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Environmental Assessment
of
Etablissements Slama Frères

Tunis, Tunisia

by

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I. EXECUTIVE SUMMARY

An environmental assessment at Slama Freres Enterprises was conducted under the sponsorship of the World Environment Center (WEC) and the United States Agency for International Development (USAID) in June 1992. The project supported USAID's Project in Development and the Environment (PRIDE).

The assessment was performed by Mr. Gerald N. McDermott, a licensed Professional Engineer, with over forty years of experience in the detergent industry and working with governmental agencies.

Slama produces edible oil and bar soap. In addition to these two manufacturing plants, a fatty oil plant is operated at Slama to provide raw material to the soap making operation.

Slama's water use is approximately 250 cubic meters per day. The usual opportunities for wastewater reduction by such measures as dry cleanup procedures (versus water flushing) and others are not relevant to the plant. Recommendations are made to improve the gravity settling basin, to recover oil particles from the wastewaters, and to recirculate water from the wet scrubber which is presently being installed for the boiler which burns extracted olive seeds as fuel. The remaining possibilities for wastewater control are the recovery of lecithin and glycerine. US organizations having information on recovery systems for these materials

are identified in this report. Finally, land treatment is suggested as a possible alternative to Slama's present wastewater treatment practices.

The major source of airborne particulate matter at Slama appears to be from the boiler which burns extracted olive seeds as fuel. The plant is presently constructing a wet scrubber to control the ash and seed particle emissions from this boiler. The report suggests that Slama become well-acquainted with the operation of wet scrubbers to avoid typical problems such as filter plugging or the emission of dirty water due to water drop entrainment.

Control of odors is a concern at Slama particularly from the cooling tower air stream of the deodorizer operation (probably the one major source) and vents from the soap kettles. To control the former, the author knows only to replace the direct condensing system with a surface condenser and to route the water condensate to the sewer with little chance for air exposure. Plants in sensitive areas of the US, however, have had to spend millions for such systems. To control odors from soap kettles, the installation of adsorption systems (typically using activated carbon) on stacks would be effective.

Sludge generation from the pretreatment plant at Slama is reported to be 480 cubic meters per year. Operating personnel would like to see sludge removal made easier. The report suggests that modifying housekeeping and other operations may be the best solution for reducing the amount of grit present in the sludge. In addition, a manual system for scraping

the grit from the bottom of the settling basin to a sump is described. Such a system avoids the expense and difficult maintenance required for mechanical scrapers.

A formal safety program is recommended to handle the hazardous materials being used at the plant - caustic and sulfuric acid. Improved protection against leakage of hexane from its storage tank is also recommended.

The report suggests that a more economic and reliable system for addressing Slama's wastewater would be treatment at a joint community facility which serves residential, commercial and industrial users.

II. INTRODUCTION

The World Environment Center (WEC) contributes to sustainable development by strengthening industrial and urban environmental, health and safety policy and practices. In June 1992, WEC furnished the services of Mr. Gerald N. McDermott, an environmental engineer, to assess the environmental control program of Etablissements Slama Frères of Tunis, Tunisia.

This assessment gives an account of Slama's manufacturing activities and facilities pertinent to environmental control. The account includes manufacturing process descriptions with emphasis on wastewater, gas emissions, and discarded material sources. Some assessment of the hazards to workers' health and to the environs of the plant is included. The information was gathered by the author during site visits.

The author is experienced in dealing with environmental problems at one of the world's largest producers of soap, detergents and food oils.

In general, plants that refine edible oil and manufacture soap treat their wastewater in community treatment facilities. The wastewaters are accepted in community systems without regard to the concentration of compatible constituents. In the United States, only one plant of approximately one hundred provides sufficient treatment for discharge of its wastewaters

directly to a stream or lake. A different system of environmental control is being established in Tunisia.

Tunisian environmental regulations limit industrial wastewater characteristics to the concentrations found in residential sewage. Such an approach requires complicated pretreatment processes. This assessment judges the appropriateness of those pretreatment processes, in-service or being planned, and suggests any possible improvements.

This report is a useful document for the future and should be updated periodically. It will be of assistance in a number of applications including:

- managing reviews and program direction;
- training supervisory and operating personnel;
- promoting understanding of the program by the community and neighbors; and
- reviewing environmental matters with environmental regulating agencies

The cooperation of Etablissements Slama Frères was flawless and the assistance of the manager and engineers was enthusiastic and complete. The author was handicapped by not being able to speak either Tunisian Arabic or French but plant personnel were tolerant of this communication barrier and patient and helpful in overcoming it.

III. FINDINGS

A. Manufacturing Processes; Wastewater and Emission Sources

1. Edible Oil Plant

a. Materials

Soy bean oil
Rape seed oil (Canola)
Palm oil
Coconut oil
Olive oil
Phosphoric acid
Citric acid
Sodium hydroxide (caustic)
Bleaching earth (clay)
Nickel catalyst
Hydrogen (generated at plant site)
Water

b. Equipment

Storage tanks
Mixing tanks
Centrifuges
Pumps
Deodorizing column
Plate and frame filters
Water
Weigh tanks

c. Products and Production Rates

Edible oil - 20,000 to 22,000 metric tons/year
Hardened oil (shortening) - 500 metric tons/year

d. Employees

150 Total plant

e. Process Description; Wastewater and Emission Sources

The refining of crude vegetable oils is accomplished at Slama by processes and equipment similar to those used universally in modern plants. There are two subordinate processes that differ among plants. The particular alternatives practiced by Slama are described below, namely, the handling of the lecithin content, and the treatment of the alkaline extract (soap stock).

Olive oil is received at Slama by tanker and transferred to storage tanks on the plant site. The oil has been mechanically extracted at plants in Tunisia and other countries. The oil first contacts a small amount of water to which a low concentration of phosphoric or citric acid has been added. The purpose of this preliminary water extraction is mainly to remove lecithin, a water soluble compound present in low concentrations in all vegetable oils.

The extraction process for lecithin is more efficient, under conditions achieved at this plant, by adding phosphoric acid. The water with its content of water soluble components, mainly lecithin, is then separated from the oil by centrifugation. This process is referred to in the U.S. industry as degumming. The water extract from the degumming process is discharged to the pipe system leading to a pretreatment plant.

Lecithin is not recovered at Slama. The recovery of lecithin from this extract is accomplished by less than half the oil refining plants in the United States. There is a significant market for lecithin as an emulsion stabilizer in other foods and as a health food product by itself. However, the market is such that much of the lecithin in oil processed in the United States is discharged in the wastewaters just as at Slama.

Lecithin recovery would reduce biodegradable organics in the wastewaters. The quantity of lecithin compared to other organics in typical wastewaters is not well known and may be only a few percent of the total organics in the wastewaters. Nevertheless, its recovery would be a step towards reducing organics in the wastewaters. The possible recovery and marketing of lecithin in Tunisia is discussed in Conclusions and Recommendations.

After degumming, oil is then mixed with a stream of caustic for extraction of fatty acids. Sodium ions from the caustic replace hydrogen ions on the free fatty acids in the oil and converts the acids to sodium soaps. The soluble sodium soaps dissolve in the water that is present in the dilute caustic. The oil, (i.e. triglycerides), is not soluble in water to any extent. The content of free fatty acids in the oil being extracted depends on the age and storage conditions of the oil. Usually, it is less than 2 percent. The water containing the sodium salts of the fatty acids is separated from the oil by centrifugation. This separated water is called "soap stock" in the trade.

There are traces of the soap stock left in the oil after caustic extraction and centrifugation. Water is then added to the extracted oil in order to rinse the traces of the caustic solution and its soap content from the oil. The rinse water is separated by centrifugation. This rinse water is referred to as "soapy water" in US industry jargon. A plant has several choices for processing the soap stock and soapy water. At Slama, the choices made are those which minimize the organic material discarded with the wastewaters. Both of the streams are pumped to the soap plant where they are processed for recovery of the fatty acids soap. This is described in the soap making section of this report.

The oil stream from the alkaline extraction contains traces of odorous compounds and compounds which impart color to the oils. The material producing color and odor must be removed to create the bland oil needed for shortening and frying purposes.

The color producing compounds are removed by a process referred to in the trade as "bleaching". Bleaching is accomplished by adsorption of the color producing compounds on a particular clay. The clay, called bleaching earth, is a natural material which through testing has been found to be effective in adsorbing the color. Natural clay deposits with this property are common and available commercially. The clay supply for Slama is obtained from Germany.

Clay is mixed with the oil in a contacting tank, which is merely a stirred tank. Clay is fed to the tank and oil is added continuously. The slurry of the clay and oil is pumped to plate

and frame filters to separate the clay and adsorbed color compounds from the clear oil. The filters are fabric filters which are supported on hollow cores.

The clay rapidly builds up a layer on the surface of the filter as the slurry is recirculated. When the filtered stream is clear, its return to the contacting tank is halted. Filtration is carried out until the filter pressure builds up to a selected level or the filter is full of clay. The slurry feed is then stopped and the oil remaining in the piping and spaces is forced on by a flow of process steam. Thus, the residual of oil in the filter spaces and in the clay is reduced. In spite of this effort, a filter cake of about 30 to 40 percent oil is produced. The filter is then emptied of the clay by opening the filter and allowing the clay cake to drop off.

At Slama, used clay is hauled to an area of the plant and dumped in piles. About once a week, the pile of clay is loaded onto trucks and hauled to a landfill operated by the utility, O.N.A.S. There appears to be no problems with this practice. This lack of problems is unusual because the oil-laden clay has the property of igniting spontaneously when stored in bulk and exposed to air and sunshine. Oxidation of the oil occurs and produces heat interior to the pile. Coupled with heat from the sun, this is likely to start the pile burning. At Slama, the piles of oil-laden clay, however, were not emitting smoke and were not at high temperature. Furthermore, even if a fire occurred, it would be in a remote and isolated area (where the material is piled) and would not destroy anything.

In the final process, the odorous compounds are removed from the oil by steam stripping under vacuum. A "de Smet" proprietary make of deodorizer is used which is similar to equipment found at numerous edible oil refining plants. The deodorizer causes the oil and steam to move countercurrently, in a series of trays which hold the oil for a short residence time as it falls, tray by tray, counter to a flow of steam. The steam passes out the overhead duct of the deodorizer into a spray of cool water which condenses it.

This condensation of the steam produces a vacuum in the deodorizer which helps to separate the volatile odorous compounds from the oil. The odorous compounds, predominantly fatty acids, and other volatile organics in the oil (that are vaporized in the deodorizer) are also largely condensed by the water spray. There may also be some entrainment of small droplets of oil in the condensing water. The condensing water is pumped to a cooling tower in which a strong draft of air is pulled over the water as it cascades over surfaces of a wetted media. Evaporation cools the water to approximately air temperature.

Condensing water is recirculated from the deodorizer to the cooling tower and back to the deodorizer. Condensed organics, principally fatty acids, accumulate to high levels in the cooling water. They appear in the cooled water, in more or less crystalline form, as suspended matter since their solubility in water is limited. Some congealed matter will build up on the surfaces of the cooling tower. This matter is referred to as "clabber" in many plants in the United States.

The cooling tower at Slama, similar to such towers elsewhere, has a basin into which the cooled water collects after it passes through the cooling tower. The suspended fatty acids will accumulate on the surface of this basin. At Slama, this material is skimmed manually and added to the soap stock so it becomes material for soap manufacturing.

Soluble material builds up to high concentrations in the cooling water unless a significant discharge from the system is maintained. The rate of water discharge from the system determines the concentration of emulsified and soluble material which will accumulate in the recirculated water. A balance will be established between water added and withdrawn from the system. A high concentration of material can be tolerated and thus, a low discharge rate of the white water is usually practiced. At Slama, this white water is discharged to the sewer leading to the wastewater pretreatment plant.

The air stream leaving the water cooling tower will contain some of the more volatile odorous materials removed from the oil. In addition, the fatty acids condensed in the cooling tower water will be degraded by bacteria that circulate in the water or grow on the wetted surfaces. The breakdown products may be volatile odorous compounds. The quantity of organics involved, however, is not great so that this stream is not considered a serious source of volatile organics in most air sheds in the United States.

Odor is not considered a health problem and is regulated as a local matter by local governments. The significance of the odor depends primarily on the proximity to the plant

of residences and the attitude prevailing in the neighborhood. In industrial neighborhoods, odor is tolerated with little if any complaint. In neighborhoods with more expensive housing, there are cases where a sensitive and active group has forced the industry to control odors. The industrial district near Slama does not appear to be such a sensitive area, and therefore, process and equipment changes necessary to control odor are not discussed in this report.

A second source of odorous compounds, in addition to the cooling tower, are the gases which are not condensed by the water sprays in the deodorizer condenser. Noncondensables, likely to be predominantly nitrogen gas, which enter the water supply will also contain volatile organics. These noncondensables are removed by a steam ejector or a vacuum pump which discharges them to atmosphere.

Most of the deodorized oil is shipped in bulk to other plants for packaging and distribution. A second portion is further processed to produce oil which is congealed at ambient temperature. This product is used as shortening in, for example, baked goods.

The oil for shortening production is altered in chemical composition through a process called hardening. Hardening is, chemically speaking, the addition of hydrogen to some of the unsaturated carbon linkages of the fatty acids of the triglycerides. Oil with many unsaturated linkages remains a liquid at all common household or ambient temperatures. Oil with a few unsaturated linkages will congeal, that is becomes plastic or solid, at approximately 50

degrees. Oils that congeal at room temperatures are popular for pastry making. The congealing temperature of an oil can be controlled by the extent that the number of unsaturated linkages are reduced by reacting hydrogen with the oil.

Hardening is accomplished by contacting the oil with hydrogen gas. A catalyst is necessary to make this reaction proceed at an economic rate and reasonable temperature. The catalyst that is universally used is the metal nickel. Nickel is used in the form of a deposit on clay particles. Such nickel catalysts are manufactured by a few chemical companies in the world. The Slama plant obtains their catalyst from Europe.

The hardening process consists of adding the clay to the finished oil and contacting the two in a stirred vessel. The slurry is indirectly heated by means of steam coils to obtain the temperature needed for the reaction. The slurry is then pumped to a plate and frame filter for separation of the clay and catalyst as a cake. The clay does not form a good filter cake so diatomaceous earth (a particular kind of clay) is added to make the filtration more practical. The clay accumulates on the filter until the pressure drop reaches a selected level and then the residual oil is flushed from the filter cake and pipes by process steam. The spent clay, after being dropped from the filter, is placed in metal drums which are closed with clamp-on lids to restrict air. This clay cake is pyrogenic if in contact with air.

The drums of spent catalyst and clay are shipped to the supplier of the catalyst for regeneration. The nickel is valuable and this operation is economic. In the United States,

the shipping costs and the value of nickel is such that processing of the spent material for nickel recovery is not available to some plants. Regulations on the disposal of discarded material containing nickel will probably result in disposal costs which will make regeneration a universal practice. Presumably, this practice will always prevail in Tunisia and a disposal problem will not occur.

The hardening process is a dry process, so no water is used. The area of the hardening plant at Slama is not equipped with floor drains or sewers. This is the best possible of situations as there is no route for nickel catalysts to be lost to the wastewater system. Incidents have been recorded in surveys of wastewaters from edible oil plants in the United States of nickel being present in them. This nickel proved to originate in repairs made to pumps and filters in which the material removed for repair was not carefully cleaned up and some was flushed to the sewers. This does not appear to be possible at Slama because the sewers are remote from the area. This situation should be maintained.

The hydrogen generation plant, from which the hydrogen gas for the process is obtained, is isolated from the other operations and buildings of the plant and has no wastewater generation. This isolation appears to provide adequate protection from explosions and fires which can occur if hydrogen is not properly handled.

Nickel is an environmentally significant element and also requires control regarding worker-health risks. Limits on the concentration of nickel to protect drinking water quality or aquatic

life are not relevant to Slama since no nickel is lost in the wastewaters. Relevant safety precautions and practices are discussed in a subsequent section on safety.

f. Process Waste Summary

The process wastewater sources from edible oil refining have been described in the preceding section. The wastewater streams are:

- The degumming waste from water washing the oil for lecithin and other non-oil constituents; and

- The stream that is sewered from the deodorizer condensing water recirculation system.

No separate information is available on the strength and characteristics of these wastewaters but there are some data on the total plant wastewaters after pretreatment.

The air emissions are air from the deodorizer cooling tower and the deodorizer noncondensable gas stream.

The solid waste material is bleaching earth.

2. Soap Plant

a. Materials

Olive oil from Slama extraction process
Olive oil from other source
Sodium hydroxide (caustic)
Sodium chloride
Soap stock and soapy water from edible oil plant

b. Equipment

Oil storage tanks
Reactor tanks
Pumps
Soap blending machine & extruder
Slicing machine
Soap drier rack and hood
Packing line conveyor

c. Products and Production Rates

Bar soap - 4,000 metric tons per year

d. Employees

Total for the plant - 150 people

e. Process Description; Wastewater and Emission Sources

Soap is manufactured from olive oil and from the fatty acid bearing streams from the edible oil refining operation at Slama. The olive oil used for soap making is extracted at the Slama plant from ground olive seeds from which the oil has been pressed. The extraction process is discussed in a subsequent section. The fatty acid content of such oil is high, making it unsuitable to use as a raw material for edible oil. Some olive oil suitable for soap making is also received by tank truck.

Oil for soap making is accumulated in tanks and pumped to the production operation. Oil which cannot be pumped, such as remnants in the tanks below the outlet and in hoses, pumps and pipes, is manually collected in steel drums. The steel drums are dumped into the oil accumulating tanks.

Wastewaters from edible oil refining that contain fatty acids are also pumped to the soap making reactors. Skimmings from the deodorizer condensing water (from the cooling tower basin) are also added to the soap making reactors. A typical charge to a reactor is about 90 percent fatty oil and 10 percent soap stock. Sodium hydroxide (caustic) is added to a batch of oil in the reactor in sufficient quantity to produce a pH of about 14. There always remains an excess of caustic above that which forms sodium soaps by reacting with the breakdown products of the oil.

The soap making process at Slama is a batch process. Four reactors are used, each holding about 15 cubic meters of oil.

The reaction called oil-splitting or hydrolysis is that of separating the three carbon backbone of the triglyceride from the three fatty acids attached to it. This results in the production of a glycerine molecule and three fatty acids. The fatty acids react, as they are produced, with sodium ions from the caustic to produce fatty acid soaps. Under these conditions, the soaps have limited solubility in the diluted caustic. High temperatures promote the splitting reaction so the batch is heated by means of steam which is sparged into the reactor. This sparging also accomplishes thorough and continuous mixing of the contents of the reactor so that the oil and caustic are well contacted together. A quantity of sodium chloride, salt, is added to the reactor. The sodium chloride helps to prevent the formation of emulsions of oil or fatty acid in the dilute caustic. The salt also increases the concentration of sodium ions so

that the formation of sodium soaps is enhanced. The solubility of the soaps in the dilute caustic is also reduced by the addition of salt.

After a period of reaction, the steam sparging is stopped and the contents of the reactor are allowed to stand quiescent for a few hours. The materials in the reactor separate into a soap layer on top and a dilute caustic layer on the bottom. In typical operations, there is a third layer at the interface of the soap and caustic which is composed of soap or oil emulsions in water. In addition, traces of caustic will remain in the soap layer. Such traces are undesirable in the soap product as they would be too harsh on skin. The remnants of caustic are reduced in the soap layer in the reactor by spraying the surface, following the settling step, with water drops and allowing the drops to settle through the soap. The caustic dissolves in the larger water droplets and is carried into the lower layer.

The soap layer is pumped to a soap accumulating tank of about 15 cubic meters capacity. The soap becomes more viscous as the temperature lowers. In the next step the viscous soap is worked mechanically in a machine which imparts to it the desired structural properties, an amorphous rather than a crystalline condition. The worked soap is then pumped to an extruder as a thick plastic material. The extruder discharges a free standing stream of soap continuously. The strand or ribbon has a square cross section. This ribbon enters a slicer which cuts it into cubes as it moves. The cubes are then placed on racks and moved slowly through a space under a hood. Air is pulled through the hooded area and exhausted. The air

cools the soap which now becomes fairly rigid. The cubes are then packed and shipped in cardboard containers.

The kettles of oil, as they are processed in the reactor and heated, tend to give off vapors some of which are odorous. There is no stream of air involved here and the odors and vapors merely enter the atmosphere from the surface. The vapor from the reactors is conducted through the roof of the building by a vertical duct extending from the cover of the reactor through the roof. The kettles were not in the reacting stage when visited but Slama engineers state that the odors are not severe. They also report that the temperature of the reactor is controlled within a low range, to a maximum of about 55°C. This is a much different situation than is sometimes encountered in which the temperature is that of boiling water and water vapor comes off in clouds.

The drying of the soap bars produces an air emission which does not have a significant content of organics.

The safety aspects of soap making appear to be limited to the use and handling of caustic.

After the settling step, the caustic layer on the bottom will contain the preponderance of non-fatty acids or non-triglycerides of the original raw materials. These impurities amount to as much as one or two percent of the raw oil. The bottom dilute caustic layer will also contain suspended matter such as pieces of olive seeds. These bottoms contain essentially all

of the glycerine produced in the oil splitting. In addition, a significant amount of unreacted caustic is present and, perhaps, a low content of oil or fatty acids. The water also contains all of the sodium chloride added to the reactor. The bottom layer from a batch of oil is added to the charge of the reactor for the next batch. Thus, some use of the residual caustic is achieved and, perhaps, some of the emulsion will be broken.

Slama engineers have not experienced the creation of much of an emulsion in the reactor layer. This is unusual. Discharging the emulsion layer to the wastewaters will be a major source of oil in the wastewaters. At plants where appreciable emulsions are present as a intermediate layer in the reactors, this layer is left in the reactor in which it is created for batch after batch. Ultimately, the emulsion is broken or its volume is so great that it has to be treated, by itself, for breaking the emulsion.

At Slama, the bottom layer after two uses is discharged to the neutralizing basins. The organic matter content is undoubtedly quite high, in the thousands of milligram per liter range. Operation of the neutralizing basins is described in the pretreatment section later in this report. This material used to be referred to, when batch soap making was widely practiced in Europe and the United States, as nigre water, nigre meaning black. The same term is used at Slama.

f. Process Waste Summary

The process wastewater from soap making is the neutralized bottoms from the kettles referred to as nigre.

Air emissions are from the vents of the kettles where the reaction of the oil with caustic is carried out and from the air blown over the finished soap cakes to dry them.

There are no discarded solid materials or other materials handled in the manner of a solid waste.

3. Fatty oil Plant

a. Materials

Olive seeds which have been mechanically extracted at other plants
Hexane
Steam
Water

b. Equipment

Extraction columns
Pumps
Boiler
Rotary drier
Cooling tower
Stack
Blower

c. Products and Production rates

800 metric tons per year of fatty oil

d. Employees

Total for the plant - 150 people

e. Process Description; Wastewater and Emission Sources

At Slama, fatty oils are recovered from olive seeds that have previously been mechanically extracted and ground at other locations. The seed particles contain a significant amount of oil. The ground seeds are shipped in bulk to the Slama plant and the residual oil is largely removed from them by solvent extraction. This process is described in the following paragraphs. The oil is the principal raw material supply for soap making at Slama.

The reason for referring to the oil as fatty oil instead of olive oil is that during the exposure between mechanical oil extraction and hexane extraction, considerable amounts of the oil in the seed particles will be oxidized and/or hydrolyzed by the action of bacteria. Hence, much of the oil will be in the form of fatty acids. The recovered material is an oil which is unusually high in fatty acids, hence the name fatty oil.

The ground olive seeds contain considerable moisture which is removed by drying the seeds in a rotary kiln with a flow of combustion gases. Obtaining the heat for the drying is cleverly engineered, as explained subsequently.

The dried seed particles are conveyed to one of six extraction vessels or columns. The extractors are connected to a manifold of pipes such that an extracting liquid can be pumped

through the six contactors in series. The extractant used is hexane. A volume of hexane is stored at the site of this plant.

Hexane is pumped at considerable pressure through the extractors, first entering the extractor which contains seeds that have been under extraction for the longest period of time. The seeds in this reactor have little oil left to be extracted, since they previously were extracted by hexane that had already passed through one contactor. Thus, in effect the hexane is caused to flow opposite the movement of the seeds even though the seeds are not moved.

The seeds in the contactor, after being extracted with virgin carbon, are isolated from the system. The hexane is pumped from the bed of seeds as they sit in the extractor. Considerable hexane will remain in the seeds. Residual hexane is stripped from the seeds by the passage of steam through the bed to volatilize the hexane.

Steam is fed into the bottom of the reactor and passes up through the bed to an overhead duct. The hexane vapors and the steam are carried in a duct to a spray condenser. Sprays of cooled water are directed into the vapor stream. The steam and hexane are condensed and flow with the condensing water to a separation tank. In the separation tank, the flow is quiescent so that the hexane, which has low water solubility, will separate out, by gravity, as a layer on top of the water. The upper layer of hexane overflows automatically to the hexane supply system.

Water passes from the bottom of the separation tank over an overflow point and to a sump from which it is pumped to a cooling tower. The cooling tower is full of media providing high surface area. A strong current of air is drawn by a fan through the tower. The evaporation of the water cools it to near ambient temperatures. The water is then pumped to the direct spray condenser in continuous recycling. Traces of hexane in the water will largely pass from the water into the air of the cooling tower.

The condensed steam used in the stripping operation becomes makeup for evaporation occurring in the cooling tower but there is more water evaporated than added by condensation. As with any cooling tower, the evaporation acts to increase the dissolved mineral concentration in the recirculated waters. At the saturation concentration of particular minerals, they will begin to coat the surfaces of the cooling tower and other surfaces involved. Excessive coating cannot be tolerated so the standard practice is to withdraw water from the system and add fresh water to make up the needed volume. This is typically done continuously so that there is a continuous discharge of wastewater to the sewer.

The extracted seeds are dumped from the reactor as a batch. The Slama engineers state that the hexane content of the extracted and steam-stripped seeds is negligible. The seed material is piled in the yard for subsequent use as a fuel. Using the seed material as fuel is the clever aspect of the drying process previously referred to. The material is burned in a boiler. The boiler is equipped with a water pipe system in the combustion chamber so that steam is generated with heat from the burning seeds. The combustion gases pass on to the seed dri..

where they pass through a tumbling mass of the seeds in a drying kiln. The purpose is to remove water from the raw seeds.

The combustion gases are drawn through the furnace and drying kiln by blowers which discharge to a stack extending about ten meters above the ground. A considerable amount of particulate matter is carried by this gas stream into the atmosphere. Slama is responding to the need for reducing the amount of particulate matter by installing a wet scrubber. This scrubber is discussed in a subsequent section.

The oil and hexane solution from the extraction column is pumped to a hexane recovery unit. The recovery unit is a vertical tube evaporator in which the liquid flows down the walls of tubes which are surrounded by steam in a steam chest. The hexane volatiles and the vapors flow upward to a duct system which conveys them to a surface (indirect) condenser. The water supply for the indirect condenser is pumped from a cooling water recirculating system. The cooling water system is the same as that used for direct condensing of the seed stripping stream. The condensed hexane is pumped to the hexane supply system. The oil is pumped from the bottom of the evaporator to a storage tank in the soap making department.

Slama management and operating staff is quite aware of the explosive hazard involved in the use of this highly volatile and easily fired material, hexane. Two continuously operating analyzers are in service and are equipped with alarms. In addition, a portable unit is available for monitoring any suspected space.

Hexane has significance to air quality as a volatile organic and there has been concern in the United States about losses at seed extraction plants. There are a number of extraction plants in the US that use hexane for extracting the virgin seed. I do not know of any combination of mechanical extraction followed by hexane extraction as is done with the oil seeds that Slama processes. There are modern plants for extraction of soy beans which maintain the hexane in the system with very little loss to the atmosphere. On the other hand, older plants extracting cotton seed have operated systems that allow practically all the hexane which remained in the extracted seeds to be exhausted to the atmosphere. In these plants, the hexane residual was removed by an air stream rather than by steam in a closed vessel as is done at Slama. The losses of hexane at Slama have not been monitored. The air streams that could contain hexane are:

- the cooling tower exhaust from the condensing of the hexane vapors in the seed stripping operation;
- hexane in the cooling tower water that is sewered (hexane has a low solubility);
- hexane in the extracted seeds that are piled on the property prior to burning in the boilers; and
- hexane in the condensed steam from the seed stripping process.

The loss of hexane would be equal to the quantity purchased of hexane required to replenish the storage tank. Records of hexane purchases over a long period would be a good estimate of hexane losses. Essentially all such losses would likely be to the air. The exception would be hexane that was in the seeds that are fed to the boiler.

f. Process Waste Summary

In summary the wastewater, air emissions and waste materials from the fatty oil plant are as follows:

The present operation has the single wastewater stream from the recirculated condensing water system. When the wet scrubber is in operation on the stack gases, there will be a new wastewater stream which will be fairly high in suspended matter content.

The air streams from the fatty oil plant that could contain hexane are the cooling tower exhaust, and the stream containing hexane volatilized from any residual in the extracted seeds.

The extracted seeds are used for fuel. The solid waste consists of the ash from the boiler.

B. Wastewater Sources Other Than Process Wastewaters

1. Laboratory Wastewaters

The laboratory where the quality of raw materials and products are checked and process control tests are made will generate a small amount of wastewater. The wastewater originates from the washing of glassware and sample bottles, spent chemical solutions from certain analytical procedures, solvents used in analytical separations, samples of product and raw materials, and cooling and condensing water. Good practices for minimal discharge of pollutants that are recommended to Slama if they are not practiced at the present time are: 1)

placing spent solvents in a separate container for disposal as a waste material, 2) no use of mercury containing compounds in the analyses, 3) thorough cleanup of any spilled mercury such as from broken thermometers, 4) no disposal in the sinks of reagents containing toxic metals or toxic organics.

2. Rainfall Runoff and Spill Protection

Concerns about stormwater are (1) that stormwater is not allowed to be discharged to the same sewer system that carries the process and sanitary wastewaters, and (2) the possibility that stormwater in the storm drainage would be significantly polluted from materials lost on the surfaces in the plant. Slama engineers are aware of the requirement of the local agency prohibiting discharge of stormwater to the process sewer. Stormwater drainage systems are impacted by spills because spilled material often flows to storm sewers.

There are no storm sewers in the plant nor in neighboring areas. There is much unpaved area and roofs that would be expected to have some oil and dust from olive seeds on them. The runoff from these surfaces would be expected to contain considerable suspended matter. The soil appears to be sandy so that an intense and prolonged rain would be necessary for significant runoff. The amount of pavement is limited. The runoff would be principally that from the roofs of factory buildings. The runoff and the roof and other property drainage flows to a drainage channel along the street and to some natural drainage channels from the property. Much of the rainfall would be expected to percolate into the ground on the plant site.

Secondary containment for the storage tanks at Slama is limited to the fuel oil tank which is surrounded by an earth berm. Other tanks and the unloading and process areas do not have spill containment systems. A large spill of olive oil would cause some problems and a rupture of the caustic tank would be dangerous. Even a small overflow of caustic could be a risk. There is a concrete wall at the property line along one side which would hold back drainage in that direction. A casual inspection indicates spilled material would spread on the plant grounds.

Three hazardous materials which would require spill protection under US regulations are hexane, sulfuric acid, and sodium hydroxide. At Slama, the hexane is stored in a buried tank which eliminates any spill concern from tank rupture or such. Spills while transferring from the truck to the tank could occur. The hexane tank is buried as a measure to protect it from reaching dangerous temperatures from sunshine. The quantity of sulfuric acid kept at the plant (i.e. a single 100 liter drum) is so small as to be of limited concern. The small house in which the drum is contained is kept locked and if spilled here, the contents would not enter a sewer.

3. Sanitary Wastewaters

The regional agency O.N.A.S. serves this area. The toilets and showers of the Slama plant are conveyed in a separate sewer which receives only such sanitary wastes. The sewer connects to the other plant sewers after the pretreatment facilities. This is important because the sludges produced in pretreatment require special precautions if sanitary sewage is present

and the recovery of oil, skimmings or the like is not possible if sanitary wastewaters are present. The volume of sanitary wastewaters is small compared to the process wastewaters. The estimated volume is 1.5 cubic meters per day.

4. Product Development Wastewaters

Slama has a separate building in which new products are made for market trial. The building has a small scale margarine making plant installed. My understanding was that the production has been only for test purposes. Margarine manufacture does have some organic and oil bearing wastewaters associated with it, ordinarily. These originate from sanitary requirements since milk products are used in the manufacturing. Bacterial growth is a constant threat. Cleanups and sterilization procedures are frequent.

5. Housekeeping Wastes

A limited area of operating floors and packaging areas may be washed at times. The areas involved and the related housekeeping practices at Slama are not extensive. Housekeeping wastewaters appear negligible here.

6. Water treatment wastewaters

The water used in the boiler for steam generation is treated to remove the scale forming minerals, calcium and magnesium. Ion exchange material in the form of grains is contained in steel tanks for this purpose. The water supply is passed through the exchange material. The calcium and magnesium become attached to the grains and replaces the chloride on the

exchange media. Once most of the chlorides have been replaced, the ion exchange material is regenerated by passing a high strength solution of sodium chloride through the system. The frequency of regeneration is typically once per day. The sodium chloride brine is recirculated for a period and then the spent regeneration solution containing sodium carbonate, sulphate and chloride is drained to the wastewater system. Water is passed through the material to flush out the brine and this flushing water is drained to waste. The exchanger is then placed back in service. The volume of the regeneration waste and rinse water is estimated at 2 cubic meters per day.

C. Existing Wastewater System and Wastewater Volume and Characteristics

The Slama facilities discharge to the sewers of the local agency O.N.A.S. The connection is located at the street in front of the plant.

The sewer system in the plant consists of two main branches. One branch serves the soap making plant. A pretreatment facility on this sewer consists of a neutralizing system for the bottoms from the soap kettles. This is described in a subsequent section. The effluent from the neutralization system joins the branch of the sewer serving the oil refinery and the combined stream flows to the main pretreatment plant. The pretreatment plant discharges to the O.N.A.S. sewer.

The wastewater discharge is not provided with a measuring device. Water use is about 250 cubic meters per day. Likely, the wastewater flow is about 240 cubic meters per day.

Slama collects and analyzes the process wastewaters discharged to the O.N.A.S. system one day per week. The sample is a composite of samples taken in equal amounts several times during the day.

Data were provided for four samples taken recently and are tabulated below:

Characteristics of Daily Samples Collected Once/Week

Week	pH	Chloride mg/l	MES (Suspended) (Solids) mg/l	RES (Total) (Solids) mg/l	Color
1	6.5	1562	244	5521	mild yellow
2	7.0	8875	413	6405	
3	6.5	1164	392	6560	
4	7	887	97	3790	

The organic content as measured by the biochemical oxygen demand (BOD) or the chemical oxygen demand (COD) is routinely included in the testing program. From information on wastewaters from somewhat similar operations in the United States, it is estimated that the BOD would range at or above 1000 mg/l.

Sludge generation from the pretreatment plant is reported to be 480 cubic meters per year. The solids content is about 2 percent. This is a small amount of sludge for the chemical

coagulation and settling of a wastewater. This results from the fact that chemical coagulation and sedimentation processes are sensitive; and continually securing the optimum doses is difficult. Nevertheless, this volume of sludge is burdensome for the plant and pumping it to a truck and disposing of it satisfactorily is not easy. With its high mineral content, disposal sites must be selected such that groundwater quality is not effected.

D. Pretreatment Facilities

The neutralization system for the soap kettle bottoms, nigre, consists of four concrete basins, a piping system which allows any one basin to receive the incoming wastewaters, and a pump and piping system such that the contents of any basin can be pumped to the sewer. The neutralization is carried out a batch at a time. When a basin is full, sulfuric acid is fed by gravity from a holding tank above the basins into the batch. Control is by hand operation of the valve on the acid tank. The pH is monitored by hand sampling. Sufficient acid is added to reach a near neutral pH. The wastewaters are then pumped to the sewer.

Batch neutralization is the best possible system for wastewaters generated in batches such as these. In addition, it does not require the sophisticated instrumentation that automated systems require.

The neutralized waste from the soap plant together with the wastewaters from the refinery flow to a small concrete basin by gravity. This basin is to allow oil to float to the surface and be held in the tank. The water passes out through a submerged outlet and overflow. Oil

is skimmed by hand from this tank and returned to the soap making process. The size of this system and its appearance suggests that it is not highly effective. To prove if a system is reasonably effective, a sample of the effluent can be taken to determine if there is a significant amount of floatable oil in it. My experience has been that no matter how crude, a gravity separation system seems to perform satisfactorily. Nevertheless, good engineering indicates that an oil separation tank more along the lines outlined in a text book should be employed at Slama and, therefore, the existing system should be upgraded eventually. The principles of gravity oil separation, as found in one text, are included in Appendix E.

Following gravity oil separation, the wastewaters flow by gravity to a system for chemical coagulation (using aluminum sulphate) followed by gravity sedimentation. The system is not in keeping with design and equipment standards that obtain good continual effectiveness, and represents a less than best choice for wastewater management.

The following discusses the extent of the practice of chemical coagulation in the edible oil refining and soap industry. To my knowledge, chemical coagulation is used at only one edible oil refining plant and one soap manufacturing plant in the United States. At these plants, it is used to remove emulsified oil from wastewaters prior to biological treatment. The processes use dissolved air floatation rather than gravity settling to remove the floc created. Gravity settling has proven to be subject to erratic performance because a settleable particle is created only with a high dosage of the flocculant relative to the oil content. If the oil content of a flocculated particle is high, the particle will not settle well or possibly will

float. The dissolved air floatation process creates fine bubbles of air in the coagulated wastewaters which attach to the particles and buoy them to the surface. A float of up to 4 percent solids can be scraped from the surface. With gravity settling, it is difficult to obtain a sludge with more than about 1 percent solids. The operation of such a system must be so sophisticated, and the cost of disposal of the float so great, that preferred disposal is to biological treatment plants.

Now, I will discuss the use of chemical coagulation and gravity settling in wastewater treatment in general. In the first place, it should be realized that coagulation is effective for removal of particulate matter only and that it will not remove material in solution. The process is subject to effective formation of settleable floc only if the chemical dose is in a suitable range and the pH is appropriate for that dose. In sophisticated plants with variable wastewater characteristics, samples for pH adjustment and flocculant dosage determinations are run frequently. Wastewaters that change characteristics markedly from hour to hour simply are not susceptible to good treatment by the process. The volume of sludge produced is substantial, five percent or ten percent or more of the volume of wastewater. This sludge is thin and there is no practical way that it can be dewatered. Filter beds or evaporation ponds may work in this location but they would have to be of considerable area.

The most advantageous system for Slama's wastewaters after the floatable fat is reasonably removed is treatment with domestic sewage by biological methods in a community wastewater system. This is discussed in a subsequent section.

Considering Slama's existing plant, the coagulant solution is made up in a tank elevated above the basins. The dose of chemicals is adjusted by operation of the drain valve on the chemical tank. The flow of chemicals is increased until a floc can be observed in the wastewater flow. The chemicals are added in a small tank where mixing is accomplished. The flocculated wastes then flow to a settling tank.

The flocculant particles supposedly settle to the lower section of the basin. Two settling basins are provided. The design concept is that when the sludge has accumulated in one basin, the wastewaters would be directed to the other basin. In the first basin, the wastewater is allowed to settle more and the sludge is removed. The operators find that removal of the sludge is difficult since pumps and lines plug. Furthermore, the appearance of the sludge removed suggests that it is not alum sludge at all but grit, sand and other heavy particles as carried in the wastewaters.

I believe that the bulk of the chemical sludge passes through the settling basins or perhaps the dose for creating the sludge is not of sufficient duration, and minimal chemical sludge is, therefore, produced. The point is that the amount of chemical sludge that this system would normally create is not accounted for in the removal and disposal schemes. Modifying or supplementing the system to make it practical and economic would be difficult. The logistics of removing and hauling in tank trucks the volume of sludge estimated appear overwhelming. In order to evaluate the possibilities, a study would have to be made of wastewater volumes,

chemical dosages, sludge volumes, sludge dewaterability, disposal alternatives, etc. Such work is beyond the scope of this assessment.

Operating personnel would like to see the sludge removal made easier. Sludge settling from edible oil wastewaters has been a problem that has not lent itself to an effective and easily implementable solution. The general practice in the industry is to allow the sludge, whatever it may be including grit, to accumulate in the bottom of the oil separation basin. After a six or 13 month period, the depth might be two feet. At plant shutdown or down times, this material is dredged and hauled as waste material. Settling basins can be equipped with mechanical scrapers along their bottoms which move the grit to sumps. These are expensive and hard to maintain. In sewage treatment, a specially designed settling basin is the first unit in the series and its purpose is to remove the grit. This design, however, appears to be a costly step for Slama's wastewaters where the amount of grit is limited.

The best solution at Slama may be to modify the housekeeping and other operations (from which grit is coming) such that little grit would be present in the process wastewaters. I have heard of a hand operated scraping system in use in India where mechanical systems were not practical. The bottom of the basin is made to slope to a sump. At intervals of once each shift, day or the like, the operator places a board on a long shaft on the bottom of the basin and at the end opposite the sump, and pulls it slowly down the slope to the sump. The sump is pumped to an accumulating tank that is constructed such that the excess water pumped with the sludge can flow back to the head of the basin.

E. Air Emission Control Practiced

The major source of particulate matter in this plant is stated by Slama to be the boiler that uses the extracted olive seeds for fuel. The ash particles and the particles of seeds themselves would be expected to be light and easily entrained in the combustion gases. Slama is doing something about this emission.

A wet scrubber was being constructed and installed at the time of the visit. Wet scrubbing can be effective. The choice was either scrubbers, electrostatic precipitators or filtration through fabric in a bag house. Scrubbers would be almost as effective as the other choices and much less expensive. This assessment did not include details which would allow evaluation of whether or not the scrubber was properly sized or designed. However, based on my intuition, I think the cross section or area of the scrubber being provided is inadequate. This is only an intuition since the air emission rate or other such data was not obtained.

Slama should learn more about scrubbers since they operate not without difficulty. The media is subject to plugging so the water spray must be adequate and properly placed for effective cleaning. Plugging is not easily detected because half the filter could be plugged and the remainder will be enough to allow the gas to pass. Also, a situation can exist where the gas velocities are too high such that water drops are carried along with the emission, and a rain of dirty water in the vicinity will occur.

In addition, no provision seems to have been made for the treatment and disposal of the wash water. The best system would be one that provided for settling and recirculation of the spray water. This system is not popular with operators because the particulate matter and mineral encrustation is prone to plug the sprays. Nevertheless, such a system is possible with a good solids removal system.

I do not think it would be advisable to discharge the scrubbing wastewaters to the sewer system leading to the oil separator. Probably, this would make the sludge problem there more difficult and interfere with the reuse of the oil skimmings.

IV. CONCLUSIONS AND RECOMMENDATIONS

The following recommendations are made to Slama and discussed more fully in the section on Findings or in the subsequent pages:

1. To minimize pollutant discharge in laboratory wastewaters, institute these practices if not already followed:

   - place solvents in a separate container for disposal as waste material;

   - do not use mercury containing compounds in the analyses;

   - clean up thoroughly any spilled mercury such as from broken thermometers;

   - do not dispose into sinks reagents containing toxic metals or toxic organics.

2. Upgrade the existing oil separation tank to be more in line with accepted principles of gravity oil separation as contained in Appendix F.

3. Recirculate the water from the wet scrubber (downstream of the boiler burning extracted olive seeds as fuel) when installed.

4. Investigate the possibilities for recovering lecithin and glycerine, materials that are currently discharged in the wastewaters.

5. Consider the installation of adsorption systems on stacks to control odors.

6. Consider, over the longterm, using a double-walled underground tank, tank in a vault, or an insulated above-ground tank to store hexane so that leakage is more effectively guarded against.

7. Consider land treatment as an alternative to current wastewater treatment practices.

8. Institute a formal safety program to include:

   - labels on tanks containing hazardous materials;

   - exhibition of safety data sheets on the tanks or in the immediate area;

- records of employee training including dates and types;

- elimination of any overhead piping of hazardous materials where possible; and

- provision of secondary spill containment for storage tanks and unloading areas for hazardous materials.

9. Promote the use of a more economic joint treatment system where industry wastewaters would be treated at a community facility serving residential and commercial customers, as well.

A. In-process Measures to Reduce Wastewater Flow or Pollutant Quantities

The usual opportunities for wastewater reduction by such common measures as using dry cleanup procedures instead of water flushing and others are not significant in the Slama plant. Improvements in the basin for gravity settling to recover oil particles from the wastewaters has been mentioned in the section on pretreatment. The recirculation of the water from the wet scrubber has also been discussed in that section. The remaining possibilities are in a wholly new and substantial operation category, namely the recovery of materials currently discharged in the wastewaters. The two candidate materials now in the wastewaters are glycerine and lecithin. Glycerin is a product that is common in commerce in the United States. I do not know of a single soap or fatty acid plant in the country that is not recovering glycerine. Lecithin on the other hand although marketed in large amounts is not recovered from oil refining wastewaters by a substantial number of plants. However, there should be a market in North Africa and in Europe where oil supplies are not as large and therefore a surplus of these materials not likely.

The recovery of lecithin from the water extraction of oil is standard technology that is described in reference books on oil refining. Relating the technology in this report is not appropriate to this assessment. Probably the Tunisian oil refining industry could approach the recovery of this material best by contacting companies in the United States which are recovering lecithin. Perhaps a joint or cooperative effort could be developed particularly if the Tunisian effort was not creating competition in the market place. It is suggested that this matter be pursued by contacting the following organizations:

Roger Sinram, Technical Director
Lucas Meyer, Inc.
765 East Pythian Avenue
Decatur, Illinois 62526

Robert M. Reeves, President
Institute of Shortening and Edible OIls, Inc.
1750 New York Avenue, N.W.
Washington, D.C. 20006

The Lucas Meyer firm is solely in the business of lecithin recovery and purification. The trade association likely could direct Slama to oil refiners who recover lecithin.

The recovery of glycerine is a matter of distilling the glycerin from the water that is separated in the soap making process. The separation is generally accomplished in United States plants by a two stage process. The glycerin containing stream is fed to the still and overhead vapors are condensed. Water vapor has a tendency to remain with the glycerin vapors. The distillation is done under vacuum. The first distillation achieves a crude glycerin with about 80 percent glycerine content. A second distillation yields a glycerine

with a low water content. Glycerin distillation is described in texts on the industry such as Bailey's.

Glycerin is generally contacted with an adsorption agent such as granular activated carbon and filtered before marketing. High grade glycerin for medicinal uses is a valued product.

Probably there are no kettle soap plants in the United States using the nigre, kettle bottoms, for glycerine recovery. I think, however, the technology is the same whether from a hydrolyzer (used in the newer plants for fatty acid splitting) or from the kettle.

When glycerine is recovered the waste picture changes markedly as the bulk of the organics are either recovered or produced as a water free still bottom. The latter is handled in the manner of waste material not as a wastewater. Again, the best help to the Tunisian industry could probably be obtained from a company recovering glycerine in the United States. The best contact should be the trade association:

Richard I. Sedlak, Jr. Technical Director
The Soap and Detergent Association
475 Park Avenue South
New York, New York 10016

A central operation for glycerin recovery might be the most appropriate system. The nigre would be shipped to the central location for distillation. An alternative would be for the crude distillation to be carried out at each plant and the final distillation at a central facility.

Likely the glycerin and lecithin constitute between 25 and 50 percent of the organics in the Slama wastewaters.

B. Control of Emissions and Odors

In the previous discussion of processes and emission sources, a description was given of the addition of a wet scrubber on the stack gases from the boiler and dryer in the olive seed operation. This should improve the past emission situation.

Slama voiced concern about odors. The cooling tower air stream of the deodorizer operation is probably one major source. Apparently, no odor control measures are being practiced at the present time. The only effective control that I know of is to replace the direct condensing system with a surface condenser and to route the water condensate to the sewer with little chance for air exposure. Plants in sensitive neighborhoods in the US have had to spend millions for such systems.

The second suspected odor source would be the vents from the soap kettles. Slama states that the temperatures of the liquids in the kettles is well below boiling so the odors may be negligible. If this is a significant source, the installation of adsorption systems on the stacks would be effective. A typical adsorption system would use activated carbon which would be changed periodically. The carbon could be incinerated or shipped back to the supplier or others for regeneration.

C. Ground Water Quality Protection

Protection of groundwater quality is of great importance in a country of low rainfall and limited water supplies. Areas of the land which contribute to groundwater of usable quality should be protected from pollution. There could be areas where saline or brackish groundwater is present or areas where there is no groundwater where such concerns are minimal.

Slama obtains their water supply from the utility serving the area. The use of groundwater or its quality beneath the plant is not known to this author. Slama has an underground tank of hexane. Although its volatilization would be likely, there is the possibility that the liquid could percolate through the soil to ground water. Explosions in wells have occurred as a result of explosive petroleum products in the ground water. Slama should have a long range objective of using a double wall underground tank, a tank in a vault or an insulated above ground tank so that leakage could be more effectively guarded against.

D. Land Treatment

Land treatment refers to spraying the wastewaters on soil at low rates of application (for instance a 1 centimeter depth per day on average over the total land used), and allowing bacteria in the soil to degrade the biodegradable organics. Land treatment of the reduced quantity of Slama wastewaters is a possible and likely economic solution. Locating this land for treatment on the outskirts of the developed area might or might not be possible. Preferably, the wastewater would be pumped to the site. If the practice of chemical

precipitation is maintained, land disposal of the slurry from the settling tanks would be an economic solution. The mineral content could be a problem, however. This would have to be investigated. If the land were located over brackish water, this problem would be eliminated.

E. Safety Considerations

Safety, referring to protecting personnel from unnecessary risk, is not the author's expertise.

Hexane, used in large quantities in the seed extraction process at Slama, is highly explosive. Slama is aware of this and has monitors in place as described in the section on waste sources. This program looks adequate and well managed.

There are two materials being handled or stored that warrant safety considerations for worker protection and environmental protection, namely, caustic and sulfuric acid. Only a small amount of sulfuric acid is stored and it is kept under lock. Plant management is aware of the hazards involved in these common materials. The tanks and areas where they are stored and used did not contain any warning or caution signs that the engineer noticed. A more formal safety program is recommended to include:

- labels on tanks containing the hazardous materials;
- exhibition of safety data sheets on the tanks or in the immediate area;
- records of employee training including, dates and type;

- elimination of any overhead piping of these materials where possible; and
- provision of secondary spill containment for storage tanks and unloading areas for these materials.

Boiler safety is an ancient practice. One boiler for steam generation is operated at this plant. Mechanical engineers who deal with boiler design and maintenance generally have knowledge of the safety measures. The art has progressed to the extent that these are text book matters. Safety valves for over-pressure, temperature controls, and fuel explosion protection are some of the requirements. Inspection of steam pipes in the boiler, etc. for impending fractures is a periodic safety measure typically taken. No attempt was made to review the practices at the company regarding the boiler safety. It suffices to call attention to the need, as Tunisian engineers are undoubtedly expert in this area.

F. Treatment of Slama Wastewaters with the Combined Wastewaters of the Community

The preceding discussion of pretreatment at Siama leads to the most important contribution the author can make to this program namely that pretreatment of wastewaters for removal of pollutants that can be satisfactorily handled in a community system is an ineffective way of operating both in terms of environmental control and economics. An approach which has predominantly been found to be of maximum societal benefit is to provide wastewater services for all members of the community: residential, commercial, and industrial. Of course, the community systems would accept only industrial wastewater with constituents and characteristics compatible with transport and treatment in their systems. The present regulations for industrial use in this area do not permit this approach to be applied, since,

they put strict limits on pollutants which can be adequately treated by the same processes that are used for residential wastewaters. For toxic pollutants, on the other hand, the limitations in present Tunisian regulation are commensurate with the treatment of combined wastewaters of the community and much like those imposed by agencies accepting all compatible constituents. This effort to serve all customers is called joint treatment -- indicating all users join in the effort. Industrial users properly consider the joint facilities as an extension of the manufacturing facilities and can be involved in the effective and economic operation to a degree, not dissimilar,to their concern in making a quality product.

Joint treatment is practiced by practically all local agencies in the United States. Each wastewater agency has appropriate sewer use regulations. The local regulations incorporate requirements imposed by the United States Environmental Protection Agency. Such regulations do not require the reduction in concentrations of compatible pollutants by pretreatment.

In the case of the edible oil industry and other manufacturers of food products and natural materials used in laundering of clothing, the products are contained in residential wastewaters. That is their route of use and disposal. The materials are necessarily compatible with the treatment of residential wastewater in community facilities. The same materials, as present in the manufacturing process wastewaters, are therefore compatible.

The quantity of these materials in the industrial wastewaters is a small percent of that normally found in the community wastewaters. The concentration discharged from any one source is not significant, in itself, but only as it contributes to the concentration at the treatment plant in conjunction with the other wastewaters. The total mass of materials from all users determines the concentration at the treatment plant. Thus, the contribution of a small volume of concentrated wastewaters will make an incremental addition of little consequence. In the case of Slama, the products involved are basically food products and not exotic organics.

In the normal practice of joint treatment, permits would be issued to each industrial user where the total quantity of each important material discharged would be registered. Thus, the treatment capacity provisions which must be included for each industry are known. For an industry to have high concentrations in its wastewaters is not an undesirable fact in itself. The important practice of conserving water will increase the concentration of constituents in an industry's wastewaters.

An approach which requires industry to install and operate costly and unrewarding pretreatment will require extensive policing of industry. The pretreatment equipment may be installed and demonstrated but not operated regularly. When pretreatment is difficult and costly, industry may choose to haul the wastewaters to a place of disposal. The hauler could very well make midnight dumps on beaches, beds of any wash, and remote places.

The costs of pretreatment will be much higher than the costs of treatment in the community system. The costs of a community system can be shared equitably among the users. The industry must provide its system with a means for measuring its wastewater volume and enough monitoring must be done to confirm wastewater concentrations so that a fair charge for its use of the community system can be made. The agency would be expected to confirm these by periodic checks. All costs of serving and policing industry would be borne by industry via service charges. Residential users need bear none of the industry generated costs. In fact, because the treatment plant for all the community members will be larger than one for the residential class alone, the scale factor will result in lower costs for all users including residential. The community facilities would also be operated by people with special training and experience.

The pretreatment of compatible pollutants will be difficult for Slama as chemical precipitation is complex and creates a sludge difficult to deal with economically. Many incidents of failure and misoperations will be encountered and the sludge disposal will probably be more of a problem to control agencies than the original wastewaters. The traffic and congestion caused by handling this sludge could itself be strong incentive to joint treatment. Biological treatment would be a more effective pretreatment option but such duplication (with community facilities) is poor economics in most situations. Only if inexpensive land-application treatment is possible could there by a close comparison to joint treatment.

The wastewater treatment processes that industry will likely install for compatible pollutants, if required, will produce volumes of sludge for disposal. Dewatering for disposal of a moist cake instead of a slurry may not be practical for them. Operating expenses for such equipment at small scale will likely be very costly compared to the alternative of joint treatment. In frustration, some industries may dump the liquid slurry on a backlot, dump it somewhere in dark hours, pile it up on the property, etc. Thus, an unsightly and odorous situation could result from the present approach.

In summary, the best approach allows a local agency to provide the treatment facilities and the experts to run them to the maximum extent possible. Such a system is less costly to everyone, more effective, much easier to manage and police, and the environmental impacts of misoperation will be minimized.

V. APPENDICES

APPENDIX A

Itinerary for Gerald N. McDermott

June 19-24, 1992: Conferred and observed, Etablissements Slama Frères

APPENDIX B

Organization Visited:	Etablissements Slama Frères
Personnel:	Taieb Ben Faleh, Directeur Technique
	Ali Mongi, Plant Engineer
	Lajili Noureddine, Engineer

APPENDIX C

Business Cards of Persons Contacted

مؤسسات سلامة إخوة
Etablissements Slama Frères

Taïeb BEN FALEH
Directeur Technique

OUED ELLIL 2021 - TUNISIE
TEL : 216.1. 535.064/164/359/317
TLX : 14.569 - FAX : 216.1.535.467

ETABLISSEMENTS SLAMA FRERES

Ali Mongi

LAJILI Noureddine

Oued Ellil - 2021 TUNISIE **Tél. : 535.064 - 535.164**
Télex : 14569 - Fax : 535.467 **535.359 - 535.317**

APPENDIX D

Excerpts from *Bailey's Industrial Oil and Fat Products*, Section on Wastewater Control and Treatment Methods, Gravity Settling. Edited by Daniel Swern, John Wiley and Sons.

Gravity Settling. The art and science of design of sedimentation and flotation facilities is found largely in engineering disciplines involving municipal wastewater and water supply treatment. A technical principle for design of sedimentation and flotation tanks has been in existence for decades. Chemical engineers have utilized sedimentation processes for liquid streams in chemical processes. The volume of such process material streams compared to water and wastewater treatment streams makes for great differences in sophistication of design. In chemical processing, many systems of feeding the inflow to a tank and taking out an effluent with settleable matter removed have been employed satisfactorily. However, more thought to scientific principles should be helpful in large flow rate situations.

The objectives of a gravity sedimentation or flotation facility is obviously to achieve a slow, smooth, tranquil, and uniform passage of the liquid stream horizontally from the inlet end to the effluent end. To achieve this ideally, the inflow would have to be distributed evenly over a cross section of the tank at the inlet and collected evenly across a cross section of the tank at the outlet. During the period when the water is moving through the tank, the oil particles that rise at sufficient velocity and are near enough the surface to reach it will be removed. Thus it appears that a shallow tank would be advantageous because an oil particle in a shallower tank would, on the average, have less distance to rise to the surface than in a deeper tank. On the other hand, for the same surface area, the deeper the tank, the longer the water would reside in the tank and hence the time available for a particle to reach the surface would be longer. A mathematical analysis shows that the theoretical removal should be independent of depth and be proportional to the surface area divided by the inflow rate. This criterion used in design is referred to as the *surface overflow rate* and is usually expressed as gallons per day per square foot. This parameter can also be expressed as a rise rate or settling rate such as feet per day. This parameter conforms to the theory that removal should be independent of depth. A shallow tank will thus have economic advantage. However, there is the obvious limit of keeping the velocity compatible with nonturbulent flow and low enough not to drag floating oil back into the current. Also depth is needed for oil accumulations at the surface and sludge on the bottom.

The concept of separation of an oil particle in a gravity-settling system may be applied to a test program to determine the time necessary for the oil particles to rise to the water surface. In the absence of reasons for expecting otherwise, the oil particles dispersed in water should be distributed uniformly from large particles that reach the surface rapidly,

down to very small particles that are subject to other actions and will not rise at appreciable rates. Theoretically, assuming a uniform distribution of particle sizes by weight and that the particles remain discrete, the removal per unit of time would be maximum at first and would drop off with time such that the removal per unit of time would soon be low. A removal time plot would theoretically be a curve of parabolic form. In laboratory tests, such removal phenomena data often fail to follow the theoretical curve closely. Tests to obtain such data are called column settling tests. The test is performed by first placing fresh oil-bearing wastewater samples in a column of about the depth to be used in the full scale settling system. Samples are collected from ports at several points in the column at selected intervals of time. The samples are analyzed for oil and a plot made of oil concentration versus time. From such a plot, a designer can theoretically choose a residence time for a wastewater flow in a settling tank that will achieve removal of the preponderance of floatable oil or some chosen portion so as to achieve all removal possible that it is cost-effective to remove.

As previously mentioned, work experience with wastewaters from edible-oil refining and soapmaking have generally not followed the theoretical prediction. The data typically show a rapid initial removal and very little additional removal after 15–30 min. A number of factors could contribute to the accuracy of the sampling and measurement as to make it difficult to predict plant performance accurately. These wastewaters are typically hot and inevitably there will arise strong convection currents in the test column. These will flow vertically down at the walls and up in the center and keep oil in suspension that otherwise might gravitate to the surface. Measures can be taken to avoid such convection currents, but in a practical sense they are unavoidable.

The employment of such a column test has been advocated for wastewater and water treatment plant design for several decades. In practice, useful data similar to the theoretical are seldom obtained. The test is more an exercise in the training of technicians and engineers than one of design utility. Thus use of such a sophisticated test to design a flotation system is not considered a worthwhile activity. To satisfy a logical need for evidence that a sedimentation system will remove a significant amount of floatable oil a simple bench top test using a beaker or graduated cylinder suffices. Accurate prediction of how much oil will be removed is difficult because if there is a layer or globs of free oil floating on the surface in the sewer, it is impossible to obtain a representative sample.

Thus in the absence of a technical basis for sizing a gravity settling facility, an alternative is to rely on past practices. An EPA-sponsored

survey of wastewaters of the edible-oil-refining industry reported that the design loads advocated by industry technicians were as follows:

Surface overflow rate	600 gal/(day · ft^2)
Residence time	60 min
Minimum liquid depth	5 ft

Such a system meets in a practical degree an objective of an effective size of facility; a slightly larger facility would cost more than the additional removal would be worth. Nevertheless, some plants employ gravity separation tanks with residence times of 6 or 12 hours. The incremental additional removal accomplished by the larger facilities are relatively small; therefore, costs per unit are high.

The details of the design of oil separation facilities are theoretically important. However, tests for floatable oil remaining in the effluents of a variety of odd and incongruous designs seldom have revealed a significant concentration of oil escaping. This is attributed to the fact that a liberal theoretical residence time was present in the systems tested. With liberal residence time involved, poor performance has been rare.

Ideal design achieves distribution of the flow coming in, which is typically in a pipe of 12-in diameter or less, evenly over a cross section of a tank typically 50 ft^2 or more. (Here the discussion involves a rectangular sedimentation tank; circular tanks are discussed subsequently.) Traditionally in large settling tanks of municipal sewage systems a number of ports or slots and a baffle ahead of the ports or slots is the practice for distributing the inflow. Such an adoption to a small tank may consist of a small baffle immediately in front of the inlet pipe. With floating oil in the system, it is important that the inlet pipe does not enter below the water surface because oil will accumulate in the pipe upstream wherever the free surface is and may congeal in the sewer and plug it. Also, the pipe should not come in above the water surface because the plunging water plume will cause currents in the tank.

Complex devices to achieve the distribution have been used. A circular baffle with a curved surface just ahead of the inlet directing the inlet velocity back against the wall is on the market. The American Petroleum Institute recommends a design of vertical slots spaced across the tank width. This design is difficult to adopt to the smaller tanks for the smaller flows of the edible-oil refinery and other industries involved. The most definitive work on inlet devices was reported by Mau (1). His laboratory investigations showed that to achieve even distribution across a tank section, the slots in a distribution device must be sufficiently narrow to

cause a significant difference in the water surface level upstream and downstream of the slots. However, with such design he found that the velocity of water through the slots was such that the jets extended well into the downstream tank and caused undesirable mixing.

This jet problem was overcome by placing target baffles a few inches downstream of the slots. Also, with the use of the target baffles a lesser velocity in the slots did not sacrifice much in the distribution pattern. Larger openings corresponding to lower velocities are better because of lessened potential for plugging.

Designers have also used a distribution device consisting of a wall across the entire tank, just downstream of the entrance, in which many small holes, say, 1-in diameter, are spaced. Slots are much easier to clean in place than holes. The placing of target baffles opposite each hole such as with the slots discussed previously would be possible but would entail an expensive design.

At the downstream end of the tank there is a need to collect the flow uniformly over the cross section. The usual arrangement is a baffle extending below the water surface to hold the oil layer and following this, an overflow weir. Flow is under the baffle and up over the weir. This flow pattern leaves opportunity for some stagnant areas of the tank. Mau (1) found these in his observations and suggested the use of a wall with slots spaced in it to achieve the full cross-sectional distribution at the outlet as is achieved at the inlet. This eliminates the need of an underflow baffle and overflow weir if a submerged pipe outlet is used. Theoretically, such a design would enable a smaller tank to do the job.

Circular sedimentation tanks are the most popular form for sewage treatment because they are more economical to construct. The most common flow pattern is from a distribution chamber, located in the center, radially to an overflow weir around the periphery of the tank. Floating scum is captured behind a baffle slightly interior of the weir. Many designs of circular tanks with different flow patterns exist, including peripheral feed and central weir, peripheral feed at low depth with a peripheral weir also, and spiral flow from wall to center. The technical considerations are basically the same as described for a rectangular tank. Some circular tanks are in use in the industries involved in this discussion. Commercial units of circular form and of rectangular form are available.

An important adjunct to the system is a means of removing the oil layer accumulating on the surface. The most sophisticated system is a continuous mechanical collector. For a rectangular tank, such a commercial device uses shallow moving collecting baffles extending a couple of inches or so below the water surface. These are mounted on endless chains and are moved slowly along the tank. At the end of the tank the baffle enters

a wide trough with the floor sloping upward and ending a few inc above the high water surface. The oil trapped in this trough behin collecting baffle is pushed up the trough as the baffle moves throug and the oil falls into a sump. This system operates satisfactorily in so applications. If the oil is very thin (nonviscous), there is difficulty in seal between the moving baffle and the trough. These devices are a expensive, in the order of $25,000 installed. Such a device for a circu tank consists of a moving baffle at the end of a rotating arm pivotec the center. The collecting baffle extends from the peripheral baffle inw just a few feet.

An alternative to the continuous mechanical skimmer is a station collector. The more sophisticated form is a cylinder about 12 in. in ameter and positioned across the water surface and mounted at the e in slip bearings. The pipe has a slot cut in it lengthwise. The pipe equipped with a means of rotating it so that the slot may be positio at any elevation desired. The slot is left at the top normally. When i desired to skim oil, the pipe is turned until the slot is below the oil surfa The oil flows into the pipe and to a sump at the end. This device enab taking a thin layer the full length of the slot so that the trap can skimmed quickly.

The simplest skimmer is a pipe system with swing connections. It m be fitted with a funnel inlet. The end of the pipe is raised or lowered a hand-cranked ratcheted axle and cable or chain.

Within the last 10 years skimming devices have come on the marl that make use of the property of some plastic surfaces for having affinity for oil in preference to water. A belt or a hose of such mate is drawn through the oil layer on the basin. The adhering oil is wiped at a point above and flows to collectors. One advantage is that the removed is relatively free of water. Some such devices have experienc plugging problems from pieces of plastic trash floating in the water. T device is not operable when not kept at temperatures that prevent c gealing. Stationary baffles in tanks and use of multiple tanks in series a to the skimming work because of the need to skim at several points.

The collection of the oil is not possible unless it remains fluid. In seve climates the oil will congeal on the surface. This may happen only f lowing plant shutdowns as on weekends. Discharge of live steam direc in the tank to liquefy the congealed material will disturb the flow a cause loss of oil. To overcome this, a system of heating pipes placed ju below the surface can be used. Steam or hot water in the pipes will ke the oil liquid. The convection currents from such practices are limit because the high-temperature material tends to stay where it is create

that is, on top. Heating has also been practiced by providing a cover for the tank and admitting steam to the air space.

The accumulations at the surface in a gravity flotation tank will commonly consist of an oil layer or an oil-and-fatty-acid layer and a second layer of water-in-oil emulsion—typically about 10–30% oil. The emulsion layer may be skimmed with the oil or the emulsion layer may be left for a suitable time to break the emulsion and release the oil.

Usually some water is drawn with the oil or oil-and-emulsion skimmings. The mix of skimmings is pumped to an accumulation tank, where the emulsions are broken by the use of heat. The operation and decanting steps may be automatic or by hand. The pumping of the skimmings must be with pumps that do not create emulsions.

In gravity flotation system design and operation, thought has to be given to any problems from settleable matter accumulating in the tank. A representative plant has a minimum of such materials in the wastewaters. Such matter is usually limited to a little decolorizing clay and perhaps some bean fragments in the raw oil. Of course, the settling tank can be equipped with mechanical devices for continuous or frequent removal of the contaminant. In plants of the industries involved here this is rarely needed. The material that settles out is suitable for transport and treatment in municipal systems. Thus contaminated material can be drawn from the tank to the downstream sewer periodically if the quantity involved does not cause a slug load at the municipal plant. If the economics favor disposal in the manner of a solid waste, this may be the method of choice. Of importance is that the sludge not be allowed to accumulate to such extent that it occupies so much of the volume of the tank as to cause poor efficiency of the system in removing oil. There is a human tendency to allow a layer of oil, emulsion and sludge to accumulate so that the system is not as effective as it could be.

The effectiveness of gravity-settling systems is significantly improved in typical cases if the wastewaters are highly acidified. A pH of about 2 is most effective. The acid conditions break emulsions and also convert fatty acid soaps to free fatty acids that are insoluble and will float. Such acid conditions can be maintained in some plants if wastes from the acidulation process are continuously discharged to the sewers without neutralization. The acid has to be neutralized, of course, downstream from the settling tank before discharge.

This leads to a caution about materials of construction of gravity-settling tanks and sewers leading to them. Typically, the wastewaters of the plants involved contain sufficient concentrations of fatty acids that they cause disintegration of common concrete in time. Disintegration of the concrete

is not corrosion because of acidity, but a property of fatty acids. Therefore, unprotected concrete tanks, concrete sewers, and manholes are not recommended. This is particularly true if the acidic conditions recommended in the previous paragraph are utilized. Tanks of stainless steel and of reinforced fiberglass have been employed. Also, concrete tanks have been provided with troweled-on liners.

Logic would indicate that pumping wastewaters to such a settling system can lower removal effectiveness by emulsifying oil as a result of the shearing action of the pump. For this reason, construction of the tank in the ground so that flow to it is by gravity is recommended. If economics dictate pumping, pumps can be selected with low peripheral speeds so as to minimize emulsification.

In some circumstances there may be an advantage in improved flotation effectiveness if continuous or frequent removal of the oil as it accumulates is practiced. If there are periodic losses of highly alkaline wastes or wastes containing emulsifiers, an accumulated oil layer can be emulsified and pass out in the effluent. In the absence of such events, the accumulation of a depth of oil and its automatic collection by an overflow set at a selected elevation are possible.

Before leaving the subject of gravity flotation, it is of interest to mention European design of such systems. European practice and even recent European literature describes practices in which three circular tanks are used in series. Inlets are baffled and outlets are from below the surface via elbows or tees. Such a design would be similar to a rectangular basin which was compartmentalized by baffles. Such baffles add to dead fun-

Professional Resume

GERALD N. McDERMOTT, P.E.

Principal
Environmental Engineer

Years Experience: 40+

Education:

Massachusetts Institute of Technology, Sanitary Engineer
Harvard University, S.M., Sanitary Engineering
University of Wyoming, B.S., Civil Engineering

Experience:

- Mr. McDermott was a member of the Commissioned Corps of the United States Public Health Service and has assigned his entire public career to the Water Pollution Control Research division in Cincinnati, Ohio. He was instrumental in industrial waste studies that developed guides to water pollution control for several major industrial categories. He participated in several field studies of water quality including the Ohio, the Pearl, the South Platte, the Yellowstone, and other rivers.

  During this work, he was the first to measure and report the quantity and characteristics of municipal landfill drainage; the first to employ bioassays in industrial waste source surveys for identification of toxic streams; and the first to investigate the use of clays for the removal of trace levels of oil and other organics. He supervised an exhaustive investigation of the tolerance level of heavy metals in biological treatment.

  He served as Chief of Process Development, Advanced Waste Treatment Program for the Public Health Service. He supervised field application of activated carbon adsorption, integrated biological chemical treatment, foam separation, reverse osmosis, algae harvesting, powdered activated carbon treatment of wastewaters, and supervised research on use of the Total Organic Carbon measurement and the dissolved oxygen monitoring for control of an activated sludge plant.

- During his employment with Procter & Gamble Company, he first served as group leader and then as Wastewater Technology Leader. He provided design and engineering service in the treatment of wastewaters for direct discharge. These facilities included activated sludge treatment, aerated lagoon treatment in the largest such facility in the world, the largest land application system in the citrus industry, reverse osmosis treatment of food oil refining wastewaters, and granular activated carbon treatment of sulfation wastewaters of a chemical plant.

  As a technology leader, his assignment included keeping abreast of all developments in wastewater treatment technology. He did this by studying the current literature, by site visits to new process installations, and attending technical sessions of various organizations.

  He also supervised research conducted by consultants and university researchers for P&G and was acquainted with most of the leaders in such work. He was particularly active in maintaining relationships with the municipalities which received P&G wastewaters and was called upon to help solve technical and financial problems of the plants and agencies.

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Professional Affiliations:

American Academy of Environmental Engineers
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Registrations:

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