NATSURV 6

WATER AND WASTE-WATER MANAGEMENT IN THE EDIBLE OIL INDUSTRY

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By

STEFFEN, ROBERTSON & KIRSTEN INC
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	neutralisation of **free fatty acids** in crude oil. See also **saponification**.
SOAPY WATER	Aqueous effluent produced from washing neutralised oil after **soapstock** has been separated off.
SPECIFIC EFFLUENT VOLUME	The effluent volume for a particular period divided by the product volume for the same period.
SPECIFIC POLLUTION LOAD	The mass of given pollutant for a particular period divided by the product volume for the same period.
SPECIFIC WATER INTAKE	The water intake for a particular period divided by the product volume for the same period.
TRIGLYCERIDE	An **ester** of **glycerol** in which each **glycerol** molecule is combined with three **fatty acid** molecules. See also **glyceride**.
VOTATOR	Trade name for a scrape surface heat exchanger, used in the manufacture of margarine and cooking fat.
WAX	Simple **lipids** consisting of **esters** of longer chain (higher) **fatty acids** than are usually found in **fats** and **oils**.
WINTERISING	A process to remove high melting point **waxes** from oil by chilling and filtering out the resulting crystals, preventing clouding of salad oils at low temperatures.

	removed. Its major components are proteins and **lipids**.
MISCELLA	The oil-solvent mixture produced in the solvent extraction of vegetable oil from seed.
OILS	Simple **lipids** consisting of a mixture of various **glycerides** of **fatty acids**; sometimes distinguished from **fats** by virtue of being liquid at room temperature.
OLEIC ACID	The most commonly found monounsaturated **fatty acid** occurring in vegetable oils $C_{17}H_{33}COOH$. See also **linoleic acid**.
PACKING	In the context of edible oil processing, this term covers the preparation of the product as well as its final packaging.
PHOSPHOLIPID	Complex **lipids** that contain phosphoric acid **(PHOSPHATIDE)** groups and nitrogenous bases. See also **lecithin**.
PHYSICAL REFINING	An alternative to **alkali refining**, in which **free fatty acid** as well as odours are removed by steam stripping, only applicable to certain crude oils.
SAPONIFICATION	The conversion of **fatty acids** to their sodium salts (soap) by hydrolysis with caustic soda.
SOAP SPLITTING	The recovery of **free fatty acids** from **soapstock** by the addition of a strong mineral acid.
SOAPSTOCK	The aqueous soap phase produced on the

	oil during refining.
HARDENED OIL	Oil whose melting point has been raised by **hydrogenation** of the **unsaturated fatty acid** chain.
HOT WELL	In the context of edible oil refining, a tank into which the **barometric legs** from evacuated vessels discharge. Direct contact cooling water and condensed distillate is collected in the hot well, passed over cooling towers and recycled.
HULL (HUSK)	External covering of oil seeds usually partially removed prior to oil extraction.
HYDROGENATION	The addition of hydrogen, as a gas, in the presence of a catalyst (usually nickel) to the **unsaturated** constituents of an oil to produce more highly or completely **saturated triglycerides**.
LECITHIN	A group of yellow-brown **phospholipids** consisting of substituted **glycerides**, a major component of gums can be used as an emulsifier.
LIPID	A generic term for fatty material, subdivided into simple lipids (which include **fats, oils** and **waxes**) and complex lipids (which include **phospholipids**).
LINOLEIC ACID	The most commonly found **polyunsaturated fatty acid** occurring in vegetable oils: $C_{17}H_{31}COOH$. See also **oleic acid**.
MEAT	The oil-bearing portion of a seed revealed once the **hull** and **husk** have been

	expelling by solvent extraction - usually with hexane.
FATS	Simple **lipids** consisting of a mixture of various **glycerides** of **fatty acids**; distinguished from **oils** by virtue of having a melting point greater than 20°C. Loosely distinguished from oils by being (semi) solid at room temperature.
FATTY ACIDS	A group of **saturated** and **unsaturated** monobasic organic acids having the general formula R.COOH. Those appearing in vegetable oil are most commonly linoleic ($C_{17}H_{31}COOH$) and oleic ($C_{17}H_{33}COOH$) acids, while marine oils may have longer chain fatty acids ($C_{20}+$).
FILTER AID	Diatomaceous earth added to oil at the **winterising** stage to facilitate subsequent filtration and removal of crystallised **waxes**.
FREE FATTY ACIDS	**Fatty acids** which have been cleaved from the **triglyceride** by natural degradation and hydrolysis during processing of the oil. Usually abbreviated to FFA.
GLYCERIDE	An **ester** of **glycerol** with an organic acid. Edible oils are primarily composed of **triglycerides** of **fatty acids**.
GOSSYPOL	A toxic compound present in cottonseeds. Largely retained in the meal but also responsible for the deep red-black colour of cottonseed oil.
GUMS	A collective term referring to **phosphatides**, sugars, resins and proteinaceous materials which are removed from crude vegetable

CHEMICAL REFINING	Classic method for refining crude or degummed oil, in which caustic soda is used to neutralise **free fatty acids** which are then removed as **soapstock**. Neutralised oil is then subjected to further refining steps.
CHLOROPHYLLS	A group of yellow-green pigments partially responsible for the colouration of crude oil. See also **carotenes**.
DECORTICATION	The removal of **husks** and **hulls** from oil seed to expose the **meats** (kernels).
DEFATTED MEAL	**Meats** from which the oil content has been extracted.
DOWTHERM	Trade name for a thermal fluid which vaporises on heating and yields its latent heat to oil being processed. Sometimes used in preference to steam in deodorisers and steam strippers since superheated or high pressure steam would be necessary to achieve the required temperatures.
EMULSIFIER	A substance which forms or stabilises an emulsion of finely dispersed water in oil.
ESTER	An organic compound consisting of two alkyl groups joined by an OCO group, i.e. R.OCO.R. Vegetable oils are predominantly composed of **esters** of glycerol with **fatty acids**.
EXOTHERMIC PROCESS	A process in which heat is released, e.g. **hydrogenation**.
EXPELLING	Partial removal of oil from meats usually by means of screw expellors.
EXTRACTION (SOLVENT)	The removal of the residual oil left after

GLOSSARY

ACID OIL	A mixture of **fatty acids** recovered from **soapstock** by the addition of a strong acid.
ACID OIL FACTOR	Measure of efficiency of the refining process defined as the percentage of **acid oil** by-product resulting from the neutralisation step divided by the percentage **free fatty acid** in the crude oil. See also **soap splitting**.
ACIDULATION	See **soap splitting**.
AUTOCLAVE	A pressure vessel in which a product is subjected to elevated temperature and pressure.
BAROMETRIC LEG	A system of pipework allowing removal of distillate from an evacuated vessel without ingress of unwanted material; effected by pipework from the vessel discharging below the surface of a **hot well** situated approximately 10 m below, corresponding to the atmospheric head of water.
BLEACHING CLAY	(Also known as bleaching earth) A clay used for the removal of pigment and other substances from oil in the bleaching stage of refining.
CAROTENES	A group of orange-red hydrocarbons partially responsible for the colouration of crude oil. See also **chlorophyll**.

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SUMMARY

There are 16 edible oil processing plants in South Africa, producing approximately 250 000 t of edible oil annually. The industry consumes approximately 1,5 million cubic metres of water each year.

Specific water intakes (SWI) were found to range between 2,1 and 3,1 m^3/t for milling and 3,2 and 4,6 m^3/t for refining. Improvements in SWI can be achieved by improved water management. Target SWI figures of 2,0 m^3/t for milling and 3,0 m^3/t for refining are proposed. A target of 5,0 m^3/t for a plant milling and refining all product oil on-site is proposed.

Specific pollution loads (SPL) were found to range between 4,3 and 13,8 kg of COD/t oil, and 10,1 and 24,8 kg TDS/t oil. Targets of 7 kg COD/t oil, and 12 kg TDS/t oil would seem to be reasonably achievable by the industry. Again these targets apply to a plant milling and refining all product oil on-site.

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FOREWORD

The need for guidelines to reduce water intake and waste-water disposal by industry is of national concern in view of South Africa's water scarcity.

To establish norms for water intake and waste-water disposal, the Water Research Commission (WRC) in collaboration with the Department of Water Affairs (DWA) contracted Steffen, Robertson and Kirsten, a firm of consulting engineers, to undertake a National Industrial Water and Waste-water Survey (NATSURV) of all classes of industry.

The consultants identified 75 industrial groupings in South Africa, one of which is the edible oil industry. The results obtained in the survey of the edible oil industry form the basis of this guide on **Water and Waste-water Management in the Edible Oil Industry**.

It is expected that this Guide will be of value to the industry itself and to other interested parties such as municipalities, administrators, researchers and consultants in the water and effluent fields.

ABBREVIATIONS

AOF - Acid oil factor

CIP - Cleaning-in-place

COD - Chemical oxygen demand

DAF - Dissolved air flotation

FFA - Free fatty acids

OA - Oxygen absorbed

SEV - Specific effluent volume

SOG - Soaps, oils, greases

SPL - Specific pollution load

SS - Suspended solids

SWI - Specific water intake

TDS - Total dissolved solids

1 INTRODUCTION

The edible oil industry consumes approximately 1,75 million m^3 of water each year. The total quantity of oil refined in South Africa has remained relatively constant over the last few years, at approximately 250 000 t/a but is expected to increase by about 3% per annum over the next few years. Good maize crops and a record oil seed production of 982 000 t enabled the industry to produce a record 275 000 t of oil in 1981.[8] The continuing drought since that year, however, has resulted in a dramatic decline in locally produced oil, and in the year 1985/86 only about 150 000 t of oil was produced from local raw material. The balance of approximately 100 000 t oil was imported, mostly in crude form, to be refined in South African refineries. Since then improved rains have led to an increase in the proportion of locally produced oil with production for the 1988-89 season being about 240 000 t/a, of which 30 000 to 35 000 t/a was imported.

There are two clearly defined stages in the production of refined vegetable oil - crude oil production conducted in an oil mill, and oil processing conducted in a refinery. In South Africa the two stages of the process are usually conducted on the same site although marine oils and animal fats, where used , are purchased as such.

An oil plant typically discharges about 35% of the incoming water to sewer. The remaining 65% is either vapourised in the many cooling circuits, or else leaves the site in one of a number of secondary products and by-products. The effluent that is discharged to sewer will contain quantities of fat, oil, sodium, sulphates, phosphates and other pollutants. The effluent thus has a high inorganic as well as a high organic loading. Municipal treatment works have to treat the majority of this effluent.

There are 16 edible oil plants in South Africa, run by a total of 10 separate groups. This guide presents data collected from eleven oil plants and concludes with several recommendations aimed at reducing both water usage by and pollution load from an oil processing plant.

2 PROCESS RÉSUMÉ

2.1 Background

The principal product of an edible oil refinery is liquid oil which may be sold as cooking or salad oil or may be further processed to increase the market value of the product. Common examples of this are the manufacture of margarine, cooking and bakers' fat, peanut butter and mayonnaise.

Vegetable oil may be obtained from a wide variety of seeds, including cotton seed, soya bean, peanuts, sunflower seed, maize, rice bran, palm kernels, linseed, olives and coconut. The varying climatic conditions found around the world favour the cultivation of different oil bearing seed and as a result of this, the seed from which oil is extracted varies with geographic location. North America's primary oil seed crops are cotton seed and soya bean, whilst the Far East's oil is extracted primarily from palm, palm kernel and coconut sources. In South Africa the most commonly grown oil bearing crops are sunflower, groundnut and maize, although other seeds, such as cotton and soya, are also processed. In addition to these vegetable oils, a large quantity of both locally-produced and imported fish oil and some animal fat is also refined.

The situation is further complicated by the fact that different hybrids of a particular oil seed thrive in different parts of the world. Thus, sunflower seed from North America may require different processing steps than locally harvested sunflower seed. The drought which South Africa has experienced over the last few years has meant that insufficient seed has been available locally to meet oil demands, and the shortfall has had to be made up with imports from elsewhere around the world. These imports may be in the form of seed or more usually unrefined or semi-refined (degummed and neutralised) oil. Recent better rains have, however, meant that a much larger proportion of the oil produced in South Africa has been derived from local seed. For the 1988-89 season only about 15% of the oil produced has been derived from imported, unrefined or semi-refined oil, compared to 26% in 1986.

Another important factor to consider is that the edible oil industry in South Africa utilises only about 65% of its processing capacity at present. This has an important bearing on the efficiency of water use by the industry as will be discussed later.

There are two distinct stages involved in the production of vegetable oil: separation of the oil from the oil-bearing seed and subsequent refining of this oil. Although final product oil from each of the many sources has similar properties, each seed type has process requirements peculiar to itself. The fundamental unit processes in the recovery of the oil and its subsequent refining are, however, similar for each oil type. These unit processes are described below and attention is drawn to the various individual requirements of each oil type.

2.2 Crude oil production

2.2.1 Seed preparation

When seed arrives at an oil mill, the first operation is the removal of all foreign matter, such as sticks, stones and metal articles. This is usually achieved by the use of magnets, bar screens, sieves and air separators. The cleaned seed is now ready for the next process stage.

2.2.2 Sunflower and soya

These seeds are first decorticated after which the meats are separated from the hulls using vibratory screens and air lifts. The hulls are removed to ensure that the protein content of the resulting meal meets prescribed standards.

The separated meats, made up of small, tough walled cells containing the oil, may be rolled into thin flakes to make them more permeable to steam in the ensuing cooking step. Here the flakes are subjected to live steam and brought up to a predetermined optimum temperature and moisture content. Conditioned seed from the cookers is passed to screw presses (expellors) where about 75% of the oil is squeezed from the flakes.

small fraction of this expelled oil, containing fines, may be mixed with the incoming conditioned meats, whilst the remainder is filtered and sent to storage.

The expelled meat or cake still contains approximately 25% of its oil content, and this is extracted using a solvent extraction process. The cake is washed with hexane leaving about 1% oil in the final meal. This is usually effected using a counter-current system in which an oil rich miscella is contacted with fresh oil cake, whilst fresh hexane contacts with outgoing cake. The discharged cake loses about 95% of its entrained hexane in a vapour desolventiser and the remainder of the solvent is removed from the cake using live steam injection. The vapours flow to scrubbers where entrained fines are removed and recycled to the extractor. Solvent-free meal is removed and cooled.

Miscella from the extractor is pumped to a rising film evaporator for primary separation of oil and solvent. The enriched miscella from the evaporator now flows to a steam-heated oil stripper where hexane is recovered from the oil with live superheated steam. The recovered oil is cooled and pumped to storage.

The evaporator and oil stripper are both equipped with condensers that liquify the solvent vapours. Hexane leaving the stripper condenser contains water that was injected as live steam into the stripper; this stream goes to a water separator where make-up hexane is added. Vapours from the evaporator condenser, the desolventiser condenser and the separating tank go to a common vent condenser where they are cooled with water. To prevent hexane losses, gases from the vent condenser are washed with mineral oil in an absorber. Water vapour and non-condensables are vented to atmosphere from this vessel and the rich mineral oil is pumped to a stripper where hexane is flashed, condensed and recycled.

2.2.3 Maize germ

In the extraction of oil from maize germ, the expelling stage associated with high oil content seeds such as sunflower is not always used. Instead, conditioned germ is fed directly to a solvent extraction plant.

2.2.4 Cotton seed

The preparation of cotton seed prior to oil extraction is more difficult than for the seeds mentioned above, since the remaining cotton lint must first be removed from the seeds before conditioning can take place. Once this step has been performed, however, the oil is extracted in a very similar manner to that described for sunflower and soya.

2.2.5 Developments

Innovations are constantly implemented in this industry, and one of the more recent of these is direct expelling of non-conditioned seed. Screw presses are now available which develop sufficient heat through friction to effectively condition the seed and expel the oil in a single unit process.

2.3 Oil processing

The crude oil is composed largely of glycerides of various saturated and unsaturated fatty acids, notably oleic and linoleic acids. There are, however, a number of impurities which must be removed from the oil before it can be considered fit for human consumption. These impurities vary according to the particular type of oil, the geographic location of the source, the season, the way in which the oil has been stored and prepared and the manner in which the oil has been extracted. These impurities can be classified into four broad categories.

(a) **Gums**

A collective term referring to phosphatides, sugars, resins and other proteinaceous material. The gum content of sunflower, maize and soya is of the order of 2%, while cotton seed can be even higher.[10,12]

(b) **Free fatty acids**

These can occur in extremely high quantities (as high as 40% sometimes) but usually range between 0,5% and 8%, depending on the oil type.[10]

(c) **Pigment**

Usually of chlorophyllic or carotenic base. Cotton oil in particular has a deep red-black colouration associated with gossypol.

(d) **Taste and odour**

Chiefly a result of volatile aldehydes and ketones.

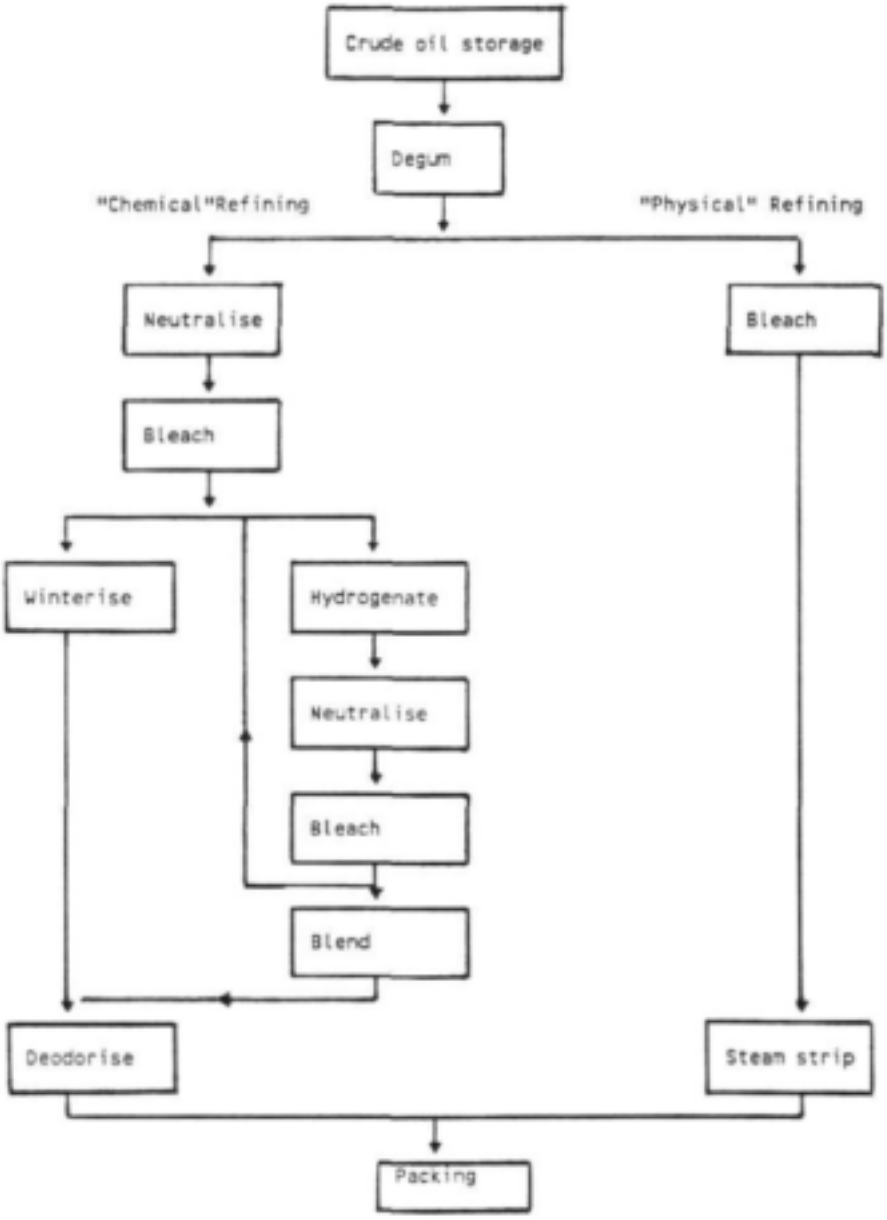
Crude oil is refined to remove this objectionable content. There are two approaches to refining and both are in wide commercial use. The classic method of refining a crude oil is neutralisation with caustic soda followed by bleaching and deodorising of the neutralised oil. Study of the deodorising step in this "chemical" method led to the introduction of what is known as "physical" refining.

Attention has already been drawn to the fact that the constituents and properties of oils depend upon their source. These differences in composition necessitate the use of slightly different processing techniques. Nonetheless, the stages in the two principal methods of oil refining are illustrated in Figure 1. The essential operating features of each of these stages is described briefly below.

2.3.1 Crude oil storage

Refining can be said to start in the crude oil storage tank, since oil-insoluble matter separates here by gravity. Semi-solid oils are maintained at slightly elevated temperatures.

Figure 1 Edible oil processing



2.3.2 Degumming

Gums may be broadly separated into hydratable and non-hydratable types. Their removal is important on at least three counts:

(a) their emulsifying properties, which increase losses during chemical refining;

(b) their tendency, on heating to deodorising temperatures, to impart deep brown colouring to finished oil; and

(c) their tendency to form complex compounds with certain trace metals which adversely affect product stability.

Hydratable gums (usually amounting to between 60 and 75% of the total gum content) are comparatively simply removed by the addition of hot water and subsequent separation of the swollen, insoluble gums in centrifuge equipment.[10,12] Removal of non-hydratable gums requires prior treatment with phosphoric or citric acid to render them hydratable.[9,14] The subsequent removal of the now hydrated gums may either be achieved by the addition of a small amount of water followed by centrifugation or by use of an activated absorbent coupled with a filter. Many variations on this two stage process are used, including combining the two operations into one.

2.4 Chemical refining

2.4.1 Neutralisation

As mentioned above, crude oil naturally contains a percentage of free fatty acids (FFA) - carboxylic acids which have been separated by natural degradation from the triglycerides. In the chemical refining process these acids are neutralised by the addition of caustic soda. Caustic soda up to 4N strength[16] is intimately mixed with the oil at a predetermined optimum temperature in either batch, semi-continuous or continuous equipment. A strong caustic solution such as is used in this step will tend to saponify the neutral triglycerides with consequent loss of neutral oil, and thus careful control of the operating conditions is required. Certain oils are particularly susceptible to saponification, and in these cases a more dilute caustic solution is used.

Besides saponifying the FFA in the crude oil, the addition of caustic provides a much more effective hydration of gums than the simple addition of water. It is therefore sometimes possible to dispense with a separate degumming step for oils with low gum contents. To a certain extent caustic will also affect pigments and this provides a valuable method of recovering poorer quality and more highly coloured oils, such as cottonseed oil.

In continuous and semi-continuous equipment the immiscible soap (termed "soapstock") produced upon neutralisation is separated from the neutralised oil using centrifuges. In batch operation, gravitational settling and subsequent separation is used. Soapstock is usually further treated on-site to produce acid oil.

2.4.2 Bleaching

In addition to colour removal, bleaching acts as a further "purification" step in the refining process.

This step in the refining process is conducted under vacuum at raised temperatures and may again be performed in batch, semi-continuous or continuous equipment. Bleaching clay (up to 2% by weight) is introduced, the clay/oil mix agitated, and filtered.[13,14,16] Sometimes the clay is added in two stages: an unactivated clay first absorbs soap while a more expensive activated clay absorbs trace metals, pigments and various oxidation products which would otherwise cause severely reduced product life.

2.4.3 Hydrogenation

Oil which is intended for use in margarine and other similar products must be hydrogenated: this produces fats with superior keeping qualities as well as higher melting points.

The process consists of dispersing hydrogen gas in oil in the presence of a catalyst. The catalyst most widely used is finely divided nickel supported on a diatomaceous earth. In order to prevent poisoning of this catalyst, oil to be hydrogenated must first be neutralised and bleached, ensuring the oil is dry and clean.

In the reaction, hydrogen is added at the points of unsaturation in the fatty acid chain. Naturally occurring oils contain fatty acids having up to six double bonds in the chain: hydrogenation attempts to saturate these selectively, reducing the six double bonds to five, the five to four, and so on.

Although some continuous plants are in use, most hydrogenation is carried out in batch equipment. An evacuated autoclave is charged with oil and heated to the required temperature. Catalyst is added and hydrogen is fed to the reactor where it is continuously mixed with the circulating oil. Hydrogenation is an exothermic reaction. If the temperature were to be allowed to rise uncontrolled the oil would undergo undesirable side reactions; consequently the temperature is controlled using cooling circuits. When hydrogenation has proceeded to the desired end point, the oil is cooled from the reaction temperature of approximately 185°C and is filtered to separate the catalyst from the product.

When hardened oil is produced in this manner, the oil suffers an increase in free fatty acid content which must again be reduced. In addition, filtration is not able to eliminate completely all traces of nickel from the hydrogenated oil. Both of these impurities are usually removed by a subsequent caustic neutralisation/bleach step, known as "post-neutralising" and "post-bleach". Hydrogenation also imports a characteristic flavouring to the product, so that hardened or hydrogenated oil must be deodorised in the same way as other oil.

2.4.4 Winterising

Certain vegetable oils, including sunflower and maize, contain wax from the seed shell or husk, and this causes an undesirable cloudy appearance at lower temperatures, when they begin to crystallise. Typically, wax content varies between 200 and 2 000 mg/kg, and this must be reduced to 10 mg/kg if adequate cold stability is to be obtained.[12] This reduction is effected by careful cooling of the oil to approximately 5°C, followed by filtration to remove the crystallised wax. This process, known as winterising, is usually only performed on oil which is to be marketed as such. It is not necessary to winterise oil which is to be hydrogenated. After winterising the oil is usually deodorised.

2.4.5 Deodorising

All refined and bleached oil goes through a deodorisation step, although oil intended for use in margarine is hydrogenated first and other oil may be winterised beforehand if necessary.

Basically, the deodorisation process involves steam distillation under vacuum. Its purpose is to remove, so far as is possible, residual free fatty acids, aldehydes and ketones (which are responsible for unacceptable odours and flavours) and decolourising final oil by thermal decomposition of the pigments. The decomposition products from the pigments are subsequently distilled off.

Once again batch, semi-continuous or continuous plant may be employed, each having its own advantages under particular circumstances. In a typical semi-continuous deodorising unit, partially heated oil is fed to a top tray or tank where air and other volatile materials are released from the oil under full vacuum. In a second tank an indirect heat exchange medium, such as Dowtherm, is used to heat the oil to the operating temperature of between 180°C and 250°C before the bulk of the total of 4% open steam is injected for deodorisation.[7,15,16] The deodorised oil is now cooled in lower tanks before being pumped to storage. Small quantities of citric acid may be injected during the cooling stages to retard oxidation of the oil.[7,16]

2.5 Physical refining

In the deodorisation process open steam, heat and very low pressure are used to remove small quantities (approximately 0,15%) of fatty acids and other impurities from the oil. The basis of physical refining (or steam stripping) is the use of deodorisers for the steam distillation of all the free fatty acids as well as odoriferous volatiles without a prior neutralising stage. The physical refining technique has two primary advantages over the conventional caustic refining route: reduction in oil loss and the elimination of soapstock and its associated effluent treatment problem.

As was mentioned in the description of the caustic refining neutralisation step, quantities of neutral oil are saponified together with the free fatty acids. This saponified oil is then separated with the soapstock and forms a significant loss of product oil. One of the values used to measure the efficiency of the refining process is the acid oil factor (AOF), defined as the percentage of acid oil by-product recovered from the soapstock divided by the percentage of free fatty acid in the crude oil. A value of 1,0 is perfection and standard caustic refining, as described earlier, range from 1,3 for easily refined oils to 4 for low FFA oils in batch units. Physical refining provides factors of about 1,2 for all oils and is capable of handling oils having an FFA content of 8% and above - which would be very difficult using the traditional caustic process.[19]

One very important requirement, however, is that the feedstock should be rigorously pretreated to ensure that it is free from phosphatides, impurities, trace metals and earth-removable pigments. If these impurities were to be allowed to remain in the oil, the high temperatures used in the process would darken the oil and cause a poor quality product. The extent of the pretreatment necessary is dependent on the particular oil and its quality; the criteria most often used are the percentage content of non- hydratable gums and of iron and the oxidative state of the feedstock.

Pretreatment of high FFA oils such as maize and sunflower prior to physical refining, typically comprises the addition of phosphoric or citric acid at temperatures of approximately 70°C followed by high speed centrifugation to remove the hydrated gums. The centrifuged oil is dried and subsequently bleached and winterised before being sent to the physical refining section. Here the oil is pumped into a vacuum deaerator before entering the top heating section of the stripper. In this section the oil is heated to a temperature of up to 270°C using a thermal fluid (such as

Dowtherm) from a vapouriser. In a continuous unit the oil is then refined by flowing over the top series of trays counter-current to the flow of stripping steam which is injected below the bottom tray. The "refined" oil now flows down to a holding section which provides the retention necessary for heat bleaching of some of the oils before a final series of trays enables steam stripping of all remaining odoriferous material.

Exiting oil transfers some of its heat to the incoming feed before being pumped to polishing filters and on to storage.

Semi-continuous units are also frequently used for physical refining and these operate on the same basic principles as the continuous unit described above.

2.6 Packaging

The term packaging, as used in vegetable oil processing, differs somewhat from that usually employed in industry in that it includes not only final product packing but also the preparation for that step. The most important product from the packaging area of a vegetable oil processing plant is margarine, although other oil based products such as mayonnaise, peanut butter or shortening may also be produced on the same site.

2.6.1 Margarine

Margarine is a water-in-oil emulsion, consisting of a continuous oil phase and a discontinuous aqueous phase finely dispersed in the oil phase; the oil phase contains fat crystals which give the margarine its body. Legislation dictates that the minimum oil content of a margarine is 80% and the maximum water content is 16%. Flavouring, colouring, emulsifiers and various vitamins (particularly A and D) are amongst the ingredients added to the oil phase, whilst salt and milk solids are contained in the aqueous phase.

The margarine industry has become extremely competitive in recent years and this has resulted in a wide variety of different formulations being prepared, some of these contain up to 40% aqueous phase - although these are no longer strictly "margarines" but fat "spreads". Various consumer preferences have resulted in, for instance, the development of salt free margarines, as well as margarines with a high polyunsaturated fatty acid content; other margarines are required to have good spreadability straight from a refrigerator. Each of these specifications require a carefully selected blend of various vegetable oils and fats.

Margarine manufacture can be performed as either a batch or a continuous operation. The two phases each have the various ingredients added to them before being intimately mixed to form an emulsion. This emulsion is then chilled in a unit known as a "votator" - a rotating drum whose inner surface is kept cold by circulating refrigerant. Rows of scraper blades remove the crystallised emulsion from the chilled surface and pass on to a resting tube (the "B-unit") where the remaining latent heat of crystallisation is released and the product solidifies.

From the B-unit the margarine is fed to the packaging machine where the product is wrapped in blocks or packed in tubs. The finished product is stored in refrigerated warehouses prior to despatch.

3 BY-PRODUCTS, WASTES AND EFFLUENTS

3.1 Seed preparation

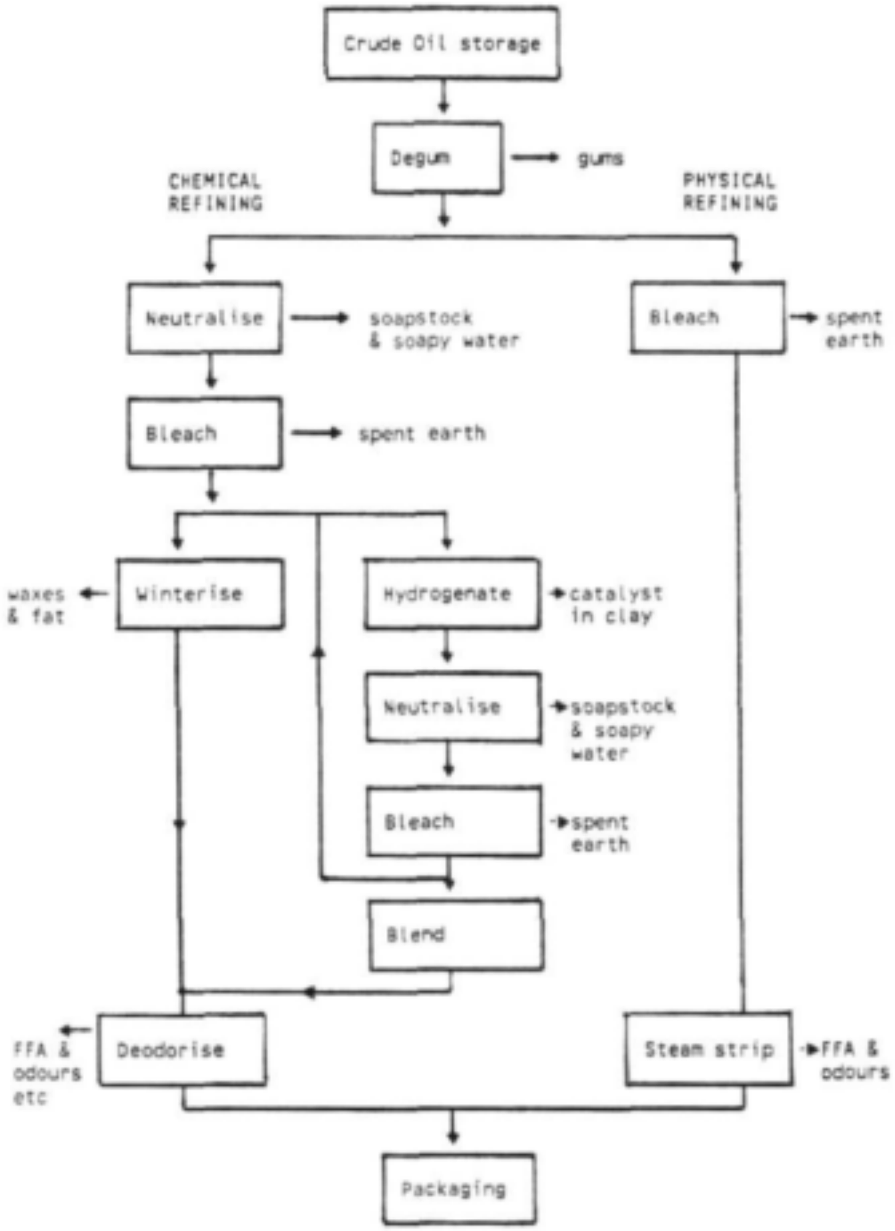
The principal by-product from this operation is the husk or hulls from which the oil bearing seed has been removed. These hulls are frequently added to animal feeds to provide fibre and roughage. Only a limited amount can be used in this way, however, since legislation restricts fibre content in standard feeds. Any surplus hulls are usually transported to the boiler house where they are used as a supplementary fuel.

3.2 Oil extraction

Regardless of whether oil is expelled or extracted using a solvent, this operation produces a large quantity of defatted meal. Residual oil content in the meal after desolventising is of the order of 0,5% with a moisture content below 10%; protein content is of the order of 40%.[5,11] This meal may be toasted to increase its nutritional value and then removed for use in animal feeds. Legislation and storage requirements dictate a maximum moisture content allowable in the meal.

The relatively complex system utilised to recover and recycle hexane in the solvent extraction process gives rise to small volumes of aqueous effluent. This effluent is primarily from condensed stripping steam and scrubbers used to prevent fines from entering the recovered solvent cycle. Blow-down from cooling towers serving the solvent extraction process probably produces a more significant volume of effluent.

Figure 2 Effluents from edible oil processing



3.3 Degumming

The gums separated from the crude oil prior to either chemical or physical refining invariably contain small quantities of oil. The gums themselves consist primarily of complex lipids, so that the mixture of gum and oil is highly nutritious. For this reason the extracted gums are usually mixed with the defatted meal for subsequent processing into animal feeds. Any citric acid introduced to facilitate degumming serves as a preservative in the animal feed.

Alternatively, it is possible to dry the gums in a thin film evaporator and process them to derive commercial lecithin products.

3.4 Chemical refining

3.4.1 Neutralisation

Chemical refining with caustic soda gives rise to the most potent effluent generated at an oil processing plant. In the neutralisation process, free fatty acids present in the crude oil are removed as highly alkaline soapstock. A quantity of neutral crude oil is also saponified in this process, the exact percentage (indicated by the acid oil factor) being determined by the oil type and neutralising procedure. This soapstock is usually converted back into fatty acids using a strong acid, either as a batch or a continuous process. The product of this operation is known as acid oil, which is used in the manufacture of paints, varnishes etc. The process, variously described as acidulation, soapstock conversion or soap splitting, consists of three basic steps:

(a) acidification of the highly basic soapstock, usually with sulphuric acid;
(b) breaking the emulsion of fatty acid and foreign material in water by means of heat (often live steam injection), pressure and agitation; and
(c) separation of the phases.

The presence of gums in the soapstock tends to favour the formation of an emulsion, so that, where no prior degumming stage is employed in conjunction with chemical refining, the resultant soapstock is difficult to split.[6,10]

The aqueous phase from the splitting operation is approximately pH 2, and after some has been recycled to dilute incoming soapstock, the remainder must be neutralised by the addition of caustic soda. The resultant neutralised liquid, predominantly a sodium sulphate solution, is discharged to drain.

After the separation of soapstock from the neutralised oil, the oil must be washed to remove all traces of caustic.

This is performed using water which is intimately mixed with the oil before being separated either continuously in a centrifuge, or gravitationally. Sometimes the resultant effluent stream, known as soapy water, is discharged to drain after neutralisation. However this results in the loss of valuable oil and contributes a large percentage of the pollution load in the final effluent. For these reasons, soapy water is often mixed with the soapstock already removed from the oil, forming an homogenous mixture from which acid oil is more easily recovered in the soap splitting operation.[5]

3.4.2 Bleaching

The majority of the pigment contained in the crude oil being refined is absorbed onto activated clays during bleaching. When removed, this clay contains a certain amount of oil as well as any remaining soap that was not washed out after neutralisation. Used bleaching earth is usually removed from the oil refinery in a skip before being dumped.

3.4.3 Winterising

Oil temperature is reduced to approximately 5°C causing high melting point esters and waxes to crystallise. These fat crystals are subsequently removed in a filter, usually with the assistance of diatomaceous earth as a filter aid. The fat/earth mixture is removed and discarded with the bleaching clay.

3.4.4 Hydrogenation

Nickel catalyst, mixed with diatomaceous earth, is removed from hydrogenated oil in a filter. This sludge is collected to enable subsequent recovery of the nickel. Wastes from the post-neutralisation and post-bleach steps are handled in the same way as their equivalents in the primary neutralisation and bleaching.

3.4.5 Deodorising

The deodorisation process involves steam distillation at pressures of approximately 5 mm Hg; injected steam constitutes up to 4% of oil weight. Vacuum in the deodorising unit is maintained by means of three stage steam- jet ejectors.

The distillate from the oil contains the volatile compounds responsible for the oil's characteristic odour as well as any remaining FFA. The vacuum pulls these vapours together with the stripping steam through a scrubber where the bulk of the FFA and any entrained oil are recovered. The stripping steam and remaining FFA vapours now mix with the motive steam from the ejectors to form a single stream which is condensed using direct contact cooling water. The volume of water in the cooling circuit is thus augmented by the condensed steam, and after collection in a hot well, the water is recycled over cooling towers and returned to the steam ejector condensers. Excessive build-up of FFA in the circuit is avoided by regular removal of floating fats in a sump just prior to the cooling towers. These fats may be recovered subsequently as acid oil. It is usually possible to balance evaporation and blowdown losses from the cooling circuit with the condensed steam being added, so that only minimal quantities of make-up are necessary.

3.5 Physical refining

Except for the higher temperatures involved, physical refining can be considered to be approximately analogous to the deodorising step used in chemical refining. Therefore the side streams produced are generally handled in the same way as those from the deodoriser.

3.6 Margarine

Incorrectly packed or off-specification margarine is usually recycled to recover and reprocess the oil content. Damaged packaging materials are removed for incineration or dumping.

The major source of effluent from this section is washdown water.

3.7 Washdown

Most of the plant used in an edible oil refinery must undergo regular cleaning. This will generally be performed after a week's production or between changes in feedstock; batch equipment may be cleaned after each batch has been processed.

Cleaning of vessels is usually effected using live steam and hot water on a CIP system, thus ensuring optimum use of steam, reduction in effluent volume, improved hygiene and reduced manual labour. Other cleaning, such as floor cleaning, is conducted using hot water as necessary. This fat and oil bearing effluent is discharged to the sewer via fat traps, where the oil rich scum is recovered and sent for reworking.

3.8 Miscellaneous effluents

The bulk of the remaining effluent, in terms of volume, emanates from the boiler house. The high steam demand of the industry requires considerable volumes of softened water, and this in turn gives rise to large volumes of regeneration effluent flowing to drain from ion exchange water softening units.

Return of condensate from the various vessels in the oil processing plant is often no more than 20%, since the risk of oil contamination is considered to outweigh any possible water savings. Nevertheless, regular blowdown of the boiler contents is necessary to regulate build-up of salts in the water.

These streams combine with cooling tower blowdown to form a significant volume of comparatively saline effluent.

4 SUMMARY OF SURVEY RESULTS

4.1 Water intake

The results obtained from the survey are shown in tabular form in Table 1.

Table 1 Typical SWI figures for the edible oil industry

	Average monthly oil production (t)		Average monthly water intake (m^3)		Specific water intake (m^3/t)	
	Range	Mean	Range	Mean	Range	Weighted average
Milling	1 000 - 3 600	2 080	2 070 - 11 070	5 390	2,1-3,1	2,6
Refining	1 000 - 3 600	2 520	3 100 - 16 600	9 650	3,2-4,6	3,8

It must be noted that almost every plant producing edible oil also produces secondary products such as margarine, peanut butter and mayonnaise. The figures quoted in Table 1 refer specifically to oil milling and refining. An average SWI of 1,4 m^3/t was found for the manufacture of margarine.

From Table 1 the weighted average SWI was found to be 2,6 m^3/t for milling and 3,8 m^3/t for refining. It is important to consider that for the edible oil industry in general, only about 65% of capacity is currently being utilised. This is of significance because many plant operations require the same amount of water to be used regardless of the plant throughput at the time. This will obviously lead to higher SWI figures when plants are operating at below design capacity. It is expected that recent better rains may result in an increase in utilisation of capacity by the edible oil industry in South Africa over the next few years. Size of plant is not really an important issue for the edible oil industry as plants are all of similar size. This is a different situation from that in, for example, the red meat industry where there is a tremendous variation in plant size and capacity.

The variation in SWI was found to be 2,1 to 3,1 m^3/t for milling and 3,2 to 4,6 m^3/t for refining. This is a clear indication that opportunities for better water management do exist within the industry.

The SWI for a combined mill and refinery is implied to be 6,4 m^3/t from addition of the individual SWI figures for milling and refining. This agrees well with the SWI figures typically found for a combined mill and refinery though certain economies of scale would tend to result in slightly lower SWI figures for the combined plant.

4.1.1. **Breakdown of water use**

Table 2 below indicates how water is used in a typical edible oil plant. Since much of the steam used in the refinery is motive steam for steam-jet ejector sets, this water enters the barometric cooling circuit and is ultimately lost to evaporation. It could therefore be argued that the cooling requirement of the refinery exceeds the figure of 10% quoted in the table.

Table 2 Breakdown of water usage at an edible oil processing plant

	Mill %	Refinery (including hydrogenation) %	Total %
Process	2	13	15
Boilers	10	30	40
Cooling	25	10	35
Washdown	1	7	8
Domestic	1	1	2
	39	61	100

Utilities are by far the largest water users in an edible oil plant with boilers typically accounting for 40% and cooling 35% of the water intake at an oil mill/refinery.

Condensate return is low with typically only about 20% of the available condensate to the hot well. The remaining condensate is either contaminated or potentially contaminated and as such is discharged as effluent. Live steam use is quite considerable and again this is obviously lost to the system as is steam used in steam ejectors. These can represent up to 10% and 20% respectively of the total steam use in an edible oil plant. Steam raising and cooling water use varies seasonally.

The figures include water used for preparing husks and hulls for use in subsequent products, but do not include the preparation of these products themselves. The figures exclude all operations not directly associated with the production of vegetable oil, such as the manufacture of margarine, peanut butter and mayonnaise.

4.2 Effluent

When considering effluent from various oil mills, there are several points which should be considered:

(a) Whether finished oil is produced from seed or whether the factory only produces crude oil or only refines purchased oil.

(b) Whether the predominant refining method is chemical or physical. This will be governed both by type of feedstock and by installed plant.

(c) Whether other products such as margarine, peanut butter and mayonnaise are manufactured on the site.

(d) Whether the existing effluent drainage system allows representative sampling of individual process effluents. The tendency of free fats to float on the surface of aqueous effluents increases the difficulty of obtaining representative samples.

(e) Whether any form of effluent treatment is practised prior to final discharge.

4.2.1 Specific pollution load

Edible oil plants discharge an effluent which varies considerably in quality over a 24-h period. Composite samples of final effluent were collected and the results summarised in Table 3 below:

Table 3 Effluent quality from an edible oil processing plant

		DETERMINAND			
Average monthly effluent discharge (m^3)	pH	COD (mg/l)	SOG (mg/l)	TDS (mg/l)	SO_4^{2-} (mg/l)
Range 2 180 - 8 200 Mean 5 130	Range 1,8 - 10,5 Mean 5,9	Range 1100 - 8990 Mean 4 580	Range 80 - 1360 Mean 630	Range 1910 - 17550 Mean 4 860	Range 130 - 10 950 Mean 1 805

Table 4 Specific pollution loads in the edible oil industry

		SPECIFIC POLLUTION LOAD			
Average monthly effluent discharge (m^3)	Average monthly oil production (t)	COD (kg/t)	SOG (kg/t)	TDS (kg/t)	SO_4^{2-} (kg/t)
Range 2 180 - 8 200 Mean 5 130	Range 1 000 - 3 600 Mean 2 520	Range 4,3 - 13,8 Mean 9,8	Range 0,2 - 3,3 Mean 1,6	Range 10,1 - 24,8 Mean 15,4	Range 2,1 - 15,5 Mean 7,6

As it is normally impossible to distinguish effluents arising from the mill and refinery in an edible oil plant, the final effluent analyses are given and the SPL figures are based on the total tonnage of refined oil produced monthly.

From Tables 3 and 4 it can be calculated that the mean SEV is 2,0 m^3/t. This gives an average percentage effluent discharge of 31%.

From the average pollutant concentrations calculated in Table 4, the following average SPL figures have been calculated:

Average COD = 9,8 kg/t

Average SOG = 1,6 kg/t

Average TDS = 15,4 kg/t

Average sulphate = 7,6 kg/t

4.2.2 Breakdown of specific pollution load

In terms of volume and load the largest proportion of the effluent discharged by an edible oil plant arises from refining operations. Typically about 80% of the effluent volume is attributable to the refinery.

The main sources of effluent in the mill are general washing and as a result of hexane recovery. In the refinery, effluents can be discharged from the degumming stage (gums), the neutralisation stage (soapstock and soapy water) and the bleaching stage (spent earth), as well as the various steam and cooling operations and general washing.

The main types of pollutant in edible oil plant effluents are fats and oils. Following neutralisation of the crude oil and subsequent soap splitting, water is used for washing, giving rise to effluents known as soapy water and acid water. These can contain considerable quantities of fats and oils and contain very high levels of sodium and sulphate. Detergents used in washdown operations often emulsify oils leading to high levels of oils in the plant effluent which are very difficult to remove.

4.3 Solid wastes and by-products

The production of large quantities of solids is unavoidable when extracting vegetable oil from seed. Table 5 indicates the approximate quantities of "waste" associated with the extraction of oil from the more common oil bearing feedstocks.

Table 5 Approximate composition of oil bearing seeds

Seed type	%Oil	%Meal	%Husk
Sunflower seed	34	33	33
Groundnut	47	-----53%-----	
Maize germ	9	-----91%-----	
Soyabean	20	-----80%-----	
Cotton seed*	16	51	20

* Approximately 13% of cotton seed consists of cotton fibre and lint.

Solid wastes generated in the total extraction and refining process, relating to a 3 600 t/month plant, are given in Table 6.

Table 6 Typical volumes of by-products and wastes

By-products and wastes	t/month
Husks	650
Defatted meal	2 900
Gums	150
Bleaching (& winterising) earth	60

These quantities are obviously proportional to the amount of oil extracted from seed on-site and also heavily dependent on the quality of additional imported oil.

These solids are normally transported off-site in trucks for subsequent resale as by-products or disposal as solid wastes.

5 CONCLUSION AND RECOMMENDATIONS

5.1 Water intake

Edible oil plants in South Africa have a range of SWI between 2,1 and 3,1 m^3/t for milling and 3,2 and 4,6 m^3/t for refining.

The varying properties of crude oil as extracted from different seeds, have a strong bearing on the type of processing steps required and this in turn will affect the necessary water intake. Thus it is very difficult to set a realistically achievable SWI for the industry as a whole. Nonetheless, target figures of 2,0 m^3/t for milling and 3,0 m^3/t for refining would seem to be realistically achievable for the industry as a whole. These figures imply a target SWI of 5,0 m^3/t for a plant milling raw seed and refining the crude oil produced without any additional crude oil being introduced from another source. Due to recent better rainfall this is increasingly the typical case and particularly if plants begin to utilise more of their design capacity, 5,0 m^3/t should be a readily achievable target.

Since some 75% of water intake to an oil processing plant is used in services, it is logical that the greater potential for saving should lie within the services. Several methods of reducing water intake are listed below:

(a) ensure maximum condensate return possible to boiler house: the use of carbon filters should be considered to enable the reuse of water which may contain minute quantities of oil;

(b) ensure cooling towers are working efficiently - allow for regular cleaning of oil-clogged packing and other internals;

(c) monitor automatic blowdown from cooling towers and boilers to avoid excessive blowdown losses;

(d) the use of boiler blowdown for moistening coal ash;

(e) consideration should be given to treating blowdown in a reverse osmosis unit to render it suitable for reuse in the boiler;

(f) use of high pressure, low volume equipment for floor washing and other general washdown requirements (each should be fitted with a self closing nozzle device);

(g) greater use of CIP installations for pipes, tanks and centrifuges;

(h) installation and control of water meters at all sections in the operation and commitment from the factory management to a water monitoring and management programme;

(i) improved staff training to increase awareness of water saving methods;

(j) shut down of pump gland cooling water lines on pumps when not in use[1];

(k) substitute air cooling for some water cooling requirements where feasible[1]; and

(l) investigate operation of cooling towers on a zero-blowdown basis which has been reported[1] as being successful on a pilot plant basis following the addition of a chromate corrosion inhibition.

5.2 Effluent

The range of SPLs for edible oil plants in South Africa is 4,3 to 13,8 kg COD/t oil and 10,1 to 24,8 kg TDS/t oil. Targets are proposed of 7 kg COD/t oil and 12 kg TDS/t oil.

Primary pollutants from an oil plant are fats and oils, with an associated oxygen demand. In addition, where acid oil is recovered from soapstock, very high concentrations of Na^+ and SO_4^{2-} occur.

Since the presence of fat and oil in the effluent constitutes loss of marketable oil, it is in the interest of the management to reduce the fat content to a minimum. Methods of achieving this are presented below:

(a) monitor caustic addition in the neutralisation stage of chemical refining very carefully as excess caustic causes saponification of neutral oil and later problems with removal as soapstock;

(b) ensure soapstock separation from neutral oil is performed accurately;

(c) use continuous soap splitting plant in preference to batch wherever possible: resultant acid water can be greatly reduced in this way;[4]

(d) ensure soap splitting operation is conducted on fresh soapstock: soapstock is split more effectively if treated immediately than if left to stand overnight prior to reheating and acid addition;[2]

(e) use as little detergent as possible in cleaning operations: emulsified oil cannot be removed from the resultant effluent very easily;

(f) removal of gums prior to neutralisation: their presence in soapstock hinders the efficiency of the acid splitting operation;[2,6]

(g) fat traps should be placed wherever washdown water is likely to contain oil or fat: recovered fat can be sent for reworking or acid oil recovery;

(h) use of a flume or similar monitoring equipment to measure effluent discharge accurately, since this is otherwise difficult to estimate;

(i) use of acid water from soap splitting operation for subsequent acid splitting of final effluent.

(j) replacement of barometric condensers with surface (non-contact) condensers which will reduce emulsified oil pick-up in barometric condenser water[2];

(k) recirculation of oily cooling water produced by barometric condensers in a separate cooling system with occasional blowdown[1]; and

(l) replacement of steam-jet ejectors by vacuum pumps, eliminating the production of oily condensate by the jet ejectors[1].

5.3 Effluent treatment

Effective treatment of refinery effluent may be achieved by a combination of screening, acid splitting of oil emulsions, skimming of fats and oils and final neutralisation.

5.3.1 Screening

Gross solids, such as defatted meal and husks, which may have entered the effluent system may be removed using a rotary, vibrating or a static "self- cleaning" screen. Both would need periodic cleaning, preferably with live steam jets.

5.3.2 Acidification

The bulk of the fatty matter contained in soapy water, deodoriser effluent and final effluent is in an emulsified form. This content, together with any colloidal or dissolved fat, will not be removed by the direct application of gravity separation techniques. Destabilisation of these emulsions can be achieved using sulphuric acid, and this has the advantage that the separated fatty material can be recovered. Where prior soap splitting has been performed, the acid water generated may be used for this purpose, with fresh acid being used on a standby basis only. Fatty matter released in this way may now be removed in a gravity settler system.

At sites where effluent streams exist which do not contain emulsified fatty substances, these streams should be segregated from the others and only mixed with the acidified stream after the de-emulsified oil has been separated. This will necessitate the use of two flotation stages, one for the acidified stream and one for the combined stream.

5.3.3 Gravity separation

Since fats and oils are less dense than water, the simplest way of separating these pollutants from oily effluent is flotation.

In its simplest form, a flotation system may consist of a tank containing a series of baffles beneath which the aqueous phase can flow freely. A manometric arm maintains the liquid level at baffle height so that fatty material is trapped; periodically fat has to be removed manually from the surface. This fat can often be reprocessed.

As mentioned above, gravity separation will not remove fats or oils in emulsion form. The effectiveness of a gravity separator depends on the water temperature, the density and size of the oil globules and the amount and characteristics of the suspended matter in the waste water[1]. It must be remembered that provision should be made for periodic removal of sludge from the separator vessels. It is important to realise the limitations of gravity separators in edible oil plant waste-water treatment. These are:

(a) they can only remove gravity-separable oils and will not separate stable emulsions;
(b) other parameters only undergo limited reduction;

(c) any emulsifier, spent caustic or detergent present will tend to reduce efficiency of removal;
(d) suspended solids attached to oils may not settle; and
(e) hydraulic overloading reduces efficiency.

5.3.4 Dissolved air flotation (DAF)

An alternative or subsequent treatment stage to gravity separation is dissolved air flotation in which air is dissolved in the effluent in a pressure vessel before the solution is released into an open flotation tank. The sudden reduction in pressure causes the air to leave solution as very fine bubbles which then adhere to any oil, fat or other suspended solids in the effluent and bring them to the surface. The entrained air causes the resulting agglomerates to have greatly improved vertical rise rates, typically[1] 0,0025 to 0,005 m/s.

The layer of frothy solids, fats and oils which forms is swept into an inclined exit chute by a rotating arm or other skimming device. Typical design parameters for dissolved air flotation units would be[1]:

Pressure	170	to	480 kPa
Air/solids ratio	0,01	to	0,1
Retention time	20	to	60 min
Surface hydraulic loading	2	to	330 m^3/m^2.d
Solids loading	2,4	to	24,0 kg/m^2.h

Polyelectrolyte addition usually enhances fat and oil removal from waste waters. Fatty material in food industry effluent is normally negatively charged and treatment therefore involves the addition of an ion of the opposite charge to destabilise the emulsion[3]. Commonly used agents for breaking emulsions include ferric chloric, sodium aluminate, aluminium sulphate, ferrous sulphate and lime.

5.3.5 Neutralisation

Effluent from the first, low pH separation will need neutralising with caustic soda before being mixed with the remaining effluent and being subjected to a final flotation process. The liquor discharged from this second flotation unit must be neutralised to bring the pH value up to local statutory requirements. This final neutralisation can be effected with either caustic soda or calcium hydroxide. Calcium hydroxide addition would avoid a further increase in the sodium content of the final discharge, but would give rise to a sludge handling problem requiring the use of a filter, probably a plate and frame type. Although requiring an additional stage of treatment, the filtration process would provide further removal of fatty matter, COD and suspended solids.

5.3.6 Biological treatment

5.3.6.1 Aerobic

A strain of bacteria has been developed which will digest fats from this type of effluent, and at least one oil plant in South Africa runs an activated sludge treatment facility as a polishing unit to complement a DAF system. Problems encountered in the running of such a plant stem from periodic shock loads of, for instance, soapstock spillages.

5.3.6.2 Anaerobic

Anaerobic treatment of readily biodegradable effluents, particularly from the food and beverage industry, is receiving much attention worldwide at this time. Research work is being conducted in Malaysia on the applicability of the technology to the treatment of vegetable oil mill effluent.[4] Palm oil mill effluent, such as was the subject of this research, is of a very different nature from effluents generated in local oil plants. Nonetheless, anaerobic treatment of effluent should be investigated especially when other highly biodegradable effluents are available from nearby sources.

5.3.7 Membrane technology

Reverse osmosis making use of ultra-thin synthetic or natural membranes may be viable for treating process effluent high in TDS such as acid water. This is particularly true in areas where strict standards are enforced regarding, for example, sulphate content, where edible oil plants are presently tankering effluents high in sulphate off their premises for disposal elsewhere.

5.4 Storm water

Storm water run-off from an oil refinery site invariably contains quantities of fats and oils. Provision should therefore be made for preventing this oil from entering the storm-water drains. A combination of two approaches can be used:

(a) storm water from potentially heavily polluted areas, such as tank farm bunded areas, should be directed to the effluent treatment plant; and

(b) all other storm water should pass through fat traps before being discharged to municipal storm-water drains.

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