

barometric condenser and heat exchanger cooling towers, spill clean-up, and sanitary. Typical pollutant parameters include: fats, oil, and grease (FOG), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS), and total dissolved solids (TDS).

Steam losses to the air occur through leaky flanges, valves, and pipes. Steam condensate and cooling water leaks from equipment collect on the floors. Frequent spills occur in the following areas:

- Tanker truck unloading;
- Caustic soda solution mixing; and
- Filling area from the filling machines and leaking containers.

Treatment

The wastewater treatment system consists of acidification, oil/water gravity separation, neutralization, aeration, coagulation, clarification, and evaporation. No flow monitoring has been performed. Except for the acidification treatment unit, the treatment system is not being operated. Upon start-up of the system, operational difficulties were encountered and the system is being repaired.

Air Emissions

There were no significant air emissions identified. Leaks in steam pipes contribute water vapor and small amounts of fatty acid components. The manual loading of powdered chemicals (e.g., sodium hydroxide and bleaching earth) produce brief localized areas of particulates.

Solid Wastes

The two major solid wastes generated at the facility are soapstock and spent bleaching clay. The soapstock is sold to a saponification plant (soap factory). The spent bleaching clay is sent to another facility that burns it.

Storm Water Management

Solid and drummed liquid raw materials, products, and wastes are stored throughout the UMIC facility. While some containment measures exist, many of the containers are stored on bare ground. Leaks and spills due to loading and unloading tanker trucks create oil-contaminated ground. During storm events, spills from vegetable oil storage tanks and fuel tanks could be discharged to the wadi. While this is an infrequent occurrence, it results in the discharge of untreated wastewater to the wadi.

Data Gaps

Data gaps exist in water quality and water quantity measurements. No water or wastewater metering devices exist to provide accurate measurements of the quantity of water consumed

or the wastewater generated by the individual process operations. The facility's total water consumption is measured by a main water meter; however, the facility also hauls water to the facility. The quantity of wastewater generated is unknown; wastewater is hauled off site for disposal. This wastewater has been sampled in the past by WAJ.

PP/WM AND WATER CONSERVATION OPPORTUNITIES

The UMIC facility already practices some PP/WM and water conservation practices such as recirculating the cooling water. Additional opportunities identified during the audit are summarized below. Some actions that the facility should initiate immediately are:

- PP/WM and Water Conservation Policy - Establish a PP/WM and water conservation policy as part of the JISICO management operating philosophy and distribute it to all employees. Implement the policy through specific goals and targets. Make it each person's responsibility to identify PP/WM and water conservation opportunities and implement any established PP/WM and water conservation measures.

- Monitoring Program - Develop and implement a plan to monitor all water uses and wastewater flows by installing flow measuring devices. All flows should be recorded daily for a period of 12 months. Develop and implement a plan to sample wastewaters at least once a month for a period of 12 months. Establish sample collection procedures.

- Employee Training - Develop and implement an employee training program that includes periodic refresher courses regarding the JISICO facility's PP/WM and water conservation policies and procedures and proper training in the use of new equipment or practices. Staff should also have the opportunity to provide input regarding additional PP/WM or water conservation activities and should be provided with incentives for program successes.

- Water Balance and Reduction Goals - Create an overall plant water balance that identifies all uses and routes of disposal and then establish a plan to reduce water use by specific amounts in each segment of production.

- Preventative and Corrective Maintenance Program - Develop and implement a preventative and corrective maintenance program for equipment, pipes, and structures.

PP/WM Opportunities

The PP/WM techniques that the facility could implement immediately are listed below.

- Operation of the Wastewater Treatment System - The wastewater treatment system should be fully evaluated to assess influent and effluent flows and treatment efficiency. In particular, monitoring of the hydraulic and organic loading to each of

treatment system should be conducted. This assessment should also evaluate the need to segregate and separately treat process wastewaters.

Other PP/WM techniques that should be investigated for feasibility studies and possible short- and long-term implementation are listed below:

- Softener Regeneration - Instead of sodium chloride, use a regeneration chemical that is less harmful to the environment, such as acetic acid and ammonium hydroxide. This chemical substitution would reduce the high concentrations of sodium and chloride salts in the wastewater.

- Wastewater Treatment System Design Modifications - Investigate design modifications, including replacement of existing equipment, and additional treatment that will enable recycle or reuse of treated wastewater.

- Crude Oil Quality Control - Investigate the cost/benefit of obtaining a higher quality crude oil to reduce water consumption during refining and wastewater generated. Work with suppliers, shippers, and transport companies to establish standard shipping and transport practices that would reduce the time in-shipment and storage, the number of transfers that occur, and the oxidation that occurs during shipment and storage.

Water Conservation Opportunities

The water conservation opportunities are summarized below. Table EX-1 provides potential techniques and the estimated savings for water conservation. As much as 73 to 97 m^3/day water savings could result from the implementation of these techniques.

Those techniques which the facility could implement immediately are:

- Cooling Tower Optimization - Assess design or operational modifications for the current cooling tower or explore new cooling tower designs to minimize the evaporative losses and increase the concentration cycle.

- Boiler Blowdown Reuse - Reuse boiler blowdown as floor washing and spill clean-up water.

- Steam Leak Prevention and Control - Implement a more rigorous preventative maintenance program to prevent leaks and a rapid response repair program to fix the leaks as soon as they occur.

- Good Housekeeping - Develop and implement floor cleaning and spill cleaning procedures that focus on water conservation.

- Domestic Waste Treatment - Reduce domestic water use by employee awareness and installation of water conservation equipment.

- Barometric Condenser and Steam Vacuum Optimization - Evaluate the current process operational procedures to optimize reductions in steam and cooling water. More process control instrumentation, more accurate instrumentation, or faster feedback could enable greater process control that would minimize water losses or decrease water usage.

The following techniques require further investigation for feasibility studies and possible short- and long-term implementation:

- Centrifuge Optimization - The centrifuge operation could be optimized to avoid build up of soapstock within the centrifuge to eliminate cleaning of the centrifuges every 48 hours.

- Wastewater Reuse - Investigate reuse of the following wastewaters:

  - Neutralization Washwater - Investigate the feasibility of the options for reducing the generation of wastewater and reuse of washwater from the second and third centrifuges in the neutralization operation, as identified in this report.

  - Softener Regeneration Wastewater - Treat the wastewater, using reverse osmosis, and reuse.

  - Barometric Condenser Cooling Water - Treat the cooling water, to recover fatty acid material, and reuse as cooling water.

  - Live Steam - Reuse the condesate resulting from the live steam heating of the tanker trucks as washwater in the neutralization operation.

- Live Steam Heating Elimination - Eliminate use of live steam for heating by using a closed-loop heating coil or a system such as the Dow-Therm closed-loop system.

- Softener System Upgrade - Continue with plans to install a larger capacity softener unit. A unit that is optimally sized for the facility's operations will reduce the frequency of regeneration. Use a newer state-of-the-art ion-exchange resin system that is regenerated with less solution and, therefore, generates a smaller volume, more concentrated wastewater.

- Water Cooling System Elimination - Investigate the use of a non-water cooling system for the heat exchangers.

- Process Equipment Design Modification - Explore design modification to the process units, the barometric condensers, and the steam vacuum system that would decrease the overall water quantity (cooling water and steam).

Storm Water and Solid Waste

Develop and implement practices to minimize storm water run-on and run-off and maximize recycling solid wastes.

E.

Table E-1 - Potential Water Savings

UMIC

Production Operation	Water Conservation Technique	Current Water Consumption (m^3/day)	Projected Water Consumption (m^3/day)	Projected Water Savings (m^3/day)	Percent Decrease in Total Water Consumption
Clean cooling tower	1. Closed-loop air radiator cooling system	20	0.0	20	13.6
Chemical refining	2.a. Treat and reuse all washwater	25.35	5	20.35	13.8
	2.b. Treat second centrifuge washwater and reuse in third centrifuge	14	6	8	5.4
	2.c. Reuse third centrifuge washwater in second centrifuge	25.35	20.35	5	3.4
Boiler	3. Boiler blowdown reuse after treatment	21.1	4.2	16.9	11.5
Process Equipment	4. Modify design or optimize operations	120	108	12	8.0
Tanker Truck	5. Capture and reuse live steam or eliminate live steam heating of tanker trucks	8.4	0.0	8.4	5.7
Floor washing	6. Reuse the boiler blowdown without treatment	5	0.0	5.0	3.4
Cooling tower	7. Optimize to decrease evaporative losses and increase concentration cycle	47.7	43.0	4.7	3.2
Softener	8. Reuse treated regeneration wastewater	6	2	4	2.6
Cooling tower	9. Treat bleed-off and reuse	4.2	0.2	4.0	2.6
Softener	10. Increase capacity	6	4	2	1.3

Mainte-nance and sanitary	11. Use dry cleaning methods and install water conservation devices	10	8	2	1.4
Acidifi-cation	12. Eliminate live steam heating	1.4	0.0	1.4	1.0
Spill	13. Improve spill control and clean-up	4	3	1	0.7
Centrifuge and filter	14. Treat and reuse washwater	1.0	0.0	1.0	0.7
Steam System	15. Reduce steam leaks	1.0	0.5	0.5	0.35
Centrifuge	16. Optimize to reduce cleaning frequency	1.0	0.7	0.3	0.2
Total Savings	-	-	50 - 73	73 - 97	49 - 66

1.0

INTRODUCTION

1.0 INTRODUCTION

This report presents the findings of an audit conducted to evaluate the Pollution Prevention and Waste Minimization (PP/WM) and water conservation opportunities for the Universal Modern Industries Company, Limited (UMIC) facility located in the Zarqa Basin near Amman, Jordan. The report includes a project background and objectives, provides documentation of the on-site evaluation of the facility's current operations, discusses water use and disposal practices, and provides recommendations for PP/WM opportunities. Additional information including industry background, audit procedures, and an overview of the facility's operations, are provided to support the audit findings and recommendations.

1.1 Background

Under Contract No. 278-0288-00-C-4026-00 with the United States Agency for International Development (USAID), Development Alternatives, Inc. (DAI) is performing an Industrial Wastewater Discharge Prevention (IWDP) Program in Amman, Jordan. The IWDP Program is one of the four components of the Water Quality Improvement and Conservation (WQIC) project funded by USAID. The Program is being performed by DAI with full coordination between the Jordanian Ministry of Water and Irrigation (MWI) and the Amman Chamber of Industry (Chamber).

The IWDP will be performed in three phases. The first phase requires completion of ten PP/WM audits by DAI and its sub-contractors. The second phase requires completion of Feasibility Studies (FS) for four of the audited facilities. Finally, demonstration projects will be completed for two selected FS facilities. Based on a ranking methodology, the PP/WM Committee selected ten industries with potential needs for PP/WM audits. One of these industries is the vegetable oil refining industry.

Harza Consulting Engineers and Scientists (Harza), Chicago, Illinois, USA, and Science Applications International Corporation (SAIC), Falls Church, Virginia, USA, have been retained as the sub-contractors to lead the audits. The Royal Scientific Society (RSS) of Jordan was selected as the local consultant to assist the lead consultants in the audit site visits and report development. The SAIC/RSS team conducted an audit of UMIC as the first step of the IWDP. This report summarizes the results of the audit.

Due to the scarcity of water in the Zarqa Basin, as well as the need to minimize the release of pollutants into waters of the basin, it is in the best interest of industries to conserve water and implement effective PP/WM practices. Companies practicing PP/WM and water conservation programs will more efficiently utilize scarce resources and minimize their impact on these resources. The hierarchy of PP/WM and water conservation practices includes:

1. Reduce waste generation

   - Substitution of less polluting raw materials in product manufacture;

- Alteration of products manufactured to eliminate need for use of polluting materials;
- Replacement or upgrading of outdated or inefficient process equipment; and
- Development of employee training programs to ensure employees can efficiently manage raw materials and resources.

2. Reuse waste materials prior to disposal

   - Reuse of uncontaminated raw materials and resources (including water);
   - Reprocessing of previously discarded materials (e.g., off-spec materials, used materials); and
   - On-site recovery of reusable materials (e.g., used solvents, waste heat, scrap).

3. Recycle waste materials.

4. Treat wastes and dispose of residues.

The PP/WM audits performed during this program will identify and evaluate available PP/WM and water conservation opportunities and will provide site specific recommendations to assist the study industry in developing a comprehensive water conservation and PP/WM strategy.

1.2 Objectives

The facility PP/WM audits are designed to assess potential opportunities for PP/WM and water conservation that may exist at the study facilities. The goal of each audit is to identify and evaluate all possible PP/WM, wastewater clean-up, and water conservation techniques that are appropriate for the study facility.

The specific objectives of this audit are as follow:

1. Review general industry background data and identify "state-of-the-art" wastewater management and processing practices.

2. Work on site with industry representatives, the MWI and the Chamber officials, and other interested parties, to review current processing procedures and identify possible options for PP/WM and water conservation.

3. Prepare a report that evaluates possible PP/WM and water conservation alternatives and provides recommendations and follow-up actions to the industry.

In order to complete the first objective, a comprehensive literature review was performed by the lead consultant. Following completion of the literature review, an on-site audit of the UMIC facility was performed. The audit was performed with close consultation of industry representatives to ensure that they were aware of and supported proposed actions. Audit activities included the careful gathering of baseline water use and waste generation data, identification and assessment of potential PP/WM and water conservation options, and

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solicitation of ideas and proposals from management and production line staff.

1.3 Report Contents

This report provides the findings of the audit conducted at the UMIC facility on January 7 and 14, 1995. The report provides recommendations for the development of a site-specific program that meets the specific needs and goals of the UMIC facility. Audit recommendations include both PP/WM techniques (e.g., water conservation techniques, housekeeping practices, alternate waste disposal practices, etc.) and suggestions for PP/WM training for facility staff and studies to assess program successes.

The report is organized into eight sections that provide a brief description of UMIC's vegetable oil refining operations (Section 2.0), a description of the audit procedures (Section 3.0), a description of the water use practices and wastes generation activities at the facility (Section 4.0), a discussion of possible PP/WM opportunities (Section 5.0), a discussion of the water conservation opportunities at the facility (Section 6.0), the audit conclusions and recommendations (Section 7.0), and the suggested follow-up actions (Section 8.0).

Several appendices are also included in the report to provide supporting documentation and reference materials. The appendices include a copy of the audit questionnaire (Appendix A), information provided by the UMIC facility (Appendix B), an overview of regulations applicable to the discharge from UMIC (Appendix C), site visit photographs (Appendix D), references used to prepare the audit report (Appendix E), and the PP/WM Background Report (Appendix F).

2.0
PROCESS OVERVIEW

2.0 PROCESS OVERVIEW

Edible vegetable oils are derived from the seeds of such plants as soybean, corn, and palms. First, crude oil is manufactured by an extraction process. The oils are extracted from the seeds by mechanical or hydraulic pressing or solvent extraction. The crude oil must then be refined to make the oil acceptable for edible purposes. The refining process removes undesirable taste and odor producing components such as free fatty acids (FFA), phosphatides, and unsaponifiable components such as sterols and tocopherols; undesirable coloring pigments such as carotenoids and chlorophyll; and metals such as copper and iron. Typical refining operations consists of: degumming, deacidification (or neutralization), bleaching, hydrogenation, winterization, and deodorization. Further details on these refining operations are provided in the background material in Appendix F.

2.1 Vegetable Oil Refining in Jordan

There are eight vegetable oil refining facilities in Jordan. The Universal Modern Industries Company, Ltd. (UMIC) facility is the oldest. UMIC was established in 1982 and the facility began production in 1986. With the addition of the physical refining process in late December 1994, the facility's production capacity has increased to 200 tons per day (T/day). It operates 24 hours per day (hrs/day), six days a week, with a current production rate of 170 to 180 T/day. The number of employees is 140. The facility refines 4 types of oils: palmoline, palm oil, corn oil, and soya oil to produce numerous vegetable oil products packaged and labeled for many customers. About 40 percent of the product is for the local market and 60 percent for export.

2.2 Process Operations at the Universal Modern Industries Co., Ltd. Facility

Described below is each sequential process operation performed in the facility to refine crude oil.

2.2.1 Crude Oil Transfer and Storage

The crude oils are imported from various countries. For example, refined, bleached, and deodorized (RBD) palm oil and palmoline are imported from Malaysia. Pretreated (semi-degummed) crude corn oil and soya oil are imported from the United States, Turkey, and other countries. The crude oil is transported from the crude oil factories to storage tanks at the shipping ports, then onto ships, then from the ships to storage tanks at Aqaba. From the storage tanks at Aqaba, the oils are transported to the UMIC facility by tanker trucks of approximately 50 cubic meters (m^3) capacity. At least 4 tanker trucks arrive each day. The crude oils are pumped from the tanker trucks to heated storage tanks. Corn oil arrives and stays in a liquid state, regardless of temperatures. In the winter, the temperatures require soya oil to be heated to prevent winterization (a separation of the oil) during storage. If palm oil and palmoline arrive in the solid state, live steam is injected into the tanker to heat the oil. The liquid oil is pumped to the storage tanks and the water is transferred to the wastewater collection tank.

There are 6 storage tanks, three with a capacity of 750 m^3 each, one with a capacity of 1,400 m^3, and two with a capacity of 2,000 m^3 each for a total storage capacity of 7,650 m^3. Each storage tank is designated for a specific type of crude oil so there is no mixing of crude palm oil with crude corn oil. The crude oils in the tanks are kept warm by closed-loop low pressure (3 bars) steam coils in the bottom of the tanks.

Due to the number of transfers that occur during shipping from the crude oil refineries in other countries to the UMIC facility, the crude oil comes into contact with oxygen. During extended periods of storage hydrolysis occurs and the FFA concentration increases. To prevent hydrolysis, storage time at the UMIC facility is reduced by practicing the "first in, first out" method. Once a storage tank is filled, the crude oil is processed until the storage tank is empty. No new shipments of crude oil is pumped into that storage tank until it is empty.

2.2.2 Chemical Refining

At the UMIC facility, two different refining processes, chemical refining and physical refining, are conducted. The process operations of chemical refining are described in this section and the process operations of physical refining are described in Section 2.2.3 below.

Corn oil and soya oil are refined by the chemical refining process. Process operations include degumming and neutralization, bleaching, and deodorization and are described below. Figure 1, Chemical Refining Water and Process Flow Diagram, provides a flow diagram of the sequence of these process operations.

Degumming and Neutralization

At the UMIC facility, degumming and neutralization are practiced in one step. These

55 percent total fatty matter and 35 - 40 percent moisture).

The crude oil and caustic soda (and phosphoric acid) mixture is centrifuged to separate the oil and the soapstock. The soapstock is discharged from the first centrifuge and falls by gravity through a vertical pipe to large polypropylene bags or drums. This soapstock is sold to a saponification plant (soap factory).

Second and Third Centrifuges - The oil is heated by a closed-loop steam heating coil. Water is added to the oil in-line and mixed. The water removes the soapstock that remains from the first centrifuge operation. The oil/water mixture is separated by a second centrifuge. The wastewater from the second centrifuge is pumped to a collection tank and then pumped with the wastewater from the third centrifuge to a 760 m^3 capacity storage tank.

The oil is again heated, water added in-line and the oil and water mixed as previously described. This oil/water mixture is pumped to a third centrifuge for separation of the oil and water. The wastewater from the third centrifuge is pumped to a collection tank where it is mixed with the wastewater from the second centrifuge and is then pumped to the 760 m^3 capacity tank.

Dryer - The oil from the third centrifuge is sent to a dryer to remove water. The dryer is a cylindrical vessel under vacuum. The oil is sprayed into the vessel where, under vacuum, water vapor is removed.

Barometric Condenser - The steam is condensed by cooling water in a 2-stage barometric condenser. Both the steam condensate and the cooling water, containing small quantities of free fatty acids, are returned to an outdoor pit, called the chemical refining hot well. From this hot well, the water is pumped to the physical refining hot well and then to an induced draft evaporative cooling tower. The cooled water from the cooling tower is reused by recycling back into the condensers. No make-up water is needed for the cooling tower. Usually, there is a balance between the quantity of water condensed from the oil and the quantity of water evaporated from the cooling tower. Sometimes there is more water condensed than evaporated; this occasional wastewater (4.2 m^3/day) is discharged to the wastewater collection tank for subsequent treatment or is pumped into trucks for disposal. This blowdown or bleed-off is necessary to prevent buildup of free fatty acids and total dissolved solids (TDS) in the cooling water.

Bleaching

After the phosphatides and free fatty acids are removed in the degumming and neutralization operation, color-producing compounds in the oil are removed in the bleaching operation. This operation is described below.

Bleacher - The oil is transferred from the dryer to an intermediate storage tank and then pumped to bleacher. The bleacher is a closed tank under vacuum. This

vacuum is generated by a vacuum pump. Bleaching earth (clay) is added to the tank and the oil and clay are mixed using a ribbon blender in this tank. The temperature of the mixture is increased to 90 to 95 degrees Celsius (°C) by steam heating coil in the bottom of the tank. Both oil and clay are being continuously added to the tank and as the mixture level rises, the mixture overflows through a line to the filters.

Filters - There are two filters that operate alternately. The oil is strained through perforated elements under 4-5 kilograms per square centimeter (kg/cm^2) of pressure with the clay remaining on the elements. As a layer of clay forms on the filter elements, the pressure changes. At a specified pressure or time interval, the flow of oil to the filter is stopped; the oil is pumped to the other filter.

Steam is injected into the filter to remove the oil in the clay layer that has accumulated on the filter elements. The steam/oil mixture is collected in an open tank where the steam escapes and the oil (1 to 1.5 m^3 per filter cycle) is recovered. From this tank the oil is pumped into the oil line prior to the first centrifuge.

Air is then passed through the filter to dry the clay layer. Then a vibrator shakes the filter elements and the clay cake falls off the elements and is transported by screw conveyor to containers for disposal.

Deodorization

The degummed, deacidified, and bleached oil contains short chain fatty matter and volatiles, such as ketones and aldehydes, that produce undesirable odors. These odor-causing molecules are removed in the deodorizer. The deodorization operation is described below.

Deodorizer - The filtered oil is pumped into a deodorizer. The deodorizer is a sealed vessel containing four trays under vacuum. The oil enters the fourth tray through a pipe where it is heated. The oil is then pumped to the first tray at the top. The first tray is equipped with a thermal oil coil that heats the oil to 200°C. Stripping steam is injected into the oil through a perforated pipe located in the bottom of the tray. As the steam rises through the oil, the short chain fatty matter, ketones and aldehydes, are transferred from the oil to the steam. The oil is pumped to the cooling operation. The steam is drawn off at the top of the vessel and sent to the primary condenser.

Primary Condenser - In the primary condenser, oil and fatty acids are condensed. This condensate is collected and sent to the soap plant.

Barometric Condenser - The steam is next condensed in a three-stage barometric condenser. The condensates and the cooling water from each of the three stages flow by gravity to an open pit outdoors, called the chemical refining hot well.

Evaporative Cooling Tower - From the chemical refining hot well, the oil/water emulsion is pumped into the physical refining hot well and then into an evaporative cooling tower. The cooled water from the cooling tower is reused to cool the condensers.

Cooling - The oil is cooled using a shell-and-tube heat exchanger. Non-contact cooling water is circulated around a tube containing the oil. The non-contact cooling water is continuously recirculated through a cooling tower, referred to as the "clean cooling tower".

Filtering - The oil receives a final filtering by one of two cloth filters, operated in parallel. Antioxidants and preservatives such as citric acid, benzoic acid, sodium benzoate, butylhydroxyanisol (BHA) or butylhydroxytulol (BHT) are added after filtering before being pumped to the final product storage tanks and the filling operation.

2.2.3 Physical Refining

Palmoline and palm oil are refined by the physical refining process, which began operation in late December, 1994. As previously mentioned, the facility receives oil from Malaysia that has already been refined, bleached, and deodorized. However, because of the contamination and degradation that occurs during storage and shipping, the oil must be refined again. Figure 2, Physical Refining Water and Process Flow Diagram, provides a flow diagram of the physical refining process operations. The refining operations are accomplished in one unit, referred to as the steam stripper. The physically refined oil and the chemically refined oil share the same lines and machines for crude oil transfer and storage and final product storage and filling.

Steam Stripper - The physical refining process uses steam stripping to deacidify (remove the free fatty acids), bleach, and deodorize the crude oil all in one operation. At the higher temperatures used in physical refining, the redish carotenoids are converted into colorless alpha and beta carotenes; thus rendered colorless without the use of bleaching earth.

The RBD palm oil or palmoline is pumped from the crude oil storage tank to a receiving tank and then to the steam stripper. This closed cylinder, containing 6 trays, is under vacuum. The vacuum is produced by steam. The tank was originally designed to be operated in a semi-continuous mode, but has been modified to operate in a continuous mode.

The tank contains 6 trays through which the oil flows from the top tray successively through each tray to the bottom tray.

Before pumped to the first tray at the top, the crude oil is preheated in the sixth tray. The crude oil enters the sixth tray through a heat exchanger. The heat from the refined oil in the sixth tray (at 230°C) raises the temperature of the incoming crude oil at 80°C to 150°C. This preheated crude oil is then pumped to the first tray where

a steam heating coil in the tray maintains the temperature of the oil at 150°C. Steam is injected into the oil from a perforated pipe in the bottom of the tray. The oil overflows through a pipe to the second tray. In the second tray, the oil is heated by a DowTherm heating coil to 240°C. The fluid in the heating coils is diphenyl and diphenyl oxide that is heated by a boiler in a closed-loop system.

The oil successively overflows into the third, fourth, fifth and sixth tray where live steam is injected into the oil from a perforated pipes in the bottom of the trays. The oil temperature decreases in each tray: 235°C in the third tray, 230°C in the fourth tray, 230°C in the fifth tray and 170°C in the sixth tray.

The vacuum continuously removes the vapors being formed. These vapors are condensed in the condensers and the oil is cooled and filtered as described below.

Primary Condenser - Fatty acids are removed in the primary condenser. The fatty acid wastestream is collected and sold to a saponification plant.

Secondary Condenser - Additional fatty acids are removed in the secondary condenser. The fatty acid wastestream is combined with the fatty acid wastestream from the primary condenser and sold to a saponification plant.

Barometric Condenser - Steam and light volatiles (short chain fatty acids) enter a 3-stage barometric condenser. The condensate and cooling water from each of the three stages flows by gravity through three individual pipes to the hot well. The water in the hot well is pumped to the cooling tower to be cooled and reused for cooling the condensers.

Evaporative Cooling Tower - The hot well is divided into seven pits of different sizes and configurations. Fatty acid deposits that form in the condensers float on the surface of the water and are removed by manually skimming them over the side wall into a soapstock collection pit. The water flows through a series of six pits before being discharged to an evaporative cooling tower.

Cooling - The oil is cooled by a shell-and-tube heat exchanger using non-contact cooling water. The non-contact cooling water is continuously recirculated to the clean cooling tower.

Filtering - The oil receives a final filtering by a series of two cloth filters before being pumped to the final product storage tanks and the filling operation. Antioxidants and preservatives such as citric acid, benzoic acid, sodium benzoate, butylhydroxyanisol (BHA) or butylhydroxytulol (BHT) are added after filtering.

2.2.4 Process Control Tests

Process control tests are performed on the oil throughout the refining process beginning with the crude oil when it is received, after each process operation and the final product. These tests determine the FFA content, phosphatides, moisture, peroxide, melting point,

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rancidity, and color. Adjustments are made to the caustic soda concentration and quantity and bleaching earth quantities if the tests indicate concentrations of undesirable components are exceeding final product specifications.

2.2.5 Filling

As described previously, the refined oil from the steam stripper or the deodorizer is cooled and filtered and is then pumped to the final storage tanks for the filling operation. The filling operation is described below.

Storage Tanks - The oil from the deodorizer in the chemical refining operation and the oil from the steam stripper in the physical refining operation are pumped to storage tanks located outdoors next to the packaging building. There are 12 tanks each with a capacity of 50 m^3. Each tank is designated for a specific type of refined oil. The oil is kept cool in these tanks by a heat exchanger.

Packaging Tanks - The oil is pumped from the outdoor storage tank to a packaging tank inside the packaging building. Additives such as aromas and food grade coloring agents (meta-carotenoid) are added to the oil in these tanks. There are four of these packaging tanks, each designated for a specific type of refined oil. These packaging tanks allow the oil to flow by gravity to the filling tanks. These packaging tanks are cleaned periodically to remove any impurities that settle to the bottom of the tanks. Cleaning is done by manually wiping the tanks; no water is used.

Filling Tanks - The oil flows by gravity from the packaging tanks to the filling tanks located above each of the filling machines. An emusifying agent is added in the production of margarine.

Filling Machines - There are several filling machines, each designated for a specific type of oil and size of container.

3.0
AUDIT PROCESS

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3.0 AUDIT PROCESS

The objective of the audit was to identify the potential for PP/WM, water conservation, and wastewater cleanup for the vegetable oil refining industry. The following subtasks were undertaken to complete the audit:

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

This section briefly describes the activities conducted under each of these subtasks.

3.1 Audit Coordination

The audit was coordinated through the Chamber and the MWI. The Chamber informed the UMIC facility about the intent and schedule of the audit prior to the site visit. An audit questionnaire, specifically developed for this PP/WM project (Appendix A), was included with the request. The UMIC staff were requested to complete the questionnaire prior to the audit. The UMIC staff were also requested to furnish an overall water flow balance, process flow diagram and description, and facility layout. This information, where available, was furnished to the audit team prior to the site visit to the facility. Copies of these materials are included in the Appendix B of this report.

3.2 PP/WM Background Material Preparation

In order to review general industry background data and identify " state-of-the-art " processing and waste management practices pertinent to PP/WM, a comprehensive literature review was performed. The review included searches of the U.S. EPA Pollution Prevention Information Clearinghouse (PPIC) repository, on-line library catalogue databases, review of PP/WM bibliographical references, and personal contacts with pollution prevention specialists. A copy of the background report is provided in Appendix F.

3.3 Pre-Inspection Meeting

The UMIC facility audit including the pre-inspection meeting, was conducted on January 7, 1995. The initial audit team consisted of the following personnel:

Ms. Rania Abdel Khaleq	Ministry of Water & Irrigation
Mr. Waleed Hussein	Water Authority of Jordan
Dr. Shawn Niaki	Program Director, DAI (Harza)
Mrs. Mary Waldron	Lead American Consultant (SAIC)
Dr. Omar Jabay	Local Consultant (RSS)
Dr. Riyad Musa	Local Consultant (RSS)

The representatives for the UMIC facility included:

Eng. Fawzi G. Saman	Manager, UMIC
Eng. Adul Azziz	Head, Operation Section, UMIC

The intent of this meeting was to inform the UMIC facility staff about the conduct and the objective of the audit, and to familiarize the audit team with UMIC's process as it related to the fresh water utilization, wastewater generation, treatment and disposal, water recycle and reuse and the overall water management at the facility. The audit team explained the purpose of the audit to the UMIC facility staff.

3.4 Audit

The facility audit was conducted on January 7 and 14, 1995. The UMIC Manager and Head of the Operation Section and the audit team toured and inspected the facility. Upon completion of the facility tour, the audit team and facility representatives continued discussions regarding overall water usage and wastewater management practices currently employed. Additional questions regarding process operations, water use and wastewater generation and disposal were presented to the Manager and a second visit arranged.

Mrs. Mary Waldron, Eng. Rania Abdel Khaleq, and Dr. Omar Jabay visited the facility again on January 14, 1995 to collect additional follow-up information and to collect wastewater samples. During this second visit, additional information was provided by the UMIC Manager.

3.5 Post-Inspection Meeting

Post-inspection meetings between the audit team and the UMIC representatives were held on both audit days. Data gaps and the preliminary impressions regarding PP/WM and water conservation opportunities were discussed. The facility staff were responsive to the team's suggestions and agreed to help with any additional data gathering requests.

4.0

AUDIT FINDINGS

4.0 AUDIT FINDINGS

The findings presented below on water use and waste disposal practices at the UMIC facility are based on information collected during the facility audit, through interviews and discussions with UMIC employees, observations made during the site visit, and data provided by UMIC both before and after the site visit.

4.1 Water Usage and Balance

The UMIC facility receives its water from the Zarqa Free Zone groundwater wells. Most, approximately 72 percent of the water the facility uses is first treated using an ion-exchange unit. The four largest consumptions of water at the facility are for:

- Generating process steam used for refining the oil and producing vacuums;
- Washing the oil in the neutralization operation;
- Cooling the barometric condensers; and
- Cooling the heat exchangers.

These and other operations and activities that consume water are discussed below. Table 1. Water Balance, presents a breakdown of water consumption. Figure 3, Water and Wastewater Flow Diagram, provides a water flow diagram for the entire facility.

4.1.1 Process Steam

Steam is used for the following purposes:

- Deodorization Operation - Live steam is used to remove odor-causing impurities from the oil. The condensed steam is reused as cooling water for the barometric condensers.
- Physical Refining Operation - Live steam is used to remove FFA, odor-causing impurities and color. The condensed steam is reused as cooling water for the barometric condensers.
- Generation of the Vacuum - Steam is used to create the vacuum in the physical refining operation (steam stripper) and in the chemical refining operations (for the dryer and the deodorizer).

Figure 4, Steam Flow Diagram, provides a steam flow diagram. The UMIC facility uses a central boiler system to generate all of the steam used throughout the facility. Softened water is used in the boilers to produce the steam. Chemicals for scale and corrosion prevention and control, anti-oxidants, and anti-foaming compounds are added to the boiler feed water. The facility has 4 boilers available; one with a capacity of 8

tons per hour (T/hr), two with capacities of 3 T/hr each, and one with a capacity of 2 T/hr. Usually, the largest one is used with the three smaller boilers as backup. Make-up water is added to the boiler system to account for steam losses through leaks and due to evaporation. Based on information provided by UMIC, an estimated 57 m^3/day of softened water, or approximately 42 percent of the total water consumption at the UMIC facility, is used to generate steam.

4.1.2 Neutralization Washwater

Softened water is used in the neutralization operation for washing the oil, to remove the soapstock. The UMIC Manager estimates that the quantity of water is 1 m^3/hr or 24 m^3/day. The second centrifuge uses approximately 400 liters per hour (L/hr), and the third centrifuge uses approximately 600 L/hr. The washwater, separated from the oil in the centrifuges, flows by gravity through two pipes, one from each centrifuge, to a collection tank. From the collection tank the combined washwater from the second and third centrifuges is pumped to the wastewater collection tank for treatment to recover the soapstock.

4.1.3 Cooling Water

The UMIC facility uses a water cooling system for the barometric condensers. There are 3 barometric condensers:

- one for the physical refining operation;
- one for the chemical refining dryer; and
- one for the deodorizer.

The water in the system is continuously recirculated and cooled by one cooling tower. The condensate generated by the barometric condensers is added to the cooling water. No make-up water is needed, as the condensate from the barometric condensers equals and sometimes exceeds the evaporative loss from the cooling tower.

Water in the heat exchangers is cooled by a separate cooling tower, referred to as the clean cooling tower. An estimated 20 m^3/day of make-up water is added to this cooling system.

4.1.4 Process Equipment Washing

Water is used to clean the centrifuges in the neutralization operation and the filters in the bleaching operation. This equipment washing is described below.

- Centrifuge Equipment Washing - The three centrifuges are washed with water once every 48 hours to remove accumulations of solidified soapstock. This equipment cleaning wastewater is discharged to an outside collection pit and hauled by trucks for disposal on land near the facility.

- Filter Equipment Washing - Steam is used to recover oil from the clay layer that

is formed on the filter elements. The oil/steam mixture is transferred to an open tank where the steam escapes to the atmosphere and the oil is returned to the neutralization operation. Water is also used to clean each filter once a month. Each filter is cleaned with caustic soda solution and steam, then rinsed with water and steam. This wastewater is pumped to an outside collection pit where it is pumped into trucks for disposal on land near the facility.

4.1.5 Other Water Uses

Water is used for various other purposes throughout the facility. These miscellaneous operations are described below. The amount of water used by these operations is difficult to quantify.

- Floor Cleaning - Water is used for cleaning floors in the filling/packaging building, the laboratory, and throughout all the process operations (neutralization, bleaching, deodorization). Some of the soapstock collected for the saponification plant is used with water to clean the floors.

- Chemical Solutions - Water is used in the dissolution of solid chemicals to make the sodium hydroxide solution, the sodium chloride solution, the calcium hydroxide solution, and the aluminum sulfate solution.

- Steam Heating - Low pressure (3 bars) steam is used in closed-loop heating coils in the crude oil storage tanks.

- Live Steam Heating - Live steam heating is used in the following three areas:

  - When necessary, live steam is used to heat the crude oil in the tanker trucks prior to pumping into the crude oil storage tanks;

  - Preheating of boiler water; and

  - Heating of wastewater in acidification treatment.

- Laboratory Tests - Over 180 tests are conducted a day for process operation control. Samples of the oil are brought to the laboratory in containers. Any unused portions of the samples are collected in a bucket and returned to the refining plant. Water is used to clean the glassware and other testing equipment.

- Clean Up of Spills - Water is used to clean up any spills from crude oil transfer from tankers to storage tanks. The six crude oil storage tanks are located on a concrete pad with a wall around the tanks, but the pumping from tanker truck to storage tanks is conducted outside of this containment. If a storage tank overflows during filling or spills occur during the pumping operation, any clean spill materials are captured in containers and sent to the chemical refining plant. Material too dirty to refine is collected in drums and sold to a saponification plant.

The ground is washed with hot water using high pressure, low volume hoses. This wastewater is directed to a pit where it is pumped to a storage tank and sent to the acidification treatment process.

- Wastewater Treatment System - Live steam is used to heat the washwater for treatment in the acidification units (wooden tanks).

- Sanitary - The UMIC facility uses water for sanitary purposes, such as toilets and lavatories. Based on 140 employees, the quantity is estimated at 10 m^3/day.

4.2 Wastewater Discharges

Wastewater is generated from process operations, utilities, and other operations. These wastewater sources are described below. Figure 3, Water and Wastewater Flow Diagram, provides a block flow diagram of the wastewater generation, reuse, and final disposal.

4.2.1 Process Wastewater

Wastewater generated by process operations where the water used in the process comes into direct contact with the product are described below. In general, these wastewaters will be contaminated with some of the oil product and the contaminates in the oil such as FFA.

- Neutralization Washwater - The washwater from the second and third centrifuges contain soapstock and, therefore, contains high concentrations of BOD and oil (principally fatty acids and phosphatides). An estimated 24 m^3/day of wastewater is generated and discharged to the outside collection pit or to the wastewater collection tank for treatment.

- Centrifuge Equipment Cleaning Wastewater - The wastewaters generated by the cleaning of the centrifuges contain soapstock and thus would contain high concentrations of BOD and oil. This wastewater is discharged to the outside collection pit for disposal by trucks onto land near the facility.

- Filter Equipment Cleaning Wastewater - The monthly cleaning of the filters results in a wastewater containing TSS, primarily the bleaching earth, and oil. This wastewater is discharged to the outside collection pit for disposal by trucks onto land near the facility.

- Cooling System Bleed-Off - With the addition of the physical refining operation, the quantity of cooling water has increased. This is overloading the cooling tower so that the facility has to remove the cooling water and refill the cooling system with fresh water. This discharge contains emulsified oils from the condensate generated by the barometric condensers and may be high in TDS. The daily average blowdown is estimated at 4.2 m^3/day, but may be much higher.

4.2.2 Water Softening Regeneration and Boiler Blowdown

Both the water softening and boiler systems generate wastewaters as described below.

- Softener Regeneration - The UMIC facility uses a water softener to treat its water supply for the boilers and the chemical refining neutralization washwater. The softener is regenerated every 16 m^3. Therefore, the frequency of regeneration will vary, but on average this regeneration is performed 4 to 5 times a day. Each regeneration produces a wastewater discharge of 1.0 to 1.5 m^3 containing salts and TDS. This wastewater (approximately 6 m^3/day) is discharged to an outside collection pit and hauled by trucks for disposal on land near the facility.

- Boiler Blowdown - Operation of the boiler for steam generation requires periodic blowdown to prevent solids buildup. The blowdown wastewater contains corrosion control chemicals, such as sodium sulfate, and TDS. Approximately 20 m^3/day is discharged.

4.2.3 Other Wastewater Discharges

Other activities generating wastewater at the facility are described below.

- Floor Cleaning Wastewater - Floor cleaning wastewater contains oil, TSS, and BOD. This wastewater is discharged to the outside collection pit for disposal by the trucks onto land near the facility.

- Sanitary Wastewater - The 6 toilets and washrooms at the facility produce an unknown amount of sanitary wastewater.

- Laboratory - The majority of the wastewater from the laboratory would come from washing of the glassware and other testing equipment. A small amount of wastewater is generated from the discharge of spent chemical reagents.

- Spills, Leaks and Clean Up from Process Operations and Materials Handling and Storage - Leaks, spills, and the clean up of these generate an unknown quantity of wastes. Areas where storage, handling, loading, unloading, or waste disposal activities occur provide opportunities for spills and leaks that result in contamination of the soil and groundwater. The materials that are spilled include crude and refined oils, caustic soda, sulfuric acid, bleaching earth, soapstock, and wastewater. The areas where such spills and leaks are evident are shown in Figure 5, Facility Location Plan, and described below:

  - Crude oil spills occur where the crude oil is unloaded from tankers to storage tank. There is no containment structure or concrete pad at the unloading area; thus, crude oil spills are discharged directly to the soil. As much oil as possible is collected; the clean oil is refined and the dirty oil is sent to the saponification plant. Wastewater generated from cleaning the spill area is sent to the facility's acidification treatment unit.

- The soapstock discharged from the neutralization's first centrifuge is collected in drums or bags; however, oily deposits on floor indicate that material has spilled from the drums or bags.

- Condensate and cooling water leaks from equipment collect on the floors and can flow through holes in the floor to floors below or to the ground.

- Steam losses to the air occur through leaky flanges, valves, and pipes.

- Drums were stored on the ground outside the buildings. No cover or containment was provided around these drums. During a rain storm, contaminants from these drums could be collected by the stormwater and eventually drain to the wadi.

- Fuel oil spills are visible on the ground around the two fuel oil tanks.

- Spills occur in the filling area from leaking containers. Refined oil spilled from the filling machines is captured in shallow trays under the filling machines.

- Spills of sodium hydroxide solution and solid sodium hydroxide occur around the sodium hydroxide mixing and storage tanks.

4.3 Wastewater Treatment System Processes

The components of the UMIC facility's wastewater treatment system are described below. Figure 6, Wastewater Treatment Process Flow Diagram, provides a block flow diagram of the system.

- Wastewater Collection Tank - Wastewater is stored in a 760 m^3 tank. The tank is heated with a closed-loop steam heating coil.

- Acidification Unit - The acidication unit consists of 4 wooden tanks, but only 2 tanks are operated. Approximately 7 m^3 of wastewater is added to each tank. Sulfuric acid from a 100 kilogram (kg) container located outdoors is pumped to each tank and the wastewater is heated to 100°C using live steam from perforated pipes installed at the bottom of the tanks. The addition of this live steam increases the quantity of wastewater to 8.5 m^3.

  The steam is shut off and the wastewater remains undisturbed for 16 hours to form two distinct layers; oil on top and water on the bottom. The oil layer is drained into 250 kg drums and then the wastewater is pumped to the gravity separation basin. Approximately 400 kg of oil is recovered from each batch of wastewater treated (200 kg from each wooden tank).

- Gravity Separation Basin - From the wooden acidification tanks wastewater is pumped outdoors to an open concrete basin. Oil is skimmed from the top of the

basin with a manually operated pump.

- Oil Separator - Wastewater is then pumped to an oil/water separator. The oil is collected in drums and the wastewater flows by gravity to the neutralization basin.

- Neutralization Basin - Wastewater flows by gravity to an open concrete basin. Solidified soapstock can be manually skimmed from this basin.

- Aeration Basin - Calcium hydroxide ($Ca(OH)_2$) is added to adjust the pH of the wastewater to 6.5 or 7. Approximately 20 bags (each bag 20 kg) of calcium hydroxide is used per month. Sludge in aeration tank is removed and dried.

- Chemical Coagulation and Clarification - From the aeration basin the wastewater is pumped to the coagulation/clarification tank. Aluminum sulfate ($Al_2(SO_4)_3$) solution (5 kg per 100 liters of water) is added at a rate of 15 mL/hr. Sludge is collected in drums for disposal. The wastewater flows by gravity to an evaporative cooling tower.

- Evaporative Cooling Tower - The final unit of the wastewater treatment system is an evaporative cooling tower that evaporates the treated wastewater effluent from the clarifier. Evaporation is aided by a steam heating coil in the wet well of the tower. The design evaporation rate is 18 m^3/day. Due to operational difficulties this unit is not used.

Upon start-up of the system, operational difficulties were encountered and the system is being repaired. The various treatment units may not have been sized to fit together, so that each unit operates at its optimum hydraulic and organic loading rates. The current decanting of oil from the acidification unit leaves too much oil with the water. The manual removal of oil and sludge from the gravity separation unit and the aeration basin creates turbulence that remixes these contaminants with the water, reducing the removal efficiency of the units. The use of live steam for heating in the acidification unit dilutes the wastewater.

4.4 Air Emissions

There were no significant sources of air emissions. Leaks in steam pipes contribute water vapor and small amounts of fatty acid components. The manual loading of powdered chemicals (e.g., sodium hydroxide and bleaching earth) produce brief localized areas of particulates.

4.5 Solid Wastes

The major solid wastes generated at the facility include oil from spills, leaks, and clean up that cannot be refined, soapstock, spent bleaching clay, and wastewater treatment sludge.

Spill clean up practices attempt to recover most of the crude or refined oil that is spilled.

This oil is returned to the refining process. Oil that is too dirty to be refined is collected in containers and sent to the saponification plant.

The soapstock is generated from several sources:

- Neutralization's first centrifuge;
- Deodorization barometric condensers; and
- Physical refining fatty acid condensers and barometric condensers.

The soapstock from the neutralization centrifuge and the physical refining fatty acid condensers are collected in containers and sent to a saponification plant. The fatty matter from the barometric condensers collect in the hot well pit and are skimmed into containers and discharged into a pit beside the acidification treatment unit. This fatty material in the pit is periodically treated in the acidification treatment unit to recover soapstock that is collected in containers and sent to the saponification plant.

Approximately 1 T/day of spent bleaching clay is generated. This waste is hauled to a facility that burns it.

Sludge that is generated by the wastewater treatment system will be collected in drums or tanks. Since the system is not operating at this time, no data is available on the amount of sludge generation.

4.6 Storm Water Management

There are numerous (at least 22 material storage tanks, 2 fuel oil tanks, wastewater collection tank) storage tanks located outside the buildings. Only the 6 crude oil storage tanks have a spill containment structure around them. Spills, leaks and overflows from these tanks contaminate the outside of the tanks and the surrounding ground. In addition, there are open collection pits, open trenches, and cooling towers containing process water or wastewater that are exposed to rain. Most of the wastewater treatment units are located outside. Storm water running on and off these structures contributes undesirable pollutants such as TSS, TDS, Oil and BOD to the surrounding soil and groundwater. The facility has completed the installation of a large underground concrete tank to collect and contain the storm water.

4.7 Data Gaps

Data gaps exist in water quality and water quantity measurements as noted below.

4.7.1 Water Quality

The facility does not conduct water quality tests on any of the wastewaters. However, WAJ has monitored the facility's wastewater discharge. The analytical results of the WAJ monitoring, conducted from February 1990 through December 1994, are presented

in Table 2, WAJ Wastewater Discharge Monitoring Analytical Results. No FOG analyses have been conducted. The BOD_5 concentrations have ranged from 55 milligram per liter (mg/L) to 49,680 mg/L. The TDS concentrations have ranged from 376 mg/L to 66,510 mg/L. These data, collected monthly for four years, reveals a highly variable wastewater that cannot meet the Jordanian Standard 202 for discharge to wadis or reuse for irrigation without treatment.

Sampling of various wastewaters within the facility were conducted as part of this audit on January 14, 1995. The wastewaters, except softener regeneration and boiler blowdown, were analyzed for FOG. Selected wastewaters were analyzed for TDS, TSS, and BOD_5. The analytical results of this sampling are presented in Table 3, Sampling Analytical Results. The extremely high FOG concentrations (47,571 mg/L and 38,838 mg/L) of the neutralization washwater wastewater suggests that this wastewater may be amenable to soapstock or oil recovery by gravity separation before being treated with sulfuric acid for further soapstock or oil recovery. The FOG concentrations of the cooling water from the barometric condensers and the hot well and cooling tower wet well reveal the potential for soapstock or oil

5.0

POLLUTION PREVENTION AND WASTE MINIMIZATION OPPORTUNITIES

5.0 POLLUTION PREVENTION AND WASTE MINIMIZATION OPPORTUNITIES

The term PP/WM, in this report, refers to the reduction or elimination of the amount of waste before it is generated. During the audit of the UMIC facility, conducted on January 7 and 14, 1995, PP/WM opportunities were identified. The focus of the audit was on PP/WM and water conservation techniquies that would reduce the volume and pollution load of the wastewater generated at the UMIC facility and/or being discharged into the wadi and Zarqa watershed basin. Several PP/WM opportunities related to storm water and solid wastes were also identified. In addition, several PP/WM techniques described in this report could result in the recovery of useful materials by the UMIC facility. These PP/WM techniques are provided in this section while the water conservation techniques are presented in Section 6.0.

The UMIC facility has recently completed installation of a wastewater treatment system. However, this system was not operating at the time of the site visit. Currently, the facility is storing wastewater in the wastewater collection tank and in an outside collection pit that is occassionally pumped and discharged to land near the facility. The discharge from the UMIC facility is governed by Jordanian Standards 202, which limits industrial point source discharges to wadis and rivers. A comprehensive overview of the Jordanian Standards 202, and other applicable regulations, is provided in Appendix C. A comparison of these standards with 1994 discharge data is provided in Table 3. There has been no discharge data collected from the wastewater treatment system.

At the UMIC facility, the following PP/WM practices are being implemented:

- Production Schedule Optimization - The production schedule is designed to eliminate the need to clean the process oil lines between the different oil types. Palm oil is refined, then palmoline, then corn oil, and then soya oil. The refined oil that is produced at the beginning of the refining process is a mixture of the two oils but becomes diluted in the final product storage tanks.

- Inventory Control - To reduce the storage time of the crude oil, the storage tanks are not continually filled with new shipments of crude oil. A tank is completely filled and the crude oil processed until the tank is completely empty before the tank is filled again. This "first-in, first-out" inventory control minimizes the increase in phosphatides while the crude oil is in storage.

  Currently, the facility has many different types of additives based on customers' specifications and different adhesives for attaching the customer's labels. The UMIC Manager plans to reduce the number of additives and adhesives to minimize the inventory of small quantities and wastage.

- Storage Tank Cleaning - A tank is cleaned and inspected after the third emptying of the tank. Depending on the production rate and schedule, the interval between cleaning may be 1.5 months for the palm oil and 3 months for the soya and corn oils.

The existing tanks have flat bottoms, so some oil remains in the tank bottom. Cleaning consists of manually scraping the oil towards a sump pump that is located below the bottom of the tank. As part of the facility's plan for increased production capacity, 2 new tanks for palm oil will be installed. These new tanks will have cone-shaped bottoms.

- Off-Spec Material Reuse - If the final product does not meet specifications, it is returned for further refining.

- Recovered Oil Reuse - Clean crude oil spilled during the transfer from tanker trucks to the crude oil storage tanks is collected in containers and transferred to the crude oil storage tanks. Contaminated crude oil from these spills is collected, treated, and sold to a soap plant. Spills of refined oil in the filling area are collected and returned to the crude oil storage tanks.

- Soapstock Recovery - In the refining process, soap is formed in the alkaline neutralization of free fatty acids. The UMIC facility captures this soapstock and sells it to a saponification plant.

- Quality Control Tests on Crude Oil Shipments - When the facility receives RBD palm oil from Malaysia that meets the specifications for the finished refined product, then the RBD oil is transferred to final product storage tanks for the filling operation with no refining conducted at UMIC.

- Process Control Tests - Tests on the oil are conducted before and after each step in the chemical refinining process and throughout the physical refining operation. These tests establish the quantities of raw materials, such as caustic soda, washwater, and bleaching clay to be added. This testing optimizes the addition of raw materials. For example, if the oil contains less phosphatides, less caustic soda and washwater are used.

- Spill Control and Containment - The storage tanks are equipped with a float level indicator on the outside of the tanks to indicate the level of oil in the tanks. The crude oil storage tanks are on a concrete pad with a spill containment wall around them.

Further PP/WM opportunities exist and are identified in this report. These opportunities identified for the UMIC facility are grouped into three general categories:

- Process Control;
- Materials Handling and Storage; and
- Control of Other Waste Generating Activities.

The PP/WM opportunities identified for each of these categories are provided in the following sections.

5.1 Process Control

While the PP/WM opportunities identified in this section are intended to reduce waste generated, changes to process operations may result in unanticipated consequences. The UMIC facility should fully evaluate the options presented before modifying process operations.

- Neutralization Washwater Reuse - Some options for reducing the generation of wastewater from the second and third centrifuges in the neutralization operation are:

  - Process the oil/caustic soda mixture with water in a countercurrent centrifugal contactor. Then treat the wastewater in a decanter followed by a cation-exchange resin column and reuse in the centrifugal contactor;

  - Segregate and treat the wastewater by gravity separation followed by hydrogen ion-exchange columns, then reuse the treated wastewater as washwater; and

  - Treat, if necessary, and reuse the washwater from the third centrifuge as washwater for the second centrifuge. This will result in a saving of approximately 5 m^3/day.

  - Treat the second centrifuge washwater discharge to recover the soapstock and reuse this washwater for the third centrifuge washwater. This would reduce the need for fresh washwater. The current volume of washwater used in the third centrifuge is 0.6 m^3/hr. Recycling of this stream, therefore, would eliminate the consumption of approximately 8 m^3/day of water.

  - Treat all of the washwater by acidification to recover the soapstock for sale to a saponification plant and reuse the treated washwater for heat exchanger cooling and cleaning equipment, floors or spills.

- Crude Oil Quality Control - The UMIC facility could investigate the cost/benefit of obtaining a higher quality crude oil. Crude oils with less phosphatides and free fatty acids will require less raw materials such as caustic soda, steam, and washwater to meet specifications. If the facility can increase the number of shipments of this better quality oil, it will reduce water consumption and wastewater generated. UMIC could establish specifications for crude oil quality that suppliers should meet; if the shipment does not meet the specifications, it will not be accepted by UMIC.

UMIC could work with its suppliers, shippers, and transport companies to establish standard shipping and transport practices that would reduce the time in-shipment and storage, the number of transfers that occur, and the oxidation that occurs during shipment and storage. Some options are:

- Nitrogen layer in tanker trucks and ships; and

- Shipping the crude oil in the same tankers from the crude oil facility to the UMIC facility. The railroad uses this system, referred to as "piggyback". The tankers are driven to the ships, disconnected from the truck cabs, loaded into

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  - Process the oil/caustic soda mixture with water in a countercurrent centrifugal contactor. Then treat the wastewater in a decanter followed by a cation-exchange resin column and reuse in the centrifugal contactor;

  - Segregate and treat the wastewater by gravity separation followed by hydrogen ion-exchange columns, then reuse the treated wastewater as washwater; and

  - Treat, if necessary, and reuse the washwater from the third centrifuge as washwater for the second centrifuge. This will result in a saving of approximately 5 m^3/day.

  - Treat the second centrifuge washwater discharge to recover the soapstock and reuse this washwater for the third centrifuge washwater. This would reduce the need for fresh washwater. The current volume of washwater used in the third centrifuge is 0.6 m^3/hr. Recycling of this stream, therefore, would eliminate the consumption of approximately 8 m^3/day of water.

  - Treat all of the washwater by acidification to recover the soapstock for sale to a saponification plant and reuse the treated washwater for heat exchanger cooling and cleaning equipment, floors or spills.

- Crude Oil Quality Control - The UMIC facility could investigate the cost/benefit of obtaining a higher quality crude oil. Crude oils with less phosphatides and free fatty acids will require less raw materials such as caustic soda, steam, and washwater to meet specifications. If the facility can increase the number of shipments of this better quality oil, it will reduce water consumption and wastewater generated. UMIC could establish specifications for crude oil quality that suppliers should meet; if the shipment does not meet the specifications, it will not be accepted by UMIC.

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  - Nitrogen layer in tanker trucks and ships; and

  - Shipping the crude oil in the same tankers from the crude oil facility to the UMIC facility. The railroad uses this system, referred to as "piggyback". The tankers are driven to the ships, disconnected from the truck cabs, loaded into

wastewater. Use of soapstock may be contributing to the oily floors and surfaces. The facility could, on a trial basis, use soapstock in one area and detergent in another and compare the results.

- Containment structures should be repaired and maintained to ensure their proper operation. Where drains are located in these containment structures, they should be closed under normal circumstances, and opened only to remove uncontaminated storm water or washwater.

- Any open containers, such as buckets used to collect process control samples for the laboratory, should be fitted with tight fitting lids and kept sealed when not used.

5.3 Control of Other Waste Generating Activities

Several additional PP/WM actions do not relate directly to process operations or to the handling and storage of materials. Instead, these opportunities address the treatment and disposal of softener regeneration wastewater, sanitary wastewater, solid wastes, and the operation of the wastewater treatment system. Opportunities in these specific areas are provided in the following sections.

5.3.1 Softener Regeneration and Sanitary Wastewaters

The following PP/WM opportunities relate to the softener regeneration wastewater and sanitary wastewater at the UMIC facility:

- Softener Regeneration - Instead of sodium chloride, use a regeneration chemical that is less harmful to the environment, such as acetic acid and ammonium hydroxide. This chemical substitution would reduce the high concentrations of sodium and chloride salts in the wastewater.

- Softener System Upgrade - Continue with plans to install a larger capacity softener unit. A unit that is optimally sized for the facility's operations will reduce the frequency of regeneration. Use a newer state-of-the-art ion-exchange resin system that is regenerated with less solution and, therefore, generates a smaller volume, more concentrated wastewater.

- Softener Regeneration Wastewater Reuse - The softener regeneration wastewater could be treated using reverse osmosis and reused.

- Domestic Waste Treatment - The UMIC facility could construct an engineered septic tank with a suitable leachfield to treat the domestic wastes generated by the facility. The treated water leaving the leachfield will support vegetation.

5.3.2 Wastewater Treatment System

The proper design and operation of the wastewater treatment system is critical to the prevention of pollution at the UMIC facility. The following suggestions are provided to

ensure proper design and operation of the wastewater treatment system:

- The UMIC facility should investigate segregation of the different wastewaters to enable the most appropriate treatment to be used for each wastewater. Wastewaters containing high concentrations of oil in emulsion should be treated by acidification. These wastewater should not be diluted with other wastewaters (such as boiler blowdown, softener regeneration wastewater, floor cleaning wastewater) containing low concentrations of oil;

- Redesign acidification treatment unit to improve capture of oil. Eliminate use of live steam for heating the unit;

- Operate treatment system daily to improve removal efficiency and decrease odors. The treatment train (particularly the oil/water separator and the aeration basin) operate optimally in a continuous operating mode rather than a batch operating mode. Storing the wastewater for a long period of time will promote biodegradation, causing odors;

- Conduct an engineering analysis to determine if the treatment units are sized properly;

- Investigate the treatment efficiency of each of the treatment units and where necessary modify the design or operation;

- Conduct an engineering analysis to determine the optimum detention time in the gravity separation tank and the aeration tank;

- Add automatic, continuously operating oil skimming devices and sludge removal; and

- Replace the evaporative cooling tower with an ion-exchange resin system or a reverse osmosis system that would enable reuse or recycle of the treated water.

5.3.3 Process Solid Wastes

The following PP/WM opportunities relate to the treatment and disposal of solid wastes generated by the UMIC facility:

- Bleaching Clay Optimization - The UMIC facility could investigate optimizing the addition of bleaching clay to reduce excess. This would reduce amount purchased, reduce losses of oil in the spent clay, lengthen the filter cycles, and reduce the quantity of spent clay generated.

- Bleaching Earth Filter Cake Recycling - The UMIC facility could investigate alternative uses for the filter cake. These are not PP/WM measures, but UMIC's uncontrolled disposal of this material as a waste could be improved by considering this material as a beneficial resource or raw material for another industry. For

example, the clay content of the cake may make the cake a suitable raw material for soil conditioner to improve sandy soils. The cake could also be used as raw material in the production of poultry feed or other domesticated animal feed.

- Sediment Control - The UMIC facility could investigate possible ways to minimize sediment in the final product packaging tanks. Less sediment in these tanks would result in less frequent cleaning, less waste to be removed, and higher quality product. One method to reduce sediment generation would be installing an ultrafiltration unit before the tanks.

6.0

WATER CONSERVATION OPPORTUNITIES

6.0 WATER CONSERVATION OPPORTUNITIES

Water conservation is an extremely important concern in the Zarqa Basin and throughout Jordan. The limited water resources require that businesses and industry view water as a valuable raw material and optimize its use. In order to optimize water use, business and industry should carefully monitor flows and uses within facility operations and develop a written strategy to coordinate water conservation activities.

The UMIC facility already practices the following water conservation techniques:

- Cooling Water Reuse - Cooling water in the heat exchangers is continuously recirculated from the heat exchangers to a cooling tower.

- Steam Condensate Reuse - The steam, used in both the chemical refining and the physical refining processes, is captured, condensed, cooled by a cooling tower, and reused as cooling water.

- Air Cleaning of Lines - The UMIC facility uses air or nitrogen rather than water to clean process lines. In the filling operation, the lines are cleaned with air or nitrogen at the end of each day and between swithing the oil types. Process oil lines are rarely cleaned; when necessary air or nitrogen is used to clean the lines.

While water conservation is an important concern, the use of water at the UMIC facility is necessary for the production of a high quality product. The water conservation opportunities identified in this report, therefore, should be evaluated by the UMIC facility to assess possible adverse impacts on production processes. A summary of these opportunities and the projected water savings are provided in Table 4.

6.1 Process Control

A number of water conservation opportunities involving water uses were identified in Section 5.0. These were:

- Washwater Reuse - UMIC could treat the centrifuge washwater discharge to recover the soapstock and reuse this washwater in the centrifuges or as cooling water for the heat exchangers or for cleaning of equipment, floors, and spills.

- Centrifuge Optimization - The centrifuge operation could be optimized to avoid build up of soapstock within the centrifuge to eliminate cleaning of the centrifuges every 48 hours.

- Softener System Upgrade - Install a larger capacity softener unit to reduce the frequency of regeneration. Use a newer state-of-the-art ion-exchange resin system that is regenerated with less solution and, therefore, generates a smaller volume, more concentrated wastewater.

- Spill Control and Clean-up Procedures - Improve spill control and spill clean-up procedures.

Additional opportunities are presented below.

- Cooling Tower Optimization - The UMIC facility could assess design or operational modifications for the current cooling tower or explore new cooling tower designs to minimize the evaporative losses and increase the concentration cycle.

- Boiler Blowdown Reuse - The UMIC facility could use boiler blowdown as floor washing and spill clean-up water.

- Steam Leak Prevention and Control - UMIC could implement a more rigorous preventative maintenance program to prevent leaks and a rapid response repair program to fix the leaks as soon as they occur.

- Water Cooling System Elimination - The UMIC facility could investigate the use of a non-water cooling system for the heat exchangers. Using a non-water cooling system would eliminate the clean cooling water makeup (20 m^3/day). Eliminate the heat exchangers that use water to cool the product. Two potential non-water cooling methods are:

    - Installing a non-water based closed-loop cooling system or an air cooling system; and

    - Pumping the heated oil through a heat exchanger located in the crude oil storage tanks; this will eliminate the water cooled heat exchanger needed to cool the heated oil and the steam heating coil needed to heat the crude oil.

- Barometric Condenser Cooling Water Reuse - UMIC could treat the cooling water to recover fatty acid material. This recovery of the fatty acids would improve the water reused for cooling and eliminate the bleed-off discharge.

- Live Steam Heating Coil Elimination - Use a closed loop heating coil in the tanker trucks and acidification tanks instead of live steam.

- Live Steam Reuse - Reuse the water from the live steam heating of the tanker trucks as washwater in the neutralization operation or treat and reuse for other purposes such as floor or equipment washing.

- Process Equipment Design Modification - The UMIC facility could explore design modification to the process units, the barometric condensers, and the steam vacuum system that would decrease the overall water quantity (cooling water and steam). Some possible modifications are:

    - Optimum volume units for the dryer, bleacher, deodorizer, and steam stripper;

- For the deodorizer and steam stripper, design modifications for increasing the ratio of the oil surface area to the total vapor space; and, optimizing the contact between the steam and the oil by using smaller perforations on the live steam pipes;

- Installing a system that will operate under lower pressure (the higher the pressure, the more steam required);

- Decreasing the distance between process units, boosters, and condensers;

- Reducing the temperature of the cooling water; and

- Replacing the chemical refining process with a physical refining process for corn oil and soya oil. The physical refining process eliminates the washwater. Installing a new system, rather than retrofitting an old system, may be less costly, will provide more opportunities to design and incorporate water conservation, pollution prevention, and waste minimization into the new system. If production costs are reduced by 50 percent using the physical refining process, the investment recapture period may be acceptable.

- Barometric Condenser and Steam Vacuum Optimization - The UMIC facility could evaluate the current process operational procedures to optimize reductions in steam and cooling water. More process control instrumentation, more accurate instrumentation, or faster feedback could enable greater process control that would minimize water losses or decrease water usage.

6.2 Other Water Uses

In Section 5.0, the following PP/WM technique was also a water conservation technique:

- Softener Regeneration Wastewater Reuse - The softener regeneration wastewater could be treated using reverse osmosis and reused.

Additional water conservation opportunities in the areas of cleaning and domestic water use are presented below.

- Cleaning - The UMIC facility indicated that approximately 10 m^3/day of fresh water was used for floor washing and equipment cleaning activities throughout the plant. A reduction in the water used and the associated wastewater generated could be achieved by developing and implementing floor cleaning and spill cleaning procedures that focus on water conservation. Such procedures should address:

  - Cleaning first with dry methods;

  - Collecting liquid spills with vacuum devices; and

  - Replacing all low pressure hoses with high pressure, low volume hoses.

Assuming that these measures would reduce overall cleaning water use by 15 percent, a savings of 7.5 m^3/day is estimated.

- Domestic Water Use - Reduce domestic water use by employee awareness and installation of water conservation equipment.

7.0

CONCLUSIONS AND RECOMMENDATIONS

7.0 CONCLUSIONS AND RECOMMENDATIONS

)uring the audit conducted at the facility, UMIC staff and management were extremely ıelpful in providing access to facility operations and in providing requested information. The staff and management of the UMIC facility also expressed a sincere interest in reducing urrent wastewater generation and water consumption practices at their facility. During the udit, and subsequent sampling visit, the audit team collected baseline information and onducted an initial assessment of the opportunities for the application of PP/WM and vater conservation techniques. The findings of the audit and the PP/WM and water onservation options were presented in Sections 4.0, 5.0, and 6.0 of this report, respectively.

ıased on the process evaluation and the assessment of PP/WM and water conservation pportunities conducted during the audit, the audit team identified the following conclusions nd recommendations. The audit conclusions are provided in Section 7.2 and the ecommendations for PP/WM and water conservation techniques are provided in Section .3.

1 Success Stories

etween 1976 and 1979 the Lou Ana Foods facility in the U.S. more than doubled its oduction but without increasing its wastewater volume. This was accomplished by iminating the use of once-through cooling, recovering the washwater from the continuous apstock acidulation process and reusing as cooling water, and reusing the steam from the ntinuous vacuum bleacher as cooling water in a closed-circuit system. The facility was so faced with designing and building a wastewater treatment plant that would meet astewater discharge standards of 15 mg/L for BOD_5, 20 mg/L for TSS, and 10 mg/L for)G. The facility built a water pollution control facility for $2.2 million that reduced the $)D_5$ from 10,850 mg/L to 16 mg/L, TSS from 12,461 mg/L to 66 mg/L, and FOG from 107 mg/L to 4 mg/L. (Morris, 1981)

ıe Toei Chemical Co., Ltd. in Japan collects the soapstock and the spent clay generated ɔm 6 vegetable oil refining facilities and from these materials manufactures fatty acids, fats d oils, and derivatives used in industrial applications such as additives to paints and inting inks and oils for rolling of iron and steel. The soapstock is treated with sodium droxide to further saponify the fatty acids, then subjected to a pressure decomposition ɔcess followed by sulfuric acid treatment and then a solvent wash. Solvent and fatty acids : separated by centrifuges and the crude fatty acids are then refined through a distillation ɔcess. Oil is recovered from the spent clay through a solvent washing process and the clay ncinerated. (Daido, 1987).

Conclusions

sed on the findings of the audit conducted on January 7 and 14, 1995, the audit team veloped the following conclusions regarding the operation of the UMIC facility:

1. There are no internal water or wastewater measuring devices. The quantity of water

used by the individual operations are based on the UMIC representatives' estimates.

2. The UMIC facility uses approximately 147 m^3/day of groundwater, most of which is treated with a water softener before being used for steam generation, process washwater, and cooling purposes. Major water uses include steam generation, neutralization process washwater, contact and non-contact cooling water, and cleaning activities. The four largest consumptions of water at the facility are for:

   - Steam for refining and producing vacuum, and cooling water for the barometric condensers, 41 m^3/day;
   - Washing the oil in the neutralization operation, 24 m^3/day;
   - Boiler blowdown, 20 m^3/day; and
   - Cooling the heat exchangers, 20 m^3/day.

   Other water uses include floor and equipment cleaning, steam heating, laboratory tests, clean-up of spills, water for chemical solutions, and sanitary uses. In general, water use at the facility is not excessive; however, opportunities for conservation do exist.

3. The major wastewaters generated at the facility are:

   - Neutralization washwater, 24 m^3/day;
   - Boiler blowdown, 20 m^3/day;
   - Floor and equipment washwater, 10 m^3/day;
   - Steam condensate from tanker truck heating, 8 m^3/day; and
   - Softener regeneration backwash, 6 m^3/day.

   Other wastewaters include blowdown from the barometric condenser and heat exchanger cooling towers, spill clean-up, and sanitary for a estimated discharge of approximately 16 m^3/day. The total wastewater disharged is estimated to be approximately 84 m^3/day. Typical pollutant parameters include: FOG, BOD_5, COD, TSS, and TDS.

4. With the addition of the physical refining operation, the quantity of cooling water has increased. This is overloading the cooling tower so that the facility is removing the cooling water and refilling the cooling system with fresh water. The daily average blowdown is estimated at 4.2 m^3/day, but may be much higher.

5. Steam losses to the air occur through leaky flanges, valves, and pipes. Condensate and cooling water leaks from equipment collect on the floors. Frequent spills occur in the following areas:

   - Tanker truck unloading;
   - Caustic soda solution mixing; and
   - Filling area from the filling machines and leaking containers.

6. The wastewater treatment system consists of acidification, oil/water gravity

separation, neutralization, aeration, coagulation, clarification, and evaporation. No flow monitoring has been performed. Operational difficulties were encountered upon start-up of the system. Repairs are currently being made to the system. The various treatment units may not have been sized to fit together, so that each unit operates at its optimum hydraulic and organic loading rates. The current decanting of oil from the acidification unit leaves too much oil with the water. The manual removal of oil and sludge from the gravity separation unit and the aeration basin creates turbulence that remixes these contaminants with the water, reducing the removal efficiency of the units. The use of live steam for heating in the acidification unit dilutes the wastewater.

7. The two major solid wastes generated at the facility are soapstock and spent bleaching clay. The soapstock is sold to a saponification plant (soap factory). The spent bleaching clay is sent to another facility that burns it.

8. Solid and drummed liquid raw materials, products, and wastes are stored throughout the UMIC facility. While some containment measures exist, many of the containers are stored on bare ground, with drainage to the wadi. Leaks and spills due to loading and unloading tanker trucks create oil-contaminated ground. During storm events, spills from vegetable oil storage tanks and fuel tanks could be discharged to the wadi. While this is an infrequent occurrence, it results in the discharge of untreated wastewater to the wadi.

.3 Recommendations

Based on the PP/WM and water conservation opportunities identified and discussed in ections 5.0 and 6.0 of this report, the following recommendations are provided. These ecommendations are grouped into five categories:

- PP/WM Policy, Monitoring, and Training;
- Operational Modifications;
- Process Modifications;
- Good Housekeeping; and
- Control of Other Waste Generating Activities.

he opportunities recommended in this section relate to both PP/WM and water onservation techniques.

7.3.1 PP/WM Policy, Monitoring, and Training

The following recommendations address the development and implementation of: management PP/WM policy; monitoring programs that will provide data to assist in evaluating the feasibility and success of PP/WM techniques; PP/WM and water conservation goals; employee training; and preventative and corrective maintenance program.

1. PP/WM and Water Conservation Policy - The UMIC facility should establish a

PP/WM and water conservation policy as part of UMIC management operating philosophy and distribute it to all employees. Implement the policy through specific goals and targets. Make it each person's responsibility to identify PP/WM and water conservation opportunities and implement any established PP/WM and water conservation measures. Show management commitment to the policy by implementing the following actions:

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

- Publicize success stories and reward employees that identify cost effe

All flows from the above devices should be recorded daily for a period of 12 months. Record the water used for each cycle of the softener regeneration.

- Develop and implement a plan to sample the following wastewaters:

  - Physical refining barometric condensers;
  - Chemical refining barometric condensers;
  - Second centrifuge;
  - Third centrifuge;
  - Before and after each wastewater treatment unit;
  - Wastewater collection tank;
  - Outside collection pit;
  - Boiler blowdown;
  - Softener regeneration wastewater;
  - Heat exchanger cooling tower; and
  - Barometric condenser cooling tower.

  Conduct a short-term intensive sampling for FOG, BOD_5, TSS, TDS, and hardness. This short-term sampling program should collect and analyze samples daily for one month. The results should be evaluated and the sampling program modified where necessary. Continue a long-term sampling program for monitoring the wastewaters at least once a month for a period of 12 months.

3. Employee Training - No PP/WM program will be successful if employees are not aware of the program goals and trained to effectively implement these goals. Employee training should include periodic refresher courses regarding the UMIC facility's PP/WM and water conservation policies and procedures and proper training in the use of new equipment or practices. Staff should also have the opportunity to provide input regarding additional PP/WM or water conservation activities and should be provided with incentives for program successes.

4. Water Balance and Reduction Goals - To begin a successful water conservation program, plant management should determine the minimum quantity of water needed for each specific process operation. The first step in the program requires an inventory of all water uses throughout the facility. This inventory should then be used to create an overall plant water balance that identifies all uses and routes of disposal. Management should then establish a plan to reduce water use by specific amounts in each segment of production.

5. Preventative and Corrective Maintenance Program - Where new equipment or processes are implemented to achieve a PP/WM or water conservation objective, the UMIC facility should provide ongoing maintenance and upkeep of this equipment. The success of any PP/WM project can be compromised if new equipment falls into disrepair, or if new processes are not correctly applied. Establishment of a long term maintenance schedule will help to ensure successful

operation.

7.3.2 Operational Modifications

The following operational modifications should be implemented immediately:

1. Cooling Tower Optimization - Assess design or operational modifications for the current cooling tower or explore new cooling tower designs to minimize the evaporative losses and increase the concentration cycle.

2. Boiler Blowdown Reuse - Reuse boiler blowdown as floor washing and spill clean-up water.

3. Steam Leak Prevention and Control - Implement a more rigorous preventative maintenance program to prevent leaks and a rapid response repair program to fix the leaks as soon as they occur.

4. Good Housekeeping - Develop and implement floor cleaning and spill cleaning procedures that focus on water conservation. Such procedures should address:

    - Cleaning first with dry methods;
    - Collecting liquid spills with vacuum devices; and
    - Replacing all low pressure hoses with high pressure, low volume hoses.

5. Domestic Waste Treatment - Reduce domestic water use by employee awareness and installation of water conservation equipment.

6. Barometric Condenser and Steam Vacuum Optimization - Evaluate the current process operational procedures to optimize reductions in steam and cooling water. More process control instrumentation, more accurate instrumentation, or faster feedback could enable greater process control that would minimize water losses or decrease water usage.

7.3.3 Process Modifications

The following long-term design modifications should be investigated. These recommendations would require investigation of major process redesign, installation of new equipment, or reconfiguration of piping, pumps, and equipment.

1. Centrifuge Optimization - The centrifuge operation could be optimized to avoid build up of soapstock within the centrifuge to eliminate cleaning of the centrifuges every 48 hours. Some options are:

    - Add a gravity separation tank prior to the centrifuges to remove the larger particles that clog the centrifuge lines; and,

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- Operate a series of centrifuges with the first centrifuge designed to remove the larger particles and the subsequent centrifuges improving the separation efficiency.

2. Wastewater Reuse - Investigate reuse of the following wastewaters:

   - Neutralization Washwater - Some options for reducing the generation of wastewater and reuse of washwater from the second and third centrifuges in the neutralization operation are:

     - Treat the second centrifuge washwater discharge to recover the soapstock and reuse this washwater for the third centrifuge washwater;

     - Treat, if necessary, and reuse the wastewater from the third centrifuge as washwater for the second centrifuge;

     - Process the oil/caustic soda mixture with water in a countercurrent centrifugal contactor. Then treat the water in a decanter followed by a cation-exchange resin column and reuse in the centrifugal contactor;

     - Segregate and treat the wastewater by gravity separation followed by ion-exchange columns, then reuse the treated water as washwater; and

     - Treat for recover of the soapstock and reuse the treated washwater for cleaning equipment, floors or spills.

   - Softener Regeneration Wastewater - Treat using reverse osmosis and reuse.

   - Barometric Condenser Cooling Water - Treat the cooling water to recover fatty acid material and reuse as cooling water.

   - Live Steam - Reuse the condensate resulting from the live steam heating of the tanker trucks as washwater in the neutralization operation.

3. Softener Regeneration - Instead of sodium chloride, use a regeneration chemical that is less harmful to the environment, such as acetic acid and ammonium hydroxide. This chemical substitution would reduce the high concentrations of sodium and chloride salts in the wastewater.

4. Softener System Upgrade - Continue with plans to install a larger capacity softener unit. A unit that is optimally sized for the facility's operations will reduce the frequency of regeneration. Use a newer state-of-the-art ion-exchange resin system that is regenerated with less solution and, therefore, generates a smaller volume, more concentrated wastewater.

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5. Live Steam Heating Elimination - Eliminate use of live steam for heating. Use a closed loop heating coil in the tanker trucks and acidification tanks instead of live steam.

6. Wastewater Treatment System Optimization - Investigate design modifications, including replacement of existing equipment, and additional treatment that will enable recycle or reuse of treated wastewater.

7. Water Cooling System Elimination - Investigate the use of a non-water cooling system for the heat exchangers. Two potential non-water cooling methods are:

   - Installing a non-water based closed-loop cooling system or an air cooling system; and

   - Pumping the heated oil through a heat exchanger located in the crude oil storage tanks; this will eliminate the water cooled heat exchanger needed to cool the heated oil and the steam heating coil needed to heat the crude oil.

8. Crude Oil Quality Control - Investigate the cost/benefit of obtaining a higher quality crude oil to reduce water consumption and wastewater generated. Work with suppliers, shippers, and transport companies to establish standard shipping and transport practices that would reduce the time in-shipment and storage, the number of transfers that occur, and the oxidation that occurs during shipment and storage.

9. Process Equipment Design Modification - Explore design modification to the process units, the barometric condensers, and the steam vacuum system that would decrease the overall water quantity (cooling water and steam).

7.3.4 Good Housekeeping

- Spill Control and Clean-up Procedures - Improve spill control and spill clean-up procedures. Some PP/WM measures are:

  - Use a vacuum pump instead of shovels.

  - Install a pump in the trays underneath the filling machines to capture oil and return to filling machines or packaging tanks. This immediate capture of the oil will prevent contamination of the oil so that it will not need to be refined.

  - Conduct quality control checks on containers to detect leaks before using containers; this will prevent leaks from defective containers. Purchase from suppliers that will provide better containers.

- Construct covered concrete loading and unloading areas and storage areas for raw materials, products and wastes. These areas should also have containment dikes.

The different materials should be kept segregated from others. These measures will isolate spills, prevent soil contamination, and eliminate storm water runoff. Eliminate any drains in containment structures and keep these structures repaired and maintained.

- Seal any holes and drains in the floors to prevent the discharge of spills and leaks to clean areas.

- Use treated wastewater to clean floors and equipment and to clean up leaks and spills throughout the UMIC facility. If the soapstock is contributing to the oily floors and surfaces, substitute detergent.

- Any open containers, such as buckets used to collect process control samples for the laboratory, should be fitted with tight fitting lids and kept sealed when not used.

7.3.5 Control of Other Waste Generating Activities

Several recommendations relating to the management of storm water, solid wastes, and sanitary wastes are provided below:

1. Bleaching Clay Optimization - Investigate optimizing the addition of bleaching clay to reduce excess. This would reduce amount purchased, reduce losses of oil in the spent clay, lengthen the filter cycles, and reduce the quantity of spent clay generated.

2. Bleaching Earth Filter Cake Recycling - Investigate alternative uses for the filter cake. These are not PP/WM measures, but UMIC's uncontrolled disposal of this material as a waste could be improved by considering this material as a beneficial resource or raw material for another industry. For example, the clay content of the cake may make the cake a suitable raw material for soil conditioner to improve sandy soils. The cake could also be used as raw material in the production of poultry feed or other domesticated animal feed.

3. Sediment Control - Investigate possible ways to minimize sediment in the final product packaging tanks. Less sediment in these tanks would result in less frequent cleaning, less waste to be removed, and higher quality product. One method to reduce sediment generation would be installing a circulation pump or an ultrafiltration unit before the tanks.

4. Domestic Waste Treatment - Construct an engineered septic tank with a suitable leachfield to treat the domestic wastes generated by the facility.

8.0

FOLLOW-UP ACTIONS

8.0 FOLLOW-UP ACTIONS

To ensure the success of a PP/WM or water conservation project, a facility implementing specific actions must follow-up on these actions to ensure that the goals of the project are achieved. It is imperative, therefore, that the UMIC facility follow-up implementation of any of the recommendations of this report with activities such as increased monitoring of water use and disposal, ongoing maintenance and upkeep of new equipment, and conduct of periodic training and instruction for management and production line staff.

1. The first item of action is to establish a PP/WM water conservation policy as part of UMIC management operating philosophy and distribute it to all employees. Implement the policy through specific goals and targets.

2. Develop and implement a plan to install water and wastewater measuring devices on selected operations. Initiate monitoring of wastewaters for selected pollutants.

3. Develop and implement employee training.

4. Develop water balance for facility and determine water conservation goals.

5. Develop and implement a preventative and corrective maintenance program for equipment, pipes, and structures. Eliminate the cause of spillage. Do not just wash it down the drain.

With respect to the PP/WM and water conservation techniques recommended in Section 7.0, the UMIC facility should follow-up on all of the elements that it determines are productive. Implementation of these recommendations will reduce water consumption and pollutant loadings. In particular, the UMIC facility should follow-up on the following recommendations:

6. Cooling Tower Optimization - Assess design or operational modifications for the current cooling tower or explore new cooling tower designs to minimize the evaporative losses and increase the concentration cycle.

7. Boiler Blowdown Reuse - Reuse boiler blowdown as floor washing and spill clean-up water.

8. Steam Leak Prevention and Control - Implement a more rigorous preventative maintenance program to prevent leaks and a rapid response repair program to fix the leaks as soon as they occur.

9. Good Housekeeping - Develop and implement floor cleaning and spill cleaning procedures that focus on water conservation. Reduce floor cleaning wastewater by developing and implementing floor cleaning and spill cleaning procedures that focus on water conservation. Such procedures should address cleaning first with dry methods, then collecting liquid spills with vacuum devices, then using water

conservation equipment for final cleaning. Floor drains should be fitted with tight fitting seals or plugs.

10. Sanitary and Other Miscellaneous Water Use - Reduce miscellaneous water use and the associated wastewater by developing and implementing procedures that focus on water conservation.

    - Provide water conservation awareness training to employees on a periodic basis.

    - Install, as much as possible, water conservation equipment such as flow regulation devices, flow restrictors, flow shut-off devices, overflow preventers, and low volume spray nozzles. Different types of water saving equipment include:

        - Flow Regulation Devices. When these devices are inserted into a water line, increasing pressure restricts flow to a constant needed 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, as this nozzle forms a fan shaped chisel pointed spray.

        - Overflow Preventors. These devices are employed to prevent overflowing of containers, tanks, or reservoirs, thus stopping waste of water or release of wastewater. Most of these devices are usually float or electronic probe operated.

11. Initiate an investigation (engineering analysis) of the following long-term design modifications:

    - Wastewater Treatment Design Modifications - Conduct an engineering analysis to modify and upgrade the current wastewater treatment system to enable reuse of treated wastewater.

    - Boiler Blowdown Reduction - Investigate reducing the quantity of boiler blowdown.

    - Wastewater Reuse - Reuse neutralization washwater, cooling tower blowdowns, softener regeneration wastewater, and boiler blowdown.

    - Softener - Use of a regeneration chemical that is less harmful to the

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environment, such as acetic acid and ammonium hydroxide to reduce the high concentrations of sodium and chloride salts in the wastewater.

- Heat Exchanger Cooling Water Elimination - Investigate non-water cooling systems.

- Cooling Water Optimization - Investigate ways to reduce the quantity of water needed for cooling and lost to evaporation and blowdown. Some options to explore are:

  - Increasing the concentration cycle of the cooling towers; and

  - Decreasing blowdown quantity.

- Live Steam Heating Elimination - Eliminate use of live steam for heating.

To ensure that UMIC management are kept updated on "state-of-the-art" technologies, the MWI and the Chamber should be consulted on a regular basis. Periodic site visits should be arranged for the MWI and the Chamber staff so that they might provide additional input and suggestions.

TABLES

Table 1 - Water Balance

UMIC

WATER IN		WATER OUT	
Source	Rate, m^3/d	Source	Rate, m^3/d
Well water	146.8	Makeup water for barometric condenser cooling tower	41.0
		Neutralization washwater	24.0
		Boiler blowdown	20.0
		Makeup water for clean cooling tower for heat exchangers	20.0
		Floor and equipment cleaning	10.0
		Live steam for tanker truck unloading	8.4
		Softener regeneration backwash	6.0
		Barometric condenser cooling tower blowdown	4.2
		Sanitary	10.0
		Live steam for wastewater acidification	1.5
		General steam use losses	1.0
		Sodium chloride solution	0.7
TOTAL	146.8		146.8

Table 2 - WAJ Wastewater Discharge Monitoring Analytical Results

UMIC

Date	BOD	TDS	TSS	COD	NH_4	Fe	ABS	PO_4	pH
02/19/90	2,411	7,096	1,672	6,993	7.04			14,100	
02/26/90	20,448	66,510	29,400	187,563	57.6			5,700	
03/12/90	4,384	9,020	3,020	20,509	49.0			223	
03/27/90	1,004	376	164	2,464	29.0			64	
04/09/90	6,090	1,652	2,154	14,247	11.0			870	
04/18/90	3,920	1,841	2,863	9,608	33.3			125	
05/29/90	5,780	24,086	8,560	12,070	73.0			9,800	8.78
06/14/90	2,093	9,292	98	4,175	119.0		0.3	1,930	2.0
06/23/90	576	1,554	42	1,163	6.4		0.4	88	5.3
07/17/90	2,256	9,226	626	4,308	60.7		0.5	210	
09/01/90	2,030	6,890	774	4,104	16.64			500	
09/20/90	1,180	11,440	150	1,799	21.8		2.8		10.65
10/31/90	5,133	21,882	1,604	11,160	102.4			2,970	1.4
11/26/90	1,734	2,344	1,280	3,893	13.95		10.0	21.0	5.5
12/15/90	1,534	12,065	3,975	4,708	53.76		0.5	1,850	3.2
01/30/91	807	18,138	3,964	6,633	27.5			1,860	3.4
02/18/91	5,433	19,811	6,281	11,320	32.15		4.0	3,800	3.2
03/21/91	14,720	9,892	28,136	118,400	188.8		12.0	445	5.0
05/14/91	3,788	10,122	2,176	9,310	31.0			1,600	5.3
05/23/91	2,200	21,526	750	18,398	25.7	18.3	1.5	0.74	11.8
07/02/91	5,133	18,720	460	10,580	38.0		1.0	3.0	7.8
11/25/91	55	2,214	224	128	2.5	2.2		5.0	8.2

Date	BOD	TDS	TSS	COD	NH_4	Fe	ABS	PO_4	pH
01/13/92	4,128	8,652	206	7,277	19.0				4.0
02/12/92	5,957	6,891	928	11,009	45.0		10		6.4
03/12/92	2,078	5,544	133	4,250	5.17				5.0
05/20/92	10,928	1,000	62	23,639	-				8.3
08/18/92	49,680	29,600	18,273	104,738	31.0				5.6
08/24/92	3,800	5,712	271	7,532	2.43		1.4		4.4
10/31/92	5,005	8,392	744	8,333	13.8				
12/10/92	3,280	11,048	362	8,328	25.0			170	2.1
01/06/93	1,460	5,946	210	3,327	13.8				2.5
01/22/93	1,442	3,594	90	2,625	4.2			107	2.4
01/07/93	1,460	5,946	210	3,327	13.8				2.0
02/01/93	5,302	7,938	820	11,300			2.3		2.0
03/09/93	4,114	6,309	1,069	6,000				908	4.3
03/11/93	7,228	9,755	1,380	48,461	83.0			1,130	4.0
04/24/93	12,072	4,493	1,483	18,180	138.0				11.0
05/11/93	7,398	11,396	820	10,155	0.00				10.5
06/12/93	8,600	10,482	294	11,149	29.0			900	4.0
07/12/93	4,302	7,380	438	9,863	18.0				2.0
07/17/93	3,257	5,098	160	4,618	55.0			1,015	2.4
08/02/93	2,364	4,922	210	4,016	34.0				2.6
09/07/93	4,104	5,828	188	9,757					3.0
10/11/93	3,780	5,680	374	6,274	79.4				4.0
10/27/93	1,404	6,372	232	2,328	46.1			492	1.2
11/16/93	2,563	6,158	268	5,395					1.9
12/6/93	2,084	9,777	205	4,821	42.4				2.3
12/9/93	6,629	1,790	8,224	36,258	2.4			624	2.5

Date	BOD	TDS	TSS	COD	NH_4	Fe	ABS	PO_4	pH
01/01/94	3,514	7,208	696	5,297	28.0				2.0
01/13/94	1,733	5,160	174	2,975	14.0			426	3.1
02/12/94	3,450	9,200	410	5,605	14.4				1.5
02/24/94	3,425	6,970	334	5,675	34.6			1,150	1.6
03/22/94	9,900	15,570	1,557	37,459		7.61		640	6.3
04/13/94	9,179	11,243	1,043	19,120	35.2		14	1,000	6.8
05/02/94	6,552	9,852	613	10,230	150.4				2.6
05/07/94	5,980	10,652	905	8,400	200.0			954	2.9
06/07/94	22,758	9,707	15,600	37,933	192.0				6.4
07/06/94	15,400	9,980	12,650	34,567	145.9				6.8
07/12/94	7,627	3,953	1,420	18,129	64.0				6.4
08/24/94	15,950	20,660	6,520	40,196	32.0			1,488	7.1
09/07/94	6,936	8,751	3,567	11,174	64.0				7.0
10/01/94	11,825	20,495	3,360	22,195	90.0				6.1
10/29/94	2,986	14,058	532	5,809	128.0			1,000	2.1
11/01/94	8,102	30,600	767	13,670	54.0			440	5.2
12/06/94	2,362	5,210	368	3,890	22.0			170	4.1

- Not Determined

Source: Waleed Hussein, WAJ

Table 3 - Sampling Analytical Results

UMIC

rameter ampling ocation	FOG[a]	BOD_5[a]	COD[a]	TDS[a]	TSS[a]	SS[a]	pH	FFA %	Moisture Content %
andards 202	5	50[b]	150	3,000[c]	50	-	6.5		
A01[a]							11		29.8
A02[a]	47,571				52,194		10	1.79	
A03	38,838				48,684		9.4	23.87	
A04	523	1,175	3,508			318	5.2		
A06							4.1		
A07	455						5.2		
A09	568	1,601	3,508			322	5.8		
A10	0			3,006			8.3		
A11				117,228			6.75		
A12				27,605			8.9		
A13	151	16,415	23,565	7,530		2,090	6.35		

nits are mg/L.
onthly Average.
DS limit is subject to the TDS concentration in the water supply and the water basin affected.
Soapstock wastestream from first centrifuge in chemical refining neutralization area
Washwater wastewater from second centrifuge in chemical refining neutralization area
Washwater wastewater from third centrifuge in chemical refining neutralization area
Condensate and cooling water from dryer and deodorizer barometric condensers
Condensate and cooling water from fatty acid condenser in chemical refining deodorizer
Condensate and cooling water from main hot well pit for physical refining
Cooling water from wet well under cooling tower
Cooling water from heat exchangers' cooling tower
Softener regeneration wastewater
Boiler blowdown
Wastewater collection tank

Table 4 - Potential Water Savings

UMIC

Production Operation	Water Conservation Technique	Current Water Consumption (m^3/day)	Projected Water Consumption (m^3/day)	Projected Water Savings (m^3/day)	Percent Decrease in Total Water Consumption
Clean cooling tower	1. Closed-loop air radiator cooling system	20	0.0	20	13.6
Chemical refining	2.a. Treat and reuse all washwater	25.35	5	20.35	13.8
	2.b. Treat second centrifuge washwater and reuse in third centrifuge	14	6	8	5.4
	2.c. Reuse third centrifuge washwater in second centrifuge	25.35	20.35	5	3.4
Boiler	3. Boiler blowdown reuse after treatment	21.1	4.2	16.9	11.5
Process Equipment	4. Modify design or optimize operations	120	108	12	8.0
Tanker Truck	5. Capture and reuse live steam or eliminate live steam heating of tanker trucks	8.4	0.0	8.4	5.7
Floor washing	6. Reuse the boiler blowdown without treatment	5	0.0	5.0	3.4
Cooling tower	7. Optimize to decrease evaporative losses and increase concentration cycle	47.7	43.0	4.7	3.2
Softener	8. Reuse treated regeneration wastewater	6	2	4	2.6
Cooling tower	9. Treat bleed-off and reuse	4.2	0.2	4.0	2.6
Softener	10. Increase capacity	6	4	2	1.3
Maintenance and sanitary	11. Use dry cleaning methods and install water conservation devices	10	8	2	1.4

Acidification	12. Eliminate live steam heating	1.4	0.0	1.4	1.0
Spill	13. Improve spill control and clean-up	4	3	1	0.7
Centrifuge and filter	14. Treat and reuse washwater	1.0	0.0	1.0	0.7
Steam System	15. Reduce steam leaks	1.0	0.5	0.5	0.35
Centrifuge	16. Optimize to reduce cleaning frequency	1.0	0.7	0.3	0.2
Total Savings	-	-	50 - 73	73 - 97	49 - 66

FIGURES

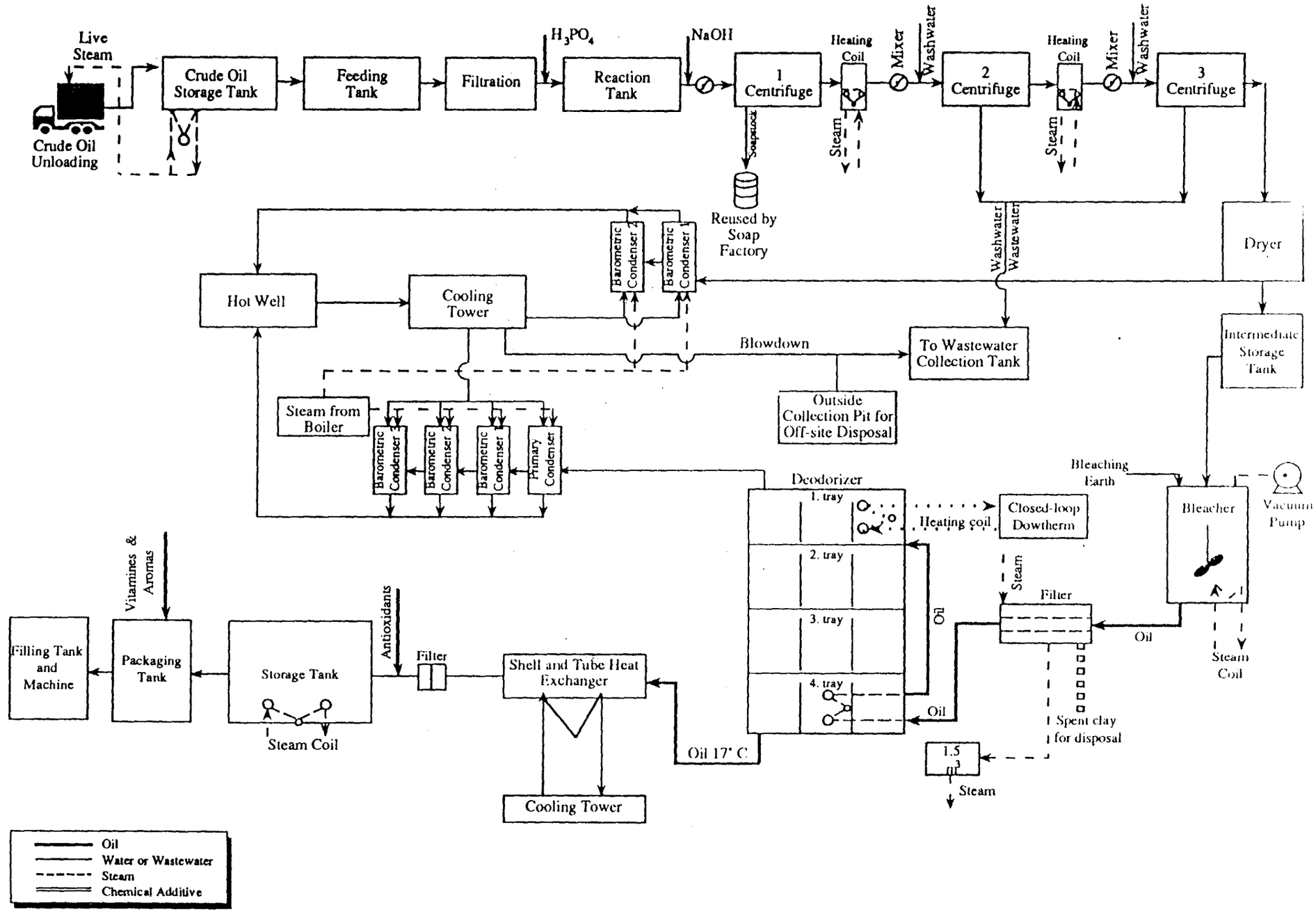


Figure 1. Chemical Refining Water and Process Flow Diagram

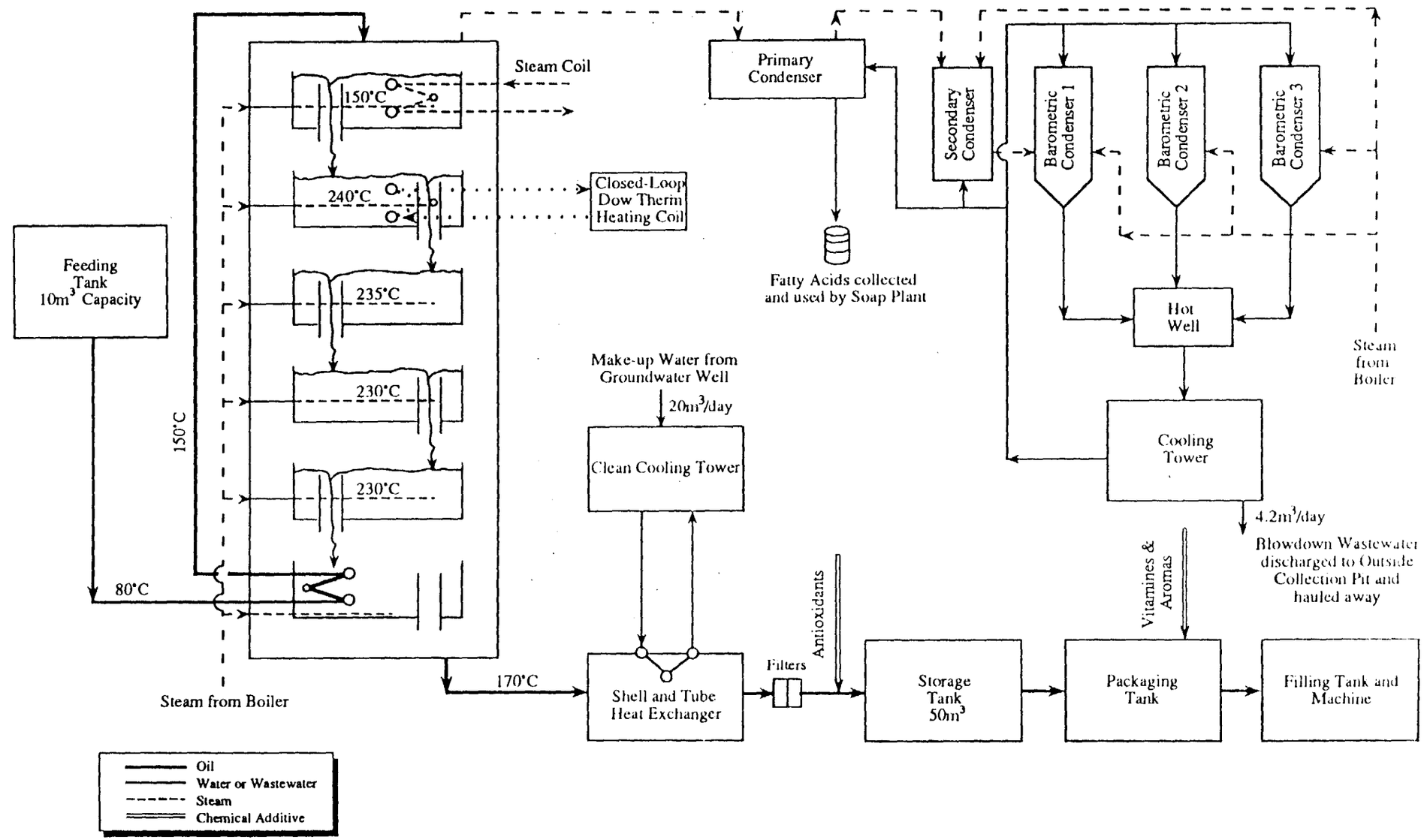


Figure 2. Physical Refining Water and Process Flow Diagram

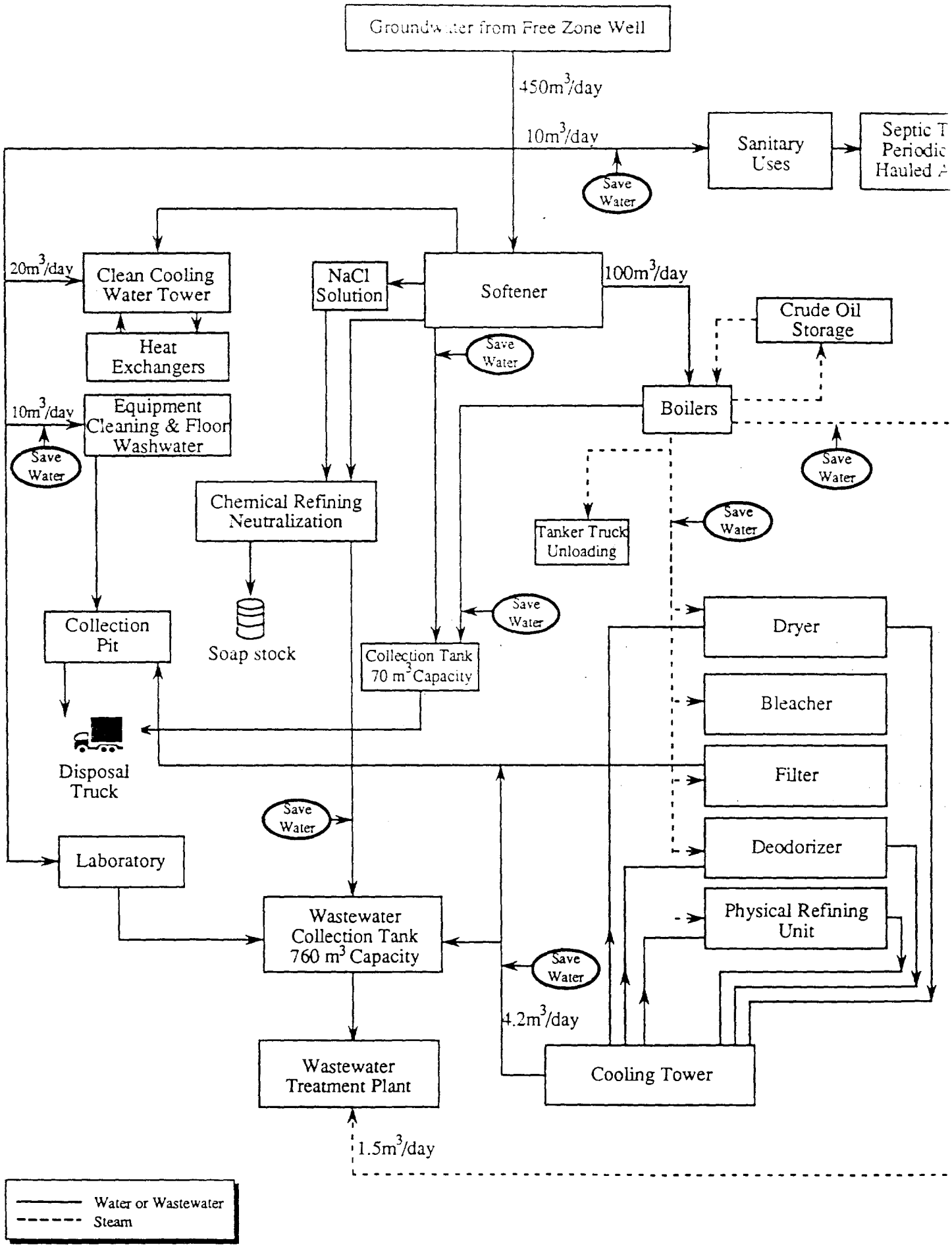


Figure 3. Water and Wastewater Flow Diagram

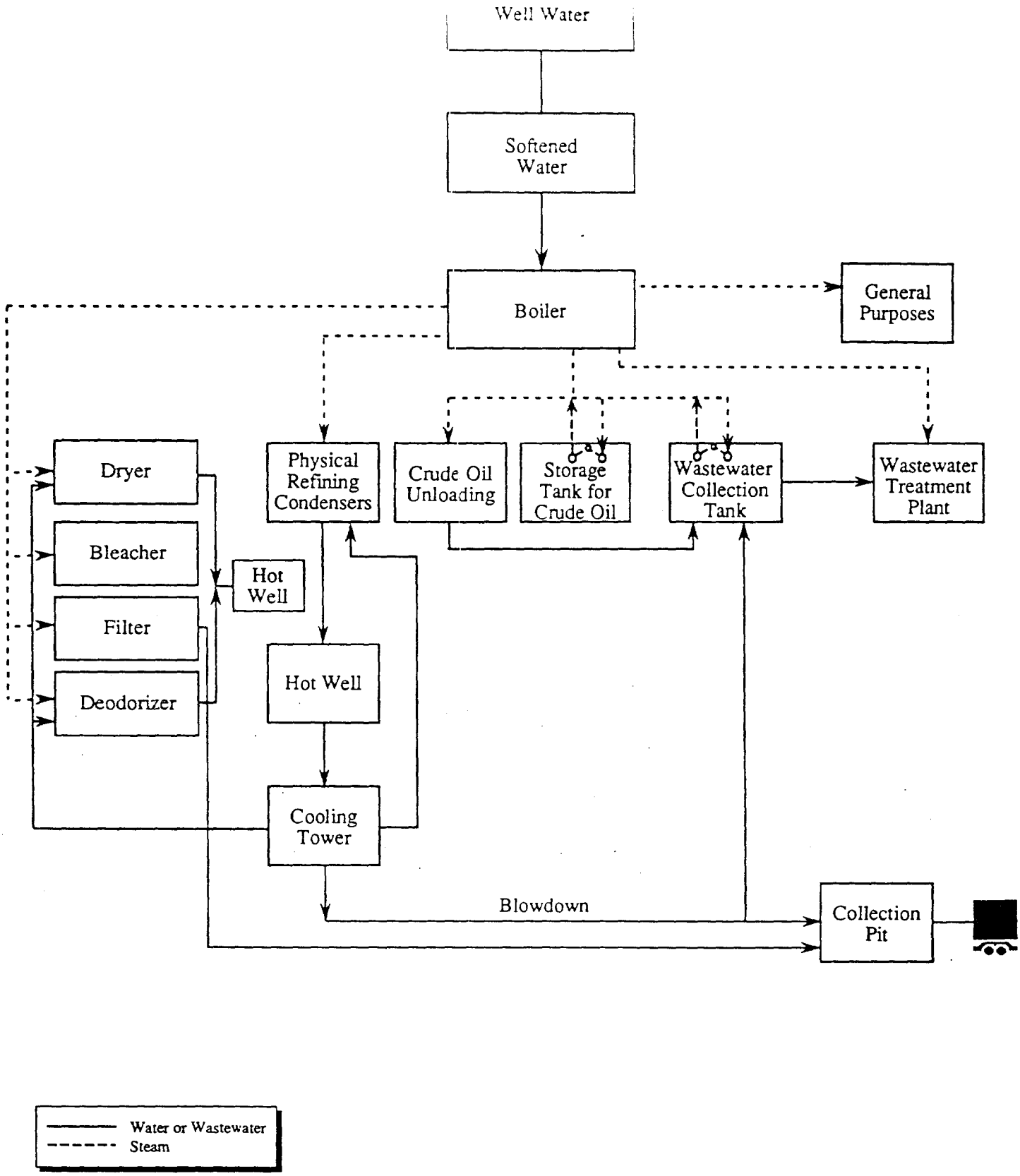
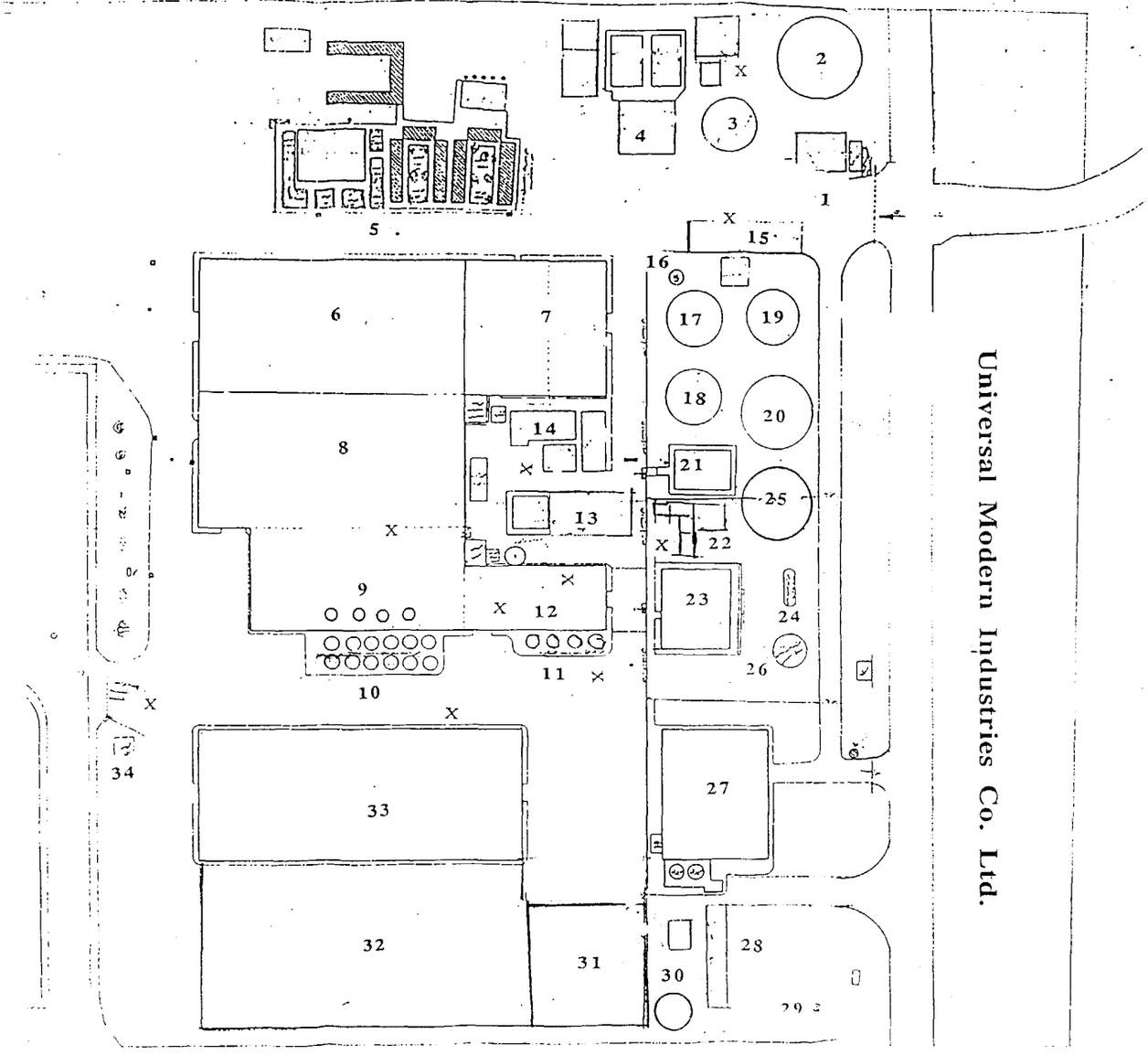


Figure 4. Steam Flow Diagram

Key

1. Gate
2. Storage tank for corn oil capc. 2000 m^3.
3. Wastewater collection tauk capc. 760 m^3.
4. Wastewater treatment plant.
5. Adminstration and offices.
6. Final product storage.
7. Maintenance workshop.
8. Filling.
9. Packaging tanks.
10. Storage tanks for refined oil.
11. Storage tanks for feeding the refinery.
12. Chemical refining.
13. Physical refining.
14. Hot pit & Clean cooling tower.
15. Storage tank for excess barometric condensate from cooling tower.
16. Crude oil unloading point and pump room.
17. Storage tank for palm oil capc. 750 m^3.
18. Storage tank for soya oil capc. 750 m^3.
19. Storage tank for palm oil capc. 750 m^3.
20. Storage tank for palm oil capc. 1400 m^3.
21. Laboratory.
22. Cooling tower for vacuum system.
23. Boiler haus and water softners.
24. Collection pit for boiler blowdown an regeneration backwash.
25. Storage tank for palm oil capc. 2000 m^3.
26. Fuel storage tank.
27. Electricity generators.
28-29. 3 water wells.
30. Freshwater storage tank capc. 450 m^3.
31. Store haus for chemicals.
32-33. Store hauses for emty oil containers for filling.
34. Outside collection pit for run-off and floor and equipment cleaning water.

X Spills



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MODERN SURVEYING OFFICE

Figure 5 Facility Location Plan

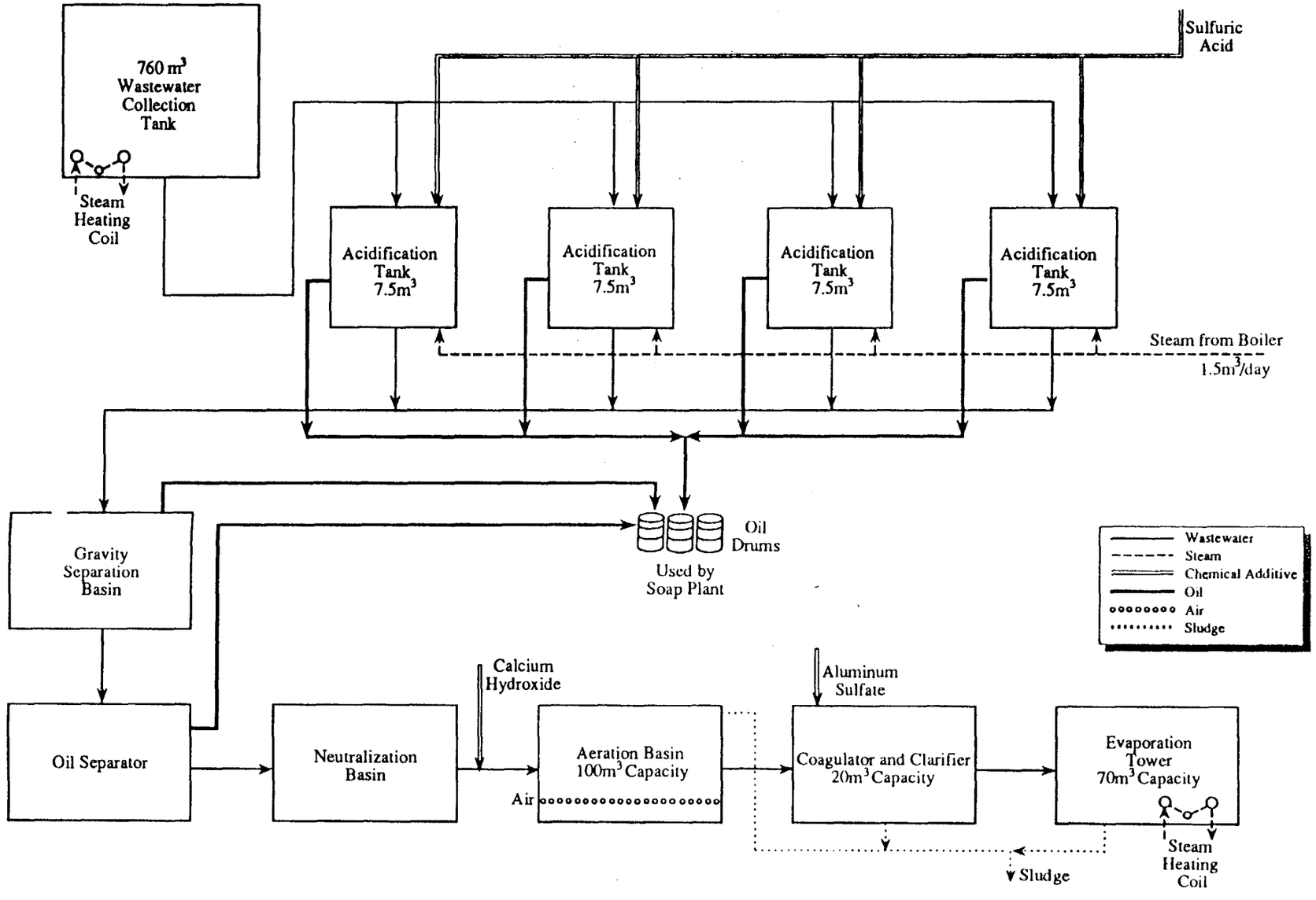

Figure 6. Wastewater Treatment Process Flow Diagram

APPENDICES

Appendix A
Example of Audit Questionnaire

WQICP WASTE MINIMIZATION AUDIT

Facility Name: UMIC Auditor/Firm: SAIC and R.S.S

Date: 7-1-95

ATTACHMENT A

AUDIT QUESTIONAIRE

SITE DESCRIPTION

Facility Name: Universal Modern Industries Co. Ltd.

Area:

Address: Zarqa - Free Zone

Telephone: 09/916005

Major Products: Vegetable eddible oils

Production Rate: Palm oil, Corn oil and Palm olein

SIC Codes: ≈ 170t/day

Major Sources of Wastewater Discharges:

1- Neutralizations washing waste water
2- Boiler blowdown
3- Softener regeneration backwash

Major Processes:

1- Water softening and steam generation
2- Chemical refining
3- Physical refining
4- Filling and storage

Facility/Equipment Age: 10 years except the physical refining unit is 22 years old

4- Equipment cleaning and floor washing
5- Bleed-off from barometric condensate
6- Oil unloading steam condensate
2- Heat exchanger clean cooling tower
'- Sanitary waste water

WQICP WASTE MINIMIZATION AUDIT

Facility Name: UMIC Auditor/Firm: SAIC and R.S.S

Date: 7-1-95

PROCESS INFORMATION

Operation Type: -✓ Continuous -- Discrete
-- Batch or Semi-Batch -- Other_____

Document	Complete? (Y/N)	Current? (Y/N)	Document Number
Process Flow Diagram	Y	Y	
Material/Energy Balance			
Design			
Operating			
Flow/Amount Measurements	Y	Y	
Stream			
Analyses/Assays			
Stream			
Plant Layout	Y	Y	
Process Description	Y	Y	
Operating Manuals	N	N	
Equipment List/Age	N	N	
Equipment Specifications	N	N	
Piping & Instrument Diagrams	N	N	
Plot and Elevation Plan(s)	N	N	
Environmental Audit Report	N	N	
Permit/Permit applications			
Raw Material Inventory Records	Y	Y	
Product Inventory Records	Y	Y	
Management method practiced for each wastewater stream	Y	Y	
Wastewater treatment facilities	Y	Y	
Waste management practice	Y	Y	

WQICP WASTE MINIMIZATION AUDIT

Facility Name: UMIC

Auditor/Firm: SAIC and R.S.S

Date: 7-1-95

INPUT MATERIALS SUMMARY

Material	DESCRIPTION[1]		
	Stream No.	Stream No.	Stream No.
Name Palm Oil, Seyapil, Cornoil, P-olin			
Source/Supplier ~~Malaya~~ Malysia and other countries			
Component of Concern Vegetable edible oil			
Annual Consumption Rate	N.A		
Overall			
Component(s) of Concern			
~~Sodium hydroxide, phosphoric acid and bleaching Clay~~			
Purchase Price, $ per	N.A		
Overall Annual Cost			
Delivery Mode[2] tank truck	50 in capc		
Shipping Container Size & Type[3]			
Storage Mode[4] outdoor above ground			
Transfer Mode[5] Pump			
Empty Container Disposal/Management	None		
Shelf Life	N.A		
Supplier Would			
- accept expired material (Y/N)	N		
- accept shipping containers (Y/N)	N.A		
Acceptable Substitute(s), if any	N.A		
Alternate Supplier(s)			
Product Inventory Records	~~N~~ Y		

1. Stream number, if applicable, should correspond to those used on process flow diagram
2. e.g., pipeline, tank truck, etc.
3. e.g., drum, paper bag, tank, etc.
4. e.g., outdoor, warehouse, underground, aboveground, etc.
5. e.g., pump, forklift, conveyor, etc.
6. e.g., crush and dump, clean and recycle, return to supplier, etc.

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WQICP WASTE MINIMIZATION AUDIT

Facility Name: MIC Auditor/Firm: SAIC and R.S.S

Date: 7-1-95

INDIVIDUAL WASTE STREAM CHARACTERIZATION

(page 1 of 4)

1. Waste Stream Name/ID: Neutralizations washing waste water; Stream No. 1

2. Waste Characterization (attach additional sheets with composition data, as necessary)

--- Gas --- Liquid --- Solid --- Mixed phase

Density kg/M³ 1000 High Heating Value Cal/kg_____

pH _____ Flash Point _____ % Water ✓

3. Waste Leaves Process as:

-- air emission ✓ wastewater -- solid waste

4. Occurrence:

✓ -- continuous

-- discrete

discharge triggered by ✓ chemical analysis_____

-- other (describe)_____

Type ✓ -- periodic_____length of period_____

-- sporadic

5. Generation Rate:

Annual _____ kg per year

Maximum _____ kg per _____

Average 1 m³/hr = 1000 kg per hour

Frequency _____ batches per _____

Batch Size_____ average _____ range

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WQICP WASTE MINIMIZATION AUDIT

Facility Name: UMIC Auditor/Firm: SAIC and R.S.S

Date: 7-1-95

INDIVIDUAL WASTE STREAM CHARACTERIZATION

(page 2 of 4)

6. Waste Origins/Sources

Fill out this worksheet to identify the origin of the waste. If the waste is a mixture of waste streams, fill out a sheet for each of the individual waste streams.

Is the waste mixed with other wastes? ---- Yes ✓ No

Describe how the waste is generated.

This waste stream is generated by washing crude oil with softened water, after the oil had been treated with small quantity of phosphoric acid and with NaOH solution to remove the phosphatides and free fatty acids.
The quantities are determined by conducting tests on crude oil.

Example: Formation and removal of an undesirable compound, removal of an unconverted input material, depletion of a key component, equipment cleaning waste, obsolete input material, spoiled batch and production run, spill or leak cleanup, evaporative loss, venting losses, etc.

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WQICP WASTE MINIMIZATION AUDIT

Facility Name: ULMIC Auditor/Firm: SAIC and R.S.

Date: 7-1-95

INDIVIDUAL WASTE STREAM CHARACTERIZATION

(page 3 of 4)

Waste Stream 1

7. Management Method

Leaves site in --- bulk
--- 55 gal drum
--- other (describe) Collected in Storage tanks prior treatment.

Disposal Frequency Not applicable

Applicable Standards/Regs Jordanian Regulations (202)

Managed ✓ onsite --- offsite
--- other (describe)

Recycling --- direct use/re-use
--- energy recovery
--- redistilled
--- other (describe) Acidified with H_2SO_4 F.F.a removed, pH adjusted aerated and coagula
reclaimed material returned to site?

--- Yes --- No ✓ used by others

residue yield
residue disposal

Treatment --- biological
--- oxidation/reduction
✓ pH adjustment
--- precipitation
--- other (describe) F.F. acids are removed

Final Disposition --- Dump
--- pond
--- other (describe) Currently disposed ~~by a tanker truck~~ owned by the Facility on industrial waste wat dump site.

INDIVIDUAL WASTE STREAM CHARACTERIZATION

(page 4 of 4)

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WQICP WASTE MINIMIZATION AUDIT

Facility Name: UMIC Auditor/Firm: SAIC and R.S.S

Date: 7-1-95

cost as of ____ (quarter and year)

Cost Element	Unit Price JD per ____	Reference/Source
Onsite Storage & Handling		
Pretreatment		
Container		
Transportation Fee		
Disposal Fee		
Taxes		
Total disposal Cost		

x Not applicable

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WQICP WASTE MINIMIZATION AUDIT

Facility Name: UMIC Auditor/Firm: SAIC and R.

Date: 7-1-95

WASTE STREAM INFORMATION

(one form for each stream)

Stream ID: 1

1. Streamname: Neutralizations washing waste water.
(wastewater, waste oil, still bottoms, etc.)

2. Discharge Identification: Centrifuge - oil washing water.
(Enter process or equipment from which stream is discharged)

3. Stream flow/quality:

minimum flow: _____ L/min
maximum flow: _____ L/min
average flow: 16 L/min

4. Is stream continuous orintermittent? Continous

5. Which of following is the cause of the waste?

a. Process chemistry = (Reaction stoichiometry, kinetic, yield)
Describe: Crude vegetable oils contain phosphatides and free fatty acids, which must be removed from the oil as soapstock. the f.f.a are neutralized with Na

avg. rest → $R-C_{OH} + NaOH \rightarrow R-C_{ONa} + H_2O$

b. Engineering Design (capacity, pressure, temperature limitations, etc.). Describe:

c. Operations = (operating rates, order of addition, etc.) Describe:

d. Maintenance = (leaks, spills, corrosion, etc.)
Describe:

6. Are the components of the waste stream a raw material (RM), product (P), useful byproduct (UPB), nonuseful byproduct (NBP), solvent (S), catalyst (C), or an impurity (I) in the raw material?

(Attach analysis records if possible)

Fill out attached Figure 1 for each waste stream

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WQICP WASTE MINIMIZATION AUDIT

Facility Name: _____ Auditor/Firm: _____

Date: _____

Component Name	Conc (mg/L)	Check One						
		RM	P	UBP	NBP	S	C	I
Soap stock				✓				
Free fatty acid				✓				

7. Waste stream characteristics - pH: ✓ TSS: ✓ TDS: ✓ FOG
Color: ____ Hardness: ____ Odor: ____ TOC: ____ Other: ____

8. Current disposition of the stream: ~~Collected in storage tank and disposed by tanker truck to industrial disposal dump site.~~ WW

9. Current effluent criteria and disposal limitation: _____
~~202 Regulations~~

10. Permits relevant to the waste stream disposition: _____

11. Current cost of disposal and/or treatment for this waste stream:

12. If stream is currently being treated, list:

a. Current treatment parameters (chemical consumption, treatment conditions, etc.): _____

b. Existing treatment equipment (identify, size and type of equipment):
~~- 4 wooden tanks capc. 7.5 m³ each for acidification~~
- Oil seperator
~~- Concrete tank for gravity oil seperation~~
~~- Concrete tank for aeration~~
~~- Concrete tank for coagulation~~
- Cooling tower

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WQICP WASTE MINIMIZATION AUDIT

Facility Name: UMIC

Auditor/Firm: SAIC and R.S.S

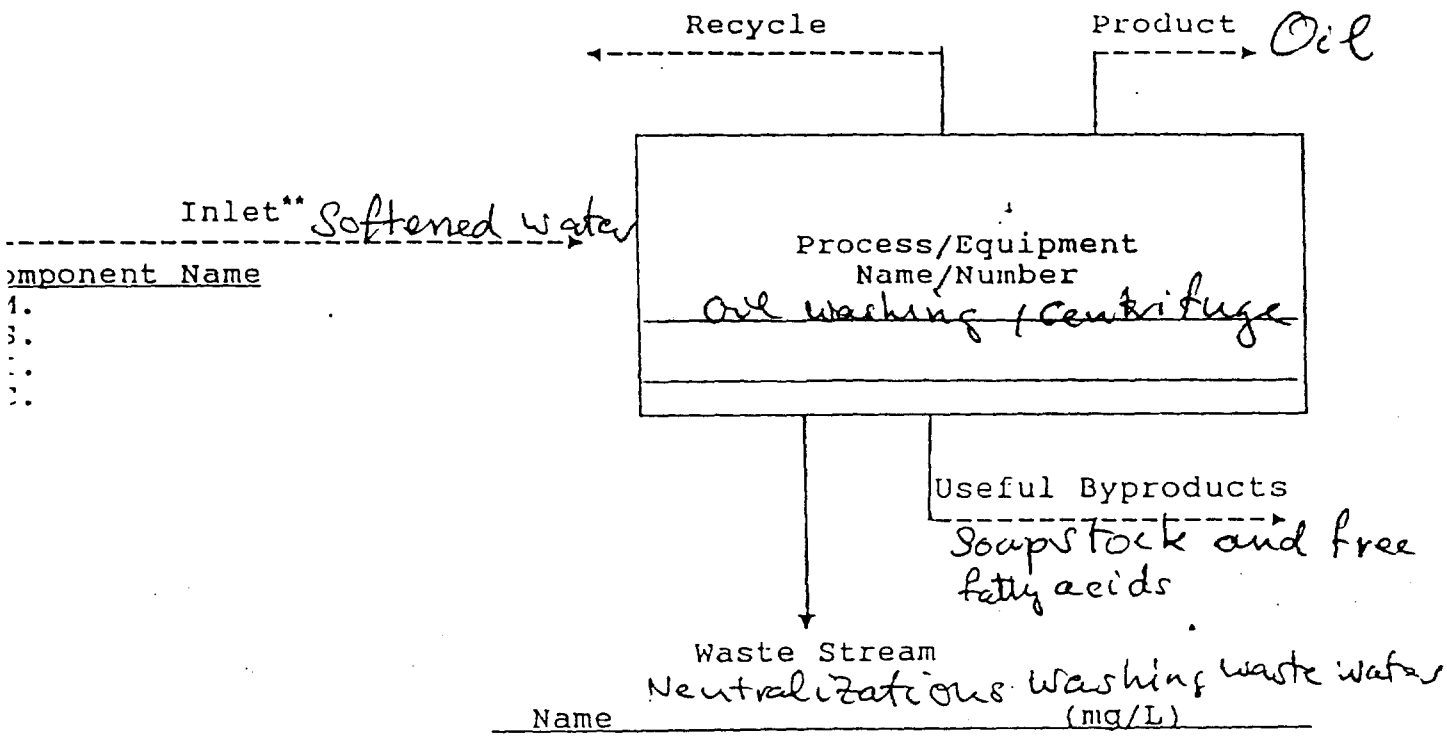
Date: 7-1-95

Other pertinent information: N/O

WQICP WASTE MINIMIZATION AUDIT

Facility Name: UMIC Auditor/Firm: SAIC and R.S.S

Date: 7-1-95



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WQICP WASTE MINIMIZATION AUDIT

Facility Name: ulMIC Auditor/Firm: SAIC and R.S.

Date: 7-1-95

WASTE STREAM SUMMARY

Component of Concerns	Stream No[1]	Stream No	Stream No
Waste ID/Name	1		
Source/Origin Oil washing	oil washing		
Annual Generation Rate (units m^3)			
Overall	6480		
Component(s) of Concern			
Cost of Disposal			
Unit Cost (JD per _____)			
Overall (per Year)			
Method of Management[2] disposed by tanker after removal of free fatty acids			

Priority Rating Criteria[3]	W	Rating (R)	R*W	Rating (R)	R*W	Rating (R)	R*W
Regulatory Compliance							
Treatment/Disposal Cost							
Waste Quantity Generated							
Waste Hazard							
Safety Hazard							
Minimization Potential							
Potential Byproduct Recovery							
Sum of Priority Ranking Scores							
Priority Rank							

1. Stream number, if applicable, should correspond to those used on process flow diagrams.
2. For example, sanitary dump, onsite recycle, dewatering, etc.
3. Rate each stream (W) in each category on a scale from 0 to 10.

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Appendix B
Information Provided by the UMIC Facility

Notes provided by the facility

نبذه مختصره عن تأسيس الشركة .

تأسست الشركة العالمية الحديثة لصناعة الزيوت النباتية في عام (١٩٨٢) كشركة مساهمة خاصة برأسمال قدره " ٣٫٥ " مليون دينار أردني .

بدأ الأنتاج الفعلي في الشركة عام (١٩٨٦) وكانت الشركة ضمن السياج للمنطقة الحره في الزرقاء .

وفي عام (١٩٨٩) تم تحويل الشركة من شركة مساهمة خاصة الى شركة عامه مع زيادة في رأسمال الشركة من " ٣٫٥ " مليون دينار الى خمسه ملايين دينار أردني .

كذلك تم فصل الشركة من سياج المنطقة الحره وأصبحت خارج المنطقة الحره .

وتقوم الشركة الأن بانتاج انواع متعدده من الزيوت النباتية مثل " زيت الصويا ، وزيت الذره ، وزيت النخيل ... الخ

وقد تم في الوقت الحاضر زيادة الطاقه الأنتاجية للمصنع حيث بلغت " ٢٠٠) طن يوميا لمختلف انواع الزيت .

Universal Modern
Industries Co. Ltd.

- The company was established in 1982 as a private shareholding company with a capital of 3.5 million JD
- Company production started in 1986 and the company was located in the free zone in Zarqa
- In 1989 the company ~~was~~ became a public company with an increase in capital to 5 million JD and the company was not considered any more in the free zone.
- The company produces soyabean oil, corn oil and palm oil. The production capacity of

"Technical Report."

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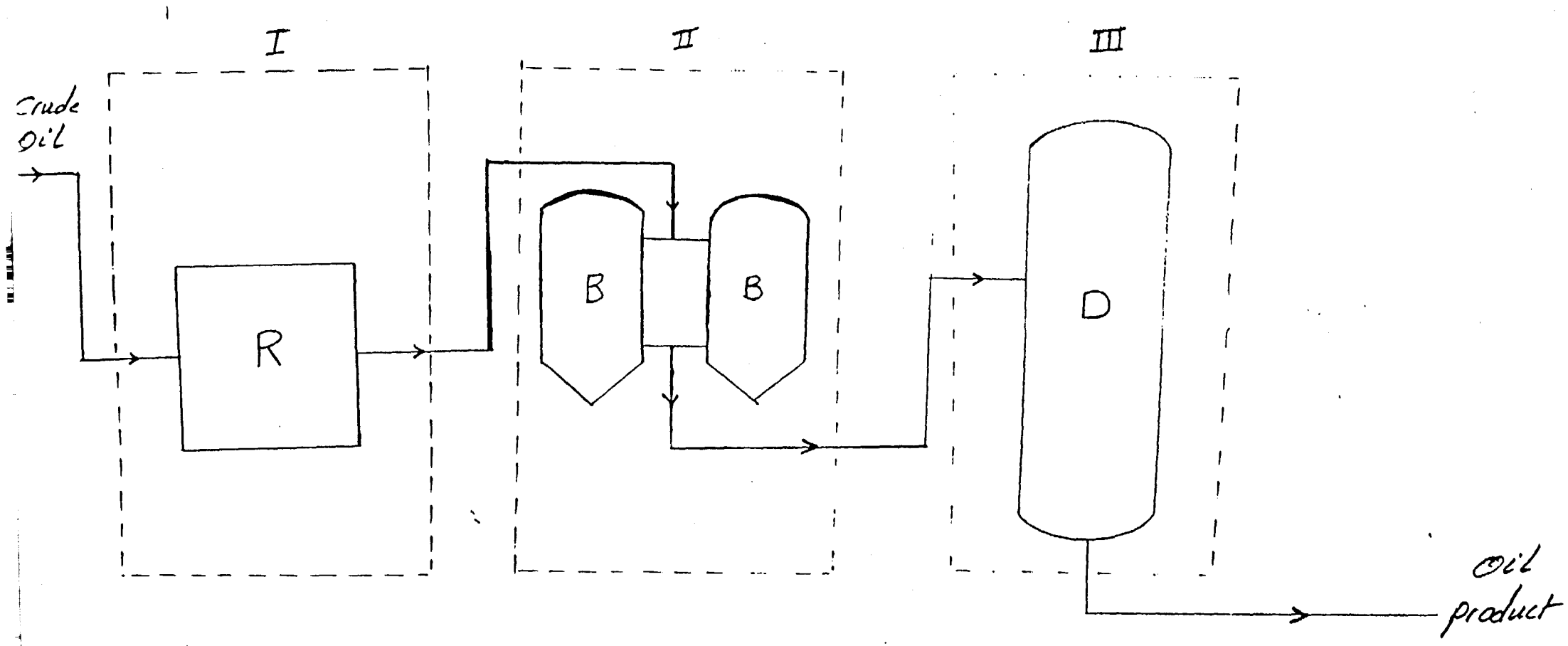


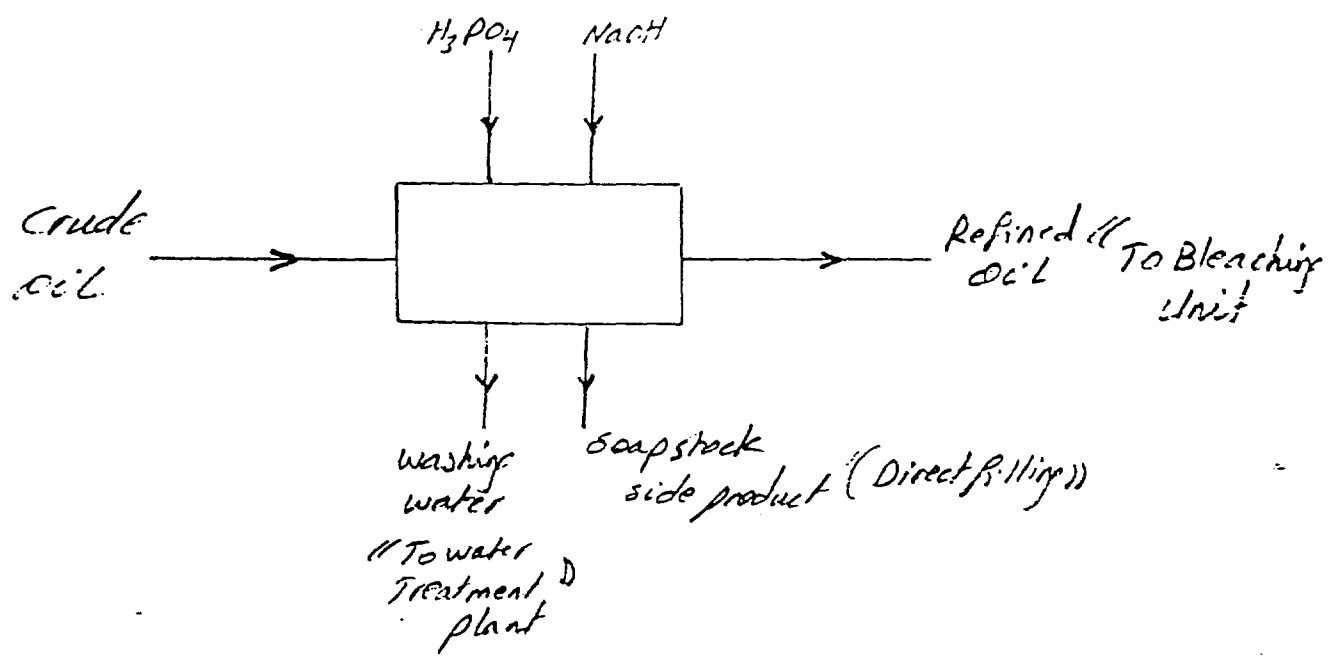
Oil Processing Plant "No. 1"

Oil Processing Plant No. 1

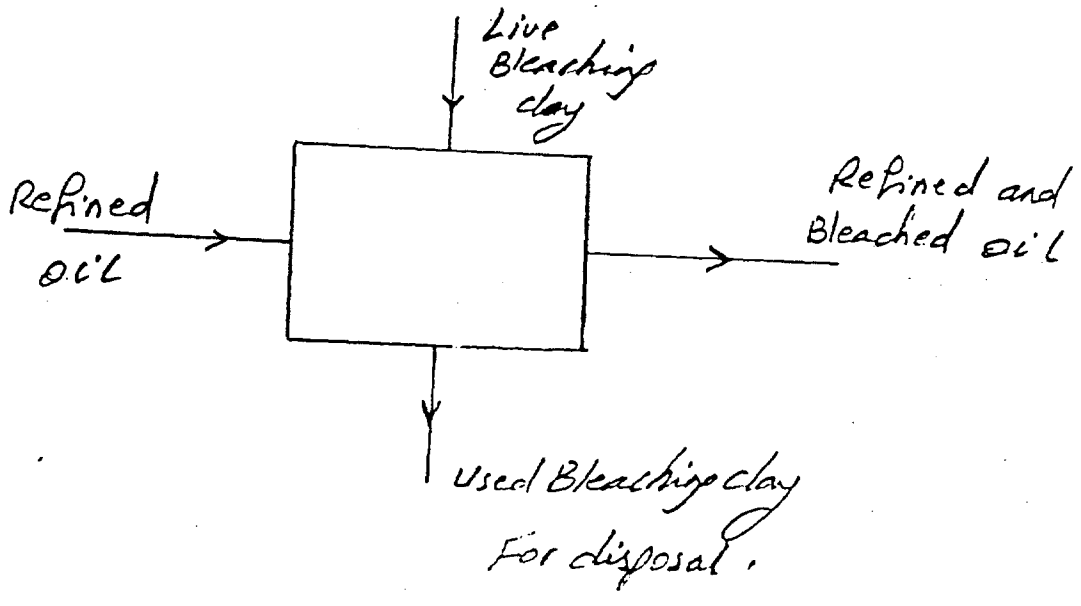
** This plant consists of Three Units :-

I - Refinery Unit :- In this unit, Crude oil is Treated with Caustic soln of a certain Concentration, to decrease the Fatty Acids Concentration of oil, also phosphoric acid is used in this unit to remove the phosphatides available in Crude Corn oil & Soya Bean.

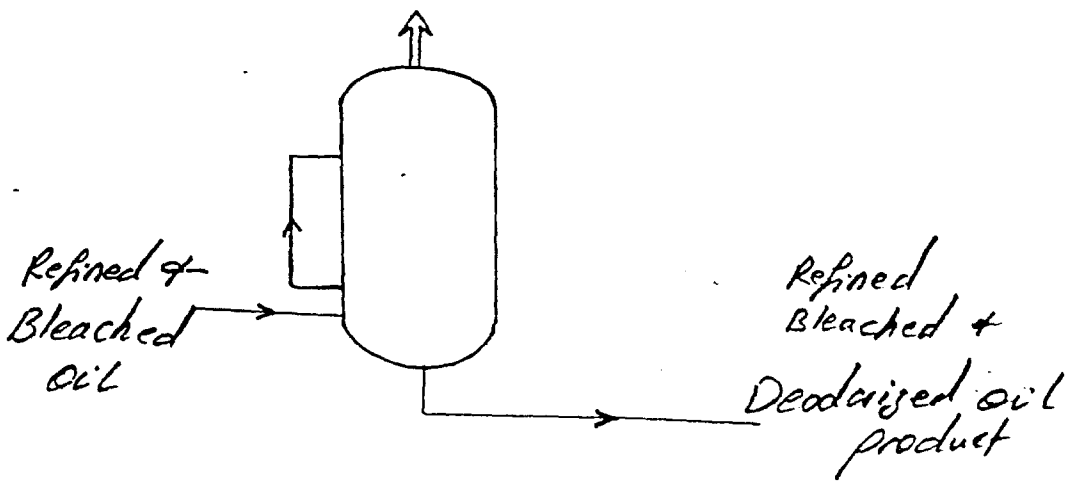
- Soft water is used For washing oil so the washing water is centrifugally seperated and Transfered to water Treatment plant.

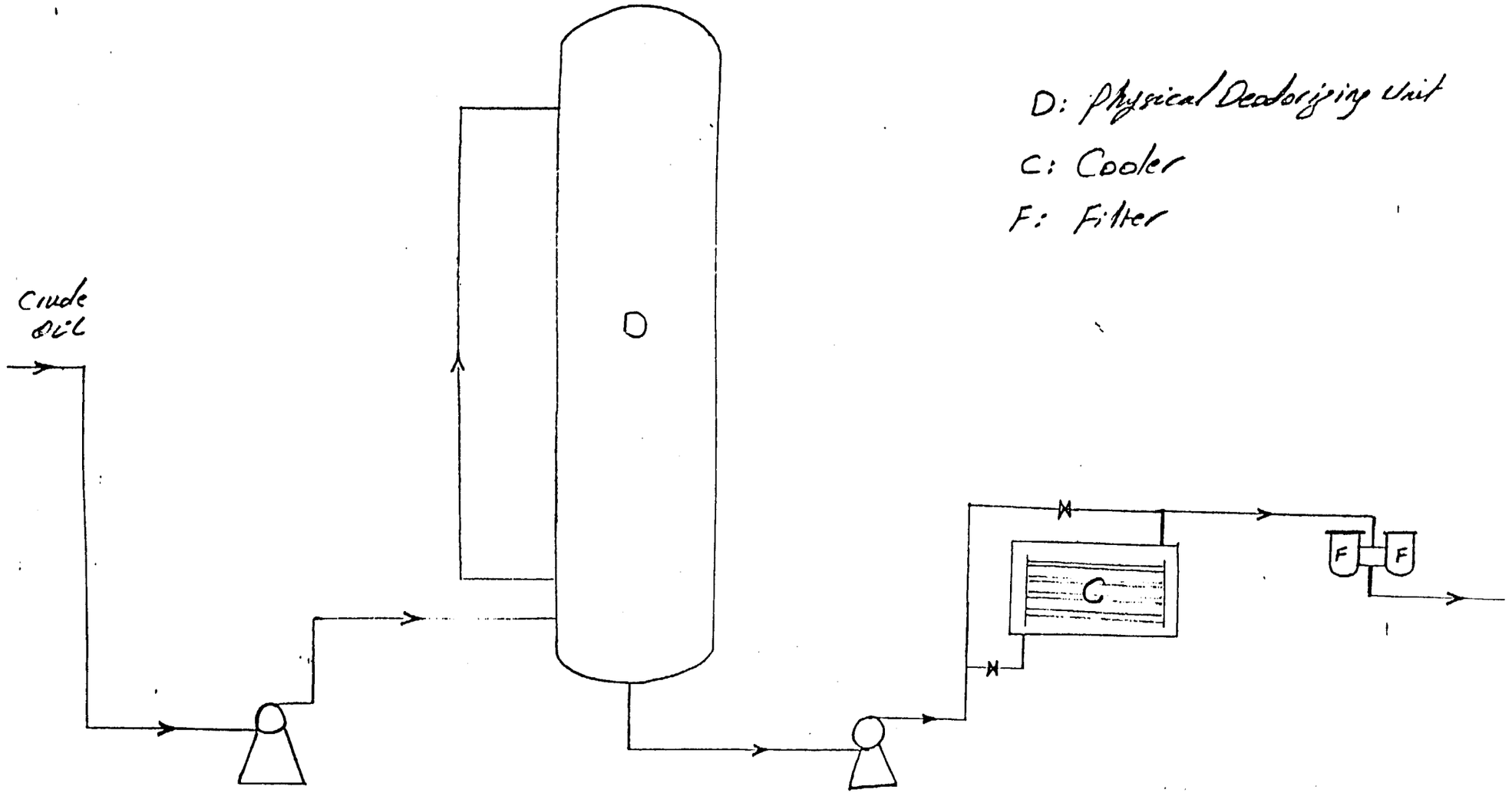


II- Bleaching Unit :- In this Unit colour of oil is Reduced by using an active clay « Bleaching earth » with a suitable dose, and Heating up the mixture of oil-clay up to 110°c, then make filtration and Transfer the product toward deodorization plant.



III - Deodorization Unit :- In this unit, the tast & smelt as well as the free fatty acid & the colour are Reduced by distillation at high temp under vaccum.

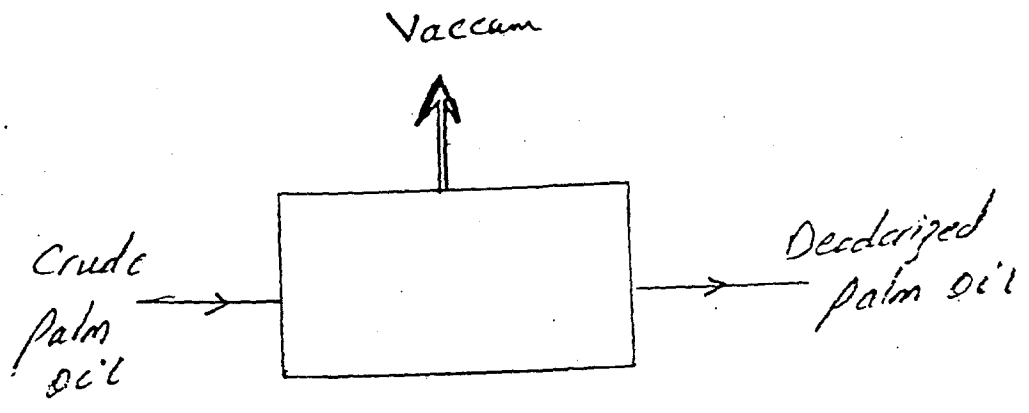




New physical Refining & Deodorization Plant

New physical Refining & Deodorization plant

- In this Unit, Crude palm oil is being fed to the system, without chemical refining. In this case it eliminates soap stock production, & consumption of washing water



Water Treatment Plant

* The feed sources of this plant:-

1- Refinery Unit: washing water & side product of Neutralization Reaction.

2- Vaccum Cooling Towers: Bleed off Towers.

3- Cleaning & ground washing water with Traces of oil included.

4- Boilers Blow down

5- Softener Regeneration (which is used for washing purposes as well)

* This unit consists of the following parts:-

1- Acid oil production plant ((Soap stock treatment plant))

2- Acid oil separator

3- pH adjustment pool

4- Coagulation plant

5- Evaporation Towers

* Operation system of the plant:-

1- Soap stock water solution being treated with H_2SO_4 Using live steam coils at the bottom of wood Tanks, inorder to boil the mixture of acid & water, then seperating the Two layers by gravity.

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2- Acid oil Filled in Drums and water Treated normally into the other plant sections, so

a) oil seperator is used to seperate traces of oil from water before aeration & pH adjustment procedure.

b) then pH of inlet water is being adjusted using $Ca(OH)_2$ solution to be "6.5 - 7.5" Then aeration by open air being done.

c) the aerated water of a suitable pH is being treated into Coagulation Tank, Specially Designed for this purpose, using Aluminum Sulfate soln doses.

d) the completely Treated water into coagulator being Evaporated into cooling Tower plant.

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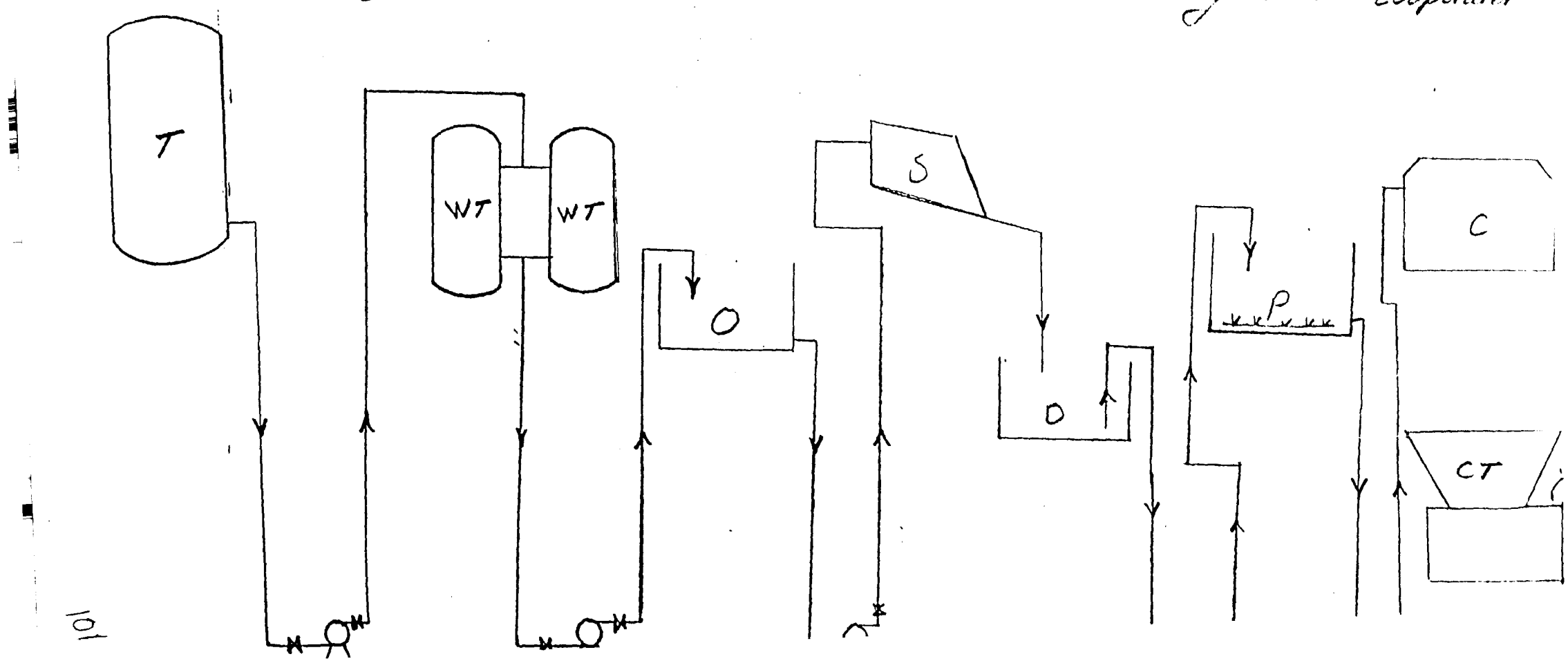
Water Treatment plant

T:- Industrial water Tank
WT: Wood Tanks for Treatment
O: Gravity seperation pool
S: Oil seperator
D: water Drain pool
P: Aeration pool
C: Coagulator
CT: Cooling Tower "Evaporator"



Water Consumption Survey -

I- Refinery Unit 24 ~ 30 m^3/day

II- Boilers 90 ~ 100 m^3/day

III- Softeners Regeneration ~ 8 m^3/day

IV- Cooling Tower Make up water 20 ~ 24 m^3/day

V- Cleaning & washing purposes ~ 10 m^3/day

Tot. Cons. = 152 ~ 172 m^3/day

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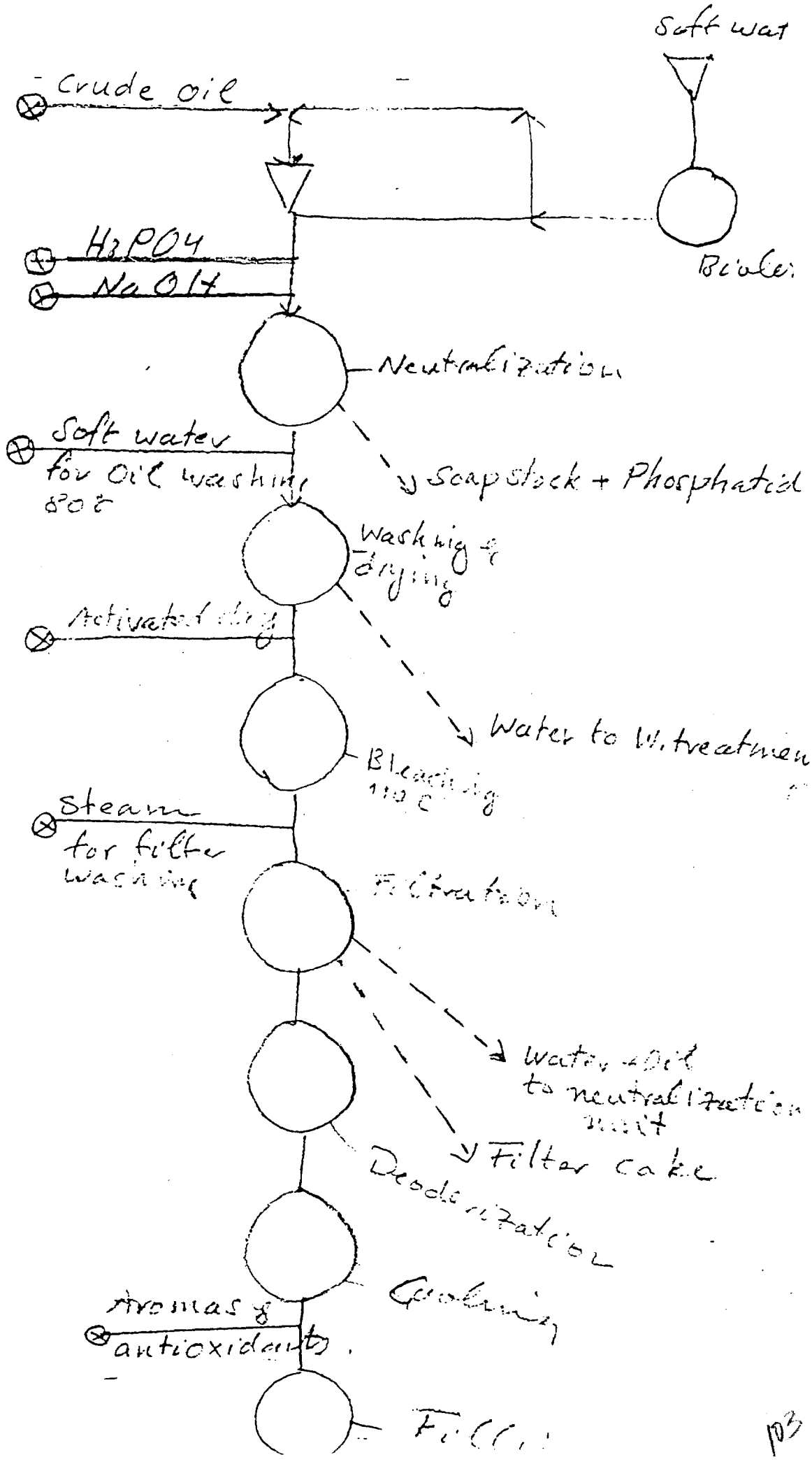
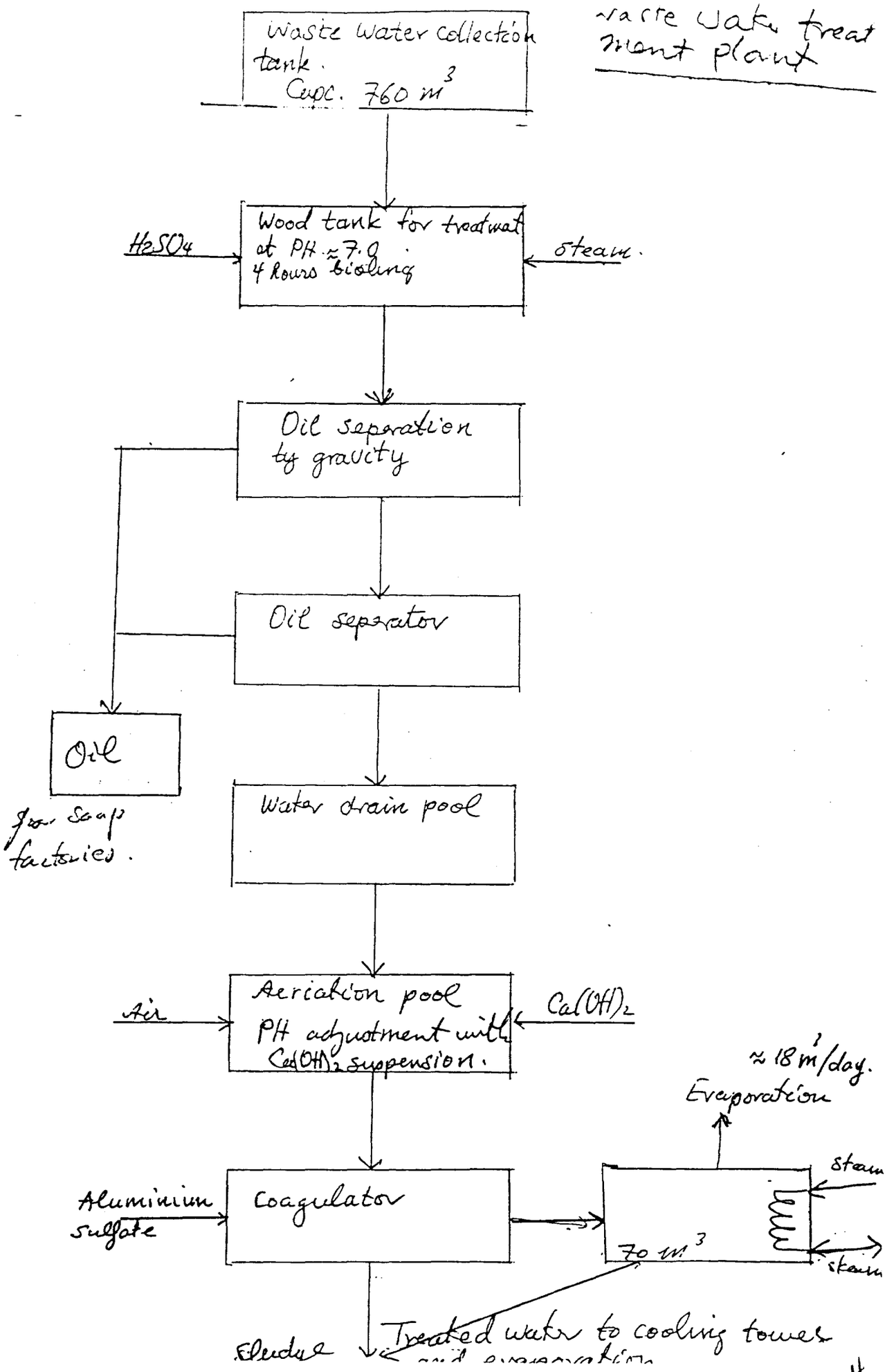
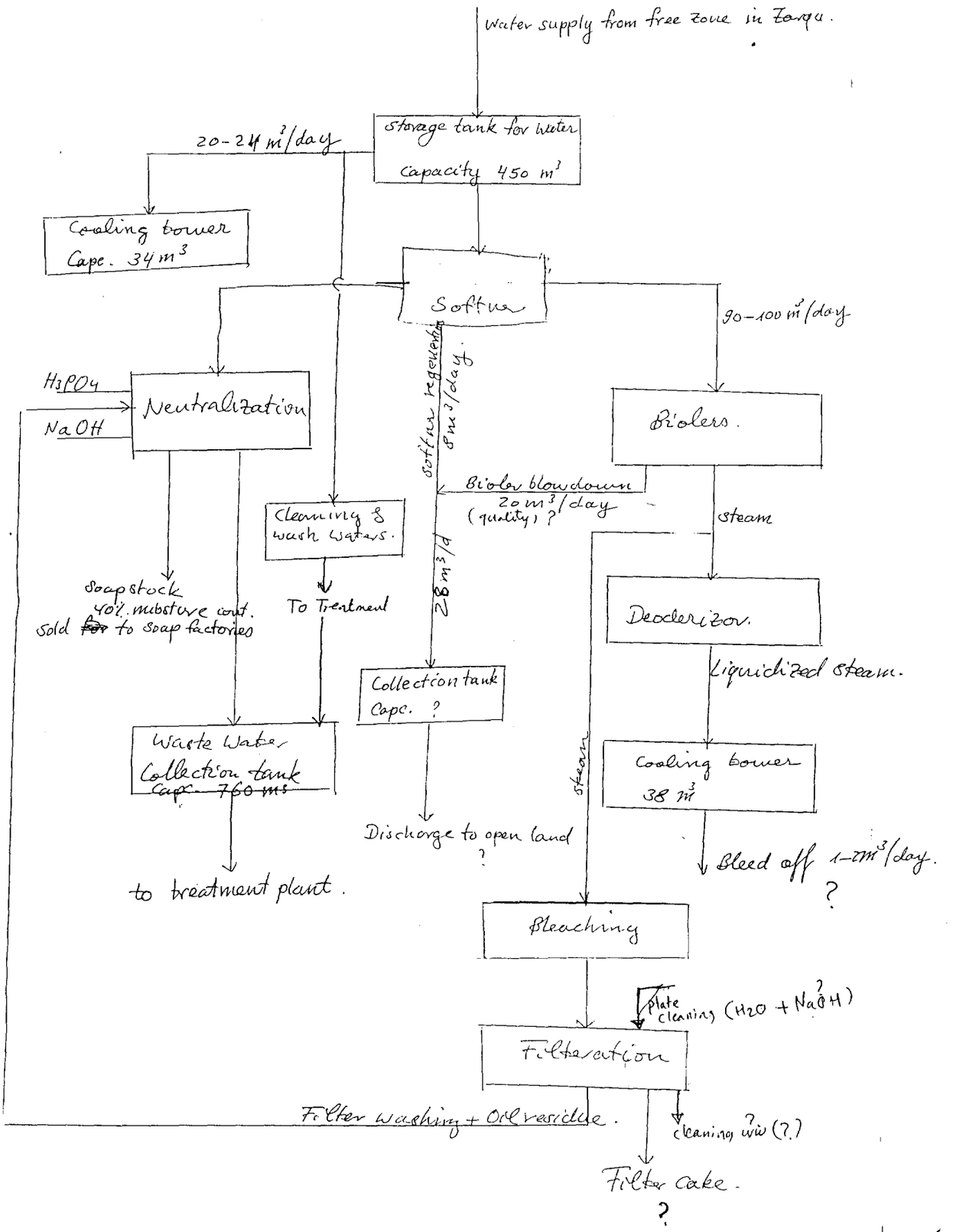
Refining process at UMIC



waste water treatment plant



Water use flow chart at Umic.



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VEGETABLE OIL REFINING FACILITY

1. Has the crude oil already been degummed or is degumming part of the alkali refining process at the facility? If degumming is one of the processes conducted at the facility is degumming conducted with water, steam, or phosphoric acid?

2. Are all processes operated on a batch, semi-continuous, or continuous basis?

3. What processes are automated, machine or computer controlled?

4. Is the same equipment used to produce the three different oils, soybean, corn oil and palmoline or are there separate process lines? yes

5. What is the volume of bleaching clay used per pound of oil? What is the production in pound of oil per day? How is the amount of bleaching clay to be added determined?

6. What is the volume of spent clay and how is it disposed?

7. Describe the packaging of the oil into the containers.

8. Describe the equipment and floor cleaning procedures. How often is cleaning conducted? Hot or cold water used? High volume, low pressure hoses or low volume, high pressure spray nozzles on hoses?

9. How are raw materials received and handled at the facility? Is the crude oil received in bulk (tanker trucks or railway cars), barrels or drums? Is the sodium hydroxide received in 55 gallon drums? Is the sodium hydroxide solution mixed on-site?

10. Is a catalyst, such as nickel, used in the hydrogenation process? If so, how much is used? No

Vegetable Oil Refining Facility :-

1- We have Four Types of oil that we are dealing w.
   a- Crude Corn oil "Needs Complete degumming"
   b- Crude Soya Bean oil "Semi degummed"
   c- RBD palmolein oil "polluted by Transportation storing"
   d- RBD Palm oil " " " " "

   - Degumming is a part of the alkali Refining process & it is conducted with phosphoric Acid

2- All processes operated on Continuous Basis.

3- The process is machine automated.

4- The same equipment is used to produce the Four types of oil.

5- The quantity of Bleaching clay used per pound of oil as fo.
   - a) Corn oil $= \frac{0.01\ lb}{oil\ lb}$,
   - b) Soya Bean $= \frac{0.009\ lb}{oil\ lb}$,
   - c) palm & palmolein $= \frac{0.003\ lb}{oil\ lb}$ "when necessary only"
   - Total production per day $\cong$ 400,000 lb
   - Amount of Bleaching clay determined According To -
     1- Colour Test of Refined oil

5 -

2 - Type of Bleaching clay & efficiency

3 - Flow Rate of oil

4 - Temp of Bleaching process.

5 - moisture and soap content of Refined oil

6 - Effeciency of Filtration system.

6 - the quantity of Bleaching clay (spent clay) per day as an average ≅ 2000 lb/day

- this disposed on a special open area outside the factory.

7 - spent clay are dried inside the Niggara Filters by steam for 20 min atleast to remove all Traces of oil then Filters being unloaded inside cubic containers

Kgs Tins
1Kgs Tins
- 1Kgs plastic
- Lit plastic

9- Raw Materials received and handled in different manners according to the type of Raw Material :-

Hence :-

a) Crude oil received in tanker trucks

b) ~~Phosporic acid and Antioxidant recieved in 30ft Bar~~

c) ~~Caustic Soda, Citric Acid, Bleaching Earth, Filter Aid recieved in plastic & paper Bags.~~

~~Based Caustic Soda recieved in 400 kgs Barrel.~~

& the Soda solution is prepared on site.

Caustic Soda flakes recieved in poly lined bags.

10- Now adays there is No Hydrogenation process.

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Universal Modern Ind. Co. Ltd

by Mr. Waleed Hussein

Raw Materials

Soybean oil, corn oil, Palm oil, Sulfuric acid, Sodium Hydroxide, steam, and bleaching earth and clay.

Manufacturing Process Steps

- Oil refining chemically in the refining unit using sodium hydroxide, phosphoric acid and hot water.
- Oil bleaching under vacuum using bleaching clay with a ratio of 1 to 2 %.
- Oil filtration under pressure to separate bleaching clay using a stainless steel filter.
- Deodorizing under a vacuum and in a temperature of 200°C to 235°C
- Cooling oil using a cooler to 40 to 50°C
- Filling in different containers

Energy Generation Unit

There are three diesel generators with capacities of 500 KW, 500 KW, and 200 KW.

There are four generators to generate saturated steam

- First boiler generates 3 tons/hour saturated steam at 15 bar pressure
- Second boiler generates 3 tons/hour saturated steam at 15 bar pressure
- Third boiler generates 2 tons/hour saturated steam at 15 bar pressure
- Forth boiler generates 8 tons/hour saturated steam at 15 bar pressure

the forth boiler is in operation and the three others are stand-by.

Water Use in I

a) Boiler water consumption is [illegible] m^3. Water is passed through a softener to remove hardness. Maximum hardness should not be more than 2 p.p.m. Softener resin is regenerated every 16 m^3. This resin is sodium based and is regenerated by sodium chloride with a concentration of 224 mg/l. The regeneration is performed 4 to 5 times a day with 1 m^3. The backwash water is discharge in a pool with a capacity of 40 m^3. Another 20 m^3 is added to this pool from blowdown water.

An oxygen scavenger (sodium sulfate) is added with a rate of 2.5 kg daily to the feed tank directly. An anti scalant (sodium sulfate) is also added with a rate of 1 kg daily to the feed tank.

b) Cooling Towers.

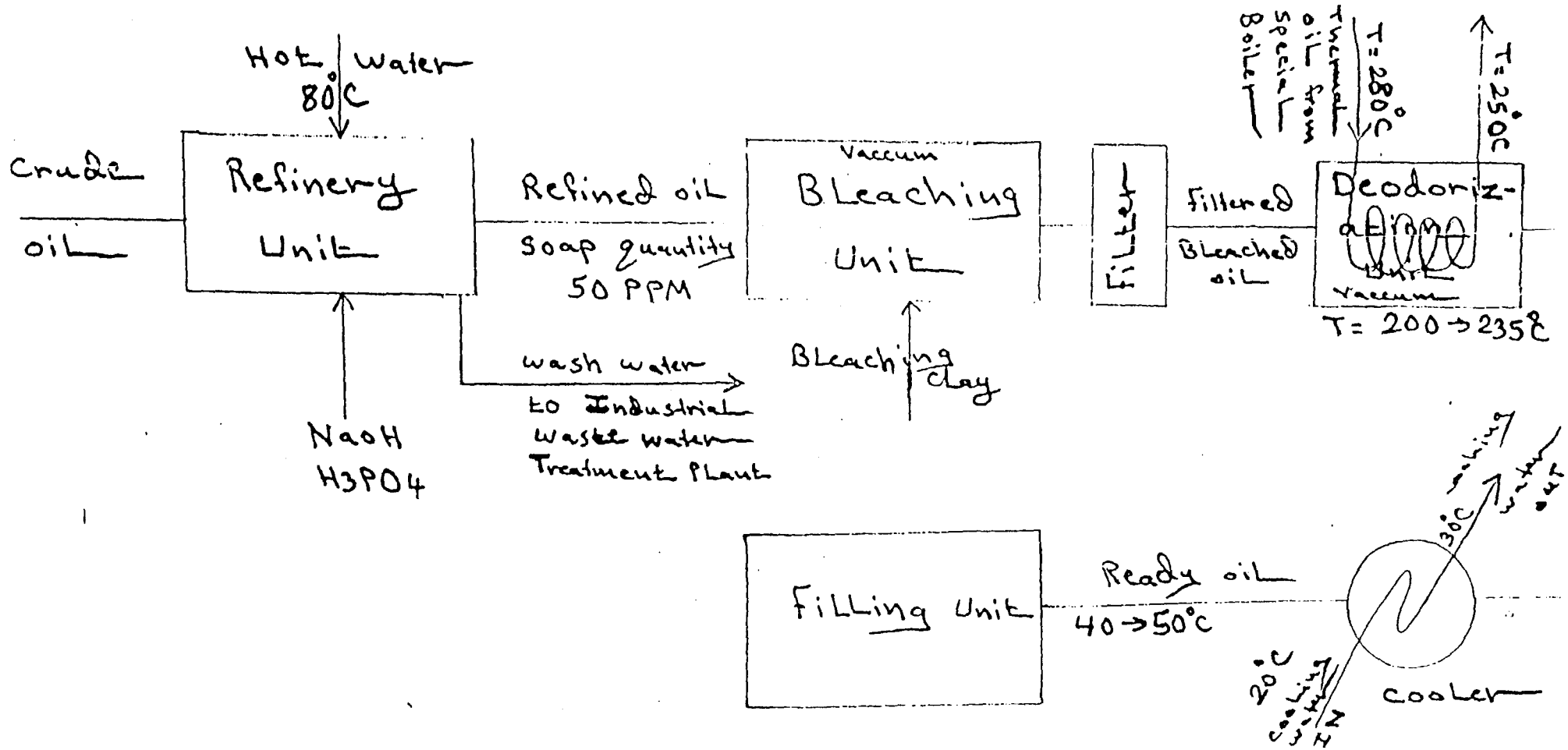
There are two types of cooling towers, one for cooling purposes and one for generating vacuum.

There is one cooling tower for cooling purposes fed from a pool with a volume of 34 m^3. The water that is fed to cooler is not softened water. Make up water is added daily with a volume of 5 to 10 m^3. Fungicides is added to this cooling water with a rate of one liter every three days.

Cooling tower used for vacuum generation in deodorizing vessel helps evaporating vapors responsible for odors. In this cooling tower there is a build up for water in the pool which requires bleed off with a rate of 1 to 2 m^3. The capacity of this pool is 38m^3. There are two towers of this type in the facility one operating and the other is under testing.

c) Cleaning Water

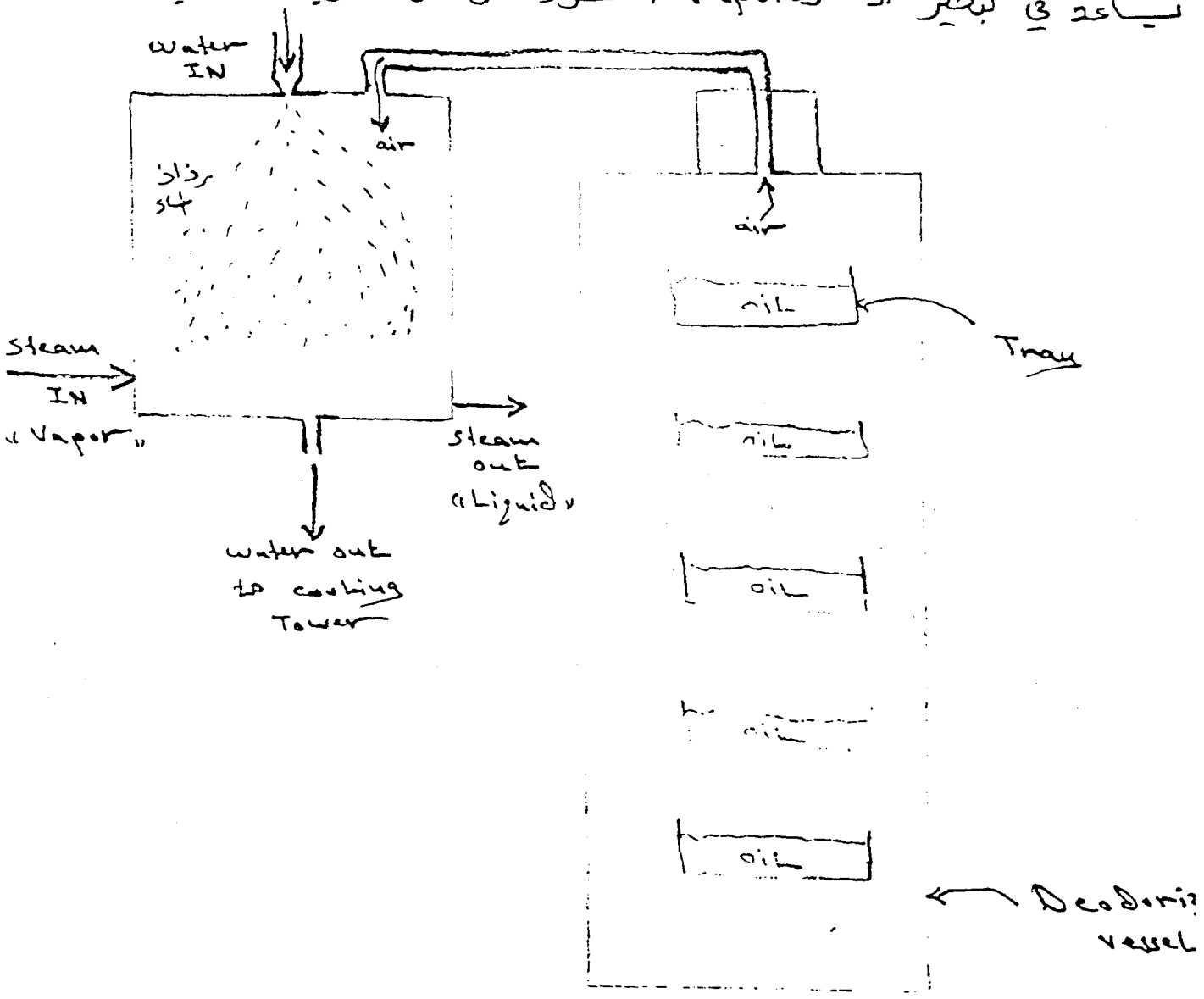
This water is collected on two impermeable basins one with a volume of 3 m^3 and the other with a volume of 10 m^3. Wastewater passes to the first basin through sewers and then overflows from the first basin to the second basin. Wastewater is vacuumed by a tanker and is used in soap unit in the wastewater treatment plant to separate oil from water.


Hot water
80°C
Crude oil
Refinery Unit
NaOH
H3PO4
Refined oil
Soap quantity
50 PPM
wash water
to Industrial waste water Treatment Plant
Vaccum
Bleaching Unit
Bleaching clay
Filter
filtered Bleached oil
Thermal oil from special Boiler
T= 280°C
T= 250°C
Deodorizer
Vaccum
T= 200 → 235°C
Filling Unit
Ready oil
40 → 50°C
30°C
cooler

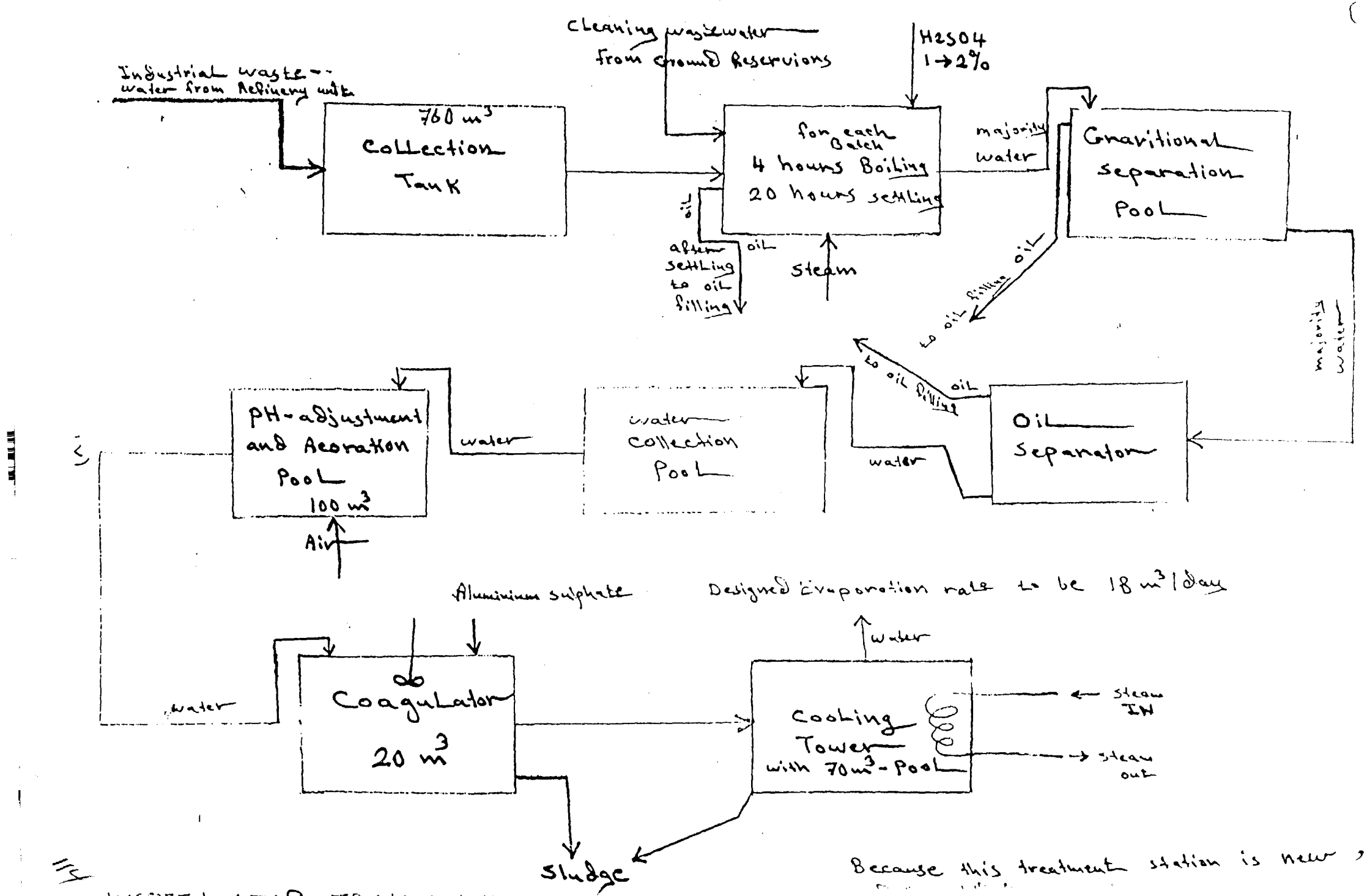
(c)

ما يتعلق بال Tower وبالمساعدات لغايات التبريد يوجد في المصنع واحد فقط ذو بركة من
ي $34\ m^3$ تتغذى من مياه عادية وليس مياه Softner علماً بان المعدل اليومي
Make UP WATE حوالي $5 \rightarrow 10\ m^3$ ويضاف عليها Fungicides بمعدل
واحد لتر كل ثلاثة ايام .

اما يتعلق بال Towers وبالمساعدات لغايات انتاج الفراغ Vaccum في Deodorization vessel
يساعد في تبخير ال Vapors المسؤولة عن الرائحة ويتم ذلك كما يلي:



تختلف هذه النوعية عن سابقتها في انه يصل هنا make up للماء في البركة وهذا يتم
بالـ Bleed لها بمعدل يومي بمقدار $1 \rightarrow 2\ m^3$ علماً بان سعة هذه البركة حوالي $8\ m^3$.
يوجد في المصنع اثنان من هذه النوعية احدهما عامل الآن والآخر قيد التجربة حيث تم انشاء
وحدة ازالة رائحة جديدة ليكون الـ Tower المساعد الثاني في خدمتها .



Because this treatment station is new,

Appendix C

Overview of the Regulations Applicable to the UMIC Discharge

APPLICABLE REGULATORY CRITERIA

Current Status of Environmental Regulations in Jordan:

In order to assess Universal Modern Industry Company (UMIC) 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 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 2a - 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

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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 3 through 5 are related to the quality of treated domestic wastewater effluents to be reused in irrigating agricultural crops. The remaining Tables 6 - 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 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 UMIC Discharges:

The UMIC facility generates wastewater from neutralization washwater operation, boiler blowdown barometric condenser cooling tower blowdown, softener regeneration, floor and equipment washing, laboratory tests , and sanitary. All of these wastewater except sanitary, are currently being hauled for discharge of wastewater onto land near the facility. Any discharge of wastewater onto ground would be subject to the Jordanian Standard 202 for discharges to the wadis or reuse for irrigation. When the UMIC wastewater treatment system is operating, the treated water is evaporated.

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Table 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**
BOD5	50M	-	50M	-
COD	150M	200	150M	-
DO	1*	5*	1*	1*
TDS	3000(1)	-	1500 (1)	2000 (2)
TSS	50	-	-	100 (3)
pH (su)	6.5-9.0	5.5-9.0	6.5-9.0	6.5-8.4
Color (unit)	15	75	15	-
TC	-	4	-	-
FOG	5	10	Absent	5
Phenol	0.002	1	0.002	0.002
MBAS	25		15	-
NO3-N	12 (4)	-	12 (4)	30
NH3	5	12	5	5
T-N	-	125	-	50
PO4-P	15	-	-	-
Cl	500	-	500	350 (3)
SO4	500	-	500	400
F	1.5	-	1.5	-
HCO3	-	-	-	500
Na	-	-	400	-
Mg	-	-	-	-
Ca	-	-	-	-
SAR	-	-	-	9
Al	5	-	0.3	5
As	0.05	0.1	0.05	0.1
B	1	-	1	1 (5)
Cr	0.1	0.3	0.05	0.1
Cu	2	0.1	2	0.2
Fe	1	2	1	5
Mn	0.2	0.2	0.2	0.2
Ni	0.2	0.02	0.1	0.2
Pb	0.1	0.1	0.1	1
Se	0.02	0.02	0.05	0.02
Cd	0.01	0.07	0.02	0.01
Zn	15	-	15	2
CN	0.1	1	0.1	0.1
Hg	0.001	0.001	0.001	0.001
TCC MPN/100ml		5000	-	-
TFCC MPN/100ml	1000(6)	-	1000 (6)	1000 (6)
Nematodes	< 1	-	-	< 1

(+) All units are in mg/l except where noted.
(*) Minimum value.
(**) Depends upon, type and quantity of crops, irrigation methods,soil type, climate & groundwater in the area concerned.
(-) Undetermined.
(M) Monthly average.

Notes:
(1) TDS allowable limit is subject to the TDS concentration in the water supply and the water basin affecid.
(2) Allowable limits of wastewater reuse determine the degree of restriction (none, slight to moderate, or severe).
(3) Method of irrigation is determined by wastewater quality being used.
(4) Nitrate concentrations allowed are determined by its concentrations in the affected water basin.
(5) Could reach 3 mg/l.
(6) Geometric mean.

Table 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 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 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 2d

Jordanian Drinking Water Standards
D: Radiation

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

Table 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 (Trichlorophenoxy propionic acid)	0.01

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

Table 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 sprinkler irrigation and low humidity (<30 percent), sodium and chloride may be absorbed through the leaves of sensitive crops.
(5) For boron 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.

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Table 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 atwidely 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).

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Table 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 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)
	Rootstocks	
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
	Cultivars	
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 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 ($HCO3^-$)[5]	me/l	< 1.5	1.5 - 7.5	> 7.5
Nitrate-nitrogen (NO3-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 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

1 Data taken from Maas (1984).

Table 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 (0.75-1.0 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*

(1) Data taken from Maas (1984)
(2) Maximum concentrations tolerated in soil-water without yield or vegetative growth reductions. Boron tol vary depending upon climate, soil conditions and crop varieties. Maximum concentrations in the irrigatio are approximately equal to these values or slightly less.

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

Table 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 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	$CO3^{--}$	me/l	0 - .1	me/l
Bicarbonate	$HCO3^{-}$	me/l	0 - 10	me/l
Chloride	Cl^{-}	me/l	0 - 30	me/l
Sulphate	$SO4^{--}$	me/l	0 - 20	me/l
NUTRIENTS[2]				
Nitrate - Nitrogen	NO3 - N	mg/l	0 - 10	mg/l
Ammonium - Nitrogen	NH4 - N	mg/l	0 - 5	mg/l
Phosphate - Phosphorus	PO4 - 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 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 pratenis)*	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 tabel.

(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 electical 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-dwart, short cultivars may be less tolerant.

(7) Tolerance given is an average of several varieties : Suwannee 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 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	5.3	3.5	8.6	57	15	10
Celery *(Apium graveolens)*	1.8	1.2	3.4	2.3	5.8	3.9	9.9	66	18	12
Cabbage *(Brassica oleracea 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. perennral *(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 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
pH	6.5-9	6.5-9
Temperature change (C°)	<3	-
D.O	≥1	-
TDS	3000	2000 (1)
TSS	50(3) / 200(4)	100 (1)
BOD5	50(3) / 50(4)	-
COD	150(3) / 150(4)	-
NH3	30	-
FOG	15	15
ABS	6	-
Cl2	0.5 (5)	-
Phenol	0.5	-
TFCC MPN/100mL	<1000	<1000 (6)
Intestinal nematodes	<1	<1 (6)

* All units are in mg/L except where noted.

(1) Depends on degree of restriction (none, slight to moderate, or severe).

(2) Depends on method of irrigation.

(3) Conventional wastewater treatment plants.

(4) Waste stabilization ponds.

(5) This is a minimum limit of residual chlorine and it should be linked with total faecal coliform count.

(6) FAO and WHO guidelines and their amendments should be taken into consideration.

Appendix D
Site Visit Photographs

Photo 1 - Crude oil tanker unloading area

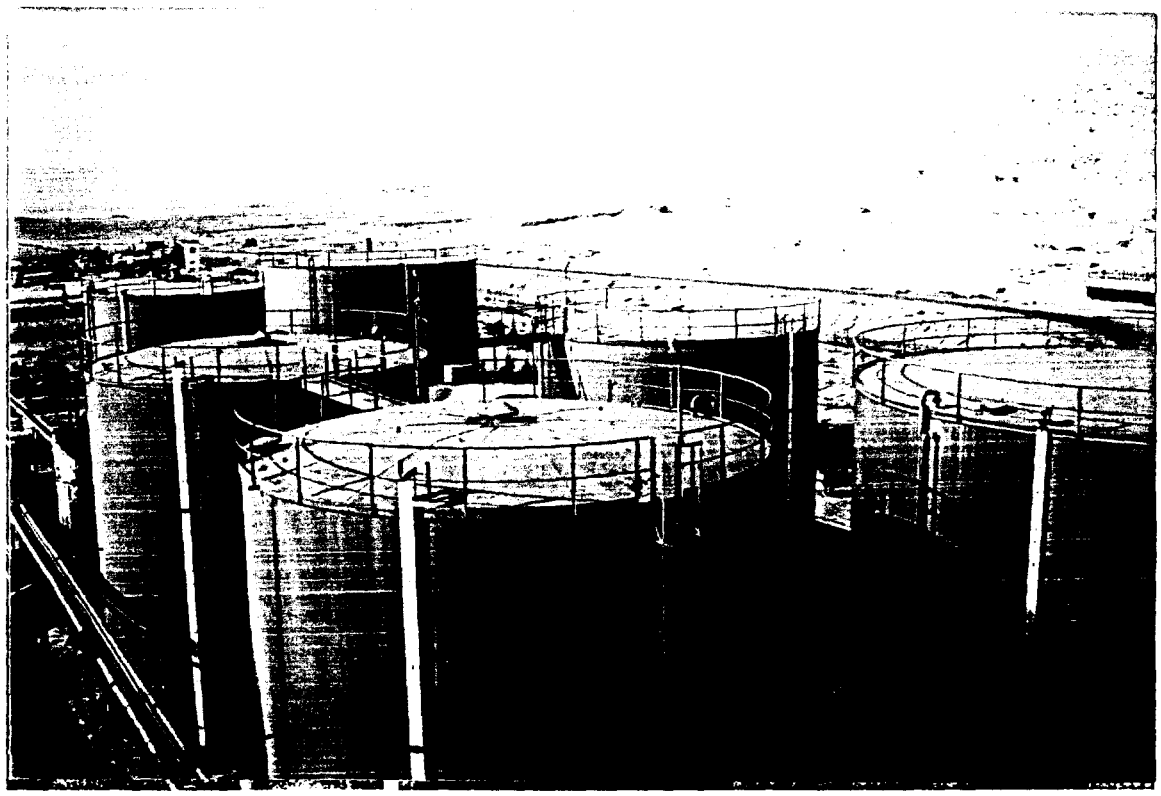

Photo 3 - Crude oil storage tanks

Photo 4 - Crude oil storage tank spills

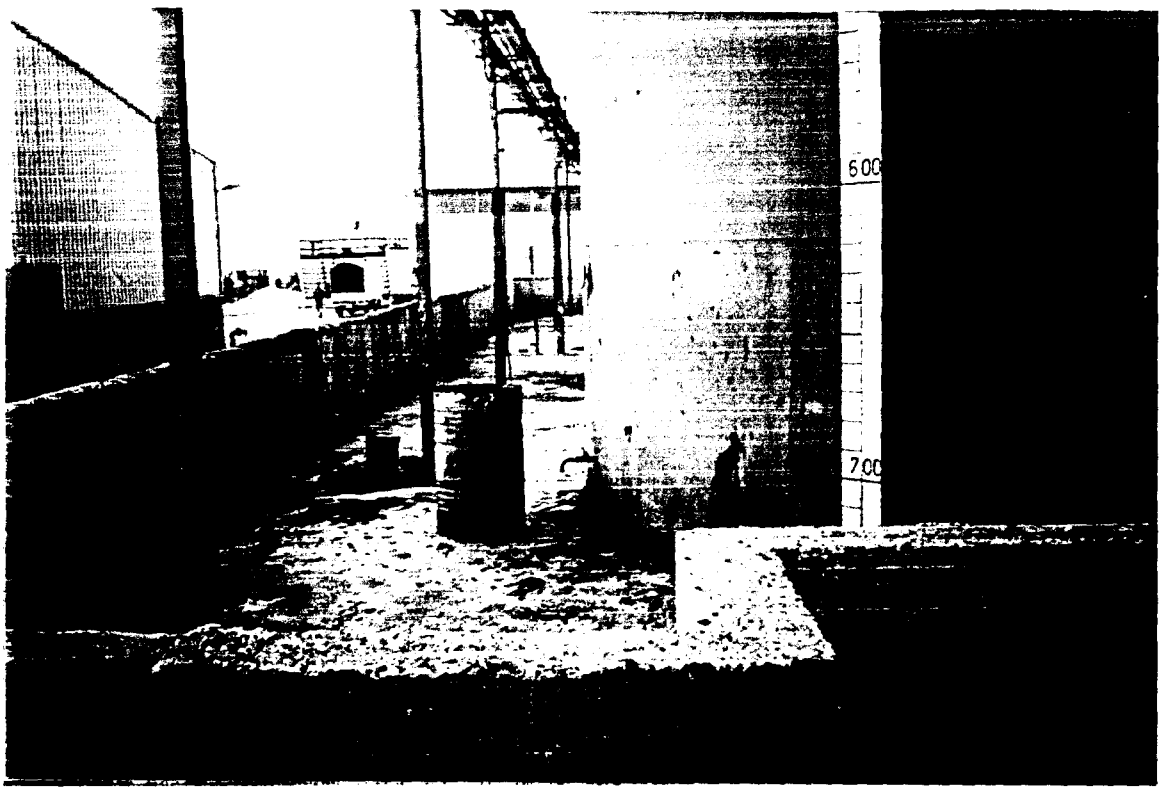

Photo 5 - Containment dike around crude oil storage tanks

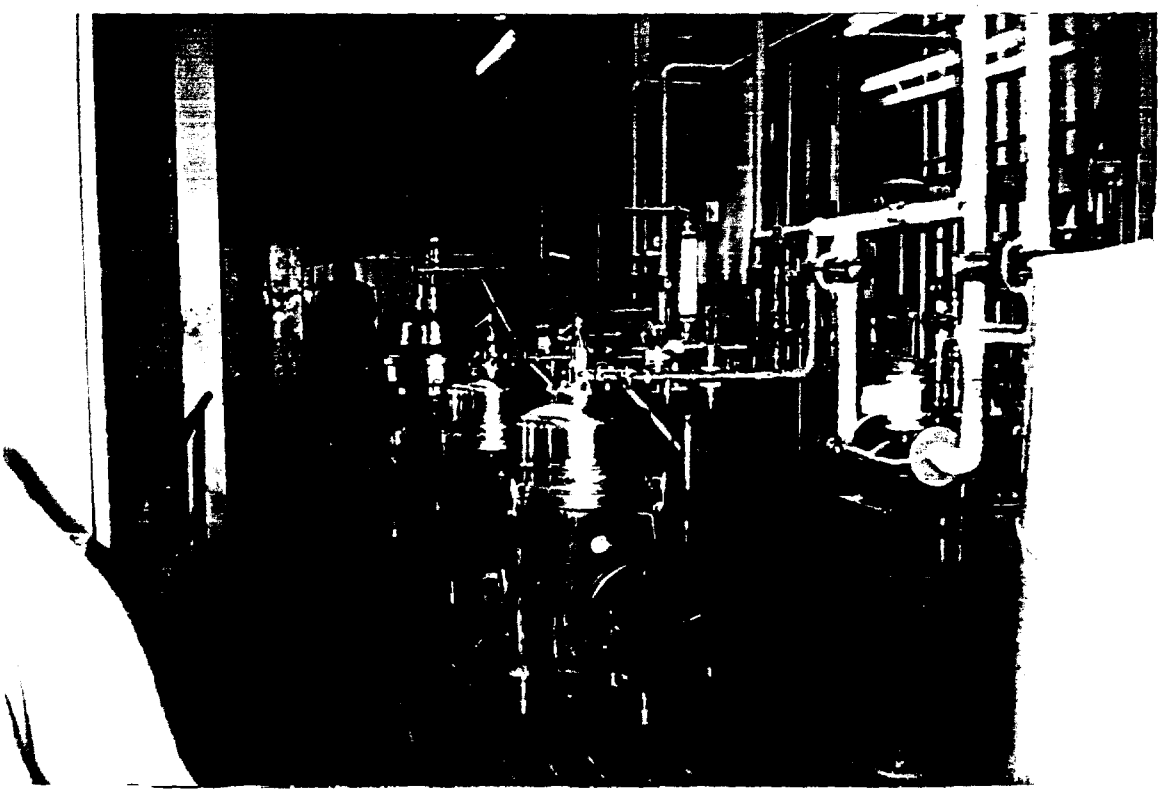

Photo 6 - Centrifuges in chemical refining neutralization area

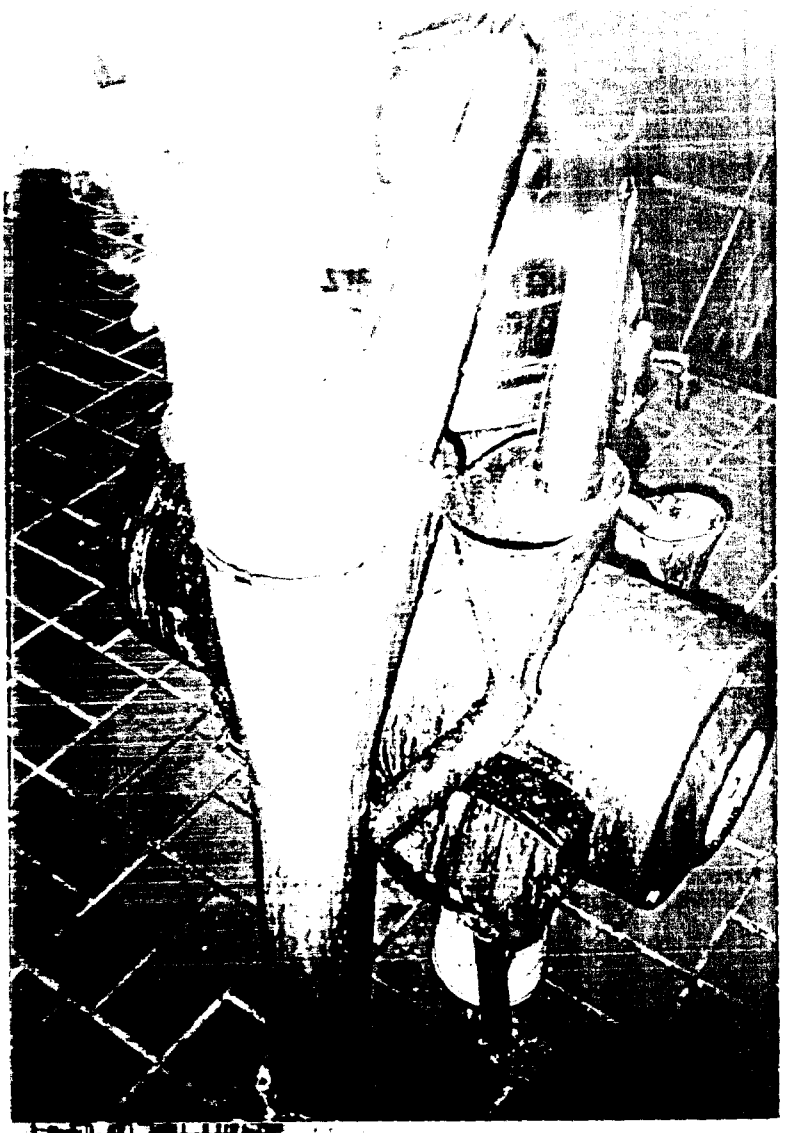

Photo 7 - Soapstock discharge from centrifuge

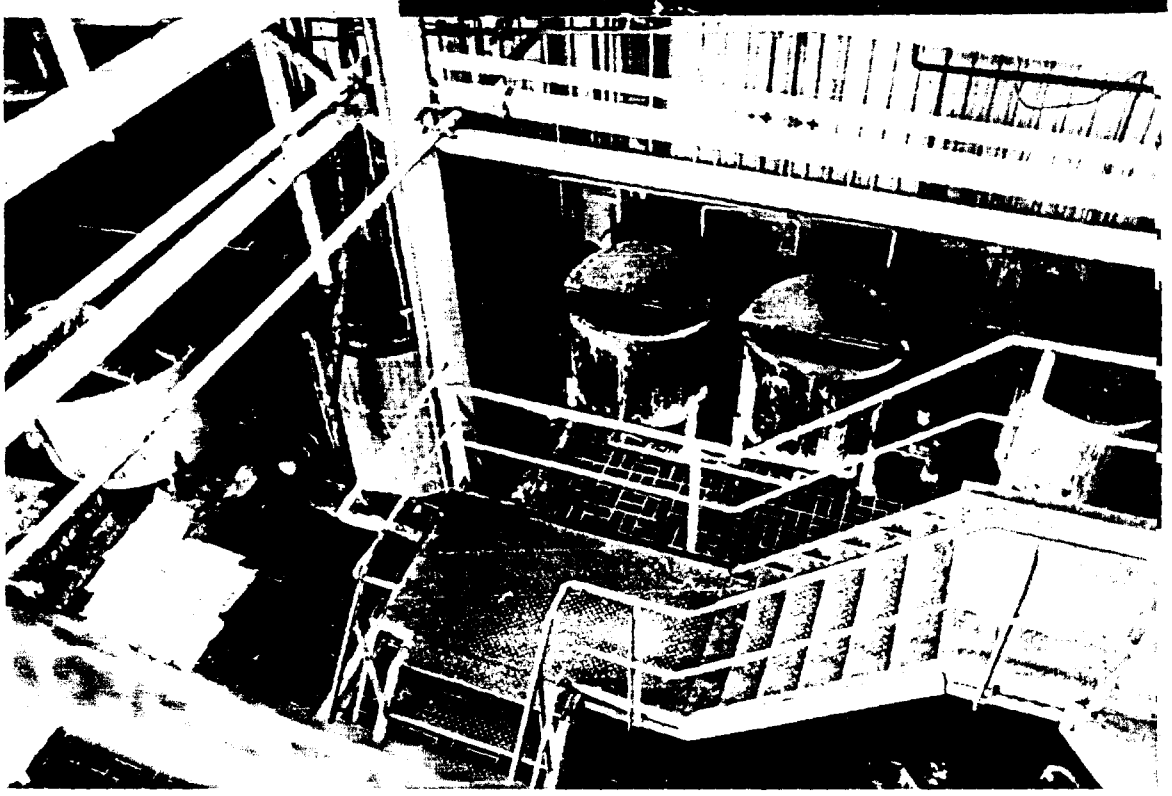

Photo 8 - NaOH solution mixing (left) and neutralization wastewater tanks (center)

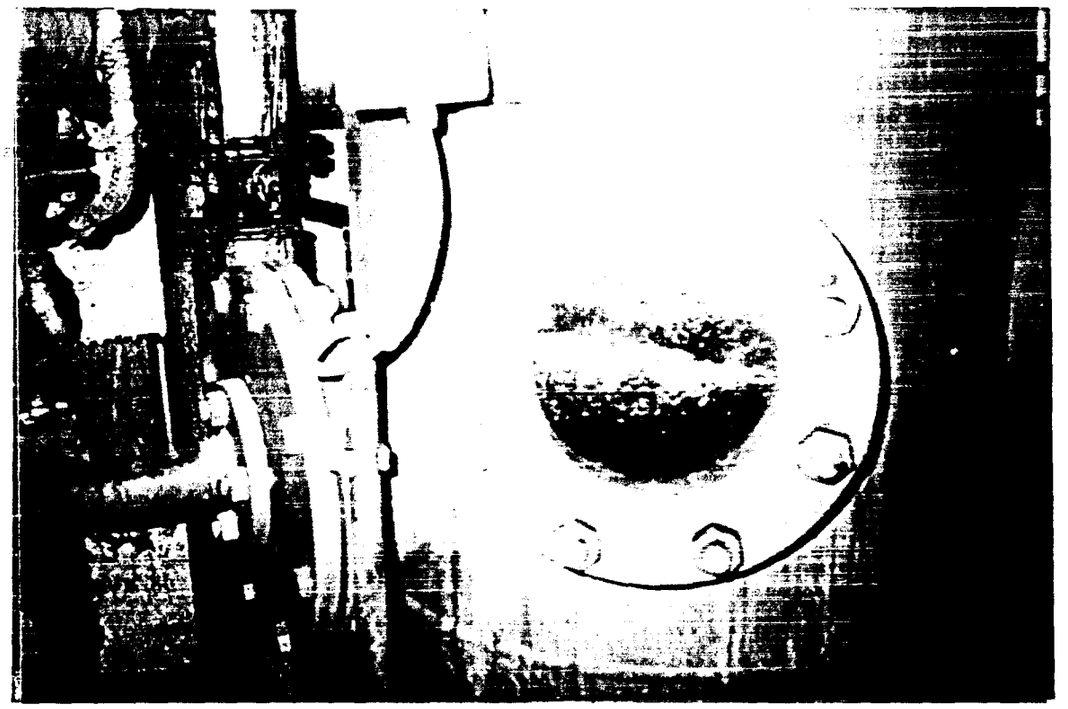

Photo 9 - Dryer

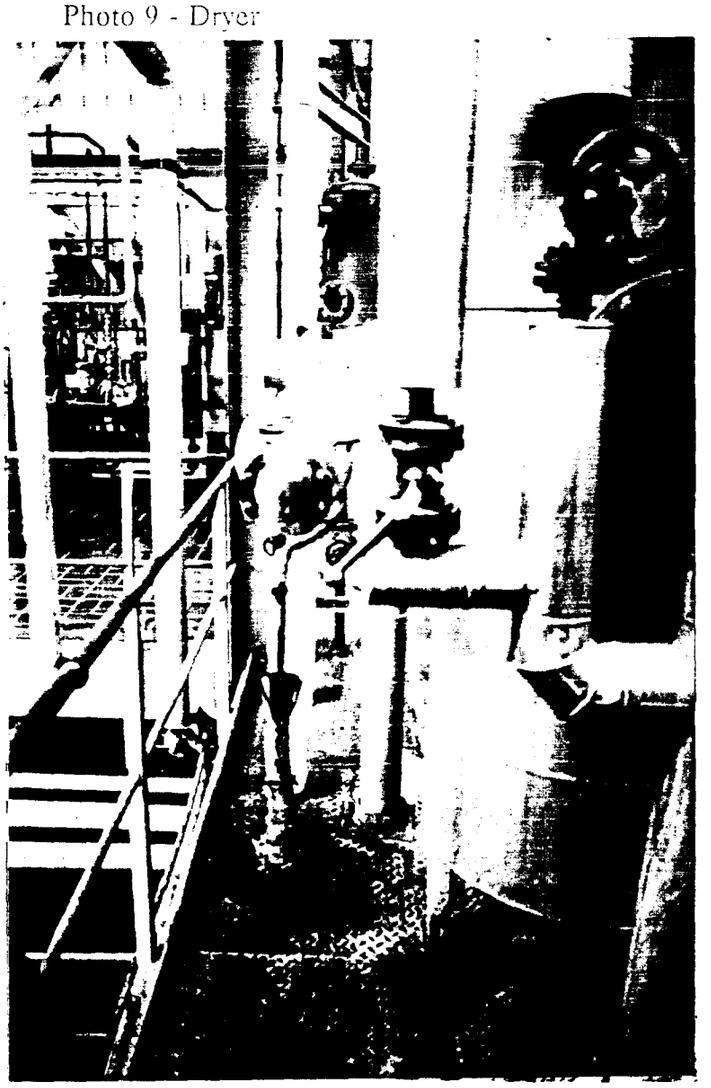

Photo 10 - Steam leaks in chemical refining area

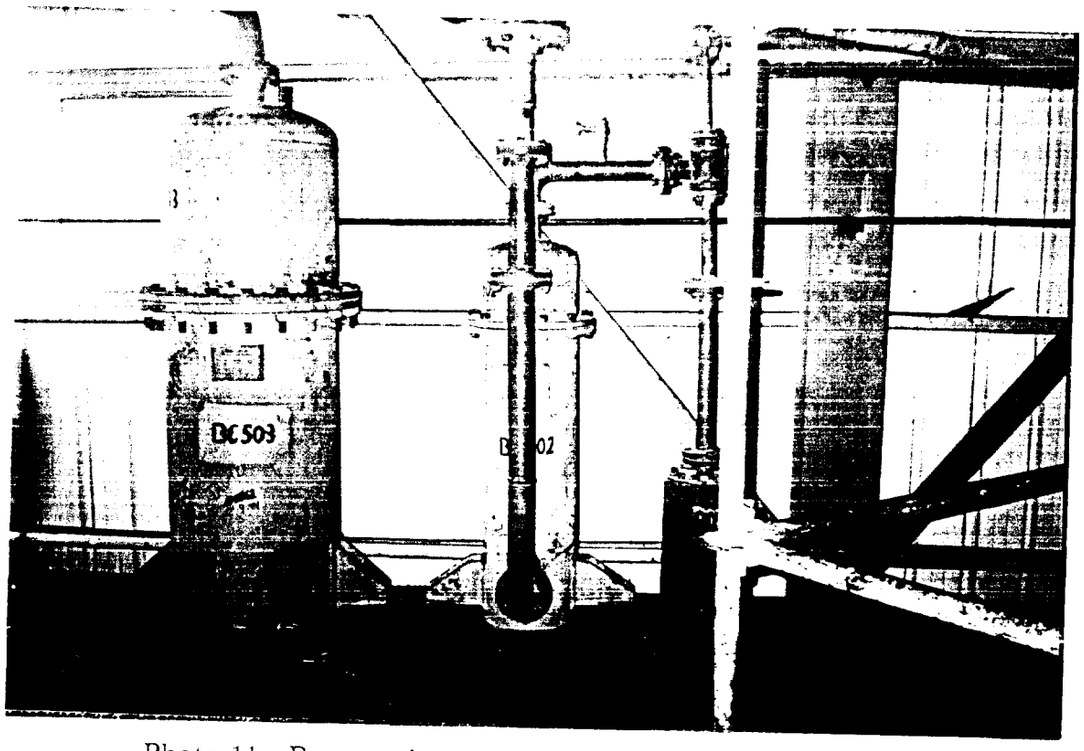

Photo 11 - Barometric condensers in physical refining area

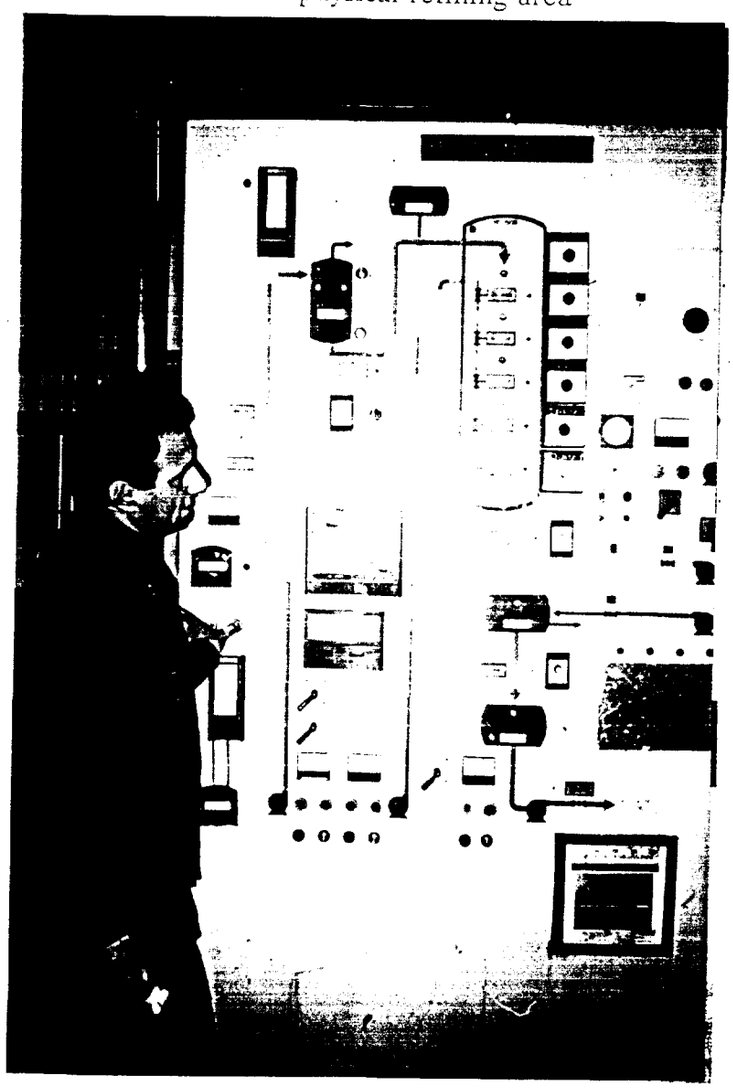

Photo 12 - Physical refining process control panel

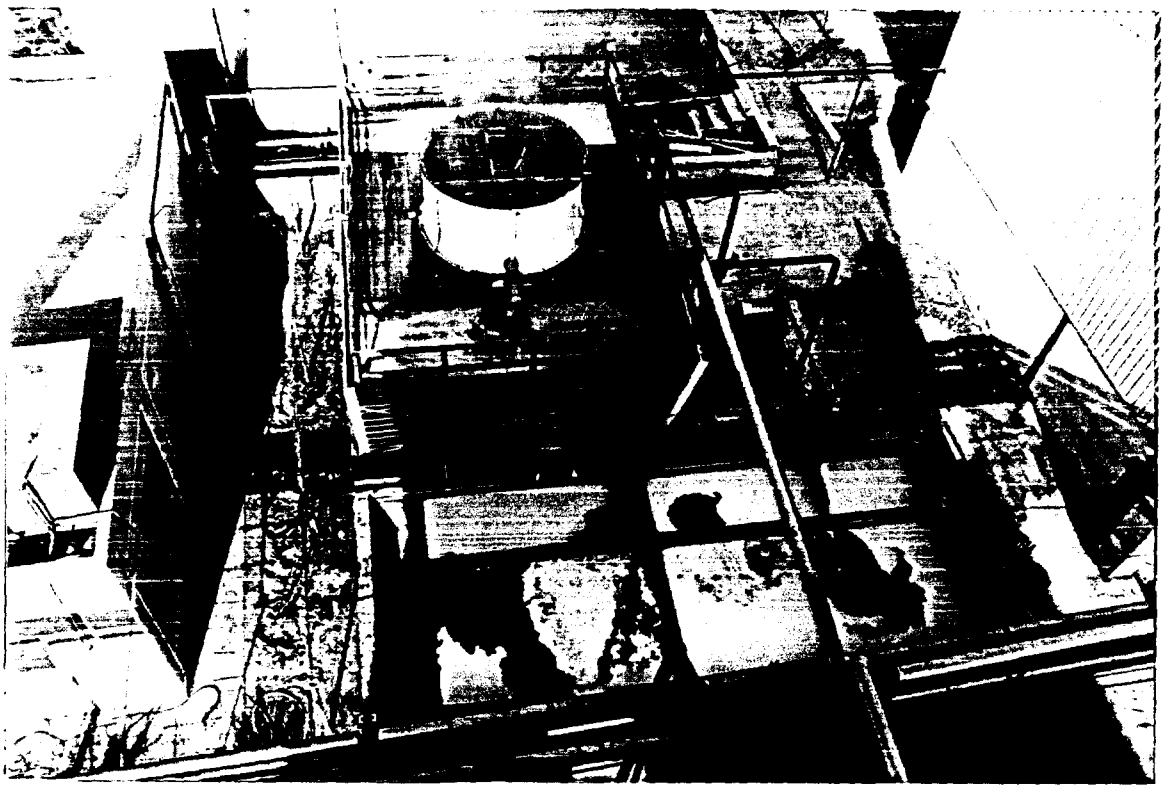

Photo 13 - Hot well and cooling tower

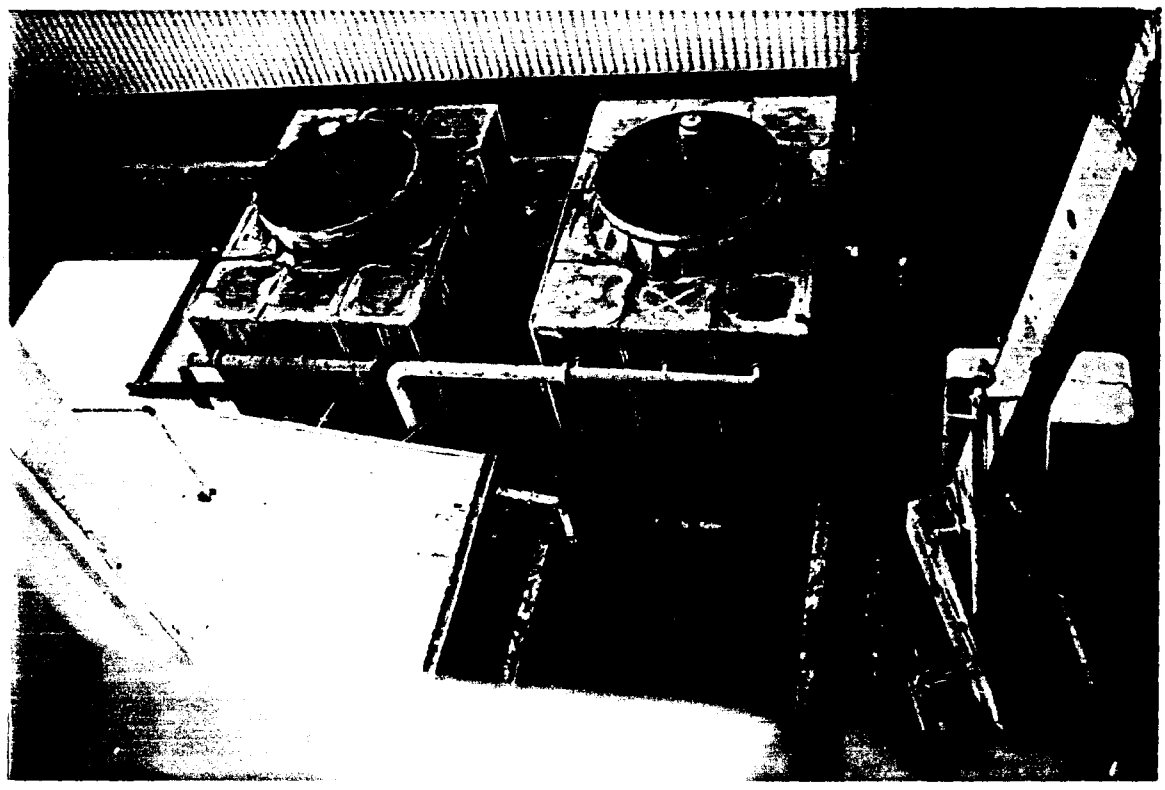

Photo 14 - Clean cooling tower (center of picture), cooling tower (left side of picture) not in operation, hot well for chemical refining cooling water (far left side of picture)

Photo 15 - Storage tanks for refined oil prior to filling

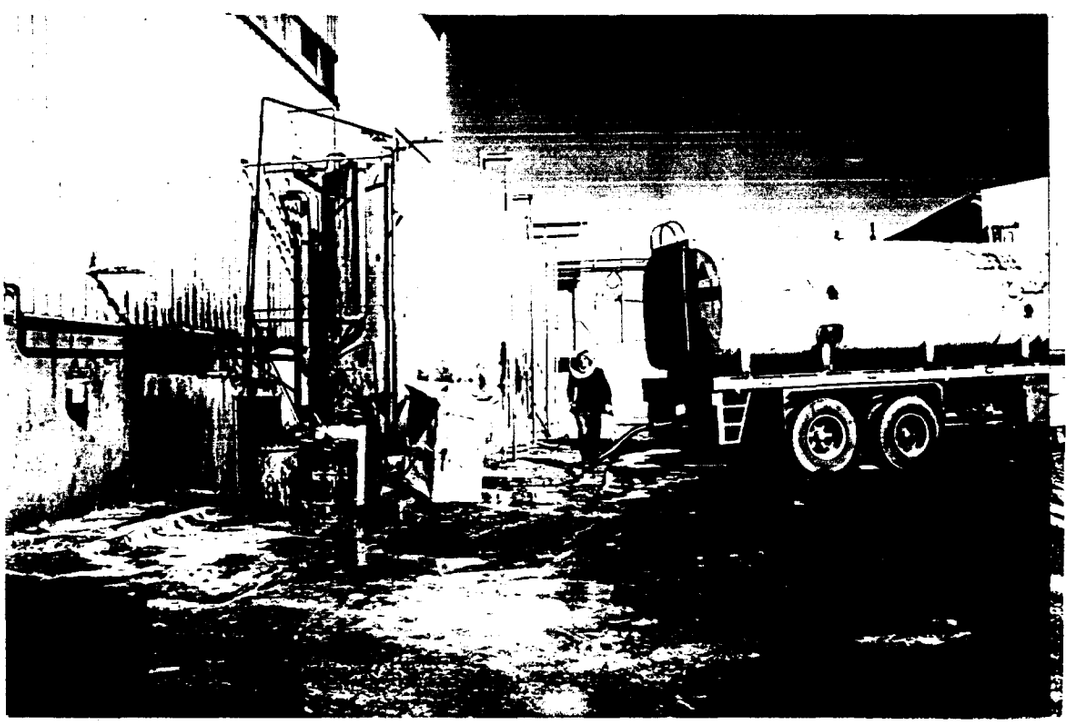

Photo 16 - Storage tanks for RBD palm oil that will not be refined, just pumped to filling operation

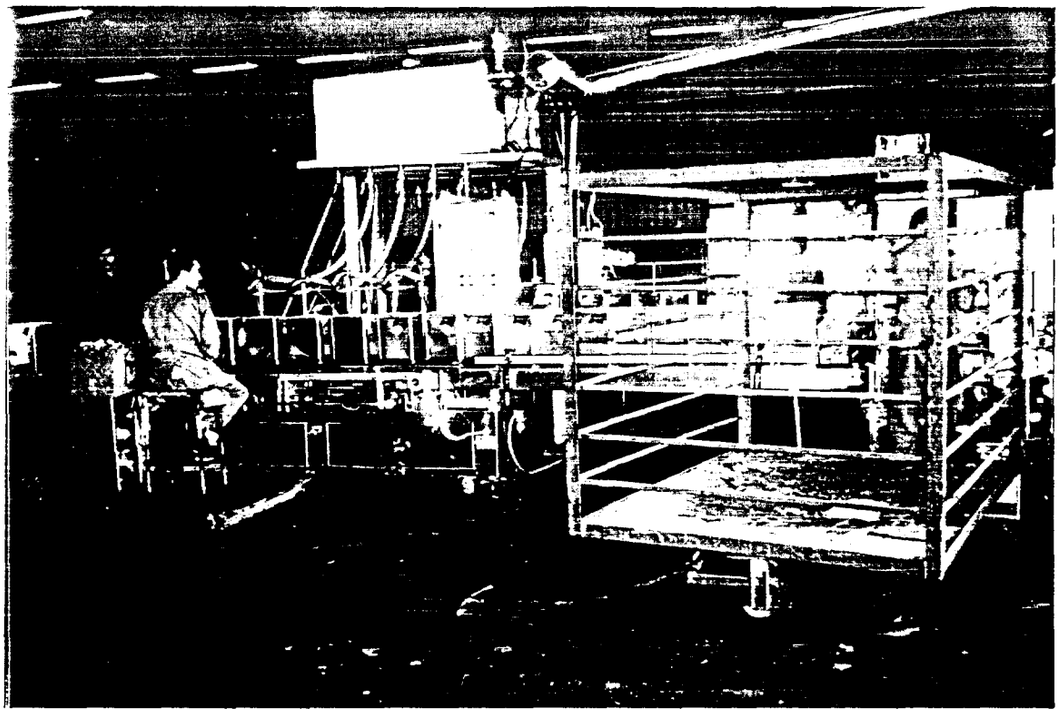

Photo 17 - Filling tank and machine

Photo 18 - Clean up of spill in filling area

Photo 19 - Outside collection pit

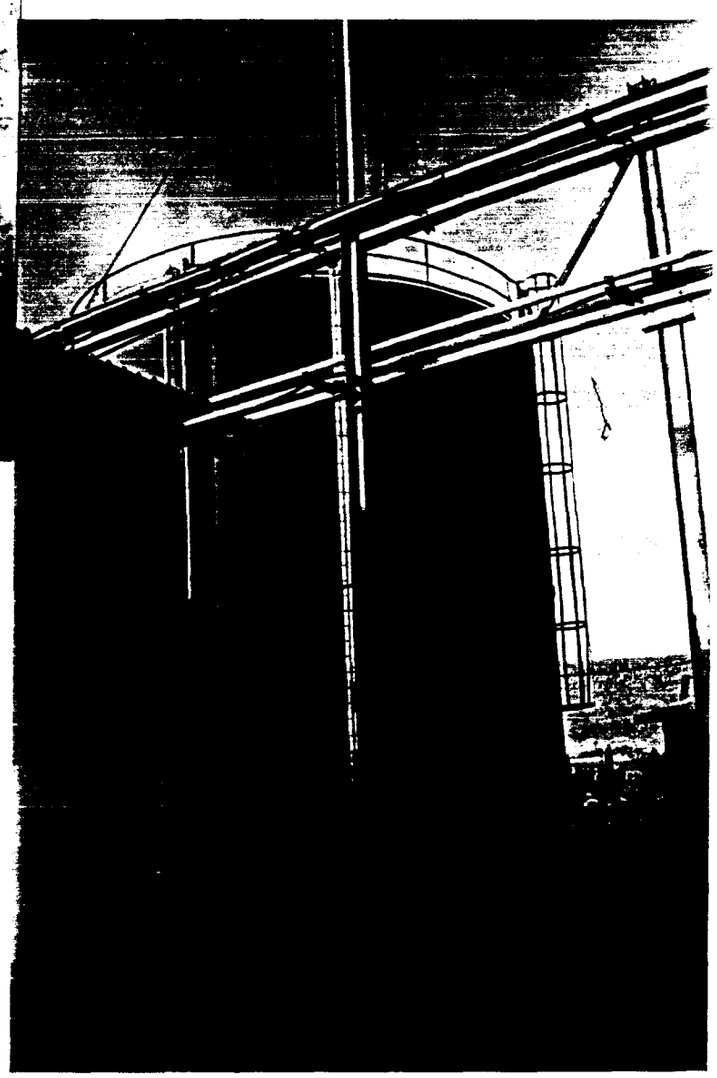

Photo 20 - Wastewater collection tank

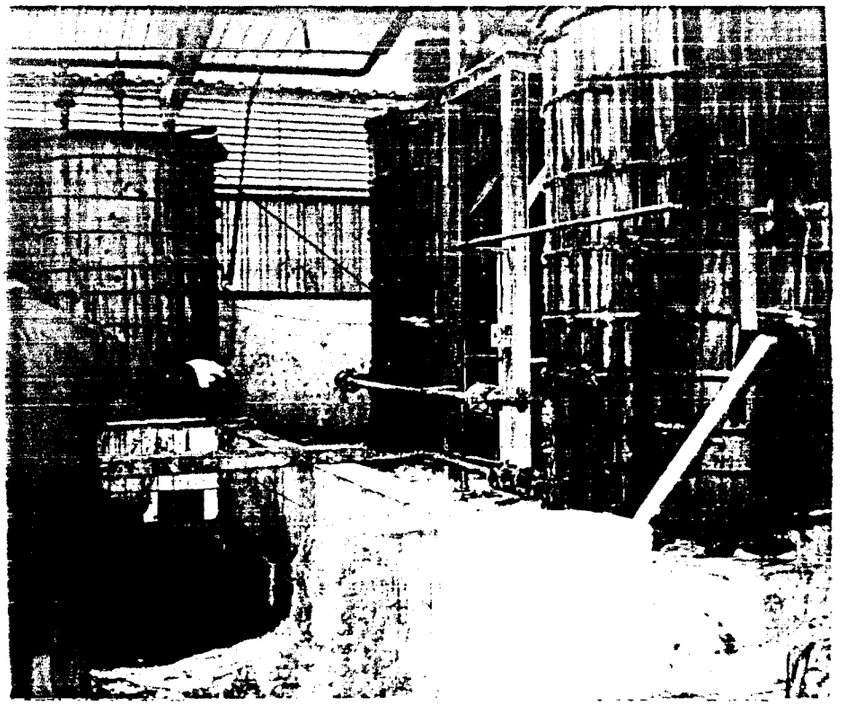

Photo 21 - Acidification treatment units

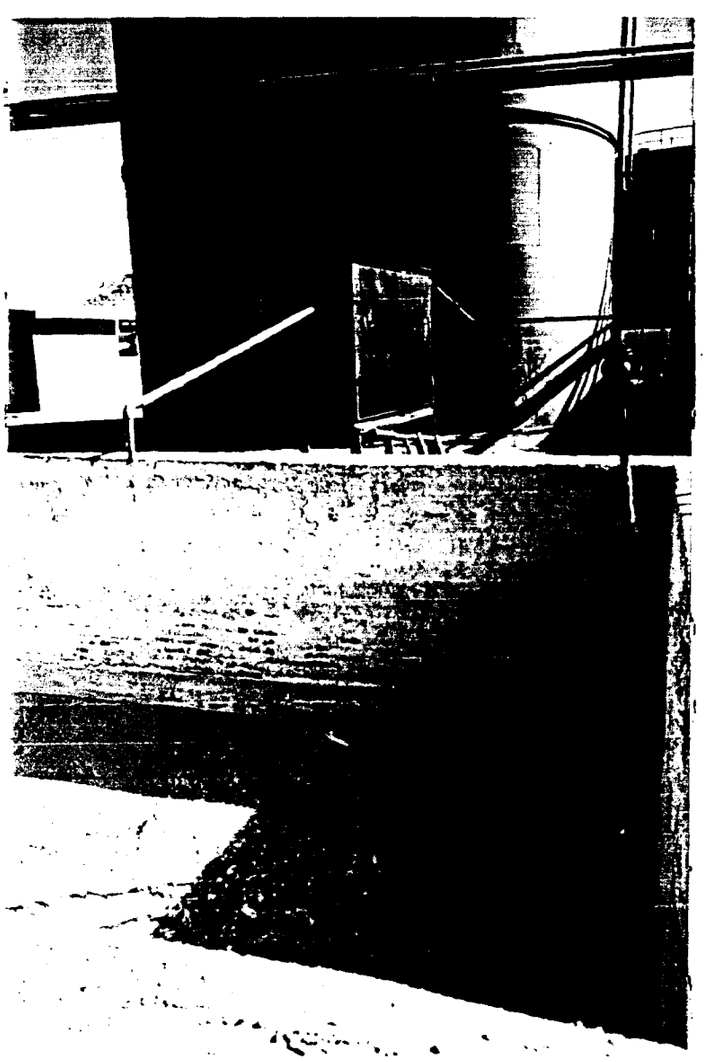

Photo 22 - Oil/water separator and neutralization basin

Photo 23 - Neutralization basin

Photo 24 - Aeration basin

Appendix E
References

REFERENCES

Kirk-Othmer Encyclopedia of Chemical Technology. Third Edition. John Wiley and Sons, New York. 1983.

Beal, R. E., et. al. "Water-Recycle Washing of Refined Soybean Oil: Plant Scale Evaluation", Journal of American Oil Chemists Society, Vol. 50, pp. 260-263, July, 1973.

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6.0 REFERENCES

Attachment A Selected Papers on Pollution Control for the Vegetable Oil Refining Industry

Attachment B Additional Sources

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1.2 Objectives

The facility PP/WM audits are designed to assess the potential for pollution prevention and waste minimization at the study facilities. The goal of each audit is to evaluate and identify all possible PP/WM, wastewater clean-up, and water conservation techniques that are appropriate for the study facility. Audit documentation will consist of a background PP/WM assessment paper and an audit evaluation report. This document is intended to serve as the PP/WM background paper for the vegetable oil refining industrial sector.

The specific objectives of this audit are as follow:

1. Review general industry background data and identify "state-of-the-art" processing and waste management practices.

2. Work on site with industry representatives, the MWI officials, and other interested groups to review current processing procedures and identify possible PP/WM options.

3. Develop a report that evaluates all possible PP/WM alternatives and provides recommendations to the industry.

In order to complete the first objective, a comprehensive literature review was performed. This review included searches of the U.S. EPA Pollution Prevention Information Clearinghouse (PPIC) repository (and its corresponding database PIES), on-line library catalog databases, pollution PP/WM bibliographical references, and personal contacts with pollution prevention specialists. The on-line library catalog databases accessed included the OCLC, an on-line catalog of approximately 15,000 libraries in the U.S. and libraries in Canada and Great Britain; the OLS, the on-line EPA library, and DIALOG, a commercial database containing abstracts of journal articles, conferences, and government documents. The review resulted in the identification of numerous references with a range of very general to very specific PP/WM techniques. Source documents were assessed to determine their applicability to this project. Documents pertinent to this project are included as Attachment A or are listed in Attachments B and C.

Following completion of the literature review, the audit team will perform the on-site audit of the industrial facility. The audit will be performed with close consultation of industry representatives to ensure that they are aware of and support proposed actions. Audit activities will included the careful gathering of baseline water use and waste generation data, identification and assessment of potential PP/WM options, and solicitation of ideas and proposals from management and production line staff.

Finally, the audit findings will be summarized and options evaluated in the audit report. The audit will recommend the development of a site-specific program that meets the specific needs and goals of the audited facility. Audit recommendations will include both technical PP/WM recommendations (e.g., housekeeping practices, treatment options, etc.) and suggestions for PP/WM training for facility staff and follow-up studies to assess program successes.

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1.0 INTRODUCTION

1.1 Background

Under a contract with the United States Agency for International Development (USAID), Development Alternatives Incorporated (DAI) is performing an Industrial Wastewater Discharge Prevention (IWDP) Program in Amman, Jordan. The IWDP Program is one of the four components of the Water Quality Improvement and Conservation (WQIC) project funded by USAID. The Program is being performed by DAI with full coordination between the Jordanian Ministry of Water and Irrigation (MWI) and the Amman Chamber of Industry (Chamber).

The IWDP will be performed in three phases. The first phase requires completion of ten pollution prevention/waste minimization (PP/WM) opportunity audits by DAI and its sub-contractors. The second phase requires completion of Feasibility Studies (FS) for four of the audited facilities. Finally, demonstration projects will be completed for selected FS facilities.

Due to the high cost of waste treatment, as well as the need to minimize waste of raw materials and resources, it is in the best interest of businesses and industries to minimize their waste generating practices. Companies with effective PP/WM programs may well be the lowest-cost producers of goods due to their efficient practices. Waste management practices can include:

1. Reduce waste generation

   - Substitution of less hazardous raw materials in product manufacture
   - Alteration of products manufactured to eliminate need for hazardous materials use
   - Replacement or upgrading of outdated or inefficient process equipment
   - Development of employee training programs to ensure employees efficiently manage raw materials and resources.

2. Reuse waste materials prior to disposal

   - Reuse of uncontaminated raw materials and resources (including water)
   - Reprocessing of previously discarded materials (e.g., off-spec materials, used materials)
   - On site recovery of reusable materials (e.g., used solvents, waste heat, scrap).

3. Recycle waste materials

4. Treat wastes and dispose of residues.

The audits performed during this project will evaluate all available waste management alternatives and will provide site specific recommendations to assist the study industry in developing a comprehensive waste management strategy.

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2.0 INDUSTRIAL HISTORY

2.1 General

Edible vegetable oils are derived from the seeds of such plants as soybean, corn, and palms. The oils are fatty-acid esters of glycerol, commonly called triglycerides. The production of edible vegetable oils can be separated into two phases: extraction and refining.

The oils are extracted from the seeds by mechanical or hydraulic pressing or solvent extraction. The crude oil that results from the extraction process must be refined to make the oil acceptable for edible purposes. The refining process removes components such as free (unesterified) fatty acids, phosphatides, unsaponifiable components such as sterols and tocopherols, carotenoids and chlorophyll (color), and metals (copper and iron).

2.2 Vegetable Oil Refining Industry in Jordan

There are 8 vegetable oil refining facilities in Jordan. The Universal Modern Industries Company, Ltd. (UMIC) facility is the oldest. The vegetable oil refining industry in Jordan uses as its raw material the semi-degummed crude corn oil; semi-degummed soya oil; and refined, bleached and deodorized palm oil and palmoline. A flow diagram of the operations conducted by the Jordanian vegetable oil refining facility is provided in Exhibit 2-1.

- **Degumming and Neutralization** - The degumming and neutralization operations are conducted in one step. Phosphoric acid is added to the crude oil to removed the phosphatides and a sodium hydroxide solution is added to remove the free fatty acids. Water is added to the oil to wash the phosphatides and fatty acids from the oil. Centrifuge separators are used to separate the aqueous solution from the oil. The aqueous stream from the separators is wastewater.

- **Bleaching** - In the bleaching process Activated Bleaching Earth (clay) is added to the oil. The clay is removed by filtering the mixture through filter presses. The filtered oil is sent to the deodorization process. The filter clay cake contains some of the oil product.

- **Deodorization** - Steam is injected into the oil under a vacuum to remove undesirable components present in the oil.

- **Packaging** - The oil is placed in plastic or tin containers.

- **Cooling** - The solid oil is cooled in four cooling rooms maintained at a -5 degree Celsius temperature.

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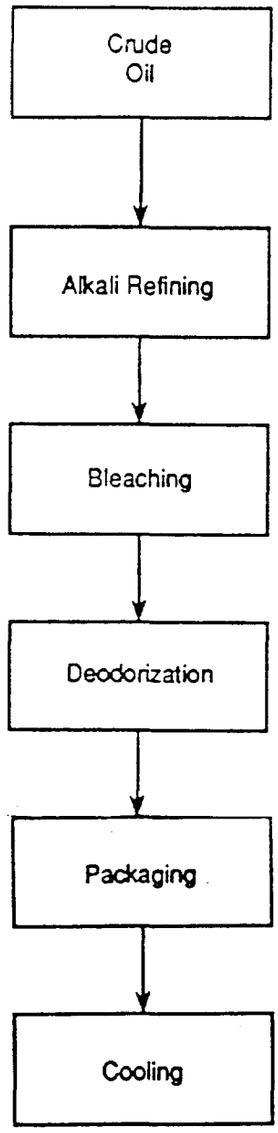

Exhibit 2-1 Process Flow Diagram of Jordanian Vegetable Oil Refining Facility

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3.0 PROCESS OVERVIEW

A flow diagram for a typical vegetable oil refining facility is provided in Exhibit 2-1 and the process operations depicted are described below.

3.1 Degumming

3.5 Deodorization

Deodorization removes volatile components such as aldehydes and ketones that are formed by oxidative and thermal breakdown of unsaturated fatty acids. A small amount of concentrated citric acid solution may also be added during the deodorization process to remove any metals. Deodorization can be conducted batchwise or using a semi-continuous or continuous process. The oil is heated and steam is sparged into the oil in the lower part of an upright cylindrical vessel. As the bubbles form and move upward, volatile components are transferred to the steam and are removed at the top with the steam.

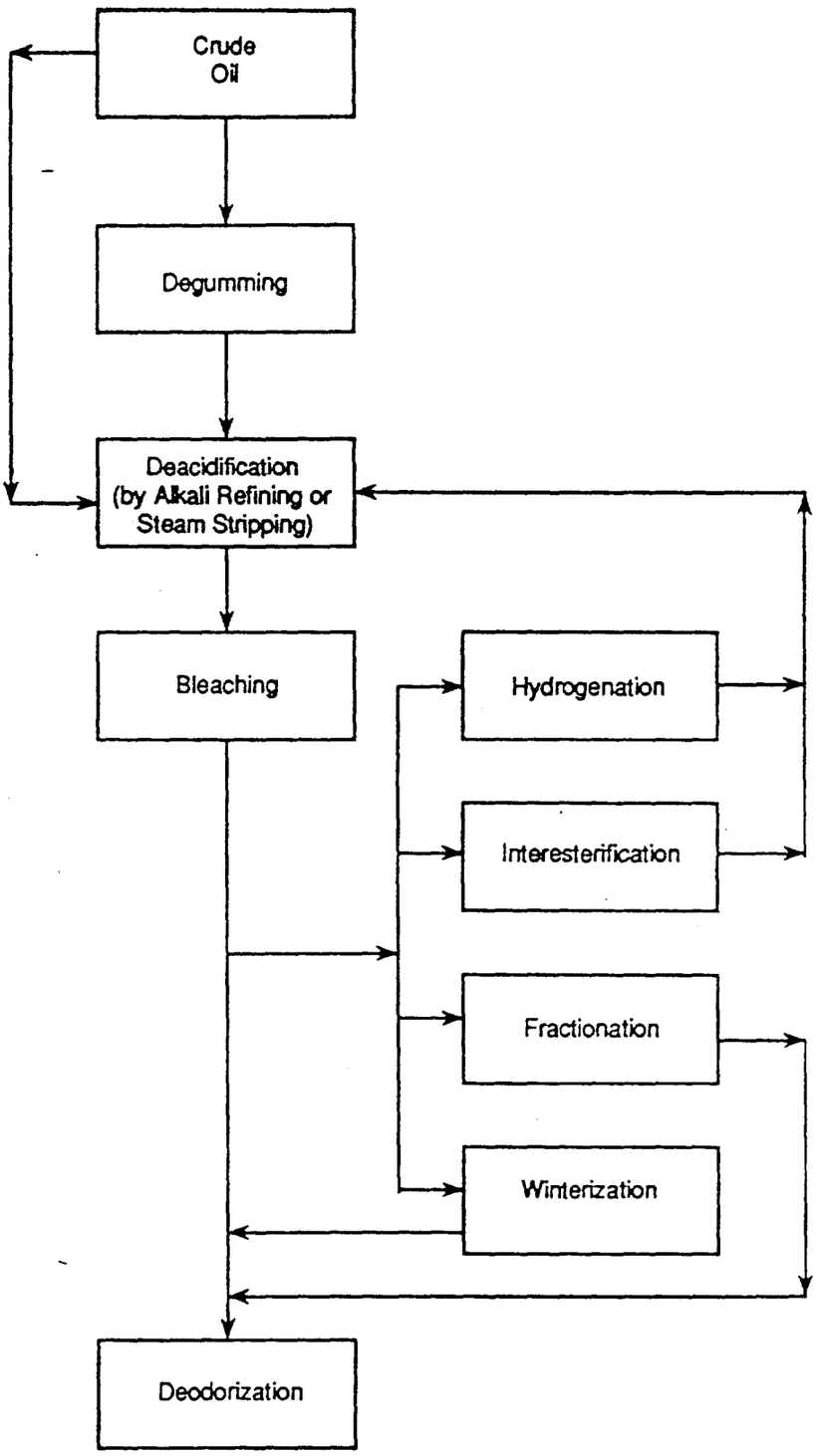

Exhibit 3-1 Process Flow Diagram of Vegetable Oil Refining

4.0 WATER USE AND WASTE GENERATION

4.1 Water Use in the Vegetable Oil Refining Industry

Direct contact of water with the oil is inherent in the process itself. Water is used in the neutralization process as part of the aqueous-based sodium hydroxide solution. Water is used in the bleaching process to clean the filter presses. Water is used to generate the steam in the deodorization process. Water is used in the hydrogenation process to generate the hydrogen gas.

The total water used and wastewater generated will depend on the design of the individual refinery. One facility in the United States that had no practices for water conservation or reuse had a water stream of 4,500 gallons per minute, but implementation of water conservation and reuse is expected to yield a water stream of 200 to 300 gallons per minute. (Grinkevich, 1974) In 1974, an achievable level of water use at a refinery employing conventional processes but practicing water conservation and reuse was reported to be 0.28 gallons of water per pound of refined oil; even further reductions to this water use may be achievable now. (Grinkevich, 1974)

4.2 Waste Generation in the Vegetable Oil Refining Industry

The largest single waste generated is wastewater contaminated by free and emulsified oil. The primary pollutants of concern in the vegetable oil refining industry include the following:

- Biochemical Oxygen Demand (BOD);
- Chemical Oxygen Demand (COD);
- Suspended Solids (SS); and
- Fats, oils and greases (FOG).

Typical vegetable oil refinery wastewater could have the following pollutant concentrations (Grinkevich, 1974):

BOD	500 to 6,700 mg/L
FOG	300 to 4,200 mg/L
SS	541 to 5,851 mg/L

The neutralization process which generates a wastewater of approximately 30 cubic meters per day is the major wastewater stream generated by the Jordanian facility. Other wastestreams include filter press cleaning wastewater, process wastewater from the deodorization process and floor wash and equipment cleaning. Wastewater is probably also generated from leaks, spills, and drainage of pipes, tanks or equipment for repairs or shutdowns. A solid waste is generated from the filter press, an oily clay cake.

4.3 United States Effluent Guidelines

The vegetable oil industry's wastewater is considered to be compatible with the biological treatment commonly used to treat domestic sewage. Thus, the United States Environmental Protection Agency (U.S. EPA) has not established any numerical "effluent limitations" for the vegetable oil refining industry. Those facilities that discharge to rivers or other surface water bodies are regulated through individual permits that establish wastewater discharge limits for BOD_5, TSS, and FOG. Most of the facilities in the U.S. are connected to municipal sewage treatment plants.

5.0 POLLUTION PREVENTION AND WASTE MINIMIZATION

Unlike other industries such as the metal finishing industry, the vegetable oil refining industry has not received much regulatory attention. EPA's Office of Pollution Prevention has not developed a specific manual on pollution prevention techniques for this industry. Some facilities have been required to meet stringent wastewater discharge limits for BOD, TSS, and oil and grease because of their location on particular rivers or connections to municipal wastewater treatment plants that cannot accept large pollutant loadings. These facilities have implemented pollution prevention and waste minimization practices to reduce the pollutant loadings.

The pollution prevention and water conservation practices that have been implemented by the vegetable oil refining industry have usually been reported under the terms pollution control or wastewater treatment. These were the terms used in the 1960s, 1970s, and early 1980s; pollution prevention and waste minimization were not in common use until the late 1980s and 1990s. Thus the papers included in Attachment A or listed in Attachments B and C do not use the term pollution prevention but instead focus on the treatment of wastestreams either to meet wastewater discharge standards or to recover by-products.

The industry has recognized the benefits of pollution prevention and water conservation in reducing the volume of wastewater that ultimately must be treated before it is discharged. Since the wastes generated by this industry are organic and non-hazardous, they are often amenable to reuse or recovery. The amount of oil present in the wastes is actually a function of the efficiency of the refining process. This oil represents wasted or unrecovered product that can be captured and reused within the process or as a potential usable by-product. The water used for refining the oil can also be reused or recycled. Water conservation and PP/WM have been practiced by many vegetable oil refining facilities and documented in successful case studies. The PP/WM techniques that have been described in the literature sources included in Attachment A or listed in Attachments B and C of this paper are summarized in this section.

5.1 Water Conservation Techniques Used by the Vegetable Oil Refining Industry

As water use increases at a facility, its overall waste load increases. Where water is used indiscriminately, valuable recoverable oils will be lost. Efficient use of water at facilities will result in lower costs for water consumption and waste disposal as well as increased revenue from reclaimed wastes. Water use minimization techniques have been successfully demonstrated in a number of facilities and have resulted in substantial cost savings.

To begin a successful water conservation program, plant management should determine the minimum quantity of water needed for each specific process operation. The first step in the program requires an inventory of all water uses throughout the facility. This inventory should then be used to create an overall plant water balance that identifies all uses and routes of disposal. Management should then establish a plan to reduce water use by specific amounts in each segment of production. Specific in-plant design modifications and operational controls and procedures should be developed that adhere to the following premises:

- The less water used, the less waste generated.
- Segregation of the individual wastestreams wherever possible to enable recovery or reuse of the wastes.
- Dilution is <u>not</u> the solution and should be avoided. Dilution decreases efficiency of recovery, reuse, and treatment and increases treatment and disposal costs.

- All drains should be equipped with threaded covers to discourage their removal. This will reduce the possibility of spills, leaks, and clean up wastewater being flushed with high volumes of water rather than being contained and perhaps recovered and reused.

- Use of fresh (new) water should be monitored and optimized.

- Wastewater should be utilized wherever possible.

- Dry clean-up should be practiced where appropriate followed by controlled wet clean-up.

One of the first water conservation techniques implemented by the industry decades ago was the replacement of once-through cooling water with a cooling water recycle system. Process redesign can also result in water savings. For example, physical refining does not use sodium hydroxide and washwater, thus this process generates less wastewater than alkaline refining.

The Jordanian vegetable oil refinery already practices one water conservation technique by reusing the water that is used to generate the steam. The steam is captured, condensed, and cooled by a cooling tower, then collected and reused.

Some other specific water conservation methods that may be applicable to vegetable oil refining operations are provided below:

- Reuse of the water (after the oil is recovered) from the oily wastewater generated by the neutralization process;

- Replacement of water-based chillers with cryogenic (e.g., nitrogen) type coolers;

- Use of low volume, high pressure sprayers for cleaning operations; and

- Use of low contamination wastestreams for first cleaning of equipment or floors.

Measures taken to improve overall facility equipment and piping maintenance can often result in water savings. For example, implementation of a rigorous preventative maintenance program to prevent steam and water leaks and a rapid response repair program to fix the leaks as soon as they occur can reduce water consumption.

5.2 Waste Minimization Used by the Vegetable Oil Refining Industry

Due to the nature of wastes generated by the vegetable oil refining industry, recovery and reuse techniques are widely practiced. In the refining process soap is formed in the alkaline neutralization of free fatty acids. The Jordanian vegetable oil refinery captures this soapstock and sells it to a saponification plant. A review of the literature identified many other examples of recovery methods for both liquid and solid wastes generated by these types of operations.

- Oil in the washwater from the caustic refining process is recovered using ion exchange, the water is recycled back to the washing process

- The wastewater from the alkali refining or neutralization process can be treated by gravity separation to recovery the oil which can be sold to the saponification plant or reintroduced back into the crude oil or at the beginning of the neutralization process.

- The filter clay cake can be land applied to agricultural fields as a soil conditioner or amendment that may be particularly beneficial to sandy soils. The cake could also be used in the production of poultry feed or other domesticated animal feed.

- Optimizing the addition of bleaching clay to reduce excess. This would reduce amount purchased, reduce losses of oil in the spent clay, and increase filter press capacity, thus increasing the process efficiency and reducing production costs.

- The catalyst and hydrogen gas in the hydrogenation process can be recovered and reused. The hydrogen gas could be dispersed into the oil by means of a sparger in the lower part of the vessel with an agitator at the top to redisperse the gas leaving the oil surface. In a recirculation system, gas could be withdrawn from the hydrogenation vessel, purified, and recycled to the sparger together with fresh gas.

- Recovery of phosphatides (can be used to form lecithin) and unsaponifiable components, i.e., sterols and tocopherols (possible valuable by-products) from the wastewater.

- The production schedule can be designed to eliminate the need to clean the process oil lines between the different oil types. Cleaning of the process lines could be done with air or gases rather than water. It may be feasible to eliminate the cleaning of the lines by capturing the end of one oil and the beginning of the other oil and returning this mixed oil to storage tanks to be blended.

- The "first-in, first-out" inventory control system could be implemented to reduce the storage time of the crude oil, thereby minimizing the increase in phosphatides while the crude oil is in storage.

- Any final product does not meet specifications could be returned to the beginning of the refining process for further refining, rather than being discarded as waste.

- Any vegetable oil spills could be collected and returned to the refining process. Any contaminated spilled material that cannot be refined could be collected for shipment to a saponification plant.

- Process control tests could be conducted on the oil throughout the refining process operations. These tests can establish the quantities of raw materials, such as caustic soda, washwater, and bleaching clay to be added. This testing optimizes the addition of raw materials. For example, if the oil contains less phosphatides, less caustic soda and washwater can be used.

- Spill control and containment measures could be implemented to reduce the frequency and volume of spills and capture the spills for possible reuse. For example, spill containment dikes could be installed around storage tanks and process equipment. Storage tanks and process tanks could be equipped with level indicators on the outside of the tanks to indicate the level of oil in the tanks. Audio alarms could also be installed to provide a warning before overflows occur.

In addition, measures taken to increase product yield through optimizing the design or operation of process equiopment or processing techniques offer gains in pollution prevention. Often automation or computerization of process controls can result in improved operations. For example, automation of process operations enable more precise chemical additions that can result in a reduction in the quantity of chemicals used. One of the most viable PP/WM options is the recirculation of the neutralization washwater, after treatment through a cation exchange resin. (Eisenhauer, et. al., 1970)

Many vegetable oil refineries treat the soapstock generated by the alkali refining process to convert the soapstock to a commercial product. The treatment of the soapstock with acid produces an acid wastewater. One method that eliminates the wastewater is the neutralization of the soapstock followed by drying with vacuum evaporation. (Beal, et. al., 1972)

5.3 Treatment Technologies Used by the Vegetable Oil Refining Industry

Vegetable oil refining wastes are generally in the form of concentrated liquid wastewaters or solid organic wastes. The liquid wastes are typically discharged to a municipal sewer system, or are treated on-site and discharged to a receiving water. Solid wastes may be use directly as fertilizers, mixed with feed as a protein supplement, recovery of oils, or landfilled as solid, non-hazardous wastes.

The liquid wastes generated by vegetable oil refining are characterized by high BOD, suspended solids, and oil. Several in-plant treatment options are available. These treatment processes can be categorized as physical, chemical or biological systems. To optimize the recovery of by-products, the treatment design should consider segregation of the individual wastestreams generated by each piece of equipment or operational unit. Individual treatment of specific wastestreams can often result in the in-process recycling of the product or raw materials and concentrated solid or liquid streams that are economically viable as by-products. A schematic diagram of an integrated waste reduction and wastewater treatment system at a vegetable oil refining facility is provided in Exhibit 5-1.

5.3.1 Physical Treatment Systems

Physical treatment processes at vegetable oil refining facilities can include: flow and loading equalization basins and oil separation units. These processes and their applications are described below.

Flow Equalization:

Flow equalization is a relatively simple process that can yield substantial benefits with respect to mitigating shock loads to a municipal treatment plant. Equalization facilities consist of tanks and basins that hold flows from various processes, mix these wastestreams, and release a wastestream to the sewer at a relatively constant rate.

Equalization basins allow vegetable oil refining facilities to combine high and low strength wastes and control the rate of discharge to their own treatment system, or a municipal sewer. This process reduces the potential for sporadic discharges of high strength wastewaters and allows the facility to release its wastestream under controlled conditions. These systems are also attractive due to their low capital cost and minimal operation and maintenance requirements.

Fat, Oil and Grease Removal:

Fats, oils and greases (FOG) can be removed from the wastestream by a variety of methods including catch basins, skimmers, and dissolved air flotation systems. The treatment and removal of free and emulsified oils and greases is typically accomplished by gravity separation, physical filtration and/or

flotation. These treatment processes may be used alone or in combination depending on the nature of the oils and greases to be treated and the strength of the wastestream.

Catch basins are relatively simple units that trap large solids and floatable materials, but allow unrestricted flow to the wastestream. Trapped solids and floatables must be routinely removed from these systems to ensure their proper operation. Removal can be performed manually, or mechanically using a combination of skimmers, rakes and vacuum equipment.

Skimmers can be used to remove FOG where they are suspended in the wastestream. These systems allow and encourage the suspended FOG to coalesce on the surface of the separation unit where they can be removed by manually operated or mechanical skimmers.

Dissolved air flotation (DAF) units are highly effective in removing dispersed FOG from the wastestream. These units utilize fine air bubbles, which are produced by diffusers in the bottom of the separation tank, that promote the coalescing of the FOG as they ascend through the wastewater. The coalesced FOG is then removed by manually operated or mechanical skimmers.

The FOG removal systems described above each require a moderate capital expenditure and must be properly operated and maintained to ensure efficient pollutant removal. The advantages to these systems, however, can include significant reductions in the FOG, SS, and BOD of the wastestream and the capture of FOG that can be recovered as a useful product.

5.3.2 Biological Treatment Systems

Because of the organic, biodegradable nature of the pollutants generated by vegetable oil refining facilities, a wide variety of biological treatment systems can be applied to these wastestreams. A brief description of anaerobic and aerobic treatment systems and their application to vegetable oil refining wastestreams is provided below.

Anaerobic Treatment Systems:

Anaerobic lagoons can reportedly remove up to 95 percent of BOD and TSS and routinely achieve over 80 percent removal. Anaerobic lagoons are relatively simple to construct and operate and are less costly than other biological treatment systems. Problems associated with these systems include the potential for significant odor generation.

Anaerobic contact systems are equally applicable; however, they require significant expenditures for equipment and operation, and are not widely used. Their advantages include a high BOD removal rate in a short timeframe. Disadvantages include high cost and operational difficulties.

Aerobic Treatment Systems:

Aerobic treatment processes are generally used by the industry as secondary treatment prior to direct discharge to a receiving water. The relatively high capital and operation and maintenance costs for these units generally preclude their use to pre-treat wastes prior to disposal to municipal sewers. A detailed description of these processes is not provided in this section, but the different types of aerobic processes includes aerated lagoons, aerobic lagoons, activated sludge, trickling filters, and rotating biological contactors (RBC).

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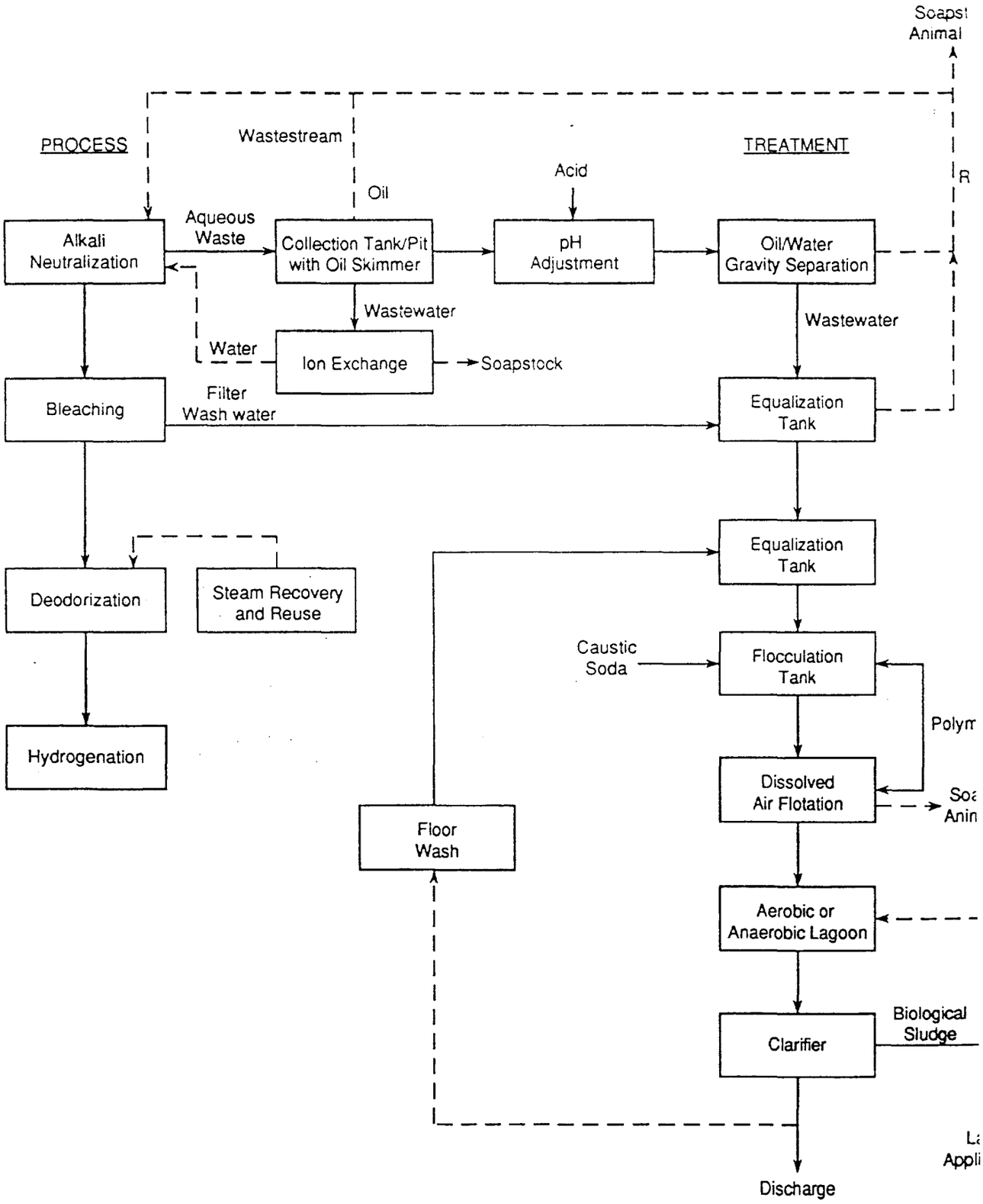

FIGURE 5-1. Integrated Waste Reduction and Treatment System at a Vegetable Oil Refining Industry

6.0 REFERENCES

Attachment A Selected Papers on Pollution Control for the Vegetable Oil Refining Industry

Attachment A

Selected Papers on Pollution Control for the Vegetable Oil Refining Industry

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Treatment of Soybean Oil Soapstock to Reduce Pollution[1]

L.L. BEAL and V.E. SOHNS, Northern Regional Research Laboratory,[2] Peoria, Illinois 61604,
and H. MENGE, Animal Science Research Division, ARS, USDA, Beltsville, Maryland 20705

ABSTRACT

Often soapstock is acidulated to convert this byproduct of vegetable oil refining to a salable commodity. The acidic waste water from this treatment constitutes a significant part of the environmental pollution from refineries. A process of neutralizing and drying was investigated as a nonpolluting method for upgrading soybean oil soapstock. Neutralization with sulfuric acid was conducted in a ribbon blender. The neutral soapstock was dried to ca. 4% moisture, either batchwise in a natural circulation evaporator or continuously in a scraped film evaporator. The product is liquid while hot but solidifies to a waxy solid when cooled to room temperature. When added to a standard broiler ration, the feed efficiency and rate of gain of chickens equaled that obtained with a commercial feed fat added at the same level. The soapstock products fed, which contained 200-300 ppm xanthophyll, gave significantly better shank pigmentation than the commercial fat, which contained 3 ppm.

INTRODUCTION

Disposition of soapstock from alkali refining of soybean oil and other vegetable oils has become a problem with many refineries because of increased restrictions on environmental pollution. Acidulation of soapstock, widely used to convert it to salable fatty acids, produces a substantial amount of acidic wastewater containing biodegradable material (1). Disposal of the waste is increasingly difficult and costly.

Various other methods of handling soapstock are used or have been proposed. Addition of soapstock directly to oilseed meal is practical under certain conditions. However the difficulty of handling wet soapstock, preventing microbial spoilage and avoiding shipping costs often precludes such disposition. National Research Council specifications require that soapstock be neutralized before it is added to a commercial feed (2). A process of drum drying soapstock and addition of the dry material to poultry feed has been described (3). The dried material presents a dust problem in handling and feed mixing. It is hygroscopic and cakes when stored. Conversion of acidulated soapstock to fatty acid methyl esters is another method of producing a salable product, but again acidulation introduces a disposal problem (4).

In this report a process is described for treating soapstock to produce a desirable and salable product without creating either water or atmospheric pollutants. A cost estimate is given to indicate the economics of the proposed process whereby soapstock is neutralized and then dried by vacuum evaporation. Neutralization converts soaps to fatty acids; the dried product becomes liquid when warmed to ca. 45 C and remains a waxy solid at room temperature. The only effluent from the process is evaporated water.

Although neutral dried soapstock (NDSS) might be a source of industrial fatty acids by splitting the glycerides it contains by continuous high-temperature hydrolysis, the main value of NDSS would be as a source of energy and xanthophyll in poultry rations.

Analytical Methods

Moisture in NDSS was determined by drying a sample to constant weight in a rotating flask evaporator (Rinco) while heating the flask in a water bath at 90-95 C and an absolute pressure of 0.5 mm mercury. Free fatty acids were determined by AOCS Official Method Ac 5-41 and unsaponifiable material by Method Da 10-42.

Total fatty acids (free and combined) were determined by the gas liquid chromatography (GLC) method of Black et al. (5).

Sodium was determined by an atomic adsorption method similar to that described by List et al. (6). An oil soluble sodium standard was obtained from the National Bureau of Standards. The instrument was a Techtron AA 120 equipped with a sodium lamp.

Carotene and xanthophyll were determined by Official AOAC Method 39.019-31.022.

Phosphorous was determined by the method of Truog and Meyer (7).

Fatty acid composition was determined by preparing methyl esters by the AOCS Tentative Method Ce 2-66 (1969 Revision) and analyzing by GLC, AOCS Tentative Method Ce 1-62 (1970 Revision).

EXPERIMENTAL PROCEDURES

Three lots of soapstock produced in a commercial plant by alkali-refining crude, nondegummed soybean oil were obtained at different times. Lot 1 of soapstock was converted to NDSS by placing 42.6 lb. in a 1 cu ft, stainless-steel, batch ribbon blender and mixing thoroughly. A 10 g aliquot of the blended lot was dispersed in 50 ml

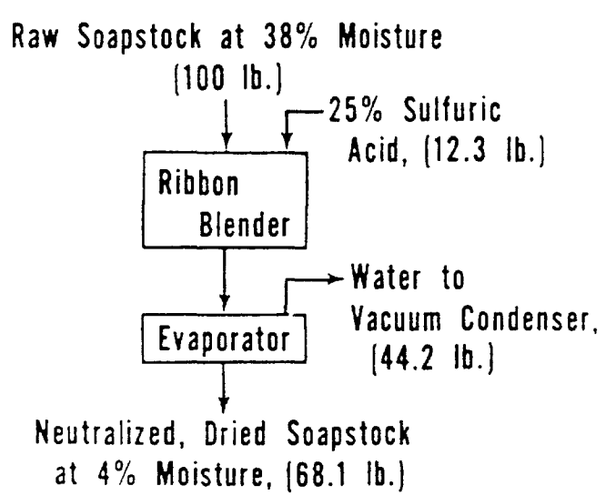

FIG. 1. Flow sheet for neutralized, dried soapstock.

[1]Presented at the AOCS Meeting, Los Angeles, April 1972.
[2]N. Market. Nutr. Res. Div., ARS, USDA.

TABLE I

Partial Analysis of Neutralized, Dried Soapstock (NDSS) and a Commercial Feed Fat

Composition	Soapstock, lot no.[a]					Commercial feed fat
	1	2	3	4	5	
Total fatty acids, %	71.0	64.0	54.0	—	—	97.3
Free fatty acids, %	34.0	28.3	27.1	—	—	41.6
Moisture, %	4.6	4.4	5.7	0.0	0.0	1.6
Unsaponifiable, %	2.0	2.0	2.1	—	—	0.046
Phosphorous, %	—	1.04	0.80	—	1.66	0.0019
Sodium, %	1.8	1.6	4.5	—	—	0.0
Carotene, μg/g	350	575	229	78.0	89.0	4.0
Xanthophyll, μg/g	202	313	231	40.0	38.0	3.0
Fatty acid composition						
C-16	—	—.	—			10.1
C_{16}	16.7	17.6	17.3			25.8
C_{18-0}, stearic	4.6	4.2	4.4			14.6
C_{18-1}, oleic	15.9	15.6	15.7			37.0
C_{18-2}, linoleic	55.7	55.7	55.4			11.2
C_{18-3}, linolenic	7.1	6.9	7.2			1.3

[a]Lots 1 and 2 prepared with a natural circulation evaporator and used in feeding trials. Lot 3 prepared with a scraped film evaporator. Lots 4 and 5 prepared by pilot-plant refining and laboratory-scale drying: lot 4 without and lot 5 with neutralization.

TABLE II

Growth, Feed Conversion and Shank Pigmentation Scores of 6-Week-Old Straight-Run Broilers

Treatment	Averages of two trials[a]		Shank pigmentation, Roche yolk color fan number[c]
	Weight at 6 weeks, g	Feed conversion[b]	
Broiler diet[d]	1312	1.87	4.84
NDSS diet[e]	1307	1.91	6.83[f]

[a]Eighty chicks per treatment in each of the two trials.
[b]Feed consumed per weight gain.
[c]Roche color fan, F. Hoffman-LaRoche Co., Ltd., Basle, Switzerland.
[d]Diet containing 4 % commercial feed fat.
[e]Diet containing 4 % neutralized, dried soapstock (NDSS).
[f]Highly significant ($p \geq 0.01$).

distilled water, and 1% sulfuric acid was slowly added from a burette with rapid stirring until a pH of 7.0 was reached that persisted for more than 1 min. From this titration the calculated amount of 25% sulfuric acid (5.25 lb.) was slowly added to the soapstock while it was being mixed in the ribbon blender. Mixing was continued for ca. 15 min after addition of the acid, and a 10 g sample dispersed in 50 ml of distilled water gave a pH of 6.9.

The neutralized soapstock was dried batchwise by drawing it into a small steam-heated, natural-circulation evaporator under a 22 in. vacuum and heating cautiously because of a tendency to foam. As evaporation proceeded, steam pressure reached 10 psi; when circulation stopped, the batch was withdrawn into a suitable container where it solidified to a waxy solid on cooling to room temperature. A flow sheet of the process and a material balance based on laboratory tests with soapstock from lot 1 are shown in Figure 1.

Lot 2 was prepared in the same manner, but lots 1 and 2 were used separately in broiler feeding studies conducted at Beltsville, Md. Lot 3, not used for feeding, was neutralized and then dried continuously by a single pass through a steam-heated, thin film (scraped film) evaporator operated under an absolute pressure of ca. 5 mm of mercury with steam at 20 psi in the jacket. Compared with the first two lots, the product was visibly darker brown, apparently as a result of the higher temperature (steam pressure) used. The relation between color and feeding value was not determined. A thin-film evaporator like that used to dry commercial lecithin should be the most satisfactory drier for NDSS because the wet material tends to foam and because its heat sensitivity is similar to that of lecithin.

Lots 4 and 5 were prepared from soapstock produce alkali-refining crude soybean oil on a continuous pilot p scale. Lot 4 was dried without neutralization or o treatment and lot 5, after neutralization with dilute sulf acid. Both lots were vacuum-dried in a rotating f evaporator at 90 C; both were tan in color, while lots and 3 were brown to dark brown.

RESULTS AND DISCUSSION

The composition of several lots of NDSS prepared in pilot plant and laboratory is given in Table I.

Witte and Sipos (3) showed that soapstock dried dir or after addition of more alkali retained a high xanthop content. However when soapstock is acidulated, xan phyll is destroyed (8,9). NDSS retains a substantial con of both carotene and xanthophyll as shown from comp tions of lots 1, 2 and 3. Refining conditions used for lo and 5 were possibly not optimum for removing xanthop and carotene from crude oil, since the material was m lower in xanthophyll than the soapstock obtained fro commercial plant and used for other tests. The similarit the carotene and xanthophyll contents of lots 4 an shows that the process of neutralizing and drying soapst resulted in virtually no destruction of these materials.

NDSS had no signs of microbiological growth or of spoilage after several months at room temperature. though solid at room temperature, it liquefies at ca. 40 C and is fluid enough at 45-50 C for easy incorporation feed.

Because of its phosphatide content, the yield of NDSS should be higher than for acidulated soapstock. Thus for lot 1, the maximum yield of acidulated soapstock from 100 lb. of raw soapstock would be ca. 50 lb., an amount considerably less than the 68 lb. of NDSS we obtained. The difference in yields would represent the glycerine and phosphatide moieties which would be lost in the wastewater from acidulation. They apparently constitute the major portion of the BOD content of the wastewater that contributes to environmental pollution problems.

According to a recent report (10), alkali refining does not selectively remove chlorine-containing pesticides from vegetable oils; therefore soapstock or products therefrom used in feeds should not contain significant levels of such materials. Another report confirms that it does not (Private communication, Wisconsin Alumni Research Foundation). However deodorizer distillate may contain substantial amounts of such pesticides, and it should not be added to feeds unless analysis shows it to be suitable.

Lots 1 and 2 were compared with a commercial feed fat used routinely in broiler rations (Table I). Two 6 week feeding trials were conducted with straight-run broiler chicks in which NDSS was compared with a commercial feed fat. Growth and feed efficiency were not significantly different for either diet as shown in Table II. However improvement of shank pigmentation with NDSS was highly significant. Mortality rates were the same for both treatments and both trials and were not related to the dietary regime. Detailed results of the feeding trials will be published elsewhere (11).

A preliminary cost estimate has been prepared for a plant producing 20,000 lb. of NDSS daily by the process described. The production of 20,000 lb. of NDSS at 3% moisture would require processing ca. 30,500 lb. of untreated soapstock at 36.5% moisture. For a plant operating 300 days per year, 24 hr a day, the estimated fixed capital investment, as detailed in Table III, is $150,000. This hypothetical installation is considered an adjunct to an existing soybean oil processing plant, and presumably adequate building space is available for the proposed process.

Estimated processing costs for producing NDSS are ca. 1.55 cents/lb. Cost items listed in Table IV and included in processing costs are sulfuric acid, utilities, labor and supervision (shared with existing plant), maintenance and supplies, fixed charges and general plant overhead. Not included in processing costs are cost for untreated soapstock, administrative and selling expenses, interest on investment and profit. If the soapstock has a moisture content of 50%, the cost to product NDSS with 3% moisture will be increased ca. 0.1 cents to 1.65 cents/lb.

TABLE III

Estimated Fixed Captial Investment for Plant Producing 20,000 lb. Neutralized, Dry Soybean Oil Soapstock Per Day[a]

Equipment delivered	Cost, $
Evaporator, agitated, thin film, 316 SS	48,000
Pumps, metering	1000
Heat exchanger, 316 SS	600
Mixer, static, in-line	800
Pumps, miscellaneous use	1300
Tanks, process and storage	16,300
Equipment delivered, total cost	68,000
Installation, piping, wiring, etc.	60,000
Engineering fees	12,000
Contingencies	10,000
Estimated fixed capital investment	150,000

[a]Plant operations: 24 hr/day, 300 days/yr.

In the hypothetical plant, an agitated thin-film evaporator is used to remove water from the neutralized soapstock. In actual practice, if a forced-circulation evaporator could be substituted for a thin-film unit, capital investment could probably be reduced. Since low pressure steam can be used for the evaporation step, exhaust steam, if available in a plant, could find application. In the estimate steam costs are based on the use of high pressure steam. It is conceivable, therefore, that actual plant processing costs could be made lower than the listed estimated costs by adopting certain process modifications.

In previous reports we described a water-recycle process for washing alkali-refined or hydrogenated soybean oil in which the water used to wash residual metal ions from the oil is passed through a cation exchange resin in the hydrogen form (12,13). The water is then reused. When the resin is periodically regenerated by rinsing it with acid, excess acid must be discarded. In the proposed method for treating soapstock, this excess acid plus additional strong acid could be used for the neutralization step and the water evaporated in drying the neutral soapstock could be used for rinsing regenerated resin. Such a setup would provide an integrated solution to a refinery pollution problem.

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TABLE IV

Estimated Processing Costs to Produce 20,000 lb. Neutralized, Dry Soybean Oil Soapstock Per Day[a]

Cost item		Dollars per day
Raw materials		
Sulfuric acid, 98%, 1008 lb., $0.016/lb.		16.13
Utilities		
Steam, 30,000 lb./day, $0.75/M lb.	22.50	
Water, 35,000 gal/day, $0.15/M gal	5.26	
Electricity, 960 kwh/day, $0.015/kwh	14.40	42.16
Labor and supervision		
Operators, 12 man hr/day, $4.50/hr	54.00	
Laboratory technician, 3 man hr/day, $4.00/hr	12.00	
Supervision, 20% of operator and technician	13.20	
Overhead	15.84	95.04
Maintenance and supplies, 6%/yr on $150,000		30.00
Fixed charges, 13%/yr on $150,000		65.00
General plant overhead		62.52
Estimated daily production costs, $/day		310.85
Estimated processing costs, cents/lb.		1.55

[a]Plant operations: 24 hr/day, 300 days/year.

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Water-Recycle Washing of Refined Soybean Oil: Plant Scale Evaluation[1]

R.E. BEAL, L.T. BLACK, E.L. GRIFFIN, J.C. MENG[2] and
G.S. FARMER,[3] Northern Regional Research Laboratory,[4] Peoria, Illinois 61604

ABSTRACT

A series of 24 hr tests was made in a commercial refinery under eight different operating conditions to select optimum conditions for a subsequent longer test of the antipollution recycle-washing process wherein wash water is recycled instead of being discarded. Alkali-refined oil was continuously washed at a rate of 15,000 lb/hr to remove sodium. Recycled wash water was then treated with a cation exchange resin to remove sodium. Two wash water pH levels, two oil-water ratios and the addition of a sequestering agent ethylene diamine tetraacetic acid (EDTA) to wash water were factors investigated. For the longer test a water pH of 3.0 and an oil-water ratio of 4:1 were used, and EDTA was not added. Operating and analytical data, equipment specifications and cost data were acquired. The washed oil had a satisfactorily low content of sodium, iron and copper. After it was bleached the oil hydrogenated at a rate comparable to that of a conventionally washed oil. The bleached, deodorized oil had satisfactory flavor and flavor stability. The exchange resin required periodic caustic cleaning to maintain capacity. The new recycle process provides an economic solution to the wash water disposal problem.

INTRODUCTION

Disposal of wastewater from conventional washing of alkali-refined soybean oil presents a problem to refiners because of increasingly stringent laws regarding vegetable oil refinery effluents. About 0.5% of the oil washed is lost in the wastewater (R.A. Eisenhauer, unpublished data). Previous small scale tests (1-3) indicated the feasibility of a process for washing alkali-refined soybean oil to remove soap cations wherein the wash water is recycled instead of being discarded. Since the usual washing process produces a high biological oxygen demand (BOD) effluent as well as a loss of oil, the recycle process offers a two-fold benefit of increasing oil yield and reducing the wastewater effluent and BOD. In order to fully evaluate water recycle washing on a commercial scale, tests were conducted in a production refinery at a rate of six tank carrs of oil per day under a contractual arrangement. These tests provided data for an assessment of operating factors which could not be realistically evaluated in our pilot scale tests.

The test program was conducted in two phases. A series of eight 24 hr tests was made with three operating variables at two levels each. At the conclusion of preliminary tests operating conditions were selected from the results for a 28 day semicontinuous operation in which the recycle washing process was used 5 days per week, 24 hr per day, except for shut-down periods to be described later.

[1]One of nine papers presented in the symposium "Processing of Edible Oils," AOCS Meeting, Ottawa, September 1972.

[2]Anderson Clayton Foods, Sherman, Tex.

[3]Anderson Clayton Foods, Dallas, Tex.

[4]ARS, USDA.

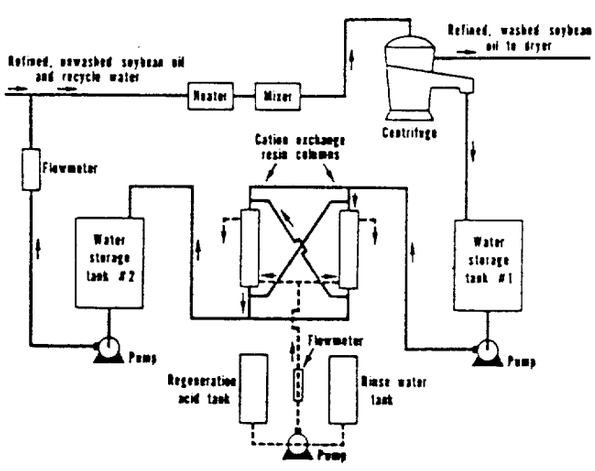

FIG. 1. Recycle washing flowsheet.

EXPERIMENTAL PROCEDURES

Analytical

Sodium in refined oil was determined by flame photometry and copper and iron by atomic absorption (4,5). BOD in wastewater was determined by the standard 5 day method (6). Free fatty acids were determined by the AOCS method (7). The 8 hr AOM peroxide value was determined by oxidizing a sample of deodorized oil 8 hr under standard conditions (8) and determining peroxides (9).

To determine the susceptibility of refined oil to hydrogenation, samples (both unbleached and laboratory bleached [0.5% Super Filtrol 15 min at 105-110 C] oils) were hydrogenated for 30 min in a Parr Autoclave modified with a gas dispersion stirrer, with 0.05% Girdler G-15 reduced nickel catalyst, at 175 C, 10 psig hydrogen pressure. Samples taken after 15 and 30 min reaction were analyzed for refractive index (40 C) and iodine value.

Operation

Equipment consisted of two 1500 gal fiberglass storage tanks, two 8 ft^3 rubber-lined ion exchange columns, two stainless steel centrifugal pumps, a flowmeter, heat exchanger, Lightnin no. 2LBS-50 in-line mixer, water wash centrifuge, 16 ft^3 of Amberlite 252 cation exchange resin (Rohm & Haas Co.) and a level control for no. 1 storage tank. The flowmeter, heat exchanger and mixer were of stainless steel. The centrifuge had stainless discs and dam but had a carbon steel bowl, dam retainer ring and cover. The retainer ring and cover underwent severe corrosion during the tests and the cover required repair, but the steel bowl was not affected by the slightly acid wash water. All pipe and fittings were of fiberglass or stainless steel construction.

A flow diagram of the system for washing alkali-refined soybean oil to remove soap cations is illustrated in Figure 1. The original oil was nondegummed crude. Steam condensate with pH adjusted to desired level with phosphoric acid was placed in water storage tank no. 2. The water was pumped through the flowmeter into the heater together with alkali-refined, unwashed oil, and then to the mixer at 180-190 F and centrifuged. During mixing, sodium ions in the oil exchange with hydrogen ions in the water. Refined

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TABLE I

Preliminary Runs, Average Data

No.	pH	Oil-water	EDTA[a], %	Sodium, ppm Unwashed oil	Sodium, ppm Washed oil	Sodium removed, %
1A	2.5	2.5:1	0.0	68	0.6	99.1
1B	2.5	5:1	0.0	47	1.8	96.2
2A	3.0	5:1	0.	40	1.9	95.3
2B	3.0	5:1	0.0	46	2.1	95.4
3A	2.5	2.5:1	0.01	48	1.4	97.0
3B	2.5	5:1	0.01	34	0.5	98.5
4A	3.0	2.5:1	0.01	50	1.3	97.4
4B	3.0	5:1	0.01	25	2.3	90.8
			Averages			
	2.5					97.7
	3.0					94.7
		2.5:1				97.2
		5:1				95.2
			No			96.5
			Yes			97.4

[a]EDTA = ethylene diamine tetraacetic acid.

washed oil from the centrifuge then was vacuum-dried before subsequent treatment. Water from the centrifuge was stored in water storage tank no. 1. From there it was pumped, at ca. 150-170 F, through two cation-exchange resin columns in series and collected in tank no. 2 for reuse. A recording pH meter monitored the water from the primary ion-exchange column and signaled by a rising pH when regeneration of the primary column resin with sulfuric acid was required. During regeneration of the resin in this column, recycle water was passed only through the secondary column. After regeneration, the fresh column became the secondary column. In this manner, the two columns were alternately regenerated for reuse as th became exhausted of hydrogen ions and saturated wi sodium and other metal ions.

Resin regeneration was conducted as follows: (a) T exhausted resin (8 ft^3) was backwashed in the column wi 100 gal of plant water at a rate of 10 gal/min. (b) T washed resin was backwashed with 2500 lb of 2.5% sulfu acid at a rate of 7.5 gal/min (for 40 min). (c) The resin w backwashed with 4.75 gal/min of plant water for 40 m (d) The resin was down-rinsed with 20 gal/min of pla water for 30 min. (e) The resin was down-rinsed with gal/min of recycle water from tank no. 1 for 10-15 min.

TABLE II

Continuous Runs, Average Data[a]

Day	Flow, lb/hr Oil	Flow, lb/hr Water	pH, from tank no. 2	Sodium, ppm[b] Unwashed oil	Sodium, ppm[b] Washed oil	Free fatty acid, %
1	15,640	3950	2.9	49	2.3	0.065
2	15,830	4000	2.6	58	2.0	0.075
3	15,920	3950	2.8	56	1.8	0.072
4	16,000	4000	2.8	54	2.1	0.065
5	15,670	3950	2.8	20	2.4	0.059
6	15,600	3950	2.9	17	2.6	0.063
7	15,600	3900	3.1	8.7	2.9	0.063
8	15,600	3900	3.0	8.9	2.9	0.063
9	15,710	3900	3.1	31	3.6	0.065
10	16,000	3900	2.8	39	6.4	0.063
11	15,600	3900	2.8	26	1.2	0.060
12	15,600	3900	2.9	28	1.4	0.053
13	15,600	3900	2.9	30	1.8	0.067
14	15,200	3750	3.0	26	1.7	0.050
15	15,000	3650	3.0	32	1.9	0.050
16	14,850	3650	3.0	48	2.5	0.060
17	14,320	3650	3.1	37	2.2	0.060
18	14,890	3550	3.0	59	3.1	0.068
19	14,660	3700	2.9	35	2.5	0.057
20	10,730	2700	3.0	32	2.3	0.055
21	9530	2350	3.0	23	1.7	0.047
22	12,380	3100	3.0	34	2.3	0.057
23	13,330	3350	2.9	26	0.9	0.053
24	13,380	3350	2.9	35	0.4	0.055
25	13,170	3300	2.9	34	1.8	0.057
26	12,730	3200	2.8	61	1.1	0.080
27	13,470	3350	2.9	31	1.6	0.062
28	13,880	3450	2.9	35	1.6	0.050
Average	14,500	3600	2.9[c]	35	2.2[d]	0.061

[a]Spot analyses of samples of washed oil for iron and copper gave: Fe, 0.02-0.09 ppm; Cu. 0.02 ppm.

[b]Sodium x 13.2 = soap (theory).

[c]pH of recycle water from tank no. 1 to ion exchange column was generally 3.5-5, but occasionally 8-10.

[d]Average sodium removal, 93.7%.

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TABLE III

Hydrogenation for Soybean Oil Washed by Recycle and Regular Methods

Sample	Extent of hydrogenation[a]			
	Refractive index, 40 C		Iodine value	
	15 min	30 min	15 min	30 min
Regular washed				
Unbleached	1.4627	1.4609	98.6	83.4
Bleached[b]	1.4609	1.4590	85.1	67.8
Recycle washed				
Unbleached	1.4656	1.4648	124.2	117.8
Bleached	1.4613	1.4596	88.9	72.6

[a]Initial refractive index: 1.4668. Initial iodine value: 131.8. Hydrogenation conditions: 175 C, 10 psig, 0.05% Girdler G-15 catalyst.

[b]0.5% Super Filtrol, 15 min at 105-110 C.

All rinse and regeneration effluents were discarded. During the 28 day test, it was found that the time between regenerations dropped from 20 hr to less than 2 hr after ca. 9 days of operation. It was then necessary to soak the resin in situ with hot 2% caustic solution for 2 hr to remove impurities. When the resin was then regenerated with acid, it was restored to a satisfactory capacity. When the recycle washing system was shut down for longer than 1 day, acid was added to the water in the resin columns to inhibit the growth of microorganisms.

During the course of the experiment, hourly records were made of the oil flow, wash water flow, pH to the ion-exchange column, temperature to the ion-exchange column and temperature from the mixer. The pH to the heater was monitored every 30 min, and the pH from the primary ion-exchange column was continuously monitored. Samples of the wash water to the heater and from the centrifuge and of the unwashed and washed soybean oil were collected every 8 hr for sodium and fatty acid analysis.

RESULTS AND DISCUSSION

Preliminary Runs

In preliminary runs, pH's of 2.5 and 3.0, oil-water flow ratios of 5:1 and 2.5:1 and the addition of EDTA were operation variables examined. The results of the eight 24 hr runs are outlined in Table I.

From these results, the best conditions for removing sodium were pH 2.5 and oil-water 2.5:1. EDTA had negligible effect.

Difficulty was encountered during the preliminary run 2B in the first attempt to maintain a pH of 3.0. The pH dropped well below the operational limits of 3.0 ± 0.2. Consideration of the problem indicated that significant anion contamination was introduced from the raw water originally used for the final rinse of the ion-exchange columns following regeneration. To overcome the problem two procedures were tried: (a) using steam condensate to rinse the resin (step *e*); and (b) using recycle wash water from storage tank no. 1 to rinse the resin (step *e*) and then adding condensate to tank no. 1 to replace water removed. Both procedures were found to be successful, but the latter was used because it offered a faster, more steady flow rate. It was then possible to maintain the pH within desired limits in run 2B and succeeding runs.

TABLE IV

BOD Tests[a]

Cycle	BOD_5, mg/liter	Water, lb	BOD lb
(a) Backwash	10,500	830	8.7
(b) Inject acid	2340	2420	5.8
(c) Displace acid	980	1580	1.5
(d) Fast rinse	140	5000	0.9
Total		9830	16.9

[a]Assuming the final rinse (e) is made with steam condensate and no BOD material is removed.

TABLE V

Estimated Fixed Capital Investment for Installation of Equipment to Convert a Normal 12 Tank Car Per Day Refinery System to a Recycle Water Wash System

Equipment	Cost in dollars
Heater	1000
Mixer	1500
Two tanks, fiberglass	1900
Two pumps	1400
Motor control valve	200
Two cation exchange columns, fully automated, with 30 ft^3 resin per column	24,200
Total equipment cost	$30,200
Installation (in existing facility)	5000
Estimated fixed capital investment	$35,200

Continuous Run

Operating conditions used for the continuous run were pH of 3.0, oil-wash water flow ratio of 4:1 and no EDTA. Selection of the 3.0 pH was made on the basis of its less corrosive effect than the 2.5 pH. The flow ratio was chosen to give as low a ratio as possible and still maintain some excess design capabilities of the centrifuges and their wash water discharge piping.

Results obtained during the 28 day continuous run are summarized in Table II. Average sodium removal was 93.7%. Several samples of washed oil analyzed during the run contained 0.02-0.09 ppm Fe and 0.02 ppm Cu.

The quality of bleached oil produced by the recycle water wash system was equal to the quality of bleached oil produced using conventional washing techniques.

A sample of refined soybean oil washed by the regular method with fresh water and a sample washed by the recycle method were evaluated for their rates of hydrogenation in laboratory tests. Both samples were taken from the vacuum dryers at about the middle of the 28 day test. A portion of each sample was hydrogenated without bleaching, and another portion of each oil was bleached before it was hydrogenated. Samples hydrogenated 15 and 30 min were analyzed for refractive index and iodine value (Table III). The oil washed by the regular method and not bleached hydrogenated substantially faster than the recycle washed unbleached oil. After both oils were bleached, the difference in rate of hydrogenation was small. Soybean oil is usually bleached before commercial hydrogenation. In similar

TABLE VI

Estimates Operating Cost for Recycle Washing of Alkali-Refined Soybean Oil

Cost item	Dollars per hr
Chemicals	
H_2SO_4, 66° Be', 240 lb at $0.0335 per lb	8.04
NaOH flakes[a]	3.08
Labor, 4 man-hr per day at $4.00 per hr	16.00
Maintenance, 6% on 35,200[b]	7.04
Resin usage, 20% per year on $1500[b]	1.00
Estimated processing cost	35.16
Estimated processing cost,[c] dollars per 100 lb oil	0.0048

[a]Based on 38 days of experimental data.

[b]Based on 300 days per year estimated production.

[c]Based on an estimated oil production of 720,000 lb per hr

hydrogenations made with samples taken during the preliminary 24 hr recycle washing tests, results were similar but there were smaller differences in hydrogenation rates between regular washed, unbleached and recycle washed, unbleached oil.

A sample of soybean oil that was recycle washed, bleached and deodorized (unhydrogenated) in plant equipment was evaluated by the Northern Laboratory taste panel. The bleached color of the oil was 0.4 (Lovibond red). The average odor and flavor scores of the deodorized (unstored) oil were 7.4 and 7.0, respectively, and after 4 days of storage at 60 C the scores were 6.1 and 5.3. The 8 hr AOM was 15.0. These values are similar to values usually obtained with commercial soybean oil and indicate the recycle washed oil is of acceptable quality.

During recycling of wash water, soluble material accumulates in the water. Two gallons of recycle water removed from no. 1 storage tank during the 28 day test was lyophilized in a freeze drier. The residue was a soft, brown, hygroscopic material, and the recycle water contained 2.4% of this material. Analysis gave the following values: total nitrogen (Kjeldahl) 1.54%, phosphorous 6.44%, reducing sugars after acid hydrolysis 16.0%, unsaponifiable 0.6%. Esterification of a sample with methanol and gas liquid chromatographic analysis of esters showed that the fatty acids had the composition of soybean oil. The soluble material is evidently largely phosphatides and related materials, but it includes no oil per se.

The ion-exchanger columns did not operate as long as they theoretically should before requiring regeneration. The two 8 ft^3 ion-exchange columns have a theoretical sodium removal capacity of 20.0 lb each. At an oil flow rate of 355,500 lb per day and a sodium removal level of 30 ppm from the oil, the column should last ca. 48 hr in theory and at least 24 hr in practice before requiring regeneration. From the data collected, the ion-exchange column lasted an average of only 8.9 hr. This indicates that regeneration acid may have been too weak or insufficient or that partial fouling of the resin by material in the recycle water lowered effective capacity.

Wasteload

Several 5 day BOD tests were run to determine the effectiveness in reducing the pollution load of the refinery of utilizing the recycle water wash method in processing the soybean oil. It was found that the load produced during each regeneration amounted to 16.9 lb of BOD (Table IV).

The average length of service for one column was 8.9 hr at an average flow of 14,500 lb oil per hour. Thus the BOD load using the recycle washing system amounted to 0.129 lb BOD per 1000 lb oil production.

Based on an average BOD of 10,400 mg/liter for the [illegible] wash water and a wash water flow of [illegible] showed that 2.08 lb BOD was produced for every 1000 [illegible] oil production.

According to these calculations, it is possible to red[illegible] the normal BOD load from an approximately six tank [illegible] per day refinery by 1.9 lb/1000 lb oil produced ([illegible]9 reduction) by employing the recycle method of wa[illegible] washing.

Cost

For a plant installation in a 12 car per day (720,000 [illegible] refinery, the estimated fixed capital investment is $35,2[illegible] assuming that a suitable centrifuge is already available. T[illegible] use of two 30 ft^3 columns in a fully automated ion-[illegible] change system would require operational labor of ca. 4 [illegible] per day including routine analysis of samples. With t[illegible] amount of labor, the cost above the normal refine[illegible] expense is estimated to be $0.00488/100 lb of oil produ[illegible] tion (Tables V and VI). This is partially offset by a wa[illegible] savings in the amount of $0.00069/100 lb of oil produ[illegible] tion. This evaluation of the actual cost for a permane[illegible] installation of the water wash system is based on the pla[illegible] test results described.

This procedure eliminates loss of oil during washing [illegible] the refined soybean oil, while the conventional wash[illegible] produces an oil loss of ca. 0.5% equivalent to a cost [illegible] $0.05/100 lb of oil processed. Thus the recycle wash[illegible] process can effect both a substantial reduction in BO[illegible] discharge and an appreciable savings in the cost of pla[illegible] operation.

ACKNOWLEDGMENTS

Laboratory hydrogenations were done by G. Nofsinger, flav[illegible] evaluation by the Northern Regional Research Laboratory tas[illegible] panel and 8 hr AOM by G. List. This work was conducted under contract to Anderson Clayton Foods, Dallas, Tex., from the USD[illegible] and authorized by the Research and Marketing Act of 1946. T[illegible] contract was supervised by the Northern Regional Research Labor[illegible] tory, ARS.

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limited strictly to edible oils but are applicable also to petroleum-type oils. We have installed a two stage system at a refinery in Oklahoma, where the first stage is designed to, and in fact does, remove hydrocarbon-type oils from the waste stream without the use of chemicals, and the second stage is used to clarify the waste water. The first stage returns essentially all of the available hydrocarbon materials to the refinery where they are reprocessed. The second stage has effectively eliminated a large ponding system for final treatment of the waste water before it discharged to a federal system.

The electrochemical process has proven effective in removing fats and oils without the aid of chemicals at a large packing plant. The flow at this plant is 1200 gal/min. Even though the waste stream is contaminated with manure, blood, and has a fluctuating pH, it is still possible to recovery fat down to a level of 20 ppm, and this fat then is augured directly to a melter for rendering.

A fat recovery system also has been designed for an edible renderer. The fats, oils, and greases are removed in this case in a single stage operation from a level of 3000-5000 ppm to less than 100 ppm. The recovered fat then is passed through a skimmings thickener where the concentration is increased from 10-45% of hexane extractables. Control equipment which is installed at this plant enables the system to operate essentially without attention.

The process also has been installed in an inedible rendering operation which was not in trouble with the sanitary district. This installation was made at the request of the owner strictly for economic reasons: the fats and oils are money and the recovery from the sewer is profits.

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Treatment of vegetable oil refining wastes to conform to government regulation[1]

MOLLIE KAYE CANTRELL and HOWARD F. KELLER, JR., GBK Enterprises, Inc., Fullerton, California 92633

Historical and conventional methods for the treatment of vegetable oil waste water are described. The results obtained and the economics of the various processes for oil-water separation are reported. A process utilizing selective adsorption filtration is described. The new regeneration procedure for cleaning the filter media allows for its total reuse. The process produces effluent water which will conform to existing government regulations for oil content. Development of the filtration/regeneration process is

by-product recovery and pollution control method almost universally by industries which have significant amounts of fats and oils in their waste water streams. The method usually involves the combining of the various plant waste water streams and dumping into a common separation station. The separation station consists of a large pit equipped with bottom sludge removal equiment and a mechanical skimmer for removing the floating oils and fats. There is also a drain for taking off excess water. This recovery

surface more rapidly and completely than in a simple skimming tank. Heavier solids will still fall to the bottom.

The results, shown in Table II,

TABLE I

Typical Results of Skimming Method (1)[a]

Impurity:	BOD	SS	FOG
Input	4010	3680	3985
Output	2440	2700	3200
Percent removal	38	33	25

[a]BOD = biological oxygen demand, SS =

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TABLE IV

Direct Cost Comparisons for 500,000 Gal/Day Waste Water Treatment Systems

	Air flotation (with chemicals)				GBK Filter unit			
Cost factor	Required amount	Daily need	Unit cost	Total daily ($)	Required amount	Daily need	Unit cost ($)	To da ($
Aluminum sulfate	500 ppm	2075 lb	6cent/lb	124.50	None	—	—	—
Polymer	2 ppm	8.3 lb	$2/lb	16.60	None	—	—	—
H_2SO_4 (concentrated)[b]	for pH 3-6	Maximin 12 gph	$60/ton	138.00	For pH 4 or less	—	—	138
NaOH (concentrated)	to neutral effluent	—	$60/ton	138.00	Same	—	—	138
Labor	1 man/24 hr	24 hr	$6/hr	144.00	4 Hr supervisory time/week	4/7 hr	8.00	4.57
Power	1370 kwh/day	—	$.015/kwh	20.55	1500 kwh/day	—	—	22
Steam[c]	3000 lb/	—	—	—	None	—	—	—
Disposal of oily sludge	gpd	—	$150/2100 gal	50.00	None	—	—	—

[a]For air flotation, the cost of treating 1000 gal water with chemicals is $1.27. For GBK system, the cost of treating 1000 gal water is $.6

[b]Continuous use of acidulation waste water reduces acid consumption proportionately.

[c]Cost of steam varies according to the availability of excess steam in the facility.

TABLE V

Equipment Response to Various Treatments[a]

Treatment system	BOD	SS	FOG
Raw plant effluent	2635	1400	485
Anaerobic lagoon	475	580	105
Trickling filter	296	602	75
Final clarifier	125	110	35
Chlorine contact basin	60	90	15
Total plant (percent)	97	94	97

[a]BOD = biological oxygen demand, SS = suspended solids, and FOG = fats, oils, and greases. These are given in ppm.

indicate an improvement in grease reduction by using an air flotation cell, but the air flotation cell appears to perform ca. equally to gravity separation for removal of BOD and suspended solids.

The efficiency of the dissolved air flotation method of FOG, BOD, and SS removal from the waste water can be improved by the use of chemical flocculants and coagulants. In one test, alum and a synthetic polymer were used to enhance the performance of the method (1).

Table III gives the overall average results of an extensive series of tests using a combination of alum and polymer with dissolved air flotation. This test was performed simultaneously with the test for air flotation cells above, without chemicals.

Better BOD, solids, and FOG removal have been reported by some sources, when the chemical concentration is increased.

Table IV gives a cost analysis of this type of operation.

BIOLOGICAL OXIDATION

Biological oxidation methods sometimes are used for food processors as secondary methods for removing pollutants prior to discharging to a stream or sewer. Aerated lagoons, anaerobic lagoons, trickling filters, and activated sludge are commonly used methods, and all are familiar to vegetable oil processors.

These types of biological treatment systems can be efficient, but variable operating conditions, such as pH, temperature, and bacterial activity, can be difficult to control. Lagoons, of course, must be located out-of-doors and require considerable amounts of land area due to retention time requirements. All of the biological oxidation methods are subject to overloading during peak production periods, and any upset in operating conditions for the systems will require hr or days for correction.

In general, each food processing plant has not one, but a combination of methods for treatment of waste water. In one report (2), results were obtained by treating the raw plant effluent with the sequence of methods shown in Table V.

TECHNOLOGY OF POLLUTION CONTROL

As can be seen, all of the methods produce an improved waste stream. Unfortunately, government agencies now are requiring that the food industry reduce the total output of FOG, BOD, and solids even further. Regulations now in effect require FOG content of no more than 10 ppm in some cases. Other areas have FOG limits of 100 ppm or less. Surcharges are almost universally imposed on plants whose effluents contain a high BOD content. The application varies from state state and from city to city but t effect is always to create an unnec sary added operating expense for t plant.

In the past, it has been econo ically unfeasible and politically u necessary for the industry to be co cerned with the removal of the ve small remaining quantities of impu ties in the waste water stream. Gove ment standards were few and were n rigidly enforced, and the industry h been allowed to discharge relativ high amounts of pollutants with t waste water stream, while fines f violations were nominal.

Technology in industry has ma tremendous advances in process i provements, increases in productivi and efficiency. With the advent stricter antipollution legislation governments throughout the world, also has become necessary for t vegetable oil industry, as well as oth food industries, to seek solutions f their water pollution problems. Rece government imposed standards f FOG and BOD content of waste wat are strict, and these are being enforc more stringently than ever before.

While the technology of polluti control has taken large strides in ma problem areas, new ideas for metho of oil-water separation have been fe This is, of course, one of the mo difficult problems in the area of wat pollution control. Skimming of t gross amounts of oil in the waste wat is still an effective and economic method for the removal of oil. Ho ever, the limits now being imposed a enforced by the government require more complete removal of oil a BOD than mere gravity separation c afford.

Ca. 5-10 years ago at the time the beginning of stricter governme regulations, filtration began to be n considered as a possibility for an effe tive and economically feasible metho

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of pollution control. For the removal of solids from liquids, the deep-bed filter always has been recognized as effective. It also is known that a granular type filter media used in a deep-bed filter can effectively remove minute quantities of oil from a water stream. However, the major drawback for using a filtration method for the separation of oil and water is that, until recently, there was no means whereby the filter media could be reused after it was saturated with the oil from the waste water stream. If the media has to be dumped each time the bed is saturated with oil, then the filtration method becomes very costly, even if highly efficient.

GBK PROCESS

Several years ago, a patent was issued for a method in which the filter media bed was cleaned by introducing solvent or steam into the media then passing it through the bed in the direction countercurrent to the liquid flow. For the petroleum industry, the above method for cleaning has proved to be satisfactory, and GBK has an agreement whereby they can sell this unique system.

GBK tried to apply the steam cleaning process to edible oil refinery water filters and was unsuccessful. The major problem encountered was due to the acitivity of the unsaturated oils compared to the petroleum oils. After several steam cleaning cycles, the filter media became cemented together by a highly polymerized varnish, caused by the steam cooking, and this was, of course, impossible to remove.

To avoid the above problem, a radical and novel method of chemical regeneration was developed and has become a part of the GBK oil-water separation process. This new process made feasible the use of a deep-bed filter with vegetable oil processors' waste stream. However, there were other important problems to be solved relating to the complete water pollution problems existing in the industry.

To arrive at the level of waste water purity desirable to conform to government regulations, it was necessary for GBK to develop a completely integrated, unique, water treating system for the edible oil industry. To this end, a process was developed which has the capability of removing and subsequently recovering virtually all of the fats, oils, and greases from an effluent stream. The heart of the treatment system is selective absorptive filtration combined with chemical regeneration of the filter media. The efficiency of the filtration method has been improved by GBK, by taking into consideration the many facets of the process. Each of these process areas was studied, tested, and changed, if necessary, to maximize the efficie[illegible] filtration process.

The first step in improving the filtration process was gaining an understanding of the theory of the selective adsorption process. The closest analogy to selective media filtration is chromatography. The mechanism is almost identical in that it is a surface absorption mechanism demonstrating a surface saturation migration potential, with total adsorptivity being proportionate to surface area. The only difference seems to be greater quantitative adsorption than would be dictated by the theory.

The quantity of oil adsorbed is a function of: (A) particle size distribution within the filter media, (B) flow rate thorugh the filter in gpm/ft^2, (C) oil content of the waste water stream, and (D) the effect of other constituents in the waste stream on the absorptivity of the oil.

As an example of the effect of particle size distribution, the following was observed in the quantity of oil adsorbed by two sands with the same mesh size nomenclature, but differing widely in their particle size distribution patterns. (Oil capacity of the bed was reached at the time oil breakthrough was observed in the effluent stream). The sands were both 30 mesh according to the suppliers, and flow rate was held constant at 10 gpm/ft^2. The feed fluid was refinery waste water containing 650 ppm FOG and 120 ppm solids (mostly bleaching clay). The two tests were run simultaneously so that variations in condition of the waste water feed stream could be ignored. Sand S retained 1.3 lb oil/ft^3 media at the time of oil breakthrough and sand M retained 6.8 lb oil/ft^3 media at the time of breakthrough. Equal volumes of wet sand were used for each test.

To demonstrate the effect of flow rate, the above beds were regenerated, and the flow rate was increased to 20 gpm/ft^2. Sand S retained 0.6 lb oil/ft^3 at breakthrough, with a pressure drop of 11 psi/ft media depth. Sand M retained 4.8 lb oil/ft^2 at breakthrough with a pressure drop of 5.2 psi/ft of media depth.

For all normal sand usage applications, the sands are identical. As a matter of fact, sand S is the most frequently used and most highly recommended, because it falls within the established National Filter Sand recommended ranges, while sand M does not.

The above noted differences in oil adsorption and throughput capacity in the two similar sand filter medias points out the necessity of properly designing the bed for the waste stream

TABLE VI

Plant Effluent Composition

Impurity source	Percent
Deodorizer water	91.7
Gravity separation basin	1.66
Water wash	1.66
Condensate	3.3
Acid waste water	0.83
Packaging	0.83

TABLE VII

Plant Effluent Response to Various Water Treatments[a]

	Feed		Product	
Sample number	FOG (ppm)	COD (ppm)	FOG (ppm)	COD (ppm)
1543	280	—	0.5	—
1608	815	2210	1.2	1580
1630	195	2340	2.8	1550
1700	260	—	2.6	—
1740	145	2930	39.0	1320
1810	750	2210	12.2	1060
1830	78	—	14.3	—
1900	60	—	19.4	—
2045	23.5	—	1.9	—
2115	16.7	—	0.6	—
2130	39.0	—	1.1	—
2145	39.0	—	0.2	—

[a] FOG = fats, oils, and greases and COD = chemical oxygen demand.

TABLE VIII

Fat, Oil, and Grease (FOG) Response to Treatment

Sample number	Pressure drop (lb)	FOG (feed) (ppm)	FOG (product) (ppm)
1630	15	45	12.7
1700	13	53	1.5
1754	14	3040	1.3
1803	15	480	0.9
1900	16	76	2.5
2000	24	49	1.6

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in a particular situation rather than using a "universal" filter sand.

TEST DATA

Initial tests of the system of adsorptive filtration on refinery waste water were conducted on 1-3 gpm slipstreams of plant effluent waters or on streams deliberately mixed to simulate total plant effluent.

An experimental, small-scale filtration study was conducted at a vegetable oil refining facility to determine the FOG removal from treatment of a synthetic waste water which is representative of the plant effluent presently being discharged to the sewer. The plant effluent composition tested is shown in Table VI.

The average pH of this blended waste water stream was 4.5 with no significant change being affected by the filtration process. FOG for the feed to the filter was an average of 225 ppm. The average output of the GBK filter was 7.9 ppm. This represents an average reduction of FOG content of 96%. The filtration test period extended over a period of 3 hr, at a flow rate of 1 gpm. There were three 1/2 hr shutdown periods during which the media was either changed or regenerated.

The results from the test are given in Table VII.

Based upon the significant FOG and chemical oxygen demand (COD) reductions with the smaller 1-3 gpm pilot units, studies were planned involving the use of a 100 gpm skid-mounted unit. This filter was set up adjacent to the gravity separation basin which collected the total plant effluent before discharge to the sewer. Suction was taken from the "clean" water section of the basin.

Average input to the filter was 623 ppm of FOG. Ten min prior to taking sample 1754, 5 gal pure vegetable oil was injected into the line feeding the filter to see what increase, if any, in FOG output would occur. Average output of the filter was 3.4 ppm of FOG, representing an average reduction of 99.5% in FOG. The pH of the waste stream was adjusted to ca. 1.0 with H_2SO_4 injection, prior to filtration. Results of the test are shown in Table VIII.

Length of the experiment was 3-1/2 hr. The pump was shut off when pressure drop across the bed reached 24 lb. This had been predetermined to represent a state of undesirable solids plugging within the filter media. As seen above, FOG removal was good, even with a partially exhausted filter media.

At the request of the refinery management, a second test with the 100 gpm unit was conducted on a day when palm oil was being processed. Information desired was related to removal of SS, FOG, and COD. The first half of this test was conducted at the deodorizer basin and the second half was conducted at the gravity separation station. The pH was adjusted to below 4.0 in every case. Length of the filter cycle at each test station was ca. 1 hr. At the end of that hr, refinery personnel took two consecutive samples of feed and product water for analysis. Results were reported by an independent laboratory and are given in Table IX.

The successive steps of scale-up for tests were 1-3 gpm, 100 gpm, and 170 gpm. GBK recently has installed a full-scale plant for a Chicago facility of an edible oil producer on a waste water stream averaging 450 gpm of flow.

The operation is initiated by pressured flow from our effluent stream into two or three vessels containing adsorptive media. An automatic programer is set for a specific time cycle that controls the amount of time the two vessels receive this flow. The time cycle can be set for any frequency of 30 min-8 hr. At a preset time, one of these vessels is taken off stream, and the third vessel comes on stream. The off stream vessel is regenerated in a patented process that recovers the oil, which subsequently is returned to our fats acid stock. The off stream vessel then is backwashed to remove the entrapped solids, and the vessel on standby, having been regener without loss of adsorptive media. next cycle of regeneration takes second vessel off stream for oil re ery and solids removal. During entire process, two vessels always filtering and one is in regeneratio on standby.

The automatic programer is resp sive to two other signals that mon the quality of water from the C filter system. A signal from a tu dimeter which is monitoring effl from the filter system can instal override the preset time cycle cause the standby vessel to come stream and place in regeneration vessel which has been longest stream.

Secondly, a pressure differen increase signal from a pressure ser can override the preset time cycle act to remove the oldest vessel fr the system for regeneration. The p sure override indicates excessive so and oil buildup in the media bed processes a clean vessel into serv These back-up override signals all for 100% recovery by the system wi maintaining the filtering efficiency cases of severe loading by solids or

The overall water treating syst which has been installed is an 800 g capacity unit. It consists of the fil pH control equipment, autom valving, flotation vessel, pumps, mi peripheral storage tanks, and equ ment. Initial performance tests h been conducted by both GBK and customer. The GBK system has pro itself to perform within the lim imposed by the city and state w reference to FOG content and SS.

The importance of total autor tion of the system has been point out by the start-up problems enco tered in using the system on a man basis. The system involves a com cated sequencing of valves and ot equipment to achieve best results d ing both the filtration cycle and filter regeneration cycle. When man operation is used, operator errors qu frequently upset the normal operati of the complex system of water tre ment. This in turn produces p average results from the treatme system. Automatic, programed c trols eliminate the need for operato decrease labor costs, and enable t filters to operate as guaranteed, wi out the uncertainty of human p formance.

Also worth mentioning at this poi is the necessity of customer control the flow rates of waste water and t impurities in the stream which is f to the waste water treatment syste Data are available which show th variations in plant operating proc dures can influence the guarante

TABLE IX

Palm Oil–GBK Filter Test

Location	Product	Time	pH[a]	Suspended solid (ppm)	Hexane soluble (ppm)	COD[b] (ppm)
Deodorizer basin	In	1:30 pm	2.53	6.7	64	290
	Out	1:30 pm	2.60	Less than 1	Less than 5	33
	In	1:35 pm	2.54	1.5	50	250
	Out	1:35 pm	2.58	Less than 1	0.5	50
Gravity separation basin	In	2:57 pm	1.76	11.6	94	350
	Out	2:57 pm	1.56	Less than 1	0.5	75
	In	3:07 pm	1.68	2.2	168	570
	Out	3:07 pm	1.80	Less than 1	Less than 0.5	70

[a]pH was adjusted to below 4.0 in every case.
[b]COD = chemical oxygen demand.

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performance of the filter system. For each individual plant, it is, therefore, necessary to make a specific evaluation of the waste water stream and the government standards which must be met. Then, we must institute plant operating changes and controls which will ensure consistency, within recommended limits, of the waste water feed to the GBK filter system.

The unit currently is being operated manually. Start-up data are incomplete at this time, but the following trends are clear: (A) surcharges for discharging the BOD to the city sewer have been reduced to a fraction of the former amount (from ca. $14,000 to $3,000 or less/month); (B) threat of fines for FOG discharge has been eliminated, as output from the filters falls within government standards; (C) oil recovered for resale has increased by 5000 lb/day over the old system (this oil has a current market price of 14.5 cents/lb); (D) the GBK unit performs as guaranteed when required operating conditions are fully met by the customer.

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Operating experience with biological cooling towers[1]

WILLIAM M. NEUNER and ERNEST K. HOLT, Lever Brothers Company, New York, New York 10022

One of our major water pollution problems concerns the purification of, and disposal of or the bottling up of, waste water from our edible oil processing plant in Edgewater, N.J., and our fatty acids distillation plant in Hammond, Ind. It was decided to investigate the use of a cooling tower as a means of developing an environment for biota growth so that aerobic bacteria would feed on the organic matter present. This preliminary work was done in 1966 on a 30 gpm prototype tower in Hammond and a 720 gpm tower (modified) in Edgewater. As a result of this test work, Lilie Hoffman cooling towers, with high fill to volume ratio and abnormally large water basins, were purchased for our Edgewater plant and Hammond plant. The towers were commissioned in September 1972. The tower systems are fitted with the necessary controls to maintain proper basin water temperature along with automatic feed systems for the nitrogen and phosphorous required for satisfactory biota growth. The Edgewater tower, with a capacity of 3700 gpm, has performed satisfactorily with regard to chemical oxygen demand values and odor problems. There have been a few minor mechanical problems. The Hammond tower, with a capacity of 380 gpm, has had mechanical problems which have precluded sufficient continuous operation to assess its performance completely.

INTRODUCTION

In the refining of fats and oils for use in edible and soap products, high vacuums are employed. These vacuums generally are obtained by the condensation of steam in barometric condensers. Part of the process also may require steaming of the product simultaneously, and steam and organic vapors may be generated by the presence of a vacuum and heat. Therefore, the condensing water not only is heated; it picks up organic matter carried out as vapor or steam distilled from the reaction vessel.

One of our major pollution problems concerned either the purification and disposal, or bottling up, of this waste water, and studies were begun several years ago to solve the problem.

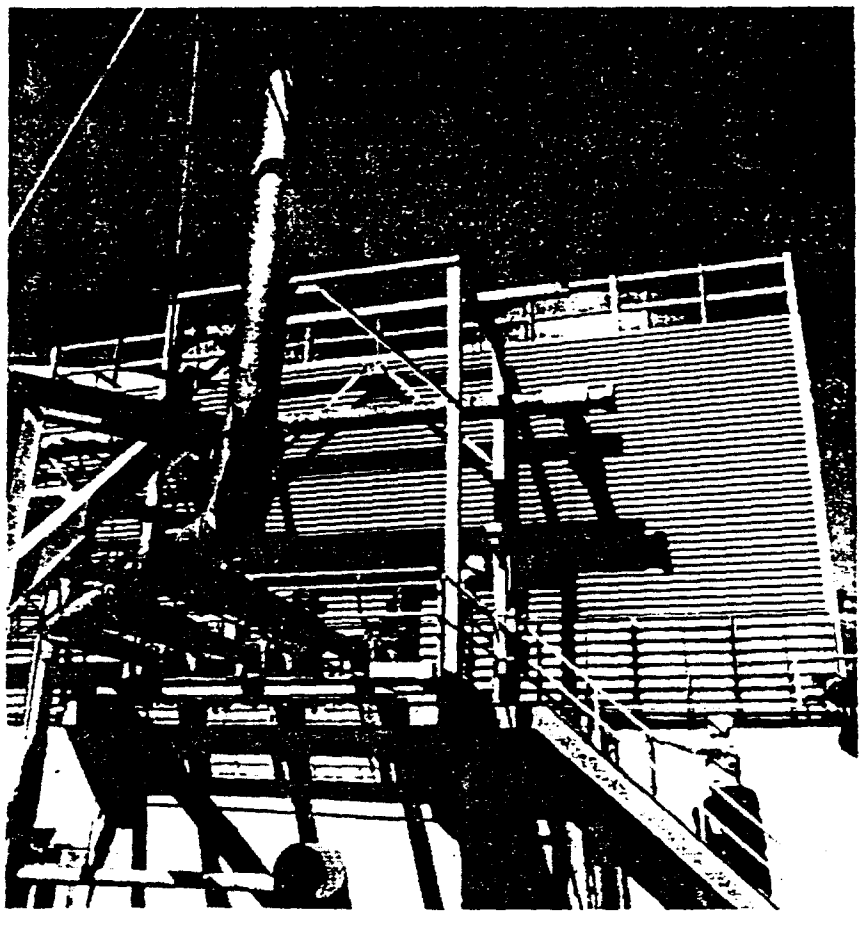

FIG. 1. Biological cooling tower shown under construction at Lever's Edgewater, N.J., plant. Piping in left foreground supplies water from cooling tower to edible process department.

[1]One of seven papers presented in the symposium, "Ecology–Practical Solutions to Environmental Problems as Practiced in the Fats and Oils Industry" at the AOCS Spring Meeting, Mexico City, Mexico, April 1974.

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Biological Treatment of Palm Oil Mill Effluent using *Trichoderma viride*

Mohamed Ismail Abdul Karim & Ahmad Qalam Ahmad Kamil

Faculty of Food Science and Biotechnology, Universiti Pertanian Malaysia, 43400 UPM, Serdang, Selangor, Malaysia

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ABSTRACT

Research was undertaken to investigate the treatment of palm oil mill effluent (POME) using the fungus Trichoderma viride *to reduce its wastewater strength, and to recover the microbial mass. More than 95% reduction in Chemical Oxygen Demand (COD) of the POME was achieved after 10–14 days of fermentation. The fungal biomass produced from the POME was 1·37–1·42 g/litre (dry weight) of mycelium with a crude protein content of 37·6–40·7%.*

INTRODUCTION

In Malaysia, palm oil mill effluent (POME) has been found to be one of the major sources of pollution from the agricultural industry. The palm oil mills in Malaysia generate annually about 9 million tonnes of effluent and the volume generated is expected to double by the year 1990 (Chan *et al.*, 1983; Yeow & Ahmad, 1985). The high organic pollutants of POME need to be treated before it can be discharged into streams or any other receiving waterbody. With the rising costs of pollution abatement and the stringent measures imposed on effluent standards, many palm oil mill operators may be forced to find alternative methods for pretreatment of the effluent prior to discharge for secondary or other treatment systems.

Biological treatment of POME to reduce the wastewater strength is one potential method that can be adopted to alleviate the pollution problem faced by the palm oil industry. Recently many researchers have resorted to

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the use of micro-organisms to treat food processing wastewaters and POME (Church & Nash, 1970; Church *et al.*, 1973; Beuchat *et al.*, 1978; Lemmel *et al.*, 1979; Barker & Morgan, 1981; Karim & Sistrunk, 1984*a,b*; Suwandi & Mohd, 1984). Biological treatment of liquid effluents from food processing plants has been established for a number of years and is the principle on which lagooning, activated sludge, and trickling-filter systems are based. Church *et al.* (1973) have reported the successful use of the fungus *Trichoderma viride* (*T. viride*) in aerated lagoon and oxidation ditch to treat corn and pea canning wastes, and greater than 95% Chemical Oxygen Demand (COD) removal of the wastes was achieved. The fungi have the ability to convert dissolved and suspended organic matter into a mycelium that is high in protein content and which can be readily recovered by simple filtration or screening. Several researchers (Sinnappa, 1979; Wong *et al.*, 1980; Quah *et al.*, 1982; Ibrahim *et al.*, 1984) have also studied the anaerobic fermentation of POME. The anaerobic fermentation process often operates with relatively long hydraulic retention time which is needed to allow anaerobic bacterial digestion of POME to take place.

This paper deals with work that was undertaken to treat the POME by biological means using *T. viride* with the objectives of reducing the waste strength of the effluent and recovering the mycelial biomass produced by the fungus which could be used as a valuable source of protein for animal feed.

METHODS

Raw material

Fresh composite samples of the POME were obtained from an effluent pond at the Bukit Rajah Estate palm oil mill, Klang, Selangor, Malaysia.

Preparation of inoculum

Strains of *Trichoderma viride* ATCC 32086 were maintained on malt extract agar (Difco Laboratories, Detroit, MI) and used as stock cultures. Spores grown on the malt extract agar were harvested into 200 ml saline solution (0·85% NaCl) and the turbidity of the solution was adjusted to 75 formazine turbidity units (FTU) using a turbidity meter (Moniter Model TRM-LD-DIGITAL, Austria). The spore suspension having 75 FTU contained $2{\cdot}4 \times 10^6$ spores/ml measured by a haemocytometer. Five per cent (v/v) of suspension was used as inoculum. For mycelial inoculation, spores of *T. viride* were grown in malt extract broth, incubated at 30°C for 4 days, using an incubator orbital shaker (Labline Model No. 3521, Malrose Park,

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IL) at 125 oscillations/min. Five per cent (w/v of sample) of the mycelium was used for inoculation of the effluent samples.

Fermentation experiment

POME was subjected to four different treatments as follows:

Raw POME (control).
Boiled POME (boiled for 10 min and cooled down to room temperature).
Raw POME with 5% inoculum of spores or mycelium separately.
Boiled POME with 5% inoculum of spores or mycelium separately.

Duplicate samples of 300 ml POME in 500 ml flasks were used for each of the above treatments and replicated twice. All the samples (not capped and left open in the culture flasks) were incubated in a shaker incubator (Labline Model No. 3521) at 125 oscillations/min at ambient temperature (28°C ± 2°C) for a period of 2 weeks. At intervals of 2, 4, 6, 8, 10, 12 and 14 days, samples, after settling for 30 min, were taken for analysis of COD and

the raw and boiled treated POME samples. The idea of using boiled POME was to eliminate most vegetative cells of microorganisms present in the sample thereby reducing growth competition from the inoculated fungi. However, some spores and thermophilic bacteria which survived the boiling were found to grow in the effluent and they caused a decrease in COD of the effluent on incubation.

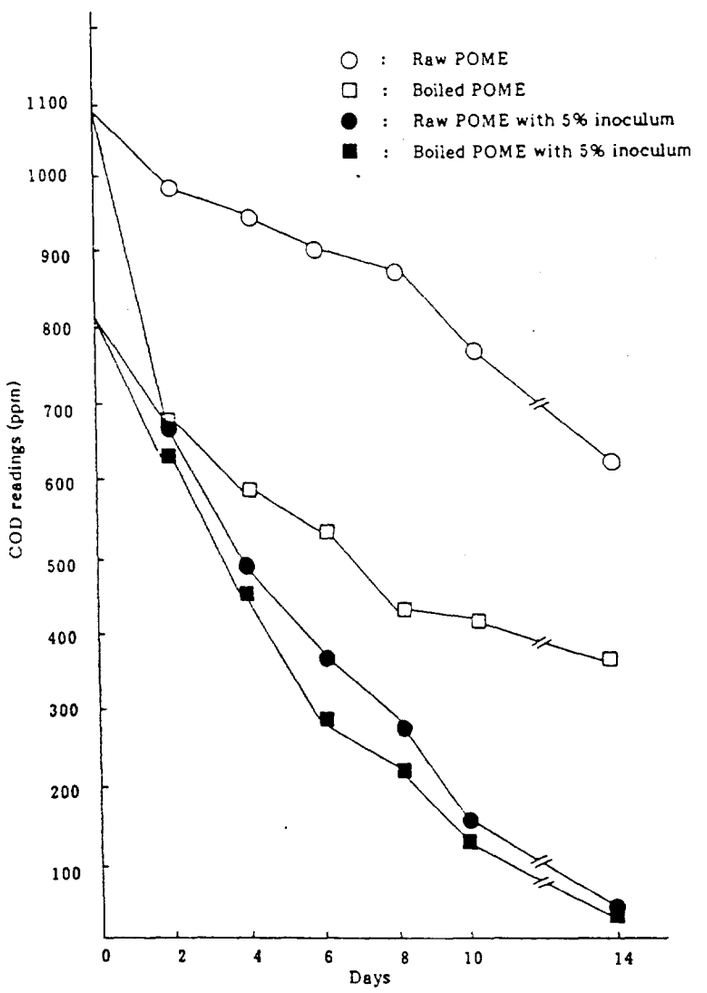

Fig. 1. Effectiveness of *T. viride* sporal inoculum on COD reduction of palm oil mill effluent (POME).

Turbidity of treated settled effluent

Greater reduction in turbidity of POME was observed with inoculated samples (Tables 1 and 2). Greater reduction in turbidity was observed with the settled POME treated with mycelium than with the sporal inoculation. The boiled treated samples had a slightly smaller decrease in turbidity than the raw samples.

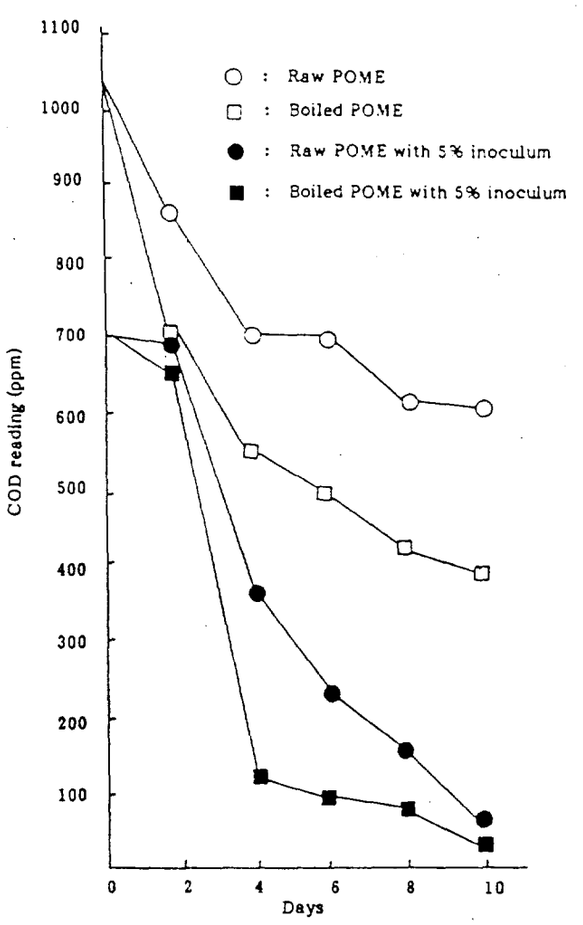

Fig. 2. Effectiveness of *T. viride* mycelial inoculum on COD reduction of palm oil mill effluent (POME).

TABLE 1
Effectiveness of *T. viride* Sporal Inoculum on Turbidity Reductions of Palm Oil Mill Effluent (POME)

Treatments \ *Incubation days*	*Turbidity (FTU) readings*								
	0	*1*	*2*	*3*	*4*	*6*	*8*	*10*	*14*
Raw POME (Control)	613	594	557	475	387	263	131	127	114
Boiled POME	649	634	614	526	413	308	188	164	148
Control with 5% inoculum	613	570	439	401	374	243	114	108	92·4
Boiled POME with 5% inoculum	649	591	488	336	238	147	85·8	74·2	70·6

Biomass production and protein content of raw and treated effluent

Results indicated that a somewhat higher recovery of fungal biomass was obtained from POME inoculated with the mycelium inoculum than the sporal inoculum (Figs 3 and 4). The fungal biomass recovered from the boiled and raw POME inoculated with the mycelium inoculum contained 1·42 and 1·37 g/litre (dry weight) mycelium, respectively after 10 days incubation (Fig. 3). On samples inoculated with sporal inoculum, 1·29 and 1·21 g/litre (dry wt.) mycelium were recovered after 14 days' incubation (Fig. 4). The biomass yield obtained from this experiment was found to be quite low as compared to the findings of other researchers using filamentous fungi grown on POME (Suwandi & Mohd., 1984; Barker & Morgan, 1981). However, their findings were based on using concentrated POME supplemented with carbon and nitrogen nutrient sources. One possibility of increasing the biomass recovery yield in our experiment is to add nutrient supplementation to the POME. However, the objective of achieving

TABLE 2
Effectiveness of *T. viride* Mycelial Inoculum on Turbidity Reductions of Palm Oil Mill Effluent (POME)

Treatments \ *Incubation days*	*Turbidity (FTU) readings*							
	0	*1*	*2*	*3*	*4*	*6*	*8*	*10*
Raw POME (Control)	664	657	655	535	497	414	385	263
Boiled POME	723	715	709	684	602	586	472	335
Control with 5% inoculum	664	651	509	385	140	105	89·7	76·1
Boiled POME with 5% inoculum	723	702	460	218	95·7	78·3	70·2	64·0

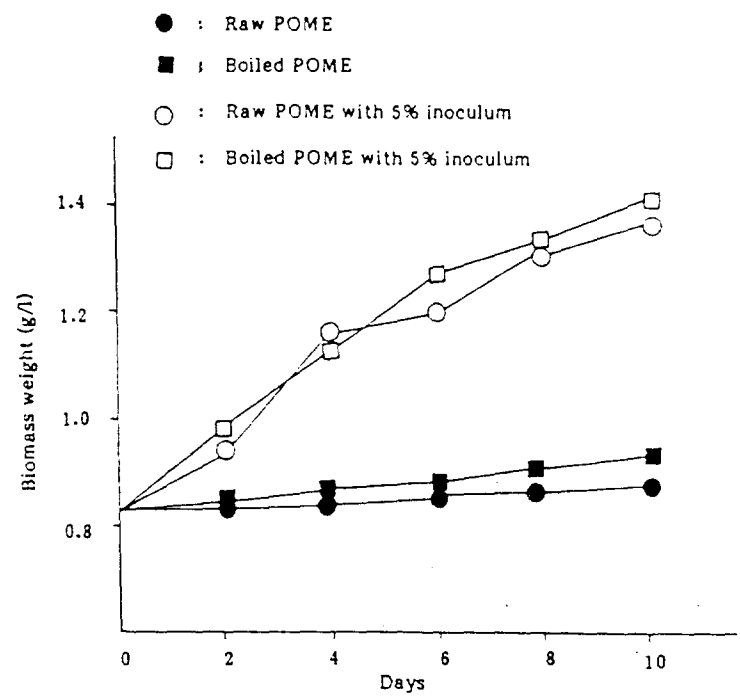

Fig. 3. Effectiveness of *T. viride* mycelial inoculum on biomass weight of palm oil mill effluent (POME).

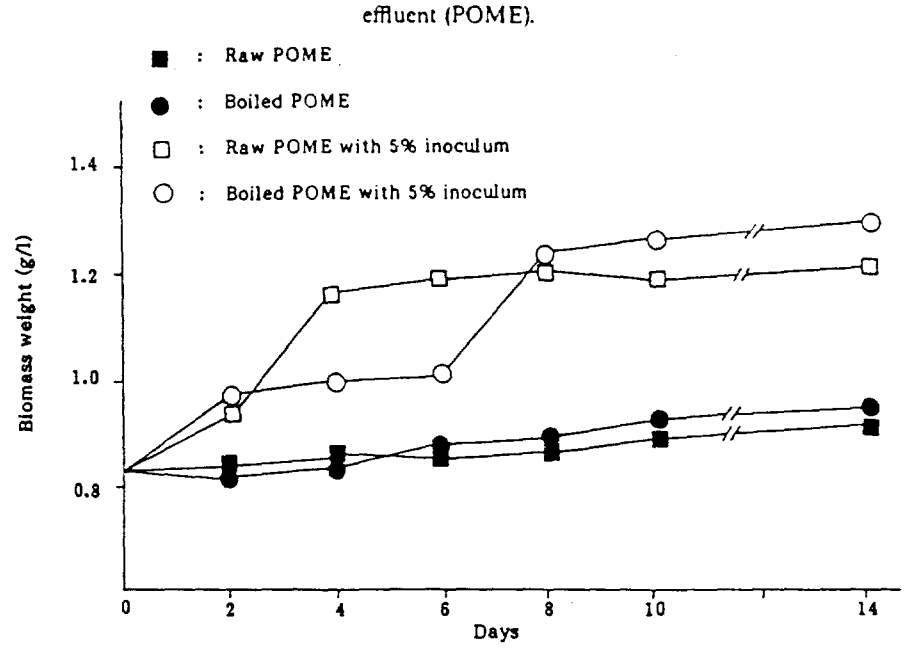

Fig. 4. Effectiveness of *T. viride* sporal inoculum on biomass weight of palm oil mill effluent (POME).

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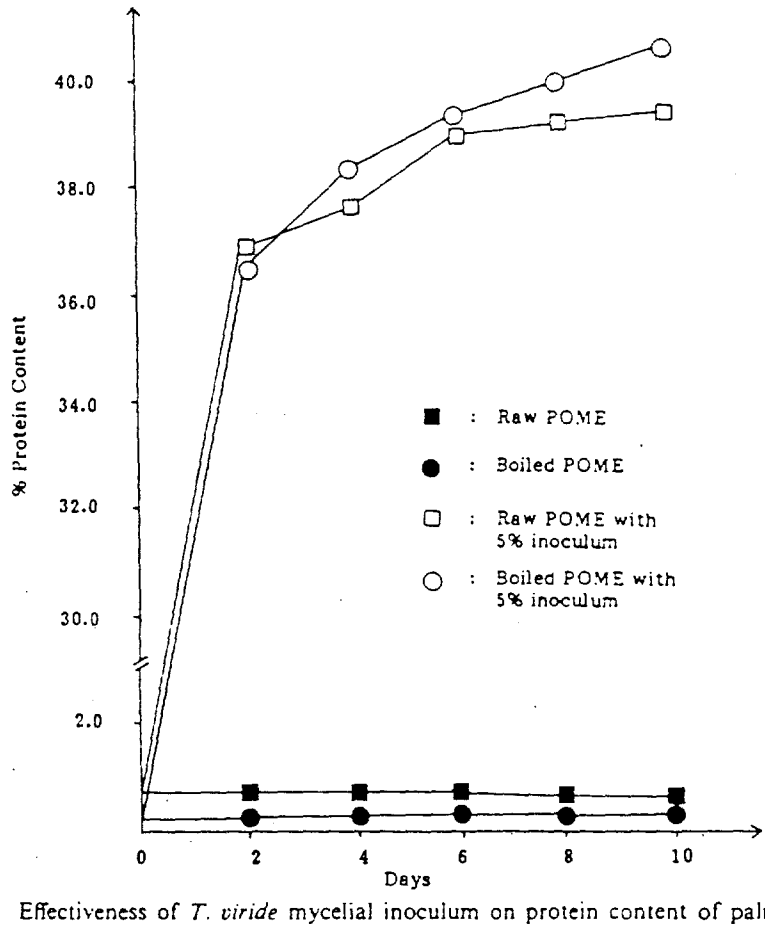

Fig. 5. Effectiveness of *T. viride* mycelial inoculum on protein content of palm oil mill effluent (POME).

maximum biomass production with greater reduction in COD of POME needs further study.

The crude protein content recovered from the fungal biomass of the treated POME was found to range from 37·6 to 40·7% using sporal and mycelial inoculation after 10 and 14 days' incubation (Figs 5 and 6). The crude protein content of the untreated POME was found to range between 0·42 and 0·55%.

CONCLUSION

Fermentation of the POME by microbiological means can be an alternative pretreatment technique in reducing the polluting strength of the effluent. Using the fungal (*T. viride*) inoculum, more than 95% reduction in COD of

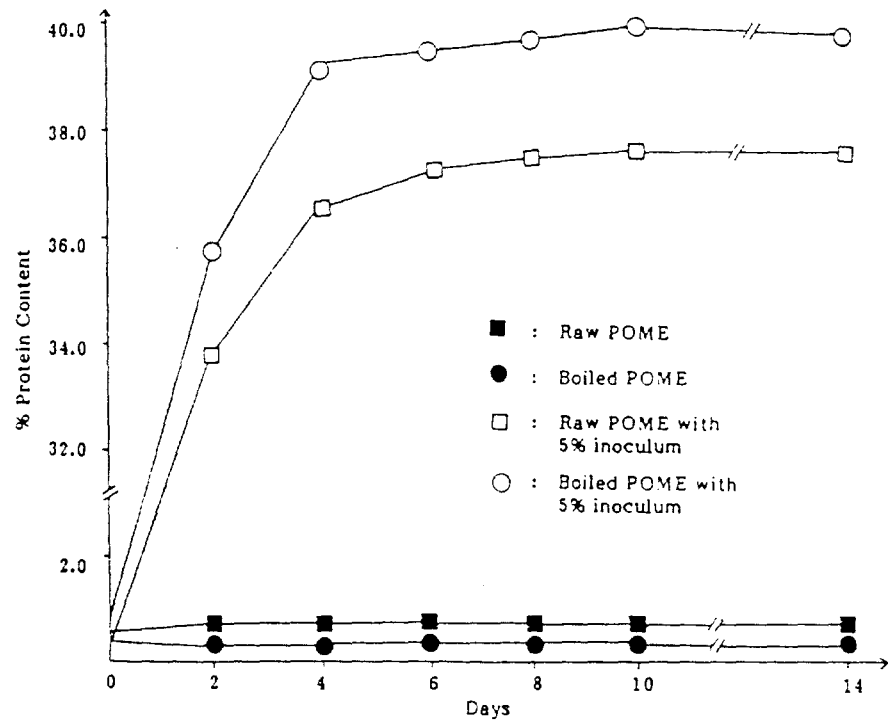

Fig. 6. Effectiveness of *T. viride* sporal inoculum on protein content of palm oil mill effluent (POME).

the POME could be achieved after 10–14 days of fermentation. There was little difference in COD reduction between the raw and boiled POME inoculated with fungi. The fungus was able to grow well and compete against the indigenous flora in the raw POME resulting in efficient reduction of COD upon incubation. The fungal biomass recovered had a 37·6–40·7% crude protein content, and a yield of 1·37–1·42 g/litre (dry weight) mycelium. Further research work is needed to exploit the use of other potentially available strains of micro-organisms for effective reduction of the pollution strength of POME, with a shorter incubation period and the possibility of a higher biomass yield.

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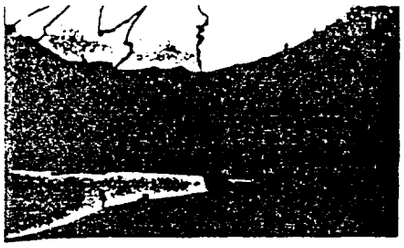
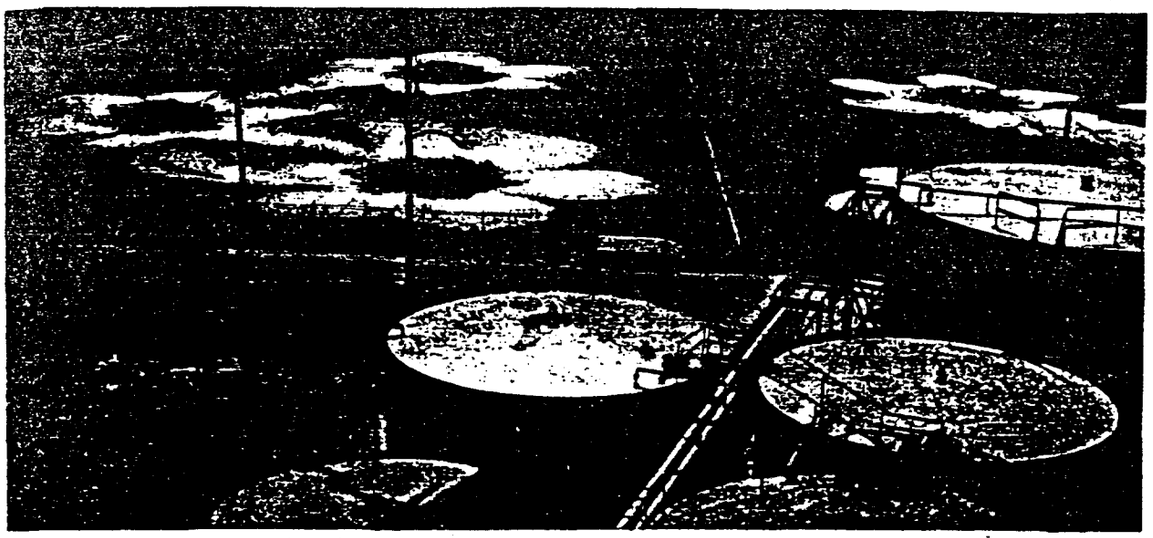


Low-cost wastewater treatment



Multi-step treatment process at Lou Ana Foods includes this 11.2 million gallon aerated lagoon.

At Lou Ana Foods, simplicity and redundancy were the keys to designing a system to handle both current and future needs at minimal cost.

CHARLES E. MORRIS, Midwest Editor

What do you do when you have no wastewater treatment facilities at all and you're given just one year to comply with federal pollution-control standards?

That was the problem facing the new engineering team at Lou Ana Foods, Inc., nation's largest independent vegetable oil refiner located in Opelousas, La., back in June of 1976.

Lou Ana today refines and processes up to 400 million lbs. per year of vegetable oils—mostly soybean, cottonseed, peanut, coconut and corn but also palm, palm kernel, sunflower, safflower and occasionally babassu—into liquid salad and cooking oils for retail, food service and food processing markets. Sales in 1979 reached $70 million—more than three times the sales volume of $19 million in 1971, when former management consultant Theodore G. Schad, Jr. purchased the struggling company, then known as Cotton Products, Inc.

Because new ownership was occupied during the early '70s with restoring the firm to profitability and expanding its business base, little attention had been directed toward wastewater treatment.

In 1975, management studied the problem and concluded it didn't have the technical resources to design and build a wastewater plant. Deadline for complying with the Federal Water Pollution Control Act—July 1, 1977—loomed ever closer and Lou Ana was still discharging wastewater into nearby Tesson Bayou.

So Lou Ana went out and hired the necessary expertise and by June, 1976, was ready to start designing a pollution control plant.

Result: By July 1, 1977—the federally-mandated deadline—Lou Ana was operating a water treatment plant which not only met but exceeded NPDES (National Pollutant Discharge Elimination System) standards—and at a total cost of only $2.2 million.

During the first eight months of operation, typical BOD (biochemical oxygen demand) of untreated effluent plummeted from 10,850 mg/l to 16 mg/l after treatment. COD (chemical oxygen demand) fell from 38,333 mg/l to 161 mg/l; O & G (oil and grease) from 8,107 to 4; TSS (total suspended solids) from 12,461 to 66.

In December, 1979, the Lou Ana plant was cited by Louisiana Stream Control Commission authorities "as an example of positive change which has occurred in the state" relative to water quality, said Norman J. Smallwood, who was, at that time, vice-president, technical services at Lou Ana.

The plant already meets stiffer 1984 standards proposed by EPA for BOD and O&G. Smallwood pointed filter—can also meet the proposed 1984 limit on TSS. BCT (Best Conventional Technology Reasonably Achievable) standards proposed by EPA for food processors starting July 1, 1984, are: TSS 20 mg/l; BOD_5 15 mg/l; O&G 10 mg/L (BOD_5 means average BOD over a 5-day period.)

Simple, redundant design

Simplicity and redundancy were the keys to designing and building a system to handle both current and future needs at minimal cost, said Smallwood, who joined Lou Ana just one year before the NPDES deadline.

To contain costs, Lou Ana's engineering team

(Continued on next page)

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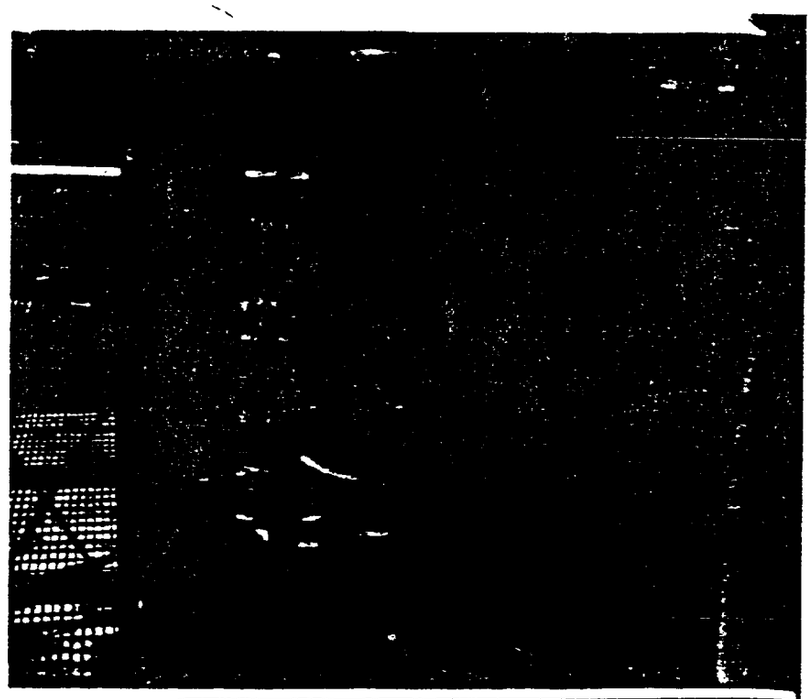
Gravity separation decanters are designed to minimize cost of recovering floating oils and free fatty acids. Decanters are made of fiberglass reinforced plastic to prevent corrosion and minimize maintenance. Oil floats to the top, where it is removed by a swinging suction pipe.



WASTEWATER TREATMENT...

(consisting at that time of Smallwood, production director Ray Scott and processing department manager Warren Barnes) functioned as its own design engineer and general contractor, with certain assignments handled by consulting engineers Domingue, Szabo & Associates of nearby Lafayette, La. Lou Ana engineers designed the overall system and many of its components; collection, pre-treatment, sump-lift and gravity-separation systems, for example, are all original Lou Ana designs. The consulting engineers designed the biological (aerated lagoon) portion of the system, prepared bids for equipment and made detailed engineering drawings. "The price tag would have been horrible" had Lou Ana been forced to rely completely on outside contractors and engineers, said Smallwood, who conceptualized the entire system and designed many of its components.

Wastewater from the vegetable oil refining process contains by weight 0.5 to 5 percent free fatty acids and glycerine resulting from the breakdown of triglycerides. These substances in themselves are non-toxic and biodegradable but produce strong, rancid odors. These are joined in the wastewater stream by caustic soda (sodium hydroxide) used in the chemical refining process and sulfuric acid used in the soapstock acidulation process, and these can be harmful. Wastewater also contains phospholipids (mostly from soybean oil but found to lesser degree in corn, cottonseed and peanut oils); color pigments such as carotene, chlorophyll, and xanthophyll plus gossypol from cottonseed; some residual protein meal from the crude-oil extraction process; traces of sugars and other carbohydrates; additional impurities removed from acidulated soapstocks, a by-product of the caustic refining process marketed by Lou Ana as a feed ingredient. (Soapstocks, like any other fats, contain 9 calories per gram and are thus nutritionally valuable.)

Lou Ana's wastewater treatment system was designed not only to purify this type of effluent at an average 1977-78 volume of 121,000 gal. per day and to meet NPDES standards in effect at that time, but to handle the additional effluent load from a planned (since completed) $7 million expansion of refining facilities (which more than doubled production capacity) and to meet future

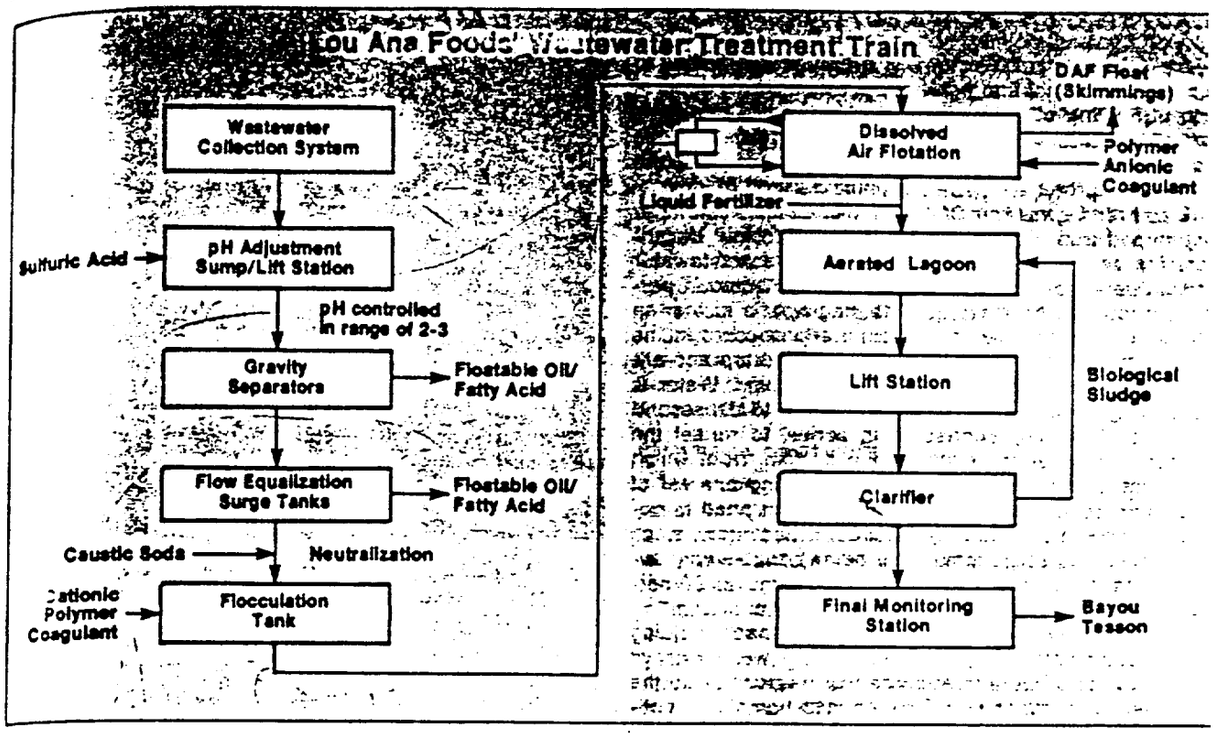
Eight fiberglass reinforced plastic surge tanks equalize wastewater flow to the dissolved air flotation unit. The tanks also function as settling tanks and gravity separators for further separation of water and oil.

EPA standards at minimum modification cost.

"You can't design a system for what your volume is today or what it will be next year, but for what it will be 5 or 10 years from now—plus a safety factor," adds owner, chairman and CEO Ted Schad. "You have to provide adequate drainage and base your design on worst-case possibilities—and thank God we did," says Schad, recalling what can happen near the hurricane-prone Gulf Coast. "We had a record 15-inch rainfall in the area. Fourteen inches fell on Lake Charles; Opelousas had 5 inches in just a few hours. Our drainage system was able to handle it."

In addition to meeting these criteria, system design included prevention of possible oil spills plus control and counter-measures capability should a spill occur.

System components are of simple design to minimize maintenance and labor costs. Wastewater treatment facilities at most vegetable oil refineries are too elaborate and too complicated, said Smallwood, and are therefore not well maintained. Oil/water separation systems, for example, usually incorporate API separators with horizontal baffles requiring costly manual scrape-down



or fat traps which also require manual cleaning. Lou Ana's oil/water separators, on the other hand, are simple gravity-separation decanters designed to minimize the cost of recovering floating oils and fatty acids, and made of fiberglass reinforced plastic (FRP) to prevent corrosion and minimize maintenance. All system components in contact with acidic (low pH) wastewater are made of FRP, Smallwood pointed out. Smallwood once worked at a vegetable oil refinery where the wastewater system was fabricated of epoxy-painted steel. "It failed," he said, "because the design engineers lacked practical experience. Our system was designed by people with operational experience in the real world."

Another factor in containing construction costs: The Lou Ana design takes advantage of natural topography for gravity flow of water to collection pumps.

Redundancy in the system allows components to be shut down for cleaning or repair without disrupting system operation and also provides backup should any component fail. Four gravity-separation tanks are available, for example, although the system can run on two. Eight flow-equalization (surge) tanks are provided, although only four are needed at any one time. All pumps are installed in pairs so system operation will not be jeopardized by pump failure. "The system is very forgiving," said Smallwood. "It was designed to be that way."

Three types of effluent

The Lou Ana system handles three categories of water effluent:

1. Process wastewater—which contains some vegetable oils, sludge from crude oil, and processing reagents;
2. Rainwater runoff—which washes away drips and spills from tank cars, tank fields and truck loading/unloading stations;
3. Cooling water—uncontaminated wellwater circulated once through a closed pipe/coil system to control process temperatures.

Process wastewater is piped for gravity discharge into a collection sump adjacent to the main processing building where it is sampled and analyzed for abnormal conditions, then flows via gravity through an underground line to the pre-treatment sump.

To contain rainwater runoff, outside areas subject to oil leaks, drips and spills (such as tank areas) are equipped with concrete mats and ringed with dikes. Underground pipes direct rainwater to a second collection sump adjacent to the pre-treatment sump, then to the pre-treatment sump via a connecting line between the two sumps. This connecting line incorporates a remotely-operated shutoff valve actuated by a rain-gauge device. Here's how it works:

In a heavy rainfall, oil spillage is washed away in the initial downpour and conducted to the pre-treatment sump. If rainfall continues for a prolonged period and reaches the preset level in the rain-gauge, the gauge transmits a signal to a controller, which closes the valve in the connecting line between the two sumps, allowing rainwater—which is essentially pure by this time—to reach a high-level overflow line, which then conducts rainwater to the cooling water outfall. (If rainwater runoff were allowed to flow indefinitely into the pre-treatment sump the entire system would be overloaded, Smallwood pointed out. The other design alternative—sizing the system to handle complete rainfall load—was not economically feasible.)

Uncontaminated cooling water discharges into a flash tank, where any steam generated vents into the atmosphere, and remaining water is pumped to two oil/water separating decanters connected in series. This feature assures that any entrained oil—which could possibly contaminate cooling water in event of coil failure, for example—will be removed. Spent cooling water discharges from the second decanter through a weir box and a final gravity separator, then on to the cooling water outflow.

Wastewater process

The wastewater treatment train combines chemical, mechanical and biological processes:

(Continued on next page)

1. *pH Adjustment:* Wastewater pH must be adjusted to a range of 2.0 to 3.0 to achieve optimum gravity separation of floating oils. A control loop in the pre-treatment sump monitors incoming wastewater and controls the addition of sulfuric acid into the sump to lower pH to the required degree.

2. *Gravity Separation Of Oils:* pH-adjusted wastewater is pumped from the pre-treatment sump to four decanters for separation of floatable oils. The wastewater stream enters the first two decanters (connected in parallel) through a horizontal distributing nozzle located in the center of each vessel. Oil separation occurs in the central zone of each vessel; oils float to the top and are pumped off daily by a swinging suction pipe. Water is continually drawn off via gravity underflow to the second two decanters, also connected in series, to repeat the process. Some solids settle to the bottom, from which sediment is periodically removed by valving one set of decanters out-of-service. The system is designed to operate on one set of gravity-separation decanters, since the succeeding surge tanks (see below) double as gravity-separation tanks. Gravity separation removes 90 percent of the pollutant load from the wastewater stream.

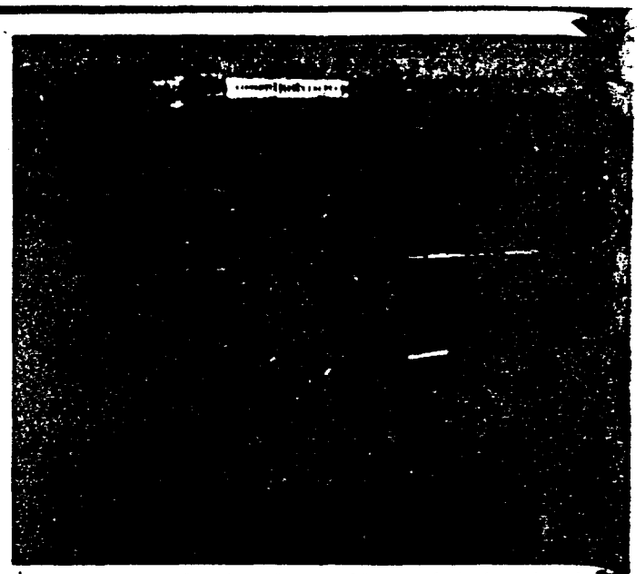
3. *Flow Equalization:* Eight 12,000-gal. capacity holding tanks accumulate a minimum of 16 hours wastewater at a flow rate of 85 gpm to equalize wastewater flow to the dissolved-air flotation unit. Flow equalization allows optimum operation of the DAF unit; the hold tanks also function as settling tanks for further removal of sediment and as gravity separators for further recovery of oil. As with the gravity-separation decanters, hold tanks can be individually valved out of service without disrupting system operation.

4. *Neutralization:* As wastewater is pumped from the hold tanks to the DAF process, caustic soda is injected into the water stream at the suction side of the transfer pump to neutralize pH to about 7.0. Neutralization is controlled by an automatic control loop; a manual control is provided for backup.

5. *Dissolved Air Flotation:* Neutralized water and a cationic polymer coagulant are discharged into a two-compartment flocculation tank equipped with high and low-speed mixing agitators. Water overflows from the flocculation tank into a coagulation tube centered in the DAF cell, then underflows through six exterior riser tubes to a peripheral collection ring at the top for recycle pressurization and discharge into the aerated lagoon. Water recycled at about 360 gpm is fully pressurized and injected with an anionic polymer coagulant aid before discharge back into the coagulation tube. Floating oils are removed by a rotating skimmer at the top of the tank. The DAF unit is sized to provide a surface loading of less than 3 gpm/sq. ft. Dissolved air flotation removes an additional 9 percent of the pollution load.

6. *Biological Treatment:* An aerated lagoon with a capacity of 11.2 million gallons and normal water depth of 16 ft. separated into two sections by a redwood baffle, accomplishes biological treatment and removes the remaining 1 to 2 percent of the pollutant load. Aeration is achieved by eight 40-hp floating aerator sprays. Liquid fertilizer is injected into lagoon influent to supply microbial life with nitrogen and phosphorous. The perimeter wall of the lagoon is lined with concrete to prevent erosion of the landscaped earthen dike forming the lagoon. At current influent rate, the lagoon provides 90 days retention time.

7. *Clarification:* Treated water is pumped from the lagoon to a clarifier for separation of biological sludge. Clarified water flows via gravity to a final monitoring station; sludge is recycled back to the inlet side of the la-



Former Lou Ana vice-president/technical services Norm Smallwood checks deodorized oil production schedule from deodorizer control board. Schematic shows operational status of the deodorizer.

WASTEWATER TREATMENT SYSTEM PERFORMANCE (1977-78)

Effluent Characteristics for Treatment Train Processes

Process	Concentration (mg/l)			
	COD	BOD	O&G	TSS
1. Collection pH Adjustment Sump	38,333	10,850	8,107	12,461
2. Decanter	[illegible]	[illegible]	635	8,013
3. Equalization—Hold	15,000	2,692	677	905
4. DAF	4,053	5,972	282	589
5. Aerated Lagoon	547	123	4	608
6. Clarifier	161	16	4	66

Performance for Each Treatment Train Process

Process	Percent Removal			
	COD	BOD	O&G	TSS
1. Decanter	0	0	67.5	27
2. Equalization—Hold	60.9	129.1	78.1	90
3. DAF	73.0	22.4	51.1	34
4. Aerated Lagoon	86.5	97.9	98.6	[illegible]
5. Clarifier	70.6	87.0	0	89
6. Total Treatment System	99.6	99.8	99.9	99

Treatment Performance with Respect to NPDES Limits

	Minimum	Average	Maximum
Flow Rate (MGD)	0.066	0.121	0.178
BOD (lb./day)	4	17 (104)	47 (256)
O&G (lb./day)	1	4 (41)	10 (104)
TSS (lb./day)	17	68 (104)	156 (256)
pH	7.0 (6.0)	7.2	7.4 (9.0)

Note: *NPDES limit conditions given in parentheses*

Wastewater, neutralized to pH 7.0 with caustic soda, is pumped to the flocculation tank, shown rising above the surge tanks in foreground, where remaining oils are coagulated with a cationic polymer coagulant before flowing into the dissolved air flotation unit.

goon. The clarifier is sized for an overflow rate of 45 gpd/sq. ft. of surface area and retention time of 3 hours.

8. *Final Monitoring:* Prior to outfall discharge, treated water flows through a monitoring station for flow measurement, sampling and recording of pH. Samples of treated effluent are analyzed weekly for BOD, COD, TSS and O&G by an independent, outside laboratory.

With 16 hours holding capacity, the DAF unit is operated only 8 hours per day; the clarifier is operated and treated water discharged only during periods when the DAF is operating. This allows operating those systems only during the day shift, when maximum attention and control can be given to their operation.

Original operating cost (as shown in Table) for the entire system is $6.89 per 1000 gallons of treated effluent. Depreciation has since increased this cost to a 1980-81 figure of $10.86 per 1000 gallons.

Skimmings, spent earth to farm

Vegetable oil residues from Lou Ana's wastewater plant and spent bleaching earth from the company's oil bleaching operation are hauled by truck to a nearby company-leased 140-acre farm and worked into the soil as fertilizer.

The oil residue—skimmings and sediment consisting of 55 percent water plus emulsified vegetable oil and fatty acids—are agricultural in origin and thus have soil-enrichment properties. Spent bleaching earth—betonite clay with about 25 percent (by weight) entrained vegetable oil—was formerly dumped as landfill on another nearby farm but has also been approved for soil enrichment by state health and environmental authorities. (Bleaching earth is used to remove color pigments—eg., carotene and chlorophyll—from refined oils.)

Spent earth disposal has traditionally posed a problem

(Continued on next page)

Doubles production capacity

Between 1976 and 1979 Lou Ana Foods increased its vegetable oil refining capacity from 190 million lbs. to 400 million lbs. per year with a $7 million capital-expansion program which includes:

—A major expansion and update of the caustic refining process;

—A new 30,000-lb. per-hour single-sheet deodorizer with steam refining capability, plus a continuous bleaching system, which became operational in June, 1979. Both systems were designed and built by EMI Corp. EMI designed the bleaching system around Lou Ana's spent-earth disposal method: Instead of the screw conveyor common to most systems, the Lou Ana plant features a unique spent-earth discharge chute from filters direct to dump trucks, which haul spent-earth daily to the Lou Ana farm.

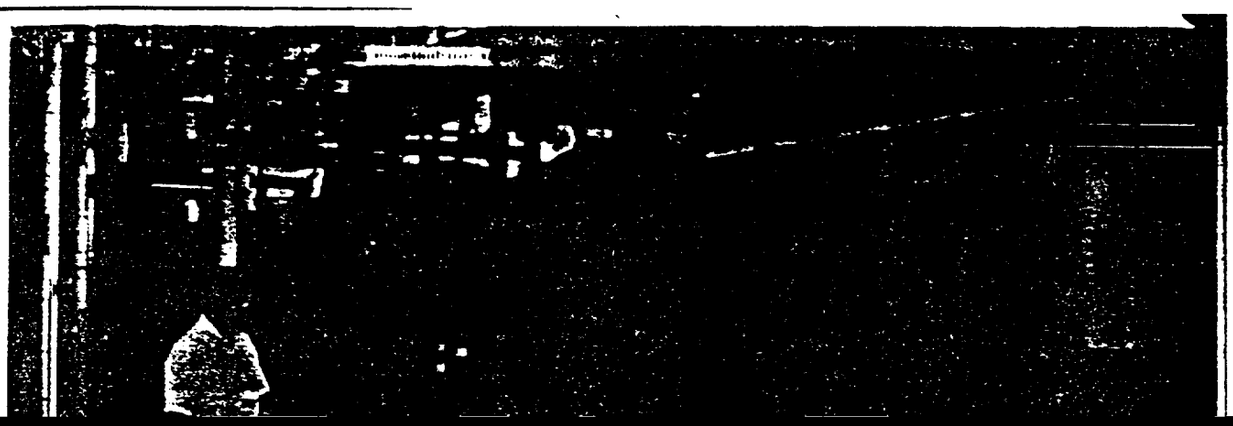
—Ten million lbs. of crude-oil storage capacity—5 giant tanks of 2 million lbs. capacity each—were added to the 6 million lbs. capacity originally available.

—Eight million lbs. of deodorized oil storage capacity—4 tanks of 2 million lbs. capacity each—were also added to bring total refined-oil storage capacity to 15 million lbs. Additional tankage for both crude and refined oils was necessary to handle the many different types of oils refined by the company. Tank field expansion, completed early in 1980, includes diked concrete mats with underground drains linked to the wastewater system, as described earlier, to contain oil spills and rainwater runoff.

—Expansion of Lou Ana's fleet of leased jumbo tank cars (capacity 150,000 lbs. each) to 235; plus an overhead tank-car washing system to allow dual use of tank cars for hauling-in crude oils and shipping-out refined oils. "We're one of the few refiners who deal in so broad a range of oils," said Norman J. Smallwood, former vice-president of technical services at Lou Ana.

—Improved lab facilities. In addition to sampling and testing incoming crude-oil shipments for freedom from solvents (hexane used in the extraction process), FFA content, odor, flavor and appearance—and outbound oils for odor, flavor, appearance, color, grade and price—Lou Ana's laboratory now monitors each step of the refining, bleaching and deodorizing process hourly to assure that oils are within acceptable processing limits for each stage. Lab equipment includes moisture analyzers, spectrophotometers for color analysis, deep-fry units for testing the frying characteristics of each oil sample, and an atomic absorption instrument which measures trace metals and minerals in parts-per-million—"not a standard test in the industry," said Smallwood.

In addition to upgrading production, the new continuous deodorizing and bleaching facilities have improved by-product yield, Smallwood pointed out. Lou Ana markets deodorizer distillate to chemical manufacturers who in turn recover sterols and tocopherols (Vitamin E) from the distillate. Sterols—basic "building blocks" for hormones—have pharmaceutical applications, including birth-control pills. Vitamin E is a natural antioxidant used to extend shelf life in many food products. The deodorizer pulls-off about one-third of the tocopherols in the distillate, said Smallwood. ■



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A CASE STUDY ON SUNFLOWER SEED OIL INDUSTRIES WASTE CHARACTERIZATION, CLASSIFICATION AND TREATMENT

Füsun Şengül

Dokuz Eylül University, Faculty of Engineering and Architecture, Department of Environmental Engineering, Bornova, Izmir, Turkey

ABSTRACT

The sunflower seed oil industry is one of the most important industrial sectors. As a part of the agro-industry, sunflower seed oil production makes a significant contribution to environmental pollution in Turkey. A lot of research studies are known to be performed on the characterization and treatment of olive oil production wastes in Turkey, but the nature, amount, waste loads and treatment of the wastewaters produced by sunflower seed oil industries have not been studied to a great extent.

In this study, a typical sunflower seed oil refinery in the city of İzmir was selected as representative of this sector. Method of production is evaluated and the refinery is investigated for the characterization of its wastewaters. During the first part of the test program, quality of combined and separate raw effluents was investigated. Possible physical-chemical treatment alternatives were studied using bench-scale laboratory models. Based on these studies, the most practicable and efficient combination of treatment operations and processes were pointed out. Waste segregation possibilities for minimization of wastewater quantities are investigated. In these investigations treated effluent quality has been evaluated with respect to the discharge parameters set by the present Turkish environmental legislation.

KEYWORDS

Sunflower seed oil refinery effluents; wastewater characterization; emulsion breaking; acid cracking; chemical coagulation.

INTRODUCTION

Turkey produces above 1 million tons of sunflower seed according to 1985 projections of the State Statistics Institute. Approximately 300 000 tons of raw and 110 000 tons of refined edible oil have been produced in the same year. (DIE, 1985; DPT, 1985).

The raw sunflower seed oil can be obtained by using one of the following methods: mechanical press method, press-extraction method and direct extraction method. All the three methods are in use in Turkey for the production of raw sunflower seed oil. Press-extraction method is the most widely used method in Turkey, but most of the sunflower seed oil is produced in primitive presses having a total press capacity of 150 000 tons, working only a few months during the year. They have small capital investments, but are not efficient in production. More modern edible oil plants use up-to-date extraction processes for the production of sunflower seed oil, too. Three such plants are operating in Trace and there are two more in the Marmara Region (TÜBİTAK, 1984).

Effluents of sunflower seed oil refineries originate from neutralization, winterization, condensation processes and cooling operations. At the neutralization stage impurities in the raw oil are settled with caustic soda and the settled material is removed. Thus, wastewaters originating from the

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neutralization process are the most polluted ones produced during the refining of oil.Temperatures of these effluents are between 50 and 70°C. Amount of wastewater generated at this stage is 10-20 % of the oil charged into the neutralization boiler. Other wastewaters produced from refineries are wash waters, which do not have as high pollution loads as the neutralization process wastewaters. Effluents of the winterization process are obtained during the cleaning of press filters and discharging of boiler waters. Refining of raw oil consists of a series of operations utilizing pressurized steam; thus condensation and cooling waters are also produced as wastewaters. Amounts of such waters are too high, but their pollutant concentrations are weak. Total amount of effluents is 32 - 46 % of soap production on a weight basis. As in the soap production caustic soda is used; soap production wastewaters contain high alkalinity, high turbidity, and suspended solids, as well as high COD and BOD_5 values.

OIL AND GREASE REMOVAL METHODS

Control of oil and grease is a stringent requirement of municipal authorities responsible for permitting connection of industrial wastewaters into the sewer system. Oil and grease tend to clog the sewer pipes and pumps and create difficulties in the municipal wastewater plants.Thus oil and grease limits are to be considered along with other indicator parameters such as BOD, pH, total suspended solids in sewer discharge standards. Industries are asked to remove oil and greasy material from their wastewaters in order to utilize the economic and other advantages of pretreatment and joint treatment. In domestic wastewaters, oil and grease concentrations may range from 30 - 50 mg/l, whereas wastewaters from communities with industrial contributors usually have higher concentrations (Tsugita and Ellis, 1981).

Free oil and grease which is not emulsified, presents no serious problem with respect to its removal from water because it will tend to float and agglomerate. The surface layer of oil and grease can then be mechanically skimmed off the surface. Emulsified oil, however, stays in suspension causing severe separation problems. That is why oil and grease treatment may be categorized into two stages: first-stage treatment can be utilized to separate free flotable oil and grease from water. At this stage, the treatment process involves gravity separation of the greasy material, which is equally effective in removing greases and non-emulsified oils. The simplest form of this first-stage treatment is the grease interceptor or grease trap. The typical process for oil and grease removal, particularly in situations where emulsification exists, is a gravity separator followed by a second-stage unit using one of the several methods for breaking the oil and grease emulsion that passes through the first - stage unit. In the second stage physical, chemical electrical and biological methods exist for breaking oil and grease emulsions. Chemical methods are presently in wide use, in conjunction with physical removal methods. Emulsions can be broken by chemicals that will balance or reverse the surface tension on each side of the interfacial film, neutralize stabilizing electrical charges, or precipitate emulsifying agents. Common chemicals that have been utilized to break emulsions or coagulate the colloidal particles include alum, ferrous sulfate, ferric sulfate or chloride, sodium hydroxide, calcium chloride, sulfuric acid, lime, soda, borax, sodium sulfate and commercial organic treating chemicals. After chemical additions freed oil and grease is concentrated and removed by a suitable physical process such as dissolved air flotation. Coagulation utilizing aluminum or iron salts has been effective for de-emulsifying oily wastes, but the precipitated sludges are difficult to dewater and the volume of sludge generated and requiring ultimate disposal creates an additional problem (Eckenfelder, 1980).

Physical methods used to break emulsions include heating. centrifugation and filtration. Centrifugation breaks oil emulsions by separating the oil and water phases by centrifugal force. Such centrifugation procedures are best applied to oily sludges or small volumes of oily wastewaters. Filtration has also been used with some success, as have high-rate sand and diatomaceous earth filters (Tsugita and Ellis, 1981).

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CHARACTERISTICS OF WASTEWATERS ORIGINATING FROM SUNFLOWER SEED OIL PRODUCTION IN TURKEY

In this study a typical sunflower seed oil refinery in the city of İzmir was selected to represent the edible vegetable oil industries. In the plant, 5000 tons of sunflower seed oil and 2000 tons of soap were produced in 1987. Raw oil is supplied from Trakya Region. Refined sunflower seed oil is sold to the inner and southern regions of Anatolia. Refining processes which are used in the plant are neutralization, drying, decolorization, boiling, deodorization, cooling and winterization. A mixture of municipal and ground water is used at the rate of 40 m^3/day, of which 30 m^3/day is discharged as wastewater. The sources of wastewaters are mainly neutralization and soap production processes.

In the city of İzmir, sewer discharge limits apply to industries located within the Metropolitan area. Therefore wastewaters of this edible oil refinery must be pretreated for oil and grease removal. Before selection of a pretreatment process scheme, a study for characterization and treatability of the edible oil refinery wastewaters must be performed. Wastewater characteristics of this selected sunflower seed oil factory were examined by the DEU, Department of Environmental Engineering during years 1986 and 1987. Experimental results are submitted in Table 1 (DEU, 1986, 1987).

TABLE 1 Wastewater Characterization of the Sunflower Seed Oil Factory

WW sample	pH	BOD (mg/l)	COD (mg/l)	Oil-grease (mg/l)	Suspended solids (mg/l)
Soap prod. (18.3.1986)	11.5	33000	71000	6455	9070
Soap prod. (8.4.1986)	12.6	70000	100800	31690	13450
Refining (16.5.1986)	12	-	29920	15045	-
Composited	12.4	-	39360	35400	-

In another study, the same properties of wastewaters originating from different processes of the same factory were studied. The results are summarized in Table 2 (Oktay, 1986). Different samples taken at different dates are numbered as I and II.

TABLE 2 Wastewater Characteristics of Sunflower Seed Oil Refinery Processes

WW sample	Temp. (°C)	Oil-grease (mg/l)	BOD (mg/l)	COD (mg/l)	SS (mg/l)	pH
Neutralization process wastewaters						
I	65	145520	155800	275000	-	13.8
II	60	132700	143600	270800	-	13.7
First wash waters following neutralization						
I	50	3540	4760	9280	-	13.3
II	55	3720	4870	9630	-	13.5
Second wash waters following neutralization						
I	56	3320	3750	8780	-	12.6
II	55	3250	3700	8690	-	12.5
Winterization process wastewaters						
I	70	350	525	980	-	11
II	75	525	840	1430	-	12
Condensation process wastewaters						
I	35	40	60	35	-	7
Soap production wastewaters						
I	55	420	65000	120000	13550	13.4
II	65	740	77500	140000	12500	13.9

In a third program aiming at the wastewater characterization of this refinery, wastewater samples from different production stages were collected at different dates and analyzed. Table 3 shows the results of this last study.

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During the experimental studies COD, BOD_5, Oil and Grease and Suspended Solids determinations were carried out according to the techniques given in American Standard Methods (APHA, 1981).

TABLE 3 Wastewater Characterization of the Sunflower Seed Oil Factory Located in İzmir

WW sample		pH	Oil-grease (mg/l)	COD (mg/l)	SS. (mg/l)
		Refining process wastewaters			
I	(4.11.1988)	11.0	597	7840	-
II	(19.12.1988)	11.3	230	1040	-
III	(3.5.1989)	10.0	1012	3360	433
		Soap production wastewaters			
I	(4.11.1988)	12.5	166	19200	-
II	(19.12.1988)	12.0	380	18640	-
III	(3.5.1989)	11.3	564	48000	1766
		Combined wastewater			
I	(17.10.1988)	13.0	2900	13600	240
II	(3.5.1989)	12.0	688	5440	845

MODEL STUDIES ON TREATABILITY OF WASTEWATERS

Physical-chemical treatment studies were carried out on composite samples obtained by combining effluents from several processes of the refinery on the first run and on combined wastewaters from soap and refinery processes. These studies were conducted by two groups of researchers in the scope of dissertation thesis works (Oktay, 1986; Yıldırım and Sancar, 1988). A laboratory bench-scale test model was used in both of the studies, however, coagulants and coagulant aids used in the jar tests were different in both cases. In the first study, many coagulants and polyelectrolytes were tested for the treatment of composited wastewaters of the sunflower seed oil factory. After determining the optimal test conditions, coagulation efficiencies have been found by adding appropriate doses of $FeSO_4$ and $FeSO_4$ and A-470 type anionic polyelectrolyte at pH 6.5. Results obtained by these chemicals are given in Table 4.

TABLE 4 Jar Test Results With $FeSO_4$ and $FeSO_4$+Anionic Polyelectrolyte

Coagulant dose (g/l)	Oil-grease Eff. conc. (mg/l)	Oil-grease Removal eff. (%)	Chemical Oxygen Demand (COD) Eff. conc. (mg/l)	Chemical Oxygen Demand (COD) Removal eff. (%)
	Ferro sulfate ($FeSO_4$)			
0	31500	-	115000	-
0.5	11340	65	51750	59
1.0	9130	71	47150	65
1.5	7870	75	35650	69
2.0	7250	77	27600	76
3.0	9750	69	41400	64
	Ferro sulfate+anionic polyelectrolyte			
1.0 g/l +2 mg/l	9450	70	39100	66
1.5 g/l +2 mg/l	8500	73	33350	71
1.5 g/l +3 mg/l	8200	74	31050	73
2 g/l +3 mg/l	7250	77	28750	75
2g/l +4 mg/l	8800	72	35650	69

When alum was used as a coagulant, the optimum pH range was found to be between 6.5 to 7.0. Lime and alum were added until the pH reached 7.0. Results of this experiment are presented in Table 5.

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Chemical coagulation with lime was also tried in these effluents. Again, pH of the wastewater sample was reduced to pH= 2.0 by adding concentrated H_2SO_4 and then lime. During the test, 90 % pure reactive lime ($Ca(OH)_2$) was used as coagulant. Lime and cationic polyelectrolyte addition alternative was also tried. The results are given in Table 6.

TABLE 5 Jar Test Results With Alum and Alum+Cationic PE (K-570)

Coagulant dose (g/l)	Oil-grease Eff. conc. (mg/l)	Oil-grease Removal eff. (%)	Chemical Oxygen Demand (COD) Eff. conc. (mg/l)	Chemical Oxygen Demand (COD) Removal eff. (%)
Alum ($Al_2(SO_4)_3.18\ H_2O$)				
0	41000	-	144000	-
0.5	12700	69	43100	70
1.0	11100	73	34600	76
2.0	6200	85	18800	87
3.0	1700	96	4000	97
4.0	1800	96	4800	96
5.0	2250	94	10000	92
Alum+Polyelectrolyte				
0	41000	-	144000	-
2 g/l +3 mg/l	6450	85	28900	80
3 g/l +3 mg/l	2400	94	7100	95
3 g/l +4 mg/l	3300	92	11500	92

For the treatment of wastewaters of sunflower seed oil factory which were examined in this study, acid cracking for de-emulsification plus chemical coagulation methods have been used. First, the pH of the oily wastewaters was lowered to pH= 2.0 with the help of concentrated sulfuric acid. After breaking the oil and grease emulsion, freed oil and grease were removed by phase separation and then chemical coagulation method was applied. By using the jar test apparatus, coagulant and polyelectrolyte doses have been determined.

TABLE 6 Jar Test Results Obtained with Lime and Lime+Cationic Polyelectrolyte(K-570)

Coagulant dose (g/l)	Oil-grease Eff. conc. (mg/l)	Oil-grease Removal eff. (%)	Chemical Oxygen Demand (COD) Eff. conc. (mg/l)	Chemical Oxygen Demand (COD) Removal eff. (%)
Lime ($Ca(OH)_2$)				
0	29700	-	98000	-
3.0	14800	50	46050	53
4.0	10400	65	35300	64
5.0	3250	89	9750	90
6.0	1800	94	5100	95
7.0	2950	90	10800	89
Lime + nonionic polyelectrolyte				
0	29700	-	98000	-
5 g/l +2 mg/l	5900	80	18600	81
5 g/l +3 mg/l	4200	86	15600	84
5 g/l +4 mg/l	4800	84	16000	84
6 g/l +2 mg/l	3300	89	7800	92
6 g/l +3 mg/l	3000	90	10000	89
6 g/l +4 mg/l	2900	90	10800	89

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In this series of experimental studies, the characteristics of the effluents of a sunflower seed oil factory were re-examined as presented in Table 5.

In performing the treatability study in this program acid cracking for de-emulsification of oil and grease was conducted as a separate process. At this stage, pH of the effluents was reduced to 2.0 and the freed oil and grease was removed by phase separation. The results of acid cracking method are given in Table 9. Coagulation with lime and polyelectrolyte was tried after the pH of the supernatant was adjusted to pH= 6.0, pH= 7.0 and pH= 8.0 at different series. At each series, selected doses were applied in separate beakers and anionic-type polyelectrolyte was added.

In the first series of tests, composited effluents from several processes from the oil refinery were treated. Chemical coagulation process consists of 2 minutes of rapid mixing with lime solution, then 45 minutes of slow mixing, with 60 min for settling. When $FeSO_4$ was used as coagulant, efficiencies of 76 % for COD and 77 % for oil and grease with 2 g/l $FeSO_4$ were found (Table 4). If alum was used on the other hand, efficiencies obtained were 96 % oil and grease removal and 96 % COD removal (Table 5). Results with lime and lime+nonionic polyelectrolyte are given in Table 6. Best efficiencies were 95 % for COD and 94 % for oil and grease.

In the second part of the treatability studies, efficiencies obtained after sulfuric acid addition to break emulsions and subsequent phase separation are found to be higher. These results are given in Table 7. For this alternative process removal efficiencies obtained for oil and grease were 86-96 % and for COD 52-57 %. When this first-stage treatment is followed by chemical coagulation utilizing lime or aluminum salts this process is shown to be more effective for the wastewaters, especially if lime and anionic polyelectrolyte (Praestol 2430) were used for pH adjustment and effectiveness of coagulation increases (Table 8).

TABLE 7. Test Results of Acid Cracking Method

Wastewater Sample (mg/l)	pH	Oil-grease Eff. conc. (%)	Oil-grease Removal eff. (mg/l)	Chemical Oxygen Demand (COD) Effluent conc. (%)	Chemical Oxygen Demand (COD) Removal eff.
Combined ww (17.10.1988)					
Raw ww	13	2900	-	13600	-
oil skimmed	2	360	86	6400	53
Refinery process ww (4.11.1988)					
Raw ww	11	597	-	7840	-
oil skimmed	2	24	96	3360	57
Soap production ww (4.11.1988)					
Raw ww	12.5	166	-	19200	-
oil skimmed	2	18	89	9300	52

TABLE 8. Results of Chemical Coagulation Carried out with Lime and Polyelectrolyte After the Removal of Oil and Grease from the Composited Sample (17.10.1988)

Chemical addition (mg/l)	Oil-grease Eff. conc. (mg/l)	Oil-grease Removal eff. (%)	Chemical Oxygen Demand (COD) Eff. conc. (mg/l)	Chemical Oxygen Demand (COD) Removal eff. (%)
0 (Raw ww.)	2900		13600	
pH= 6.0				
6 mg/l PE			1920	86
10 mg/l PE	200	93	1760	87
12 mg/l PE			1440	89
14 mg/l PE			1600	88
100 mg/l Alum+ 10 mg/l PE	870	80	2680	80

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Results obtained at the second part of the study are given in Tables 7,8,9. In this series of studies, refinery and soap production effluents are treated separately. Test results indicate that acid cracking and oil separation is to be followed by lime + polyelectrolyte coagulation. Then, sludge volumes to be formed from the treatment of refinery wastewaters will not be as high as the amount of sludges to be obtained from the treatment of soap production wastewaters.

TABLE 9. Experimental Results of Acid Cracking + Chemical Coagulation Tests

Wastewater sample	pH	Oil-grease Eff. conc. (mg/l)	Oil-grease Removal eff. (%)	Chemical Oxygen Demand (COD) Eff. conc. (mg/l)	Chemical Oxygen Demand (COD) Removal eff. (%)
Refinery process wastewater (12.4.1989)					
Raw ww	12	4840	-	6400	-
oil skimmed	2	80	98	-	-
+lime added	6	60	-	488	-
oil skimmed +lime added	10	30	99.4	400	93.4
oil skimmed +3.0 mg/lPE	6	30	99.4	432	93.3
Refinery process wastewater (3.5.1989)					
Raw ww	10	1012	-	3360	-
oil skimmed	2	800	21.0	2000	40.5
oil skimmed +lime added	7.6	100	90.1	[illegible]	88.0
oil skimmed +lime added	10.7	-	-	350	89.6
Soap production wastewater (3.5.1989)					
Raw ww	11.8	564	-	48000	
oil skimmed	2	460	18.4	25600	46.7
oil skimmed +lime added	7	-	-	17600	63.0
oil skimmed +lime added	10.6	250	55.7	16000	66.7
Combined ww. (3.5.1989)					
Raw. ww.	12	688	-	5440	-
oil skimmed	2	570	17.7	4640	14.7
oil skimmed +lime added	7.3	-	-	4350	20.0
oil skimmed + lime added	10.1	-	-	4200	22.8

DISCUSSION OF RESULTS

According to the Turkish Water Pollution Control Regulation passed in 1988, the discharge limits into the sewerage system are given on the basis of guidelines for municipalities that want to have such provisions to be: pH 6.5-10.0, suspended solids 500 mg/l, oil and grease 250 mg/l, tar and petroleum oils 50 mg/l, chemical oxygen demand 4000 mg/l, sulfate 1000 mg/l.

Sunflower seed oil effluents investigated in this study are oily, turbid, alkaline and yellowish-brown in color. Most important pollutants in samples are oil and grease, chemical oxygen demand (COD) and biochemical oxygen demand (BOD) which are present in excessive amounts. The wastewater qualities obtained from the pretreatment studies that were carried out show that the pretreatment standards for the discharge into the sewerage system have been met in most of the cases. Chemical treatment alternative without using acid cracking was not so effective as acid cracking plus chemical coagulation methods. Although many chemicals can be successfully used in the de-emulsifying process, sulfuric acid was found to be the most efficient. Acid cracking skimmings containing oily materials may be recovered and returned to the process in order to be used as acid oil or for production of soap. This may reduce the amount of sludge to be formed in the treatment plant.

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For acid cracking of refinery process wastewaters, the required acid was 0.4 l/m^3 wastewater. Sulfuric acid was concentrated (98 % pure, BDH). Amount of acid required for combined effluents of refinery and soap production was found to be 2.0 l/m^3 ww. For the adjustment of the pH from 2 to 7, amounts of required lime (90 % pure) were found to be 0.6 kg/m^3 ww for refinery process wastewater and 0.6 kg/m^3 ww for combined wastewaters.

CONCLUSION

In the city of İzmir, sewerage system construction project is underway and the responsible authority (İZSU) declared that it will accept industrial wastewaters into the sewerage system provided that the pretreated water quality will be in compliance with the local discharge limits. Effluent quality after these pretreatment stages was acceptable for discharging into the sewerage system; but insufficient for discharge into the receiving water. Thus, this edible oil refinery may discharge its treated wastewaters into the sewer system, because the proposed pretreatment scheme of acid cracking (acidification and phase separation) followed by lime coagulation, gives out a sufficiently good quality effluent for the sewerage system.

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Appendix F
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