Natsurv 6:

Water and Wastewater Management in the Edible Oil Industry

(Edition 2)

PJ Welz, M le Roes-Hill, C Swartz

WATER RESEARCH COMMISSION

TT 702/16

NATSURV 6

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Report to the

Water Research Commission

by

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EXECUTIVE SUMMARY

The NATSURV series of documents

This NATSURV (National Survey) document forms part of a series of such documents reporting on surveys of various industries in South Africa. In many instances, previous surveys were undertaken between 1986 and 2001. The purpose of the new NATSURV documents is to provide more recent and relevant information on water, wastewater, and energy management practices to all stakeholders involved in the chosen industries.

Methodology for NATSURV on the edible oil industry

To obtain current information on the South African edible oil industry, desktop research was performed, site visits were conducted, and questionnaires were disseminated and collected. To assess changes in the industry, information was compared with that which was published in the previous NATSURV (NATSURV 6 of 1989). For example, since 1989, there has been a notable increase in the cultivation of olives for olive oil, and soy beans and Canola seeds for oil and oil cakes.

Industry compliance with survey

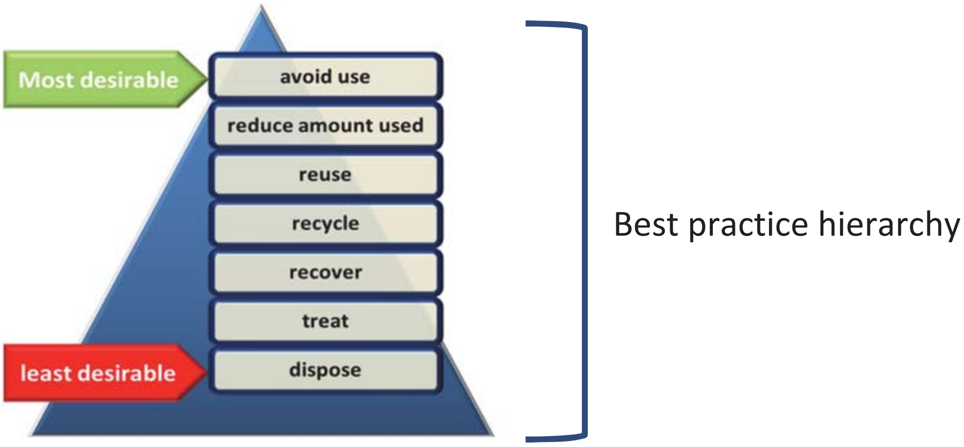
Vegetable oil extraction and refining consume large volumes of water and energy and are waste intensive. However, during this project, relevant water consumption and qualitative and quantitative discharge ranges were difficult to obtain due to (i) Lack of global and local data in the public domain, and (ii) Local industry reluctance to provide data. In terms of water and wastewater management, the original NATSURV was based on figures obtained from one seed oil processor. For the current NATSURV, 24% of seed oil facilities, 5% of olive oil processors, and the major avocado oil processer took part. This reflected a low level of compliance in the first two categories. In addition, vital information was missing from most of the questionnaires that were collected.

Water and wastewater management

The limited water usage and wastewater generation data that was collected from seed oil extraction and/or refining facilities and municipalities is presented in the document in Tables 10, 11, 13 and 14.

Best practice guidelines

In industry, in order to reduce the amount of water used, and improve the quality and/or quantity of the effluent, it is strongly recommended that a ‘best practice’ approach is adopted, where avoidance of water usage is the most desirable, and disposal of wastewater the least desirable practice.



There are a number of actions that can be implemented to save water, either generic or specific to the edible oil industry. A list is provided in Section 4.3 of this document. These range from: (i) simple, low-cost measures such as the installation of self-closing and water-wise hose nozzles, wiping spills before washing-down with water, and educating staff, to (ii) more costly measures such as installing water meters and cleaning-in-place equipment, to (iii) those requiring major retro-fits or additions to existing infrastructure, e.g. replacing chemical refining with physical refining. Edible oil processors should evaluate which of these are practically and economically feasible. It is recommended that a water-saving 'plan of action' be formulated, so that different actions can be implemented sequentially.

Likewise, measures can be implemented to improve wastewater quality and reduce wastewater generation, and should be dealt with in a similar manner to those for water-saving. Qualitative and quantitative measuring of wastewater from different processes is essential to assess where improvements can be made. Section 5.3.3 in this document lists various 'best practice' measures that can assist in reducing the amount of wastewater generated and/or decrease the potential environmental toxicity of the effluent.

Contents

Section 1: Introduction

Manufacturing and processing industries consume significant quantities of energy and water. In addition, unwanted liquid, solid and gaseous waste is generated along with the intended products. Novel, more sustainable methods are constantly being sought to reduce qualitative and quantitative industrial pollutant loads and re-use water and waste. This move is largely in response to a number of interrelated factors, including higher costs of waste disposal, more stringent legislative requirements, and increasing environmental awareness.

Between 1986 and 2001, the Water Research Commission (WRC) of South Africa (SA) commissioned 16 National surveys (NATSURVs) of various agri- and non-agri industries [malt brewing, poultry, red meat, edible oil (EO), sorghum malt and beer, dairy, sugar, metal finishing, soft drink, tanning and leather finishing, laundry, textile, oil and refining, power generating]. This culminated in the publication of 16 separate NATSURV documents, one for each industry. One of these, entitled "Water and wastewater management in the edible oil industry" (WRC TT-40-89) included information about specific and generic production processes, water usage, solid waste generation, and wastewater quality, quantity and treatment practices in SA EO industry.

This new survey serves to update the content of the original document, highlighting the changes which have taken place in the industry over the last two and a half decades. The report includes information stemming from an audit of the industry from both a local and global perspective. Limited information about the local EO industry was obtained using combined desktop, site-visit, and laboratory based approaches. In addition to water and wastewater management, the document includes a section on energy audits and the adoption/non-adoption of sustainable procedures by the industry at large.

The objective of this document is to serve as a comprehensive guide and benchmark tool for local governments, industry players, academics, researchers and engineers. The types of EOs included in this document are delimited to oils which are liquid at standard temperature and pressure. The only major animal oil that fits these criteria and is produced in SA is fish oil. In fact, SA accounts for almost a quarter of the global annual production of 980 000 metric tons (FAO, 2014; Oceana integrated reports; OECD-FAO). Fish oil is included in a separate NATSURV dealing with the fish processing industry. The oil types are thus delimited to seed and fruit oils and the processes are delimited to those directly and indirectly pertaining to cleaning, milling, pressing, extraction, and refinement of EOs. A particular emphasis is placed on extraction and refinement. Upstream and downstream processes are largely excluded. However, in some instances, downstream processes cannot be entirely discounted. For example, wastewater emanating from the generation of value-added products such as margarine or mayonnaise may be combined with that from oil extraction and refining. Facilities that produce milled goods as their primary products, with oil being seen as secondary have also largely been excluded.

The **methodology** employed for data collection consisted of desktop studies, site visits and distribution and completion of questionnaires. Only a small fraction of the local industries completed questionnaires, many of these only partially. Detailed information, especially on water and energy utilisation, and wastewater quality, was not always readily available during site visits and in some instances was provided at a later date. In other cases, this additional information was not forthcoming. To enlist industries in the project, all facilities (Table 1, Table 2) were emailed and telephoned at least once. If possible, municipal contacts were used to introduce the project team to key industry personnel. Unless the executive manager or operations manager expressly declined the invitation to participate, between one and five follow-up phone calls were made in order to elicit a response from olive and seed oil facilities, respectively. In each instance, when a positive response was forthcoming, a particular individual was identified to complete the questionnaire. An introductory letter from the WRC (Appendix 1) was emailed to each respondent together with the relevant questionnaire (Appendix 2 and 3). Thereafter, the respondent was contacted on a weekly basis, either until the questionnaire had been returned or four weeks had elapsed.

1.1 Industry overview

1.1.1 Uses for edible oils

It is possible to extract oils from almost any vegetable matter, but seeds and fruits are the most common sources. Most plant-derived oils are edible and form part of the human diet, mostly as basic food components, but also as nutraceuticals and flavouring additives. Other examples include wood preservative oils and essential aromatherapy oils. The residue left over after pressing of seeds, grains and groundnuts, known as oilcake, is an important source of animal fodder.

Figure 1: There has been much debate about the use of food crops, including oilseeds for the production of biofuels

Apart from these traditional uses for EO, the growing impetus away from fossil fuel dependence has led to an increase in fuel sources that can be replenished, including biodiesel generated from plant oils. According to the Food and Agricultural Organisation (FAO) of the United Nations, the conversion of EOs for biodiesel is set to increase from around 12% in 2010/2012 to 15% by the year 2022. The regions which currently convert the highest percentages of EO to biodiesel are Argentina (~70%), the European Union (~40%), Thailand (~40%), and Brazil (~35%). In these countries, crops are grown specifically for biofuel production. However, the world population is increasing and, together with the effect of global warming on agricultural yields, food supplies are threatened. There is therefore on-going debate on the merits of using agricultural land and food crops for the production of biofuels. However, the conversion of inferior ‘edible’ oils, used oils, or reject seeds into biodiesel to supplement energy requirements can be seen as a sustainable initiative.

1.1.2 Global and local edible oil production volumes and trends

Vegetable oils are typically produced from seeds or fruits. In contrast to seed oils, which can be ensilaged, fruits are more prone to spoilage and are typically processed soon after harvesting. Regional oil production profiles are principally related to prevailing climatic conditions that favour the growth of specific crops. For example, tropical climates are suited to the cultivation of palm trees for palm oil. The range of EOs extracted from locally grown crops in SA differs from the global profile.

Figure 2: Fruit oils are extracted from the flesh of avocados (left) and olives (right) in SA

Globally, Indonesia, China and Malaysia are the three largest producers of EOs. China is the largest producer of soybean oil, while Indonesia and Malaysia alone account for approximately 34% of total EO production, and 85% of palm oil production. In terms of oil type, the production trends have remained relatively consistent over the last five years, i.e. palm oil has been produced in the highest volumes, followed by soybean, rapeseed, sunflower seed, palm kernel, groundnut (peanut), cottonseed, and olive oil. However, the overall volumes of each have increased, so that the total has risen from 149.0 to 174.9 million metric tons during this period. As the global population increases, these upward trends are set to continue (Figure 3).

The EO production landscape in SA has changed considerably since the publication of the first NATSURV in 1989, when sunflower seeds, groundnuts, and maize were seen as major contributors, and soya beans and cotton seed as minor contributors to local EO production. Notably, since then:

(i) **Canola oil** has emerged as a significant agri-industrial product. Canola (Canadian oil, low acid) is a cultivar of rapeseed that is low in erucic acid (a myocardial toxin found in rapeseed). From a nutritional perspective, it also has a desirable fatty acid profile, making it a highly marketable product for human consumption. From an industrial perspective, the high extractable oil content of Canola offers an economic advantage. It is therefore not surprising that more and more arable land is being planted with Canola crops. Canola was first planted in SA in the early '90s. Since then, production of Canola seed has risen steadily to 86 000 tons in 2012/2013, and 126 000 tons in 2014/2015.

(ii) The local **olive oil** industry has grown significantly. It is estimated that 2 000 metric tons of olives were processed for olive oil production in 2012/2013 (SA Olive, personal communication). The consumption of extra virgin olive oil, an unrefined product, has proven health benefits associated with a favourable fatty acid profile and high quantities of antioxidants. Currently, the local product only satisfies 20% of local demand, which itself is predicted to grow. The olive oil industry in SA is thus in an expansion phase, which is projected to continue.

(iii) Due to high protein content, there is a demand for high value milled **soybean** products and oilcakes for human consumption and animal feed. Improved yields are being obtained from genetically modified seeds, so that soybean farming has become more economically viable in SA. There has been a concomitant increase in the production of soybean oil.

(iv) It is assumed that production of **cotton seed** oil has dramatically decreased because it is an ancillary product of cotton grown for the (declining) textile industry. Although the umbrella body for the cotton industry (Cotton SA) does not release figures on cottonseed oil production (only on agricultural yields, amount ginned and lint produced), the assumption is based on the fact that the amount of land planted with cotton decreased by > 95% between the 1987/88 and 2012/13 planting seasons (estimate, DAFF).

Grain SA (GSA) and the South African Grain Information Society (SAGIS) release comprehensive monthly data on the quantities of soybeans, sunflower seeds, Canola seeds and groundnuts processed to oil and oilcakes. These two bodies furnish agricultural and trade data to the industry and other stakeholders, including historical information and projections on the commercial supply and demand of locally produced and imported seeds and grains. In terms of volume, sunflower seed, followed by soybean and canola seed are presently the most important feed-stocks for locally-produced EOs (Figure 3). For each crop, the oil yield is dependent on a number of factors, including the varietal, climate, seasonal variances, and farming methods. There are no national figures available on the total amount of seed oils produced, but estimates can be deduced from the theoretical oil yield from sunflower and Canola seeds (approx. 40%) and soybeans (approx. 18%). Maize is the largest agricultural product in SA and contains 3-6% fat, mainly in the germ. Oil is produced from germ that is separated from the rest of the maize. There are no SAGIS statistics on the quantity of maize germ from which oil is extracted.

Other minor vegetable oils produced in SA include peanut (groundnut), grape seed and avocado oil, which collectively constitute a small fraction of the total EO production. Unlike Canola and sunflower seeds, very little of the groundnut crop is destined for the EO market. Over the last three years (2011-2014), between 65 and 75% of groundnuts were converted into peanut butter or distributed as 'directly edible', while only 2-3% was crushed for oil and oilcake.

South Africa is one of the largest producers of avocado oil in the world, with around 100 tons of refined avocado oil per annum being produced at the country's largest facility. Approximately 13% oil can be extracted from avocados, with a further 2% loss during refining. Although avocado oil is classed as edible, and is purported to have excellent health benefits, it is a high value product which is also widely used in the cosmetic industry.

Around 220 metric tons of crude grapeseed oil per annum is produced from solid waste at a local biorefinery. Currently, > 90% of this is exported for refining and is seen as ancillary to cream of tartar and tannin production (personal communication, Brenn-O-Kem). It is impossible to separate the grapeseed oil production from other processes in terms of energy usage, water consumption and wastewater production. Grape seed oil is thus not considered further in this document.

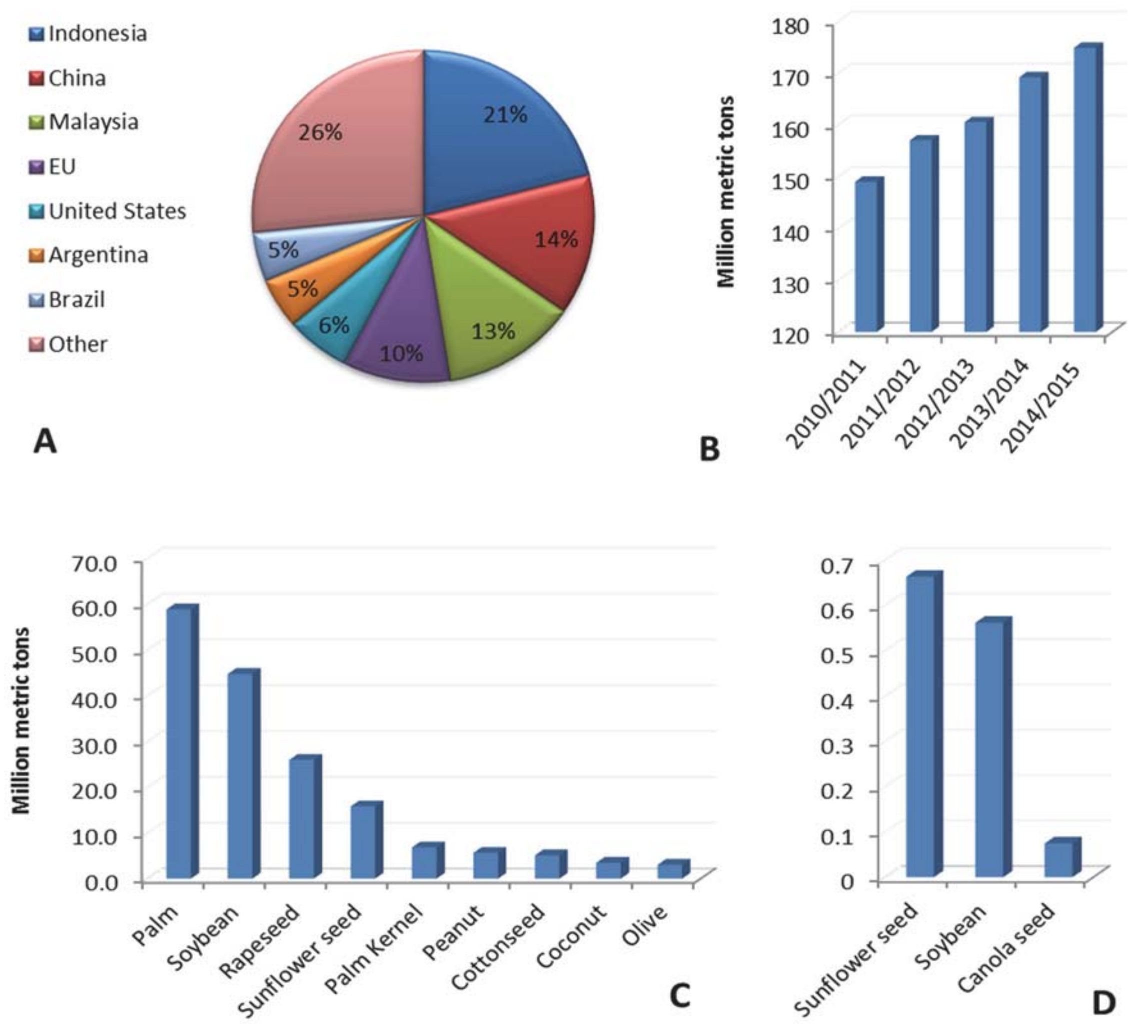


Figure 3: Global edible oil production figures according to the US Dept. of Agriculture, Foreign Agricultural Services Statistics: (A) per country in 2013/2014, (B) total annual growth since 2010, with projections to 2014/2015, and (C) per type of oil in 2013/2014, and (D) Tonnage of major oilseeds crushed to oil and oilcake in South Africa in 2013/2014, according to the South African Grain Information Society, 2014 statistics.

1.1.3 South African trade in plant oils

There are seasonal variances in the quantities of plant oils imported to and exported from SA. South Africa is a net importer of all vegetable oils, although sunflower and soybean oil is also exported in significant quantities [Figure 4 (BFAP, 2014; Ferreira, 2014)]. The Food and Agricultural Organization (FAO) of the United Nations estimates that we import an average of 67% of our vegetable oil. However, the origin of the FAO "official and non-official sources" is unclear and should be taken with caution. Official import/export data from the South African Revenue Services show that between April and September of 2013, 388 000 metric tons of plant oil was imported at a cost of close to R3.5 million, while only 81 000 metric tons with a value of R1.1 million, was exported (figures to nearest thousand metric tons and R0.1 million). Overall, locally produced oils were of higher value (R13 471/metric ton) than imported oils (R9 239/metric ton)(Ferreira, 2014). Depending on the harvest and annual demand, the local commercial demand for sunflower seeds is supplemented by small volumes (2-13% per annum since 2011/2012) of imports (SAGIS, 2014; BFAP, 2014).

1.1.4 Geographical location of vegetable oil crops in South Africa

The geographical location of oilseed crops is included in the GSA/SAGIS database (summarized graphically in Figure 5). The actual volumes of EO from these crops can be estimated from the expected oil yields of each particular feedstock (Section 1.1.2). Although the harvesting of sunflower seeds, Canola and soybeans is seasonal, the seeds are stored in silos and production can take place year round. At present, all of the Canola is grown in the Western Cape, with more than 98% of locally grown Canola seed being crushed to oil and oilcake (SAGIS, 2014).

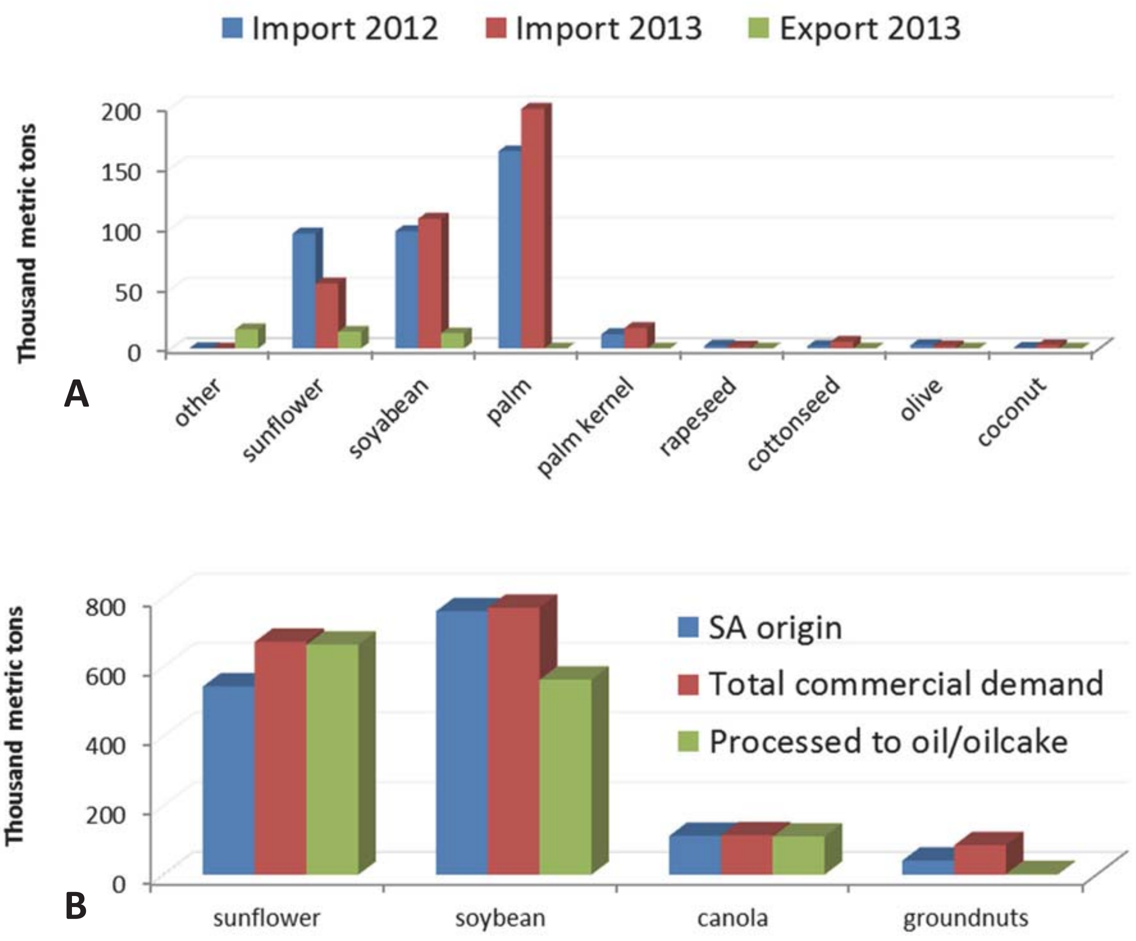


Figure 4: (A) Vegetable oil imports between April and September 2012 and 2013, and exports for the same period in 2013 (Ferreira, 2014), and (B) Producer deliveries of oilseed and groundnuts of SA origin, total commercial demand volumes, and volumes processed to oil/oilcake in 2013/2014 (SAGIS, 2014)

Although maize is grown in all 9 provinces in SA, a review of SAGIS reports for the 2011/12 to 2013/14 seasons show that yields are highest from the Free State (41%), Mpumalanga (23%) and the North West (18%) (SAGIS, 2014). Cotton is mainly grown in Limpopo, the Northern Cape, KwaZulu Natal and Mpumalanga (Cotton SA).

Table olives and olives destined for extra virgin oil production are locally grown and processed in the Western Cape. The Mediterranean climate of this province is particularly suitable for growing olive trees that produce fruit containing oil with desirable taste and aroma properties. Currently 10% of the processors account for the production of 90% of this high-end product. The rest is produced by boutique estates disseminated across the province.

Avocado farming takes place mainly in Limpopo (approx. 60%), Mpumalanga (approx. 30%), and KwaZulu Natal (approx. 8%).

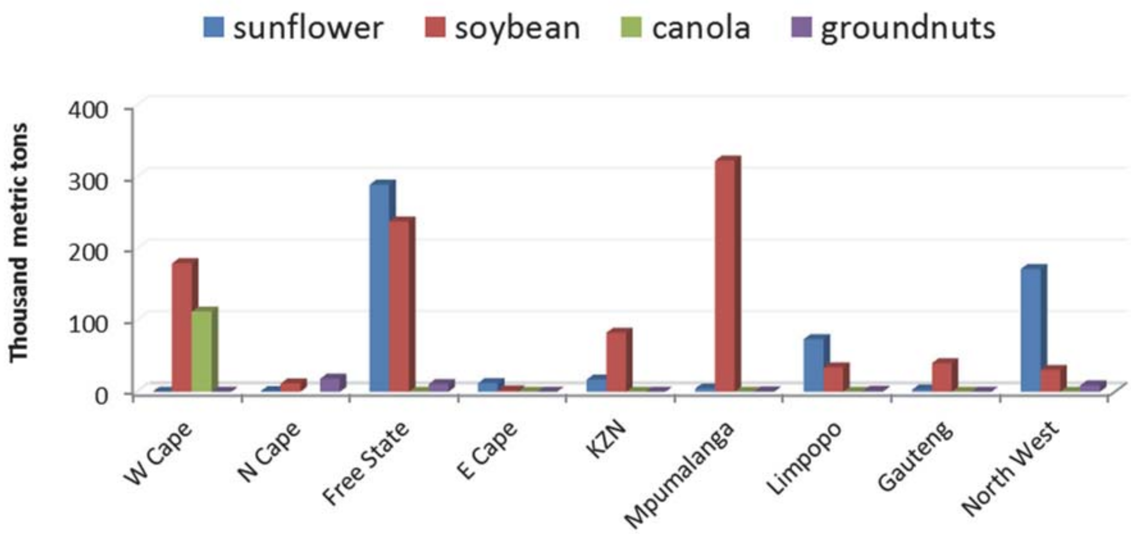


Figure 5: Provincial distribution of producer deliveries of oilseed and groundnuts in SA in 2013/2014 (SAGIS, 2014)

1.1.5 Overview of edible oil processing and participating companies

Of the seventeen seed and/or palm oil processing facilities in South Africa, most are located in Gauteng (>50%), followed by KwaZulu Natal and the Western Cape (Table 1).

Table 1: Basic overview of location, oil types and processes of seed oil facilities in South Africa

Province	Municipality	Type of oil/s*	Processes
KwaZulu Natal	eThekwini (M)	Sunflower, palm	Refining, value add
KwaZulu Natal	Hibiscus coast (L)	Sunflower, palm	Refining, value add
KwaZulu Natal	Msunduzi	Sunflower, other	Refining, value add
KwaZulu Natal	Msunduzi	Sunflower, other	Refining, value add
Western Cape	Swellendam (L)	Canola	Extraction, refining
Western Cape	City of Cape Town (M)	Sunflower, other	Extraction, refining
Gauteng	Ekurhuleni (M)	Unknown	Unknown
Gauteng	Ekurhuleni (M)	Unknown	Unknown
Gauteng	Ekurhuleni (M)	Unknown	Extraction
Gauteng	Randfontein (L)	Sunflower	Unknown
Gauteng	Randfontein (L)	Sunflower	Unknown
Gauteng	Mogale (L)	Unknown	Unknown
Gauteng	Mogale (L)	Unknown	Unknown
Gauteng	City of Tshwane (M)	Sunflower, Soya	Extraction, refining
North West	Ditsobotla (L)	Unknown	Unknown
Free State	Moqhaka (L)	Sunflower, palm	Unknown
Limpopo	Mogalakwena (L)	Unknown	Unknown

***other oils such as maize germ may also be extracted or refined, but in relatively minor quantities**
L = Local municipality M = Metropolitan municipality

SA olive is an organisation that seeks to uphold the quality of olive oil in South Africa. Anecdotal evidence suggests that the majority of processors belong to this organisation. Forty producers belong to SA Olive, with only one being located outside of the Western Cape. In addition, all but one is located in local municipalities, reflecting the rural nature of the industry in comparison to the seed oil industry (Table 2).

Table 2: Basic overview of location of SA olive member olive oil processing facilities in South Africa

Municipality	No of facilities	Participant	Municipality	No of facilities	Participant
Western Cape					
City of Cape Town (M)	1	No	Bergrivier (L)	1	No
Langeberg (L)	8	No	Oudtshoorn (L)	1	No
Stellenbosch (L)	6	No	Drakenstein (L)	1	Yes
Prins Albert (L)	5	No	Matzikama (L)	1	No
Theewaterskloof (L)	4	No	Witzenberg (L)	1	No
Breede valley (L)	3	Yes	Overstrand (L)	1	No
Cape Agulhas (L)	2	No	Cedarberg (L)	1	No
Swellendam (L)	2	No	Kannaland (L)	1	No
Gauteng					
Madibeng (L)	1	No			

L = local municipality

1.1.6 Response to requests for site visits and completion of questionnaire

1.1.6.1 Seed oil facilities

Despite protracted attempts to engage industry, participation in the NATSURV was low. Six facilities granted access for site visits. Two of these are not included in all of the data given in this report. This is because in one, the primary product is dry milled soya, with oil production being incidental, and the second only produces value added products such as margarine and mayonnaise from refined oil as the raw material. Nevertheless, the visits to these two sites were informative and provided valuable insight into the industry at large.

Five of the seventeen facilities that were identified for inclusion allowed access for site visits and populated questionnaires **(24% inclusion rate)**. Unfortunately, none of the questionnaires were completed fully, and critical information was lacking, particularly that pertaining to wastewater quality.

1.1.6.2 Fruit oil

Two small olive oil producers, from the 40 members belonging to SA Olive agreed to complete the questionnaire **(5% inclusion rate).** The data thus excludes the large producers that account for > 90% of production. The major avocado oil producer responded positively and completed the relevant questionnaire **(100% inclusion rate)**.

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US Dept. of Agriculture, Foreign Agricultural Services statistics http://apps.fas.usda.gov/psdonline/ accessed August, 2014.

Section 2: Edible oil process overview

The processes for the production of EOs can be roughly divided into **pre-treatment**, **pressing and/or extraction** and **refining/purification** steps (Figure 6). Separation of oil from the rest of the feedstock is performed **mechanically (pressing)** and/or **chemically (extraction)**. These are used alone, or in combination. Typically, extraction is most applicable for feedstock with low oil content, such as soybeans; both pressing and extraction are applied for oilseeds with high oil content, while pressing alone is used to produce 'cold-pressed' oils such as extra virgin olive oil. The initial plant investment to set up solvent extraction is much higher than for mechanical pressing, which is one of the reasons why this technology is inappropriate for small scale processing.

*The variety of methods and equipment used across the globe during these processes is exhaustive. Because the major focus of this NATSURV is to relate energy and water consumption and waste and wastewater generation to industrial production processes, the production processes and principles are **briefly** described. The processes are delimited to those most commonly employed to extract and refine seed oils. If required, more detailed descriptions of the various production steps are available on the internet.*

Figure 6: Edible oil production can be divided into 3 major processes that differ according to the starting material and personal choice of the manufacturer

2.1 Seed oil processing

2.1.1 Pre-treatment of raw material

The preparation of raw material typically begins with quality checking, and where appropriate, mechanical screening/sieving to remove debris, removal of stones, and magnetic removal of any metals. These, and other operations, are often performed before storage. Seeds may be dried to prevent spoilage of the raw material during storage, as well as to increase the efficiency of downstream processes.

Pre-treatment/preparation is required to render the particular biological material susceptible to the release of oils; because there are major cellular and structural differences in the different feedstock, the steps differ somewhat for each.

2.1.1.1 Cracking

The process of cracking (or sizing) is used for larger seeds, the main purpose of which is to reduce the size of the seeds. Cracking also assists with dehulling. The cracking machinery typically consists of horizontal rollers through which the seeds are passed.

2.1.1.2 Dehulling

The hard hulls (shells) of some seeds are removed to reduce the wax content of the oil, increase the oil content of the feedstock for extraction, increase the capacity of the plant, reduce wear on the pressing machinery, and, if appropriate, to increase the nutritional value of the oilcakes for animal fodder.

Figure 7: Photograph depicting a sunflower seeds with (right) and without (left) a hull

2.1.1.3 Conditioning treatment

Conditioning, also known as heat treatment or cooking, can increase the ease of extraction and the quality of the oil, principally by decreasing oil viscosity, breaking cell walls, coagulating proteins, promoting moisture conditioning of seeds, and inactivating and destroying thermo-labile enzymes and toxins.

2.1.1.4 Flaking (flattening)

Flaking involves crushing the material under particular time, temperature and moisture conditions. This process partially breaks the seeds and increases the surface area. The permeability of the oil cake is improved, thereby promoting solvent extraction. However, unless the pressing temperature is high (100°C), flaking can result in increased residual oil in the oilcake after pressing.

2.1.1.5 Expanding/extrusion

Expanding is used to prepare low oil content material for extraction. The expander has a cylindrical shape containing a rotating shaft with a screw-like shape. As the material passes through the expander, it is compressed, and the resultant pressure leads to an increase in temperature to >150°C. The subsequent release of pressure after compression causes the extruded feedstock to expand and flash evaporation of the water content takes place.

Some of the cellular structures in the extruded contents are destroyed, making the oil droplets more accessible to extraction. The extruded contents are also less fragile than the preceding flakes. The heating fraction lasts for around one minute, with no detrimental effects on the oil. The order of the pre-treatment steps are shown in Figure 8, coded in red.

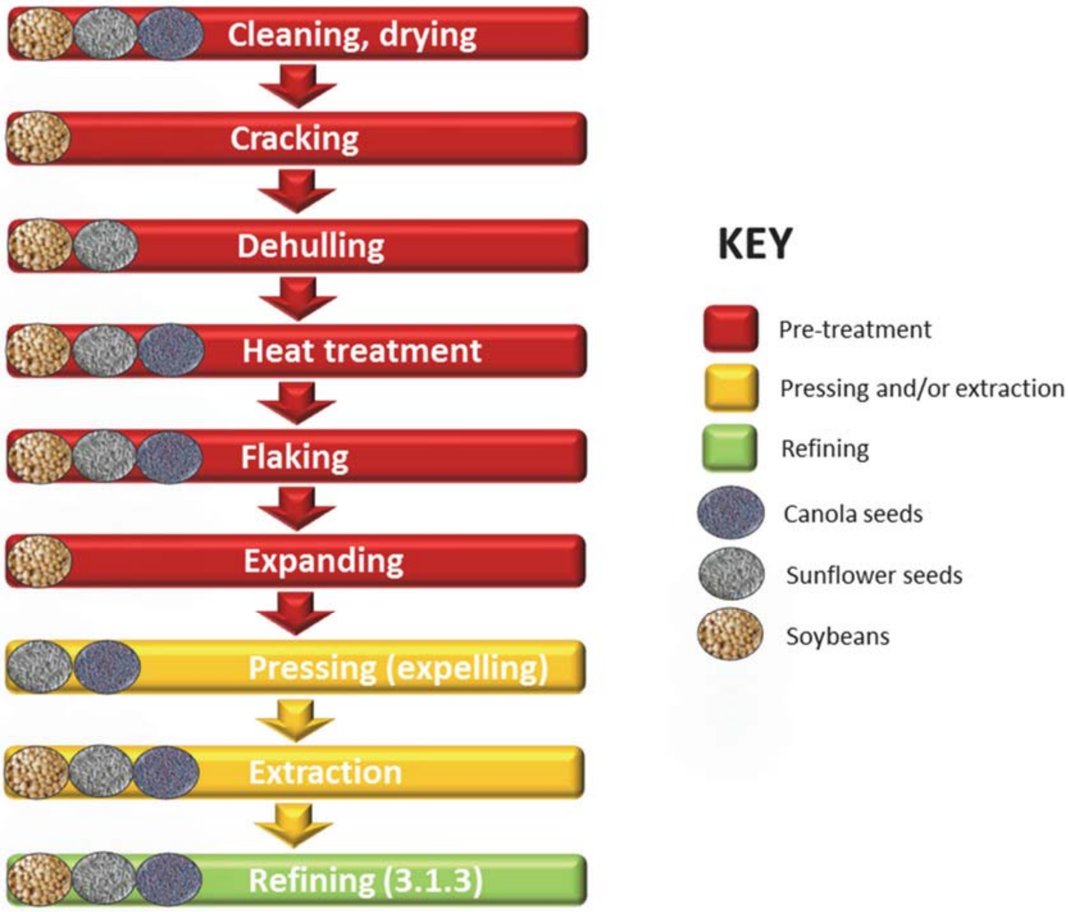

Figure 8: Flow diagram showing the different typical industrial-scale pre-treatment, pressing and extraction steps for Canola seed, sunflower seed and soybean oil production

2.1.2 Oil pressing (expelling) and extraction

After initial pre-treatment, mechanical separation of oil from the rest of the seed material takes place by **expelling** (typically referred to as **pressing)**. In the case of high oil content seeds (sunflower and canola), a combination of expelling and extraction is usually performed, and the expelling step is referred to as '**pre-pressing**'. Pre-pressing employs screw-presses and has a lower oil yield (approx. 70%) than full pressing (> 90%), but also lower energy costs and higher throughput. The residue left after pressing is known as oilcake.

Solvent **extraction** is the most common process which is used to extract oil from low oil content feedstock (soybeans), and to extract residual oil from oilcakes. Commercial hexane, which is a mixture of hexane isomers, is by far the most common solvent used for extraction. Oils are highly soluble in hexane and are washed out to form an oil-solvent mix, called the **miscella**. Hexane has a low boiling point (69^{o}C), which allows the oil and solvent to be easily separated by distillation after extraction. Almost all of the hexane is recovered for re-use. The types of pre-preparation processes employed, the solvent ratio, and the temperature all affect the efficiency of the extraction process.

2.1.3 Oil refining

Most crude oils are refined to prevent spoilage and to remove substances that may affect the taste, odour and appearance of the oils. These include gums, waxes, free fatty acids, pigments, aldehydes and ketones. There are a number of physical and/or chemical processes that can be used to refine crude oils (Figure 9). The most widely used processes are briefly described in Section 2.1.3. **In the SA study cohort of four facilities, one facility uses physical refining, one uses chemical refining with phosphoric acid, and two use chemical refining with citric acid. The latter is preferable in terms of wastewater quality.**

2.1.3.1 Degumming

Gums are residues of phosphatide phospholipids, entrained oils and meal particles that are formed when the oils absorb water and the phosphatides become hydrated. To prevent the formation of gums during storage, most oils are degummed. There are many degumming methods, including water degumming, acid degumming, organic degumming, chemical degumming with ethylene diamine tetraacetic acid (EDTA), and enzyme degumming using phospholipases. Water degumming is used for oils with low concentrations of non-hydratable phosphatides (NHPs). This process exploits the hydration phenomenon to remove potential gum-forming substances and other hydrophilic substances by adding warm water to facilitate gum formation, and then physically separating them from the oil. Low concentrations of phosphoric acid are added to dissociate the NHPs into hydratable phosphatidic acid. In acid degumming, higher concentrations of acids, usually phosphoric or citric, are used to degum oils with higher concentrations of NHPs.

2.1.3.2 Neutralization (removal of free fatty acids)

Neutralization can be achieved by chemical or physical means (see 2.1.3.4). In alkali (chemical) refining, phosphoric acid is used to condition the oil, after which sodium hydroxide is mixed with the oil. The sodium hydroxide saponifies the free fatty acids, neutralizes phosphoric acid from upstream processes, and hydrates and saponifies phospholipids. After a specified reaction time, the oil is mixed with hot water and the unwanted soapstock is split from the oil by centrifugation or gravitational settling. The residual moisture is then removed from the oil under vacuum.

2.1.3.3 Bleaching

As the name suggests, bleaching removes pigmented molecules that may impart undesirable colour/s to the oil. Primary and secondary oxidation products, soaps and polyaromatics are removed simultaneously. Molecules are adsorbed onto the surface of activated bentonite clays by electrostatic forces or chemical reactions. The oil is then separated from the spent clay by filtration.

2.1.3.4 Winterising (dewaxing)

Some oils, including sunflower and Canola oils, may contain waxes that become insoluble at cold temperatures. Waxes impart a hazy appearance to the oil. Historically, this took place in winter; hence the name 'winterising' was given to the wax removal process. Dewaxing is typically accomplished by cooling the oil and separating the waxes by filtering or centrifugation.

2.1.3.5 Deodorising/distillation

Deodorising removes most of the volatile compounds responsible for off-odours in the oils. It also eliminates some pesticide residues and other potentially harmful chemicals such as polycyclic aromatic hydrocarbons. However, the steam stripping process is quite indiscriminate, and desirable molecules like antioxidants may also be removed. The volatiles are stripped from the oil by steam at 160-260^{o}C.

A similar steam stripping process, distillation, also removes free fatty acids from oils that have been physically refined (i.e. have not been chemically neutralized).

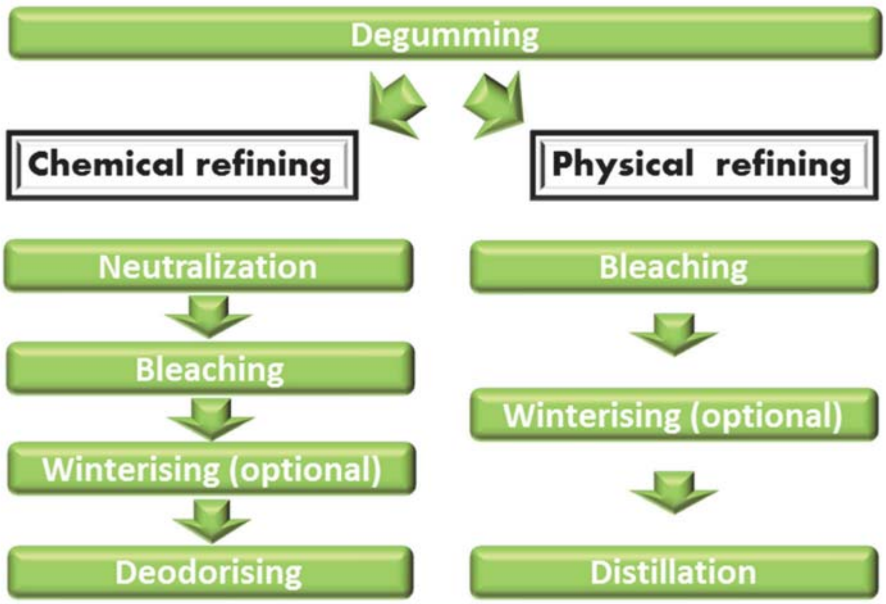

Figure 9: Flow diagram comparing common chemical and physical oilseed refining processes

2.1.4 Process inputs and outputs: beneficial uses for by-products

Figure 10 is a flow diagram that depicts the typical inputs (raw material, water, energy, chemicals) and outputs (products, solid waste, wastewater, and by-products) from seed oil processing. The water, wastewater and energy are dealt with in more detail in sections 4, 5 and 6 of this document.

2.1.4.1 By-products from seed oil extraction

Sunflower and canola **hulls** are by-products of pre-treatment. In SA, these are sold as a low quality component of animal feed, as animal bedding, or are burnt as a source of energy in boilers. The **solvent** used for extraction (usually hexane) is almost completely recovered by distillation and re-used in the process, whereas the **oilcakes** are sold as high grade animal fodder or further refined for human and/or animal consumption (e.g. soya meal) (Figure 10A). In fact, in the case of soya, the oilcakes may constitute the most important product, with the oil being seen as a valuable by-product. In this country, in facilities geared towards the production of high value milled products such as soya meal and flour, maize meal, porridge, etc., the oils are not solvent extracted, but cold-pressed.

2.1.4.2 By-products and solid waste from seed oil refining in South Africa

In SA, a number of by-products of the refining process are used beneficially (Figure 10B). The gums are generally sold as animal fodder, often added to the hulls and/or other lignocellulosic by-products (to aid with digestibility). The saponified fatty acids in **soapstock** are typically split from the salt (Na^+) using H_2SO_4. This process is known as soap-splitting or acidulation and results in the generation of acid oil and acid wastewater. In SA, there are a number of facilities that make soap and/or candles from the acid oil and other by-products of oil refining. In some instances, the **spent bleaching clays** are sold as (low value) fertilisers, but they are also sent to landfill. Not only is landfill disposal costly, but it also creates an environmental burden. There is a need to further **research** uses (or re-use) of bleaching clays in SA. Most of the facilities that were visited indicated that they would be interested in exploring clay regeneration, processes to add value to the spent clays, and/or cost-effective means of recovering lost product from the clays.

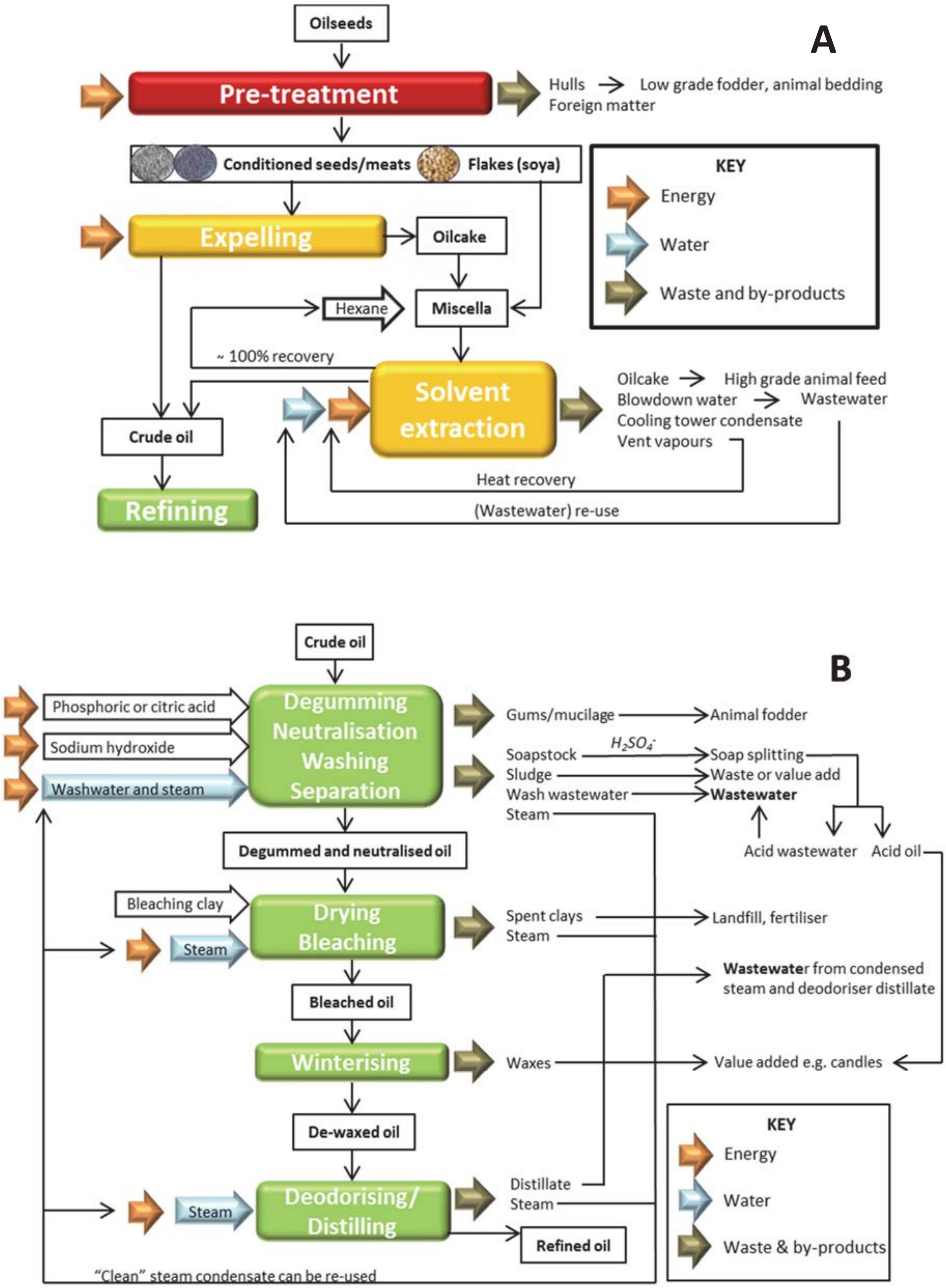

Figure 10: Flow diagrams showing (A) the typical overall pre-treatment and oil extraction processes, and (B) refinement processes, in relation to the basic energy and water inputs, waste/wastewater and by-product generation, and recycling

2.1.4.3 Solid waste from fruit oil production in South Africa

Both respondents from the olive oil industry indicated that they used the pomace/slurry for compost with no detrimental effect. One of the respondents was also experimenting with the manufacture of fire bricks from the solid residues.

2.2 Fruit oils

Oils are extracted from the soft pulp of fruits, the composition of which is considerably different to oilseeds. Consequently, the extraction processes are also completely different. In SA, all olive oil is cold-pressed, which means that it is not refined after extraction. The product is known as virgin olive oil (Figure 11). Avocado oil is also cold-pressed. A proportion is refined and mixed with the cold-pressed oil.

2.2.1 Pre-treatment of raw material

On arrival, olives are sorted and leaves, grit, and other unwanted debris is removed by mechanical means and by washing with water. Thereafter, the olives are pre-treated to render the fruit pulp suitable for pressing. Pre-treatment of avocados involves stone removal, skin removal and disintegration of the pulp.

2.2.1.1 Crushing

The oil is found mostly in vacuoles, but to a lesser extent in the mesocarp cell cytoplasm of the fruit. Crushing and malaxing help to release these oils. The fruit is crushed into a paste using mechanical crushers such as hammer mills. The crushing process must be carefully controlled (for example, to prevent over-heating which may cause oxidation, or over-crushing which can release bitter-tasting phenolics into the oil).

2.2.1.2 Malaxing

Malaxing releases additional oils from the tissues of the fruit and causes dispersed oil droplets to coalesce, thereby improving the qualitative and quantitative oil yield. The crushed paste is slowly stirred under controlled time and temperature conditions. The temperature is controlled by the circulation of heated water in jackets of the malaxers. Higher temperatures increase the oil yield, but temperatures over 30°C causes chemical changes which result in undesirable colour and sensorial properties. Malaxers that operate in nitrogen-controlled atmospheres, at temperatures between 25°C and 27°C, with a maximum processing time of one hour, have proven to be most effective in producing oils with superior sensorial and nutritional qualities.

2.2.2 Oil pressing/extraction

2.2.2.1 Centrifugation and decanting

The term ‘cold-pressing’ is misleading because, as in the case with oilseeds, fruit is no longer actually pressed. Nowadays, oils are most commonly separated from the pomace by centrifugation. In the case of olives, 3-phase centrifugation was historically used, where water (40% to 60% w/w) was added into the centrifugal process and three separate phases were obtained (oily must, olive mill wastewater, and pomace). More recently, 2-phase centrifugation has been introduced in which no additional water is added and 2 phases are obtained (oily must and watery pomace). Due to the fact that the olive oil industry in SA is relatively young, 2-phase centrifugation dominates in this country.

2.2.3 Refining

Although virgin oil is considered to be un-refined, fine solids that would negatively impact the quality of the oil during storage are removed after centrifugation. This is performed by adding warm water to the decanted oily must and centrifuging to the separate oil, water and solids.

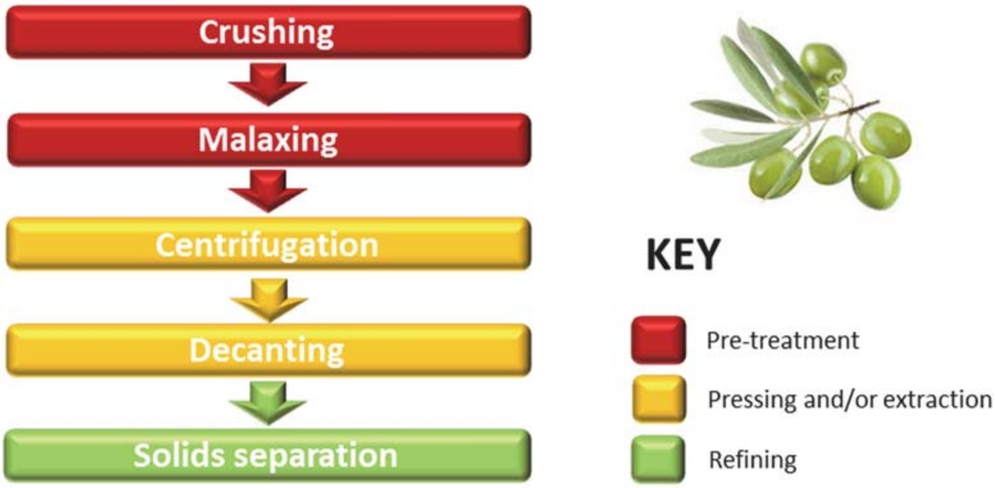

Figure 11: Flow diagram for the production of cold-pressed fruit oil using modern methods

Section 2 References:

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Section 3: Regulations, policies, by-laws and tariffs for water use, wastewater generation, and the environment

South Africa has a three-tier system of government, i.e. national, provincial and local government. In general, national government is responsible for high level security functions, economic regulation and social development. The provincial government is responsible for regional economic planning, housing, environmental management, rural livelihoods and human development, and the local government is responsible for basic service provision and for creating an enabling environment for local businesses. The relationship between these three spheres of government is based on a system of co-operative governance defined in the Constitution.

On a local level, governance takes place through municipalities such that all urban and rural areas fall under local municipal control. There are three types of municipalities – metropolitan, district and local municipalities. The largest metropolitan areas are governed by metropolitan municipalities which have exclusive municipal executive and legislative authority in their respective areas, while the rest of the country is divided into district municipalities, each of which consist of several local municipalities. There are eight metropolitan municipalities, 44 district municipalities and 226 local municipalities within South Africa.

3.1 National policies

The Bill of Rights in the Constitution of the Republic of SA (Act 108 of 1996) enshrines the concept of sustainability. Rights regarding the environment, water, access to information, and just administrative action are specified in the act. These rights and other requirements are further legislated through the National Water Act (NWA; Act 36 of 1998). The latter provides the legal basis for water management in SA by ensuring ecological integrity, economic growth, and social equity when managing water use.

The NWA Act introduced the concept of Integrated Water Resource Management (IWRM), which provides for resource and source directed measures to manage the aquatic environment. Resource directed measures aim to protect and manage the environment that receives water, while source directed measures aim to control the impact on the receiving environment by preventing pollution, reusing water, and treating wastewater. The integration of resource and source directed measures forms the basis of the hierarchy of decision-taking aimed at mitigating the effect of waste generation. This hierarchy is based on a precautionary approach and the order of priority for water and waste management decisions and/or actions are shown in Figure 12.

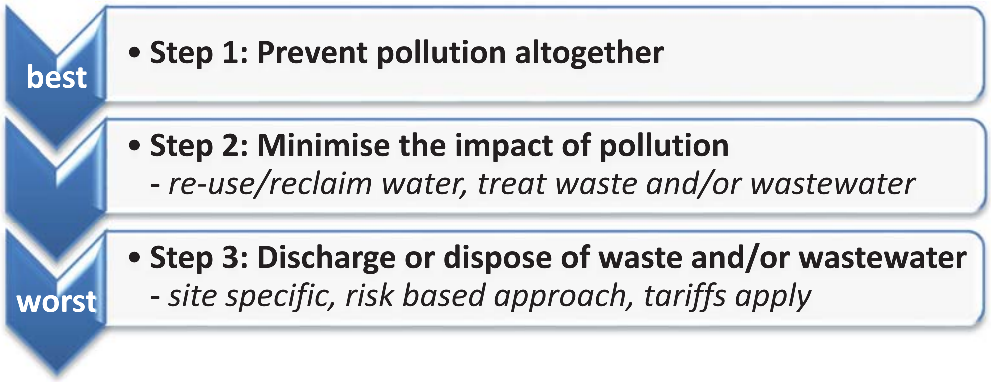

Figure 12: Hierarchy of decision making to protect water resources

3.1.1 Water policies

The recently formed Department of Water and Sanitation [DWS, 2014 – formerly the Department of Water Affairs (DWA) and the Department of Water Affairs and Forestry (DWAF)] is the water and sanitation sector leader in SA. DWS is the custodian of SA's water resources and of the NWA and the Water Services Act (WSA; Act 108 of 1997). DWS is also the national regulator of the water services sector.

The NWA provides the legal framework for the effective and sustainable management of water resources within SA. The WSA deals mainly with water services or potable (drinkable) water and sanitation services supplied by municipalities to households and other municipal water users. It contains rules about how municipalities should provide water supply and sanitation services. Within each municipal area, by-laws are developed which outline the water supply and effluent discharge regulations and tariffs for that area (Section 3.2).

3.1.2 Wastewater policy

Under the NWA, norms and standards for the treatment of wastewater or effluent prior to discharge have been set. These consist of general and special standards and set limits for parameters such as pH, temperature, chemical oxygen demand (COD), suspended solids, metals, etc. The assays that may be used to determine these levels are also specified. Any industries, or municipal or private wastewater treatment works discharging to river or sea must comply with these limits. In turn, the entity operating a wastewater treatment works must set limits for industries discharging to the works such that the DWS final discharge limits can be met.

3.1.3 Environmental policies

The constitution of SA stipulates that everyone has the right to an environment that is not harmful to his or her health or well-being. This includes the right of environmental protection for the benefit of present and future generations through reasonable legislative and other measures to prevent pollution and ecological degradation, promote conservation, and secure ecologically sustainable development and use of natural resources. These rights must be balanced with the promotion of justifiable economic and social development. Regulation that addresses these rights falls under the responsibility of the Department of Environmental Affairs (DEA).

Policies that are the most relevant to the EO sector are the National Environmental Management Act, 1998 (Act 107 of 1998), the National Environmental Management: Waste Act, (Act 59 of 2008), and the National Environmental Management: Air Quality Act (Act no. 39 of 2004). Broadly speaking, these Acts outline the requirements for the storage and handling of waste on-site, licensing requirements, the establishment of waste management plans, the setting of limits for air emissions, and the setting of penalties for offences.

3.2 Municipal by-laws, and water and effluent tariffs

The WSA sets out the regulatory framework for institutions tasked with the supply of water services. The act makes provision for different water service institutions to be established as follows:

- The water services authority – i.e. the responsible municipality
- The water services provider – the entity whose role is to physically provide the water supply and sanitation services to consumers

Municipal units are governed by municipal policies and by-laws for the provision of water and sanitation services, water services development, and sewage disposal. The latter includes the discharge of domestic, commercial and industrial effluent. Tariffs are set for these services at a municipal level, and are generally revised on an annual basis. Any industry wishing to discharge to a wastewater treatment works must apply to the relevant municipality for a trade effluent permit. Trade effluent may not be accepted if it contains concentrations of substances above stated limits, which vary from municipality to municipality. In terms of by-laws, municipalities are entitled to take random or scheduled samples of effluent to ensure compliance with regulations and permits. Separate limits may apply for wastewater treatment facilities with different capacities, or for discharge to sea outfalls for coastal municipalities. Depending of local by-laws, requirements for obtaining permits may include stipulations about discharge days and/or times, and requirements for up-front assessments to identify possible means of reducing water consumption and wastewater generation at source. The effluent discharge costs may include punitive fines for non-compliance to stipulated limits. However, many municipalities strive to rather work with industry to attain acceptable water usage and wastewater discharge quality, than to apply punitive measures.

There is a great deal of variation in the formulae used by different municipalities to calculate tariffs, discharge limits, and punitive fines. The by-laws, formulae and tariffs for selected metropolitan municipalities where EO facilities are located are described briefly in Section 3.2.

3.2.1 eThekwini metropolitan municipality

Industrial, commercial and institutional customers are charged for the acceptance of sewage into the municipal sewerage reticulation system by means of a volume based sewage disposal charge.

In addition, industries permitted to discharge trade effluent with a pollution load exceeding that of typical domestic sewage, are charged for disposal according to Equation 1. Data on basic unit costs for water and effluent and the values for V and Z used in Equation 1 are provided in Table 3.

$$\text{Volume based charge} + V\left(\frac{COD}{360} - 1\right) + Z\left(\frac{SS}{9} - 1\right) \qquad \text{Equation 1}$$

Where:

COD = chemical oxygen demand in mg/L, SS = settleable solids in L/L, V = rate for the treatment of domestic effluent (COD < 360 mg/L), Z = rate for the treatment of domestic effluent (SS < 9 ml/L)

The volume of trade effluent discharged is determined by an effluent meter. If no meter is in place, the volume is determined from a water balance questionnaire which is filled in by the company. The effluent volume is calculated by deducting the volume of domestic effluent, process water, and evaporative losses from the incoming water volume.

Table 3: Basic unit costs for water and industrial effluent

Period	Effluent	Effluent	Effluent	Water
	Unit cost (R/kl)	COD charge (V) (R/kl)	SS Charge (Z) (R/kl)	Unit cost (R/kl)
2011-2012	5.34	0.57	0.52	12.80
2012-2013	5.68	0.60	0.56	14.79
2013-2014	6.07	0.65	0.59	16.63
2014-2015	6.54	0.71	0.64	18.78
2015-2016	7.06	0.76	0.69	20.84
2016-2017*	7.62	0.82	0.74	23.14

*predicted values

3.2.2 City of Tshwane metropolitan municipality

The relevant policies within the City of Tshwane are the sanitation and water tariff policies which outline the approach taken by the municipality when setting water and sanitation charges. There are three different charge categories for industrial effluent:

1. **Normal conveyance and treatment charge**: Applies to effluent of the same quality as domestic wastewater discharged to sewer and is calculated by multiplying the combined unit conveyance and treatment cost by the volume discharged. Industrial consumers are charged the tariff cost with a rebate of 10%.

2. **Extraordinary treatment charge:** Applies when the pollution loading exceeds that of 'normal' domestic wastewater and is calculated according to Equation 2:

$$Tc = Qc.t[0.6\,\frac{(CODc - CODd)}{CODd} + 0.25\,\frac{(Pc - Pd)}{Pd} + 0.15\,\frac{(Nc - Nd)}{Nd}] \qquad \text{Equation 2}$$

Where:

T_c = extraordinary cost to the consumer, Q_c = wastewater volume (kL), t = unit treatment cost of wastewater (94c/kL in 2014), COD_c = total measured COD (mg/L), COD_d = COD of domestic wastewater (710 mg/L), P_c = measured orthophosphate (mgP/L), P_d = orthophosphate concentration of domestic wastewater (10 mgP/L), N_c = measured ammonia concentration (mgN/L), N_d = ammonia concentration of domestic wastewater (25 mgN/L)

3. **Non-compliance with by-law limits**: where the stipulated limits are exceeded, the tariff is calculated according to Equation 3:

$$T_C = Q / D.N\,[C_{AIP} - B_{LL}/W_{PL}]t_{NC} \qquad \text{Equation 3}$$

Where:

T_c = charge for non-compliance, Q = monthly volume in kL, D = working days in the month, N = number of days exceeding by-law, C_{AIP} = ave. concentration of parameter exceeding by-law, B_{LL}= by-law limit, W_{PL}= Water Affairs standard limitation on parameter exceeding by-law, t_{NC} = tariff (65c/kL)

The cost for potable water provided by the City of Tshwane is calculated using a sliding scale determined by how much water is utilised. The more water consumed, the less the charge (Table 4). There is one basic charge (per kL) for effluent discharge (Table 4), calculated on 60% of incoming water.

Table 4: Basic unit costs for water and industrial effluent

Period	Effluent	Water	Water	Water
	All volumes R/kl	0-10000 (R/kl)	10001-100000 (R/kl)	>100000 R/kl
2012-2013	4.66	11.89	11.29	10.52
2013-2014	5.13	13.08	12.42	11.57
2014-2015	5.64	14.39	13.66	12.73

3.2.3 City of Cape Town metropolitan municipality

The discharge of industrial effluent has been promulgated in the City of Cape Town industrial wastewater and effluent by-law of 2006, which was amended in 2014. The volume of industrial wastewater discharged is calculated by the municipality after deducting "fair" amounts for atmospheric losses, water used for irrigation, and water present in product. The charge for industrial wastewater discharge to sewer is calculated according to Equation 4 and 5. Limits are set for certain parameters (Table 5). If these are exceeded, surcharges apply in accordance with Equations 4 and 5.

$$Vw(SVC) + \frac{VieT(COD-1000)}{1500} + VieT(SF) \quad \text{Equation 4}$$

Where:

Vw = Total volume of water discharged, SVC = Sewage volumetric charge, VieT = Total industrial effluent discharged, SF = surcharge factor calculated according to equation 5

$$SF = (X - L)/L \quad \text{Equation 5}$$

Where:

X = concentration of one or more parameters from schedule (Table 5), L = limit applicable to particular parameter (Table 5).

Table 5: Parameter limits for industrial wastewater for discharge to sewer

General parameters		Chemicals (non-metals)		Metals	
Parameter	**Limit**	**Parameter**	**Limit**	**Parameter**	**Limit**
Temp	< 40°C	**TS, Cl, SO_4^{-2}**	1 500 mg/l	**Fe**	50 mg/l
EC (at 25°C)	500 mS/m	**Na**	1 000 mg/l	**Zn**	30 mg/l
pH (at 25°C)	5.5-12	**FOG + waxes**	400 mg/l	**Cr, Cu**	20 mg/L
COD	5000 mg/L	**PI, SO^{2-}**	50 mg/l	**Total**	≤ 50 mg/l
Sett.S	50 ml/L	**P**	25 mg/l	**A, B, Pb,**	
SS	1000 mg/L	**CN**	20 mg/l	**Se, Hg, Ti**	5 mg/l each Total ≤ 20 mg/l
TDS	4 000 mg/L			**Cd, Ni**	

EC = electrical conductivity, Sett.S = settleable solids, SS = suspended solids, TDS = total dissolved solids, TS = total sugars and starches as glucose, FOG = fats, oils, grease

Table 6: Basic unit costs for water for industry and industrial effluent

Period	Effluent Standard	Effluent Oxidation dams	Water
	R/kl	(R/kl)	(R/kl)
2014-2015	11.84	11.13	15.41
2015-2016	13.14	12.36	17.10

Calculated on 95% of water consumption. This figure may be adjusted by the director of water services

3.2.4 Ekurhuleni metropolitan municipality

There are many industries in this metropole and the wastewater treatment facilities discharge to inland systems. The charges levied by Ekurhuleni municipality, in terms of their by-laws and tariff structure, are particularly complicated. There is a general stipulation that no effluent is allowed to be discharged if it is above 44°C, if it contains tars, bitumen or asphalt, or if it contains substances that are explosive, flammable, poisonous, corrosive, give off offensive gases or vapours, create excessive foam, have an undesirable colour, impart a bad taste after chlorination, have a negative effect on the receiving wastewater treatment facility, or are hazardous to the staff at the facility. Industrial wastewater discharge costs are calculated according to Equation 6, and limits are imposed (Table 7). Limits are subject to a degree of flexibility on consultation with the council on an individual basis. If there is no accurate flow meter, the discharge volume is determined in consultation between the service provider and user "as accurately as is reasonably practical".

$$Ti = c/12(\frac{Qi}{Qt})[a + b\left(\frac{CODi}{CODt}\right) + d\left(\frac{Pi}{Pt}\right) + c\left(\frac{Ni}{Nt}\right) + f(\frac{SSi}{SSt})] \qquad \text{Equation 6}$$

Where:

Ti = monthly charge, C = full cost of effluent treatment for municipality, which is the sanitation cost + 15%, Qi = ave. flow from premises (FP) in kl/d, Qt = ave. daily inflow in kl to council treatment system over 5 years (CS5Y), CODi = ave. monthly COD, CPDt = ave. COD to CS5Y, Pi = ave. montly σ-P conc., Pt = ave. σ-P conc CS5Y, Ni = ave. monthly NH_3/NH_4 conc., Nt = ave. NH_3/NH_4 conc. CS5Y, SSi = ave. SS conc., SSt = ave. SS conc. CS5Y, a = portion of fixed cost for wastewater treatment and conveyance, b,d,e,f = portion of cost directly related to the removal of COD (a), σ-P (b), NH_3/NH_4 (e), and SS (f)

COD, P and NH_3/NH_4 all measured in mg/l

Table 7: Fixed costs applicable to Equation 6

	Qt	CODt	Pt	Nt	SSt	a	b	d	e	f
2014/15	698605	757	4.4	23.1	294	0.29	0.26	0.16	0.15	0.14
2015/16	718370	753	3.81	22.7	296	0.29	0.26	0.16	0.15	0.14

Table 7: Basic unit costs for water for industry and industrial effluent

Period	Effluent	Effluent	Effluent	Water	Water	Water
kl	**0-5000 (R/kl)**	**5001-25000 (R/kl)**	**> 25000 (R/kl)**	**0-5000 (R/kl)**	**5001-25000 (R/kl)**	**> 25000 (R/kl)**
2014-2015	6.89	4.03	3.39	14.21	14.45	15.08
2015-2016	7.54	4.41	3.71	16.28	16.55	17.27

Above costs are exclusive of VAT

If limits (Table 8) are exceeded, the additional charge (2015/2016) that is imposed is the highest of R1.66/kl or R1649/month for each parameter exceeding the limit.

Table 8: Parameter limits for industrial wastewater for discharge to sewer

Determinant		Determinant		Metals and other elements	
Parameter	**Limit**	**Parameter**	**Limit**	**Parameter**	**Limit**
pH	>10 < 6	**Na**	500 mg/l		
EC (@ 25^{o}C)	500 mS/m	**NH_4 (as N)**	200 mg/l		
COD	5000 mg/L	**σ-P (as P)**	50 mg/L		
Phenols	150 mg/l	**SO_4^{-2}**	1800 mg/l		
Suspended non organics	100 mg/l	**SO^{2-} (as S)**	10 mg/l	**Ni, Zn, Co, Cr**	20 mg/l each Total 40 mg/l*
FOGW **>10000 kl/month**	1000 mg/l	**H_2S**	5 mg/l	**Pb, Cu, Cd, As, B, Se, Hg, Mo**	5 mg/l Total 20 mg/l*
FOGW **>10000 kl/month**	500 mg/l	**CH_2O**	50 mg/l	**Al, Fe, Ag, W, Ti, Mn**	20 mg/l*
FOGW in ether	500 mg/l	**HCN**	20 mg/L		
Anionic surface active agents	500 mg/l	**Available Chlorine (Cl)**	100 mg/l		
Caustic alk.	2000 $CaCO_3$ mg/l	**Chloride (Cl)**			
TS	1500 mg/l				

EC = electrical conductivity, TS = total sugars and starches as glucose, FOGW = fats, oils, grease, waxes

***metal limits: if exceeded, in addition to fines, inspection charges ranging from R1346.00 (first inspection) to R8237 (third inspection) will be charged (2015/2016 rates)**

Section 3 References:

City of Cape Town metropolitan municipality by-laws and tariffs: www.capetown.gov.za / accessed August 2015

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eThekwini metropolitan municipality by-laws and tariffs: www.durban.gov.za / accessed August 2015

Section 4: Water Use and Management

In comparison to many other industries, there is limited information in the public domain on water management in the EO industry. Compliance of the local EO industry with data collection was low. Much of the data and information in Section 4 has therefore been extracted from available literature and global figures.

4.1 What is water used for in the edible oil industry?

4.1.1 Seed oils

Significant volumes of water in the form of **process water**, **steam,** and **cooling water** are required for EO production. In addition, water is used to clean the equipment and floors. Open steam is used for some processes, while condensing steam and/or hot water in **heat exchangers** is used to heat the oil to the required process, storage and transfer temperatures. Conversely, cool water in heat exchangers is used to decrease the temperature of the oil (Figure 13 A). Typically, the oil and water is compartmentalised in the heat exchangers, and the water can therefore be recycled. Heat can be re-captured in heat exchangers, and latent heat from steam can be captured in condensers, but excess warm water needs to be cooled for re-use. This is achieved in **cooling towers**, where evaporation provides the mechanism for cooling (Figure 13 B). However, some water is lost via evaporation or drifts into the atmosphere from the cooling towers. In addition, the water eventually becomes contaminated and must be wasted. This is known as blow down water. The water used to make up the deficit is known as make-up water.

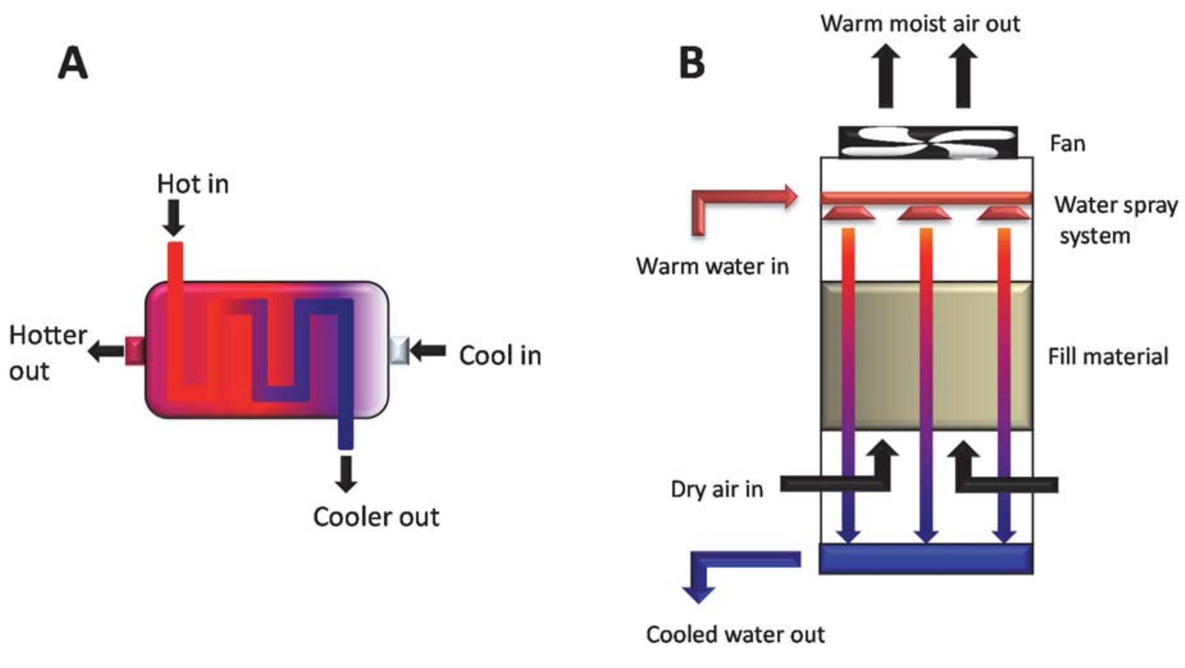


Figure 13: Schematic diagrams illustrating the principles of heat exchange systems (A) and countercurrent water cooling towers (B)

Water is required for both extraction and refining. Although the largest process water requirements are for steam and cooling during solvent extraction, this water is recycled. Water used for washing equipment, floors, and truck wash bays is wasted. The water that is not lost to the atmosphere in the form of steam, and which is used (during extraction) and for washing the oil after degumming, neutralising, and winterising (during refining), is wasted.

Table 9 gives a comparative assessment of water usage for different processes at a glance: Blue drops and red drop symbolise direct water and cooling water, and direct and indirect steam/hot water, respectively. The number of drops represents comparative water usage, with three drops representing the most water demanding processes. In addition, the Table indicates whether the water is discharged directly, or whether it can be recycled. For example, relatively large volumes of cooling water and small volumes of steam are required for solvent extraction. However, the former is typcially recycled, while the latter is not.

Table 9: Typical relative water usage for various extraction and refining processes in the edible oil industry

	Direct water	Cooling water	Direct steam or hot water	Indirect steam or hot water
				
EXTRACTION				
Conditioning			-	-
Expanding	-	-		
Solvent extraction				
REFINING				
Degumming			Hot or cold	
Neutralising		-	-	
Deodorising	-			-
Winterising			-	

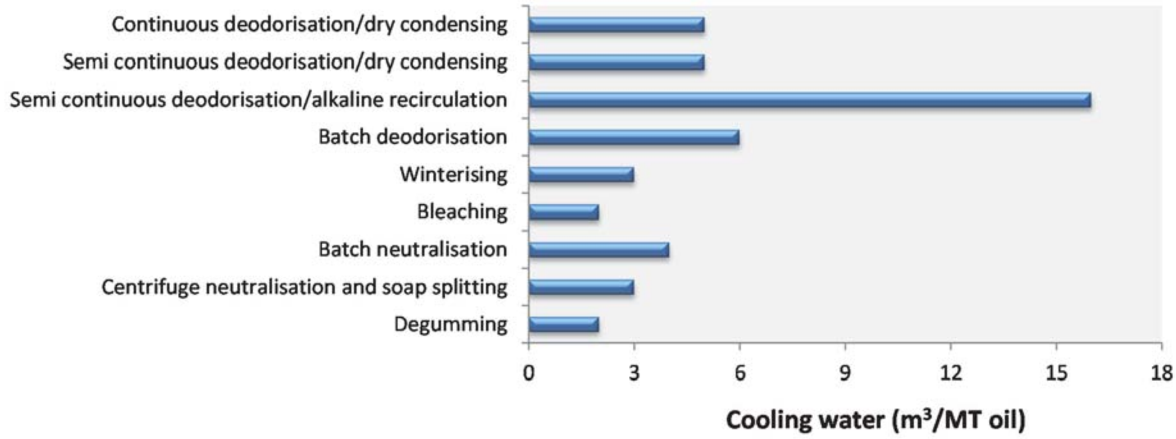
 **to**  **relative use of direct water and cooling water for each process**

 **to**  **relative use of direct steam/hot water and indirect steam/not water for each process**

 **Recycled or partially recucled**  **Wasted after use**

In EO refineries, different process options can have vastly different water requirements. For example, refineries that employ continuous or semi-continuous deodorisation with dry condensing use < 0.05 MT steam/MT oil, while those employing semi-continuous deodorisation with alkaline recirculation or batch deodorisation, can use approximately 2 and 5.5 times this amount, respectively (Figure 14).

Figures for steam utlisation were obtained from one facility in SA. This facility uses 0.09 MT steam/MT oil for neutralision, which is lower than the 0.15 MT cited by Hamm et al. (2013). The same facility uses 0.16 L/m^3 oil of water for steam, slightly higher than the 0.14 MT cited by Hamm et al. (2013) for semi-continuous deodorisation with alkaline recirculation (Figure 14).



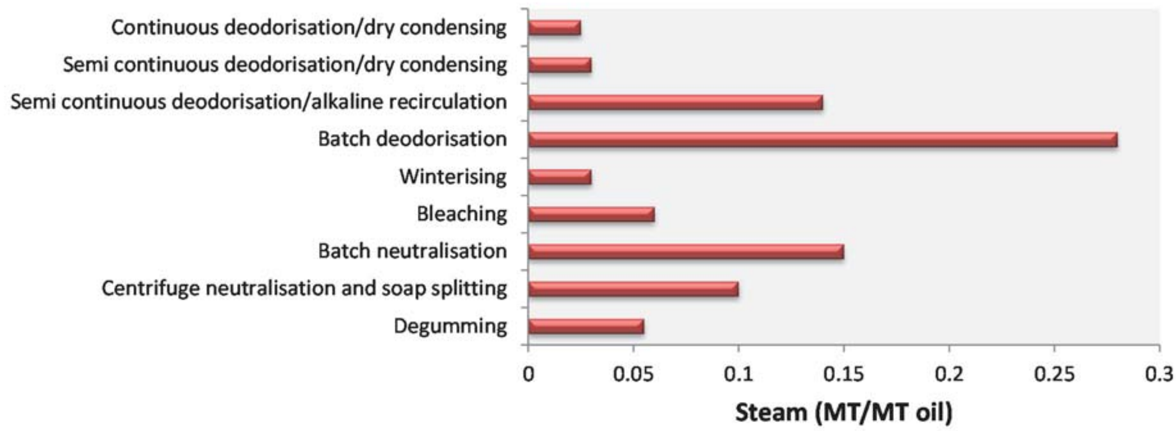


Figure 14: Relative volumes of cooling water and steam required for various processes in a typical edible oil refinery (adapted from Hamm et al., 2013)

4.2 Water usage in the edible oil industry

4.2.1 Seed oils

In the previous NATSURV, published more than two decades ago, the specific water intake (SWI) was calculated from **one EO processing facility**. Although this figure is dated, it still compares favourably with more current literature values (Table 10). There seems to be a downward trend in the SWI from the previous NATSURV, but there is insufficient sufficient data from either NATSURV to ascertain whether this is statistically significant.

There are a number of dry mills in SA that produce varying volumes of EO as ancillary products. These mills do not use water in the milling process, and do not generate significant quantities of wastewater requiring treatment.

All seed oil respondents from SA use mainly potable municipal water. Of the seven respondents, one professed to have water use reduction targets in place. However, this facility could not provide any water usage figures. Regarding 'unnecessary' water use, one industry identified that large volumes of water are being used to dampen boiler ash. This is applicable to a number of industries in South Africa. *It was suggested that the WRC fund research into alternative methodologies to limit formation of dust from boiler ash in order to save water*.

Table 10: Comparison of specific water intake at edible oil processing facilities

Process(es)	Oil volume	Specific water intake		Country/Reference
	(MT/year)	Ave (m^3/MT oil)	Range (m^3/MT oil)	
E,R	24 000	4.1	N/A	Egypt, SEAM (1999)
M	24 960	2.6	2.1-3.1	SA, NATSURV (1987)
R	30 240	3.8	3.2-4.6	SA, NATSURV (1987)
M,E,CR	50 000 crude 30 000 refined	<1.5*	NG	SA, NATSURV (2015/16)
PR,V	24 000 refined	0.29	NG	SA, NATSURV (2015/16)
M,E,PR	± 125 000 crude Variable refined		NG	SA, NATSURV (2015/16)
M,E,CR,V	150 000 crude Variable refined	NG	NG	SA, NATSURV (2015/16)
M,E,CR	36 000 refined	NG**	NG	SA, NATSURV (2015/16)
DM	52 000 crude	Negligible***	NA	SA, NATSURV (2015/16)

M = milling DM = dry milling E = extraction R = refining V = value added processes CR = chemical refining
NG = not given NA = not applicable
***only refined oil used for calculation, additional 20 000 MT crude oil not taken into account**
****5% of water used for degumming and 10% for neutralising**
***** wash water only**

Benchmarks for usage of cooling water, water for chemical neutralisation, and deodorisation have recently been published by the International Finance Corporation (IFC), mainly based on documents emanating from the United States and Europe, and originally published in the European Commission (EC) Integrated Pollution Prevention and Control reference document on Best Available Technology in the food, drink and milk industries (2006). There is no updated data available. Two SA respondents provided figures for water ustilisation for some processes, which were far lower than the benchmark cited in the IFC/EC documents (Table 11). This may be because the benchmarks are out-dated and/or that the SA respondents have implemented production processes with low water usages. However, due to low compliance by industry, it is not known whether these figures are representative of the industry at large.

Table 11: Specific water intakes: benchmarks and/or South African values for cooling water, neutralisation, deodorising, and degumming

	Cooling water (m^3/MT oil)	Neutralisation (m^3/MT oil)	Deodorising (m^3/MT oil)	Degumming	Reference (m^3/MT oil)
Benchmark	2-14	1-1.5	10-30	NG	IFC, 2015
SA 1	NG	0.1	0.18	NG	NATSURV, 2016
SA 2	NG	NG	NG	5.8×10^{-2}	NATSURV, 2016

Water costs in SA are predicted to rise substantially over the next decades in response to the effect of climate change on water availability, and a growing population on water usage. Many industries will be forced to save water in order to remain financially sustainable and competitive on a local and global scale. In 2015, the different municipal tariffs for industry were highly variable (Tables 5 to 9).

The annual cost of municipal water to produce one MT of product ranged from R 2.97 (physical refining, value add) to 9.30 R/MT oil (milling, extraction, chemical refining) (Table 12).

Table 12: Edible oil processing facilities in South Africa: annual water use tariffs

Process/es	Water source/es	Municipal tariff	Volume	Cost
		R/kl	kl/year	R/MT oil
M,E,CR	Municipal	10.25	45 000	9.30
PR,V	Municipal	10.19	7 000	2.97
M,E,PR	Municipal	17.27	200 L/hr*	NG
DM	Municipal	NA	NA	NA

Tariffs as at December 2015

M = milling E = extraction R = refining V = value added processes CR = chemical refining PR = physical refining NG = not given NA = not applicable

***For degumming – no other figures provided by facility**

4.2.2 Fruit oils

In South Africa, three phase extraction is used for olive oil processing, so water is only used for washing the olives before processing, and washing equipment and floors after use. Of the two study respondents, one facility uses borehole water and the other harvested rainwater. These facilities each produce ≤ 12 MT of oil/year, and estimate that the SWI is ± 0.02 kL/MT. If other boutique olive oil producers in SA have similar water usage practices, it can be roughly estimated that this sector of the industry consumes a total of 10 kl water/year. To put this in perspective, this is about half the volume of water used by the average South African taking a daily shower for one year. It is possible that the figures for larger facilities differ, but this could not be verified as none elected to take part in the survey. The major avocado oil processing facility in SA utilises 'farm' water and does not quantify the volume used. However, the facility only produces 100 MT of oil/year, so the overall volume is also likely to be relatively negligible.

4.3 Water Use: Best Practice

Best practice can be defined as "strategies, activities or approaches that have been shown through research and evaluation to be effective and/or efficient". The term is somewhat controversial, because some feel that there are always ways to improve, and application of the word "best" suggests that no further innovation is necessary. Nevertheless, it is an accepted term that is widely applied. The catch-phrase 'reduce, re-use, recycle' applies to just about all the world's resources, including water, and forms part of the best practice hierarchy (Figure 15).

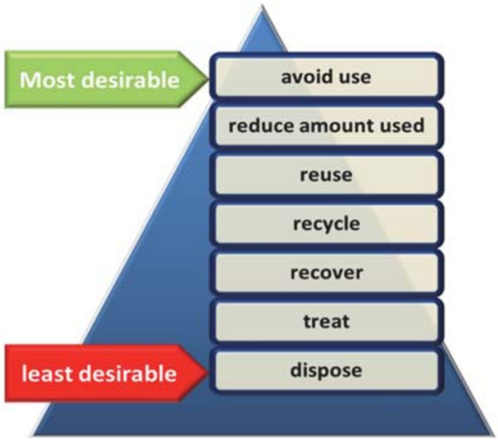


Figure 15: Best practice hierarchy – towards a sustainable future

There are a number of recommendations for optimising water efficiency in the EO industry:

- **Physical refining:** Where possible, physical refining should be employed instead of chemical refining.
- **Continuous deodorisation:** This uses significantly less water than batch processes and should be considered as a better alternative.
- **Mechanical conveyer systems**: Mechanical systems are preferable to water-based conveyer systems.
- **Cleaning in place (CIP)**: If possible, CIP procedures should be installed for tanks, pipes, and centrifuges.
- **Heat condensates:** Condensates should be recovered and re-used as much as possible.
- **Equipment upgrade**: It is relatively affordable to upgrade water sprayers (e.g. nozzles that use less water, self-closing nozzles), high-pressure, low-volume washing systems, auto shut-off valves. It has been shown that the use of these can save significant volumes of water.
- **Dry clean-up techniques** Equipment and spills should be wiped up a before washing or rinsing with water (e.g. floors, vessels).
- **Cooling towers:** Cooling towers should be kept clean and in good working order to maximise efficiency. Automatic blow-down should be monitored to prevent excessive water losses.
- **Blowdown wastewater**: Recycled water, such as blowdown water should be used to moisten coal ash. Blowdown water could also be treated by reverse osmosis for process re-use.
- **Water meters**: It has been shown that installation of water meters as part of a water management and monitoring program results in water savings, because it creates awareness of where water is being wasted.
- **Educate staff**: It is critical that the factory workers are trained how to apply water-saving measures. Education about the reasons for saving water is an important aspect that should be included in training.
- **Re-use water**: Water re-use can easily be accomplished in processes where lower quality water is acceptable.
- **Re-use treated effluent:** If suitable, this can be used for floor washing and/or beneficial irrigation.

Section 4 References:

European Commission Integrated pollution prevention and control reference document on best available technology in the food, drink and milk industries (2006).

Hamm, W., Hamilton, R.J., Calliauw, G. (2013) Edible oil processing. 2nd edition. Markono print media: Chennai.

International Finance Corporation (IFC) Environmental, Health and safety guidelines for vegetable oil production and processing (2014).

SEAM Project (1999) Industrial pollution prevention case study: oil and soap sector. Waste minimisation at Sila Edible Oil Company, Fayroum, Egypt.

Van Zyl, H.J., van Zyl, J.E., Geustyn, L., Ilemobade, A., Buckle, T.S. (2007) Water consumption levels in selected South African cities. WRC report no 1536/1/06. ISBN 978-1-77005-480-6.

Section 5: Wastewater Generation and Management

5.1 Wastewater generation

5.1.1 Introduction

In EO processing facilities, the wastewater emanates from oil extraction and refining (Figure 16), as well as general cleaning activities (spills, truck wash-bays, and equipment). In modern facilities, with sound equipment maintenance protocols and cleaning-in-place (CIP) machinery, wastewater generation from non-processing activities can be minimised.

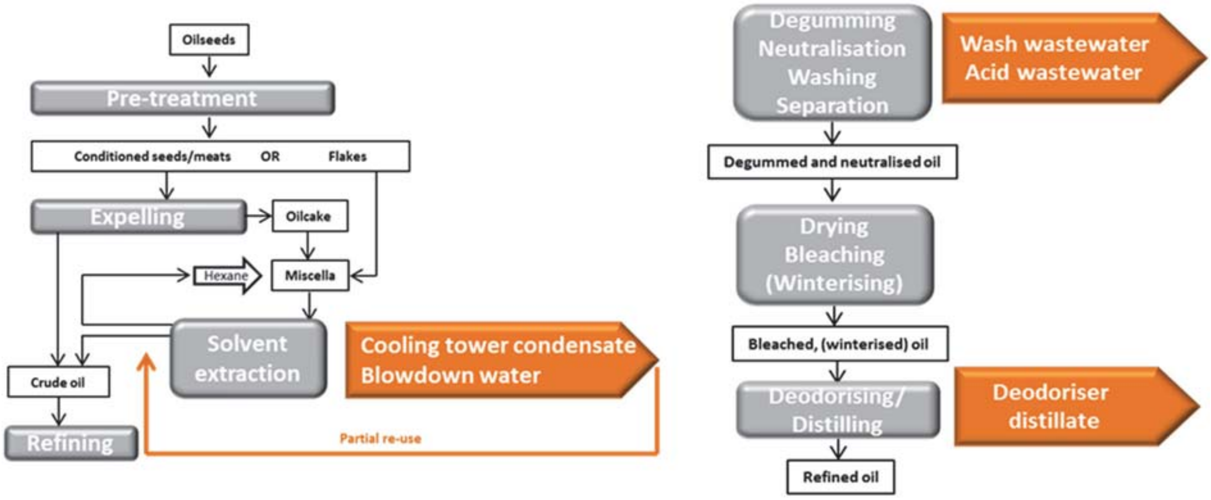


Figure 16: Flow diagram showing the major sources of process wastewater in edible oil facilities

The water used in the **pre-treatment** and **extraction processes** is in the form of steam, most of which is re-captured in cooling towers. The **blow-down** water from the cooling towers and boilers is not characterised separately from the other sources, but is recognised as being relatively uncontaminated. For example, in a sample taken at a large processing facility in SA, the COD of the hexane extraction blow-down water was 45 mg O_2/L.

The **refinery** is the major contributor to the wastewater burden in term of effluent quality and quantity and from this perspective, physical refining is preferable to chemical refining. There are two broad categories of effluent streams, each with different inorganic and/or organic constituents: (i) Wastewater from **distilling** (physical refining), or **oil washing** and **deodorising** (chemical refining), and (ii) The **acid wastewater** generated from **soap splitting** (chemical refining only). The first stream is comprised mainly of high concentrations of free fatty acids, as well as residual gums, pigmented and non-pigmented aromatics, pesticides and degumming acids. If phosphoric acid is used in degumming and/or chemical neutralisation, the total phosphorus concentration is elevated. Residual soaps are also present in effluents where chemical refining is employed. The acid wastewater contains the excess sulphuric acid from soap splitting, as well as free fatty acids and other organics that may have adhered to the soap. Acid wastewater is regarded as more hazardous and difficult to treat than the other wastewater streams.

The acid wastewater may be partially separated from the other stream/s at first. However, the final effluent typically contains treated wastewater from all processes, including the production of value-added products such as margarine, mayonnaise, soaps and candles. The presence of wastewater from other processes can affect the characteristics of the final effluent. For example, emulsifying agents that are added during the production of margarine, and metal catalysts (nickel or palladium) used to hydrogenate oil during the production of margarine, may be present. These agents can negatively affect the wastewater quality, and complicate treatment. For instance, the presence of emulsifiers can retard gravity separation of oil from wastewater.

5.1.2 Wastewater quantification and characterisation

5.1.2.1 Seed oil

In SA, effluent from the seed-oil industry is discharged to sewer and is subject to local municipal tariffs for the quantity discharged (Section 3). Some municipalities impose punitive fines if the effluent does not comply with discharge limits, while others prefer to 'work with' the industry to remedy the situation. The rationale for this approach is based on the fact that it is impossible to regularly police industry. Therefore, if punitive fines are imposed, industry is more likely to discharge highly contaminated wastewater at times when official sampling is unlikely to take place. This ultimately has a negative effect on the wastewater treatment facilities.

Refining typically accounts for more wastewater generation than pressing/extraction. Cooling water can account for large volumes of wastewater, which can be minimised by effective recirculation. In this survey, two respondents included figures for wastewater volumes (Table 13). These compare favourably with literature values, but due to low compliance for this NATSURV, this does not necessarily reflect the SA industry at large.

Table 13: Local and global quantitative wastewater generation data

Oil type	Process/es	Specific effluent volume	Reference
Seed (not defined)	Extraction, refining	2.0 m^3/MT oil	NATSURV, 1987
Seed (not defined)	Extraction, refining	2.7 m^3/MT oil	SEAM report, 1999
Rapeseed – crude	Extraction	7-12 m^3/m^3 oil	AWARENET,2002
Rapeseed – refined	Extraction, refining	10-12 m^3/m^3 oil	AWARENET,2002
Vegetable – crude	NG	0.2-0.5 m^3/m^3 seed 0.2-14 m^3/m^3 seed**	CIAA-FEDOIL, 2002 BMU, 2002
Vegetable – refined	Refining – soap splitting	1-1.5 m^3/MT oil	CIAA-FEDOIL, 2002 BMU, 2002
Vegetable – refined	Refining – cleaning	≤ 0.5 m^3/MT oil	CIAA-FEDOIL, 2002 BMU, 2002
Vegetable – refined	Refining – deodorisation condensate	0.01-0.1 m^3/MT oil	CIAA-FEDOIL, 2002 BMU, 2002
Vegetable – refined	Refining – deodoriser condensate with steam ejection	0.02-0.04 m^3/MT oil	CIAA-FEDOIL, 2002 BMU, 2002
Vegetable – refined	Refining – Distillation neutralisation and deodorisation. No recirculation	10-30 m^3/MT oil	CIAA-FEDOIL, 2002 BMU, 2002
Seed – crude	Solvent extraction	0.3 m^3/MT oil	NATSURV, 2016
Seed – refined	Physical refining, value added	0.1 m^3/m^3 oil	NATSURV, 2016
Seed – refined	Neutralisation	0.07 m^3/MT oil	NATSURV, 2016
Seed – refined	Soap splitting	0.03-0.05 m^3/MT oil	NATSURV, 2016
Seed	Condensate from neutralisation	0.03-0.08 m^3/MT oil	NATSURV, 2016
Seed – refined	Chemical refining	0.15 m^3/MT oil	NATSURV, 2016

NG = not given **cooling water waste**

The acid wastewater may be separated from other wastewater streams at some stage. However, in SA, and globally, the individual streams are not always considered when routinely monitoring the final effluent. In the SA study cohort, one facility uses physical refining, two use chemical refining with phosphoric acid, and two use chemical refining with citric acid. The latter is preferable in terms of wastewater quality.

Typically, wastewater quality is monitored on a regular basis in-house. In addition, the local municipalities take grab samples for testing at random or scheduled intervals. Selected parameters in the final effluent are monitored (Section 3).

The most important parameters to monitor in final effluent from the EO industry are the COD, fats, oils and grease (FOG), total suspended solids (TSS), and pH. In addition, if phosphoric acid and/or sulphuric acid are used in the process from which the effluent originates, high concentrations of phosphorous and sulphates, respectively may be found. Literature values for BOD/COD ratios suggest that in some instances, the wastewater consists of highly biodegradable organics (e.g. Pintor et al., 2014; Table 14), while in other instances it may be recalcitrant (e.g. Aslan et al., 2009; Table 14). It is therefore imperative that historical data is collected from individual facilities before any biological treatment process is installed.

None of the EO facilities that submitted questionnaires provided historical wastewater quality data. Relevant persons at selected Metropolitan municipalities were approached, and results were obtained from one of these. Tables 14 and 15 therefore contain (i) literature figures for wastewater quality, (ii) results from once-off sampling and analysis by the project team (one facility), and (ii) those included in the previous NATSURV (one facility), and historic municipal wastewater quality data (one facility). The lack of information makes it impossible to speculate on the efficiency of the wastewater treatment processes employed in SA. However, from global and local data, it is clear that the effluent produced by the EO industry is problematic in terms of management to reduce the high organic and inorganic load.

Table 14: Processes, production volumes and selected wastewater quality parameters from edible oil facilities

	Country	Oil type/s	pH	COD	BOD/COD	FOG/SOG	TP	SO_4^{2-}	TSS	Na	References
				gO_2/L	ratio	(mg/L)	(mg/L)	(g/L)	(g/L)	(mg/L)	
E, R	SA	Seed	5.9[a] (1.8-10.5)	4.6[a] (1.1- 9.0)	ND	63[a] (80-1360)	ND	1.8[a] (1.9-17.6)	ND	ND	NATSURV, 1987
R	Turkey	S/flower	4.0 ± 0.5[a] (3.5-4.5)	9.2 ± 0.8[a] (8.3-9.7)	0.2	664 ± 117[a] (533-760)	177 ± 210[a] (52-420)	11.4 ± 0.5[a] (10.8-11.7)	1.7 ± 0.2[a] (1.5-2.0)	ND	Aslan et al., 2009
R	Turkey	Corn	2.3 ± 0.1[a] (2.7-2.8)	12.9 ± 2.2[a] (11.5-15.4)	0.2	375 ± 107[a] (308-499)	583 ± 270[a] (275-775)	12.0 ± 0.5[a] (11.9-12.3)	2.9 ± 1.0[a] (1.1-3.0)	ND	Aslan et al., 2009
CR, PR, V	Poland	Seed and palm	6.5[a] 6.5[b]	2.8 ± 0.6[a] 1.0 ± 0.3[b]	0.6 ± 0.1[a] 0.5 ± 0[b]	ND ND	359 ± 38[a] 178 ± 2[b]	1.3 ± 0.3[a] 1.0 ± 0.2[b]	0.6 ± 0.2[a] 0.2 ± 0.1[b]	ND ND	Chipasa et al., 2001
NG	SA	S/flower	ND[a]	100[a] (15.2-251.6)	ND[a]	80310[a] (12224-200560)	ND	ND	80[a] (0.7-29)	705[a] (410-1000)	Roux-Van der Merwe et al., 2005
NG	India	NG	5.0[b]	2.5[b]	NG	< 50[b]	NG	0.1[b]	0.4[b]	NG	Sridhar et al., 2002
NG	Portugal	S/flower	6.32 ± 0.01[c]	4.1 ± 0.4[c]	1.0[c]	700 ± 300[c]	900 (PO_4^{3-})[c]	3.4 ± 0.1[c]	2.4 ± 0.3[c]	2800 ± 200[c]	Pintor et al., 2014
NG	Portugal	S/flower	1.62 ± 0.0[d]	11 ± 4[d]	0.5[d]	3000 ± 1000[d]	400 (PO_4^{3-})[d]	0.2 ± 0.1[d]	8.9 ± 0.5[d]	62 ± 4[d]	Pintor et al., 2014
E, CR	SA	S/flower	7.2[b] 4.6-10.6	7.2[b] 1.0-11.8	ND	328[b] 103-631	1954[b] 500-4510	4336[b] 1170-5980	0.3[b] 0.1-0.4	ND	Surujlal et al., 2004
E,CR	SA	Seed	7.2	33.2[a]	ND	41738[a]	1290[a]	ND	ND	ND	NATSURV, 2016
E,CR	SA	Soya and S/flower	10.7 (8.8-11.6) 2.8[d] (1.8-5.7)	6.2 (0.9-11.7) 4.4[d] (1.5-8.4)	ND ND	5450 1600[d]	88 (σ-P) 6-152 401 (σ-P)[d] 186-602	274 (23-775) 3978[d] (37-9341)	811 (181-1318) 1577[d] (154-6068)	174 (EC) 47-273 883[d] (12-1720)	NATSURV, 2016

[a]Samples taken before primary treatment **[b]Samples taken after physicochemical treatment** **[c]Samples taken from homogenisation tank** **[d]Acid wastewater**
Where available, ranges are given in brackets **EC = Electrical conductivity** **σ-P = ortho-phosphate**
ND = not determined **E = extraction** **R = refining (not specified)** **CR = chemical refining** **PR = physical refining** **V = value added processes** **NG = not given**

Some wastewater quality data for different processes have been published and snapshot samples were taken by the project team from different areas at one SA EO facility (Table 15). It is clear that some waste streams are highly contaminated, while others may be considered for re-use.

Table 15: Wastewater quality parameters from various edible oil production processes

Source	COD				References
Crude oil production	0.1-1.0 kg/t seed				BMU-GFM, 1986 CIAA-FEDOIL, 2004
Chemical neutralisation & soap splitting	≤ 5 kg/t refined oil				BMU-GFM, 1986 CIAA-FEDOIL, 2004
Deodorisation	≤ 7 kg/t refined product				BMU-GFM, 1986 CIAA-FEDOIL, 2004
Conventional chemical refining	≤ 15 kg/t refined product				BMU-GFM, 1986 CIAA-FEDOIL, 2004
Source	**COD (mg/L)**	**COD/ BOD_5**	**FOG (mg/L)**	**TSS (mg/L)**	
Neutral oil washing	15000	0.07	100-500	NG	GME, 2001
Neutralisation	7200	0.60	670	2900	GME, 2001
Barometric condensers	500-600	ND	20-200	40-100	GME, 2001
Steam boiler	40	0.5	NA	100	GME, 2001
Water softening	40	0.5	NA	100	GME, 2001
Floor and equipment wash-water	2000	0.75	NG	300	GME, 2001
Cooling tower hexane extraction	45	ND	ND	ND	NATSURV, 2016
Chemical neutralisation condensate	84000	ND	1505	ND	NATSURV, 2016
Truck wash-bay	3700	ND	3382	ND	NATSURV, 2016
Acid wastewater	8400	ND	110	ND	NATSURV, 2016

5.1.2.2 Fruit oil

There is anecdotal evidence that most olive oil producers in SA use two-phase centrifugation (extraction), which results in the generation of low volumes of concentrated slurry, when compared to other technologies (Table 16). The SA study respondents (olive and avocado oil) did not monitor wastewater quality, but used the wash-water and process water beneficially for garden irrigation and composting.

Table 16: Wastewater quality and quantity from different olive oil production processes

Technology	Volume (m^3/t oil)	BOD_5 (mg/L)	COD (mg/L)	TSS (mg/L)	pH
Traditional pressing	2-5	2.2-6.2 x 10^4	5.9-16.2 x 10^4	6.5 x 10^4	4.6-4.9
3-phase extraction	6-8	1.3-1.4 x 10^4	3.9-7.8 x 10^4	6.5 x 10^4	5.2
2-phase extraction	0.33-0.35	9.0-10.0 x 10^4	12.0-13.0 x 10^4	12.0 x 10^4	4.5-5.0

Adapted from GME, 2001

5.2 Management of wastewater from edible oil facilities

5.2.1 Introduction

There are many different primary, secondary, and tertiary treatment methods used to treat wastewater, some of which are applicable to the EO industry. However, an in-depth discussion is beyond the scope of this document. If more detailed information is required, the WRC report no 1084/1/04 by Surujlal et al. (2004) is freely available on the WRC website www.wrc.org.za and is highly recommended.

Ideally, best practice pollution prevention measures (Section 5.3.4.1) should be applied within the facility to limit effluent contamination and the need for intensive wastewater treatment. In SA, the collected wastewater from seed oil production typically undergoes primary and sometimes secondary treatment before discharge to the municipal reticulation system for further treatment in centralised facilities. The impact of the wastewater on these facilities is incumbent on the fraction of wastewater from the EO facility in relation to the total inflow to the facility, the quality of the EO wastewater, and variability in the quality and quantity of wastewater discharged. If the EO wastewater negatively impacts the downstream treatment processes, more intensive on-site treatment is strongly recommended.

The respondents from the olive and avocado oil producers indicated that they used the wastewater for beneficial irrigation. In the case of the avocado oil processor, the wastewater is first treated by aeration.

5.2.2 Conventional treatment

As discussed in Section 5.1, the wastewater generated by the EO industry emanates from different processes. The **acid wastewater** is seen as the most hazardous fraction, and is often treated before being mixed with the rest of the effluent. For example lime and calcium chloride may be added to increase the pH, and as a coagulating agent, respectively. This results in the formation of calcium soaps, and sulphate- and phosphate-calcium salts. The calcium salts adsorb oils and other organic suspensions and the solids are removed by flocculation and sedimentation. Once the acid wastewater is mixed with the rest of the wastewater (which is typically alkaline), it is usually left to stabilise before treatment.

5.2.1.1 Primary treatment methodologies

The most widely applied primary treatment for EO effluent is **gravity separation and skimming.** In some facilities, this is applied as a stand-alone technology, but is generally employed after upstream **physicochemical treatment**. **Dissolved air flotation** (DAF) is often used in conjunction with gravity separation.

Physicochemical treatment

Chemical coagulation can be assisted by flocculation of finely dispersed and/or suspended solids. Popular coagulants include ferric chloride, aluminium chloride, aluminium sulphate, polyaluminium chloride, ferrous sulphate, and hydrated lime. Coagulants facilitate coalescence of oil and other particles. There are a variety of flocculants available, including anionic and cationic polymers. Chitosan can be used simultaneously as an adsorbent and coagulant, and is a more environmentally friendly alternative.

Electrocoagulation is a form of physicochemical treatment that utilises aluminium or iron electrodes as sacrificial anodes. The metal species react with negatively charged particles in the effluent water to form flocs.

Dissolved or very stable emulsified fats are difficult to remove by physicochemical means, but the treatment is successful for the removal of suspended solids, solvent extractables, sulphates and phosphates.

Dissolved air flotation

DAF enhances flotation of emulsified fats on the surface of the wastewater. Compressed air is passed through the wastewater and bubbles are formed. Fine particles and oils attach to the bubbles and are removed by a sludge scraper. Chemical agents can be added to enhance gravity separation by de-emulsifying the oils, promoting coagulation, and enhancing floc size.

5.2.1.2 Secondary biological treatment

Suspended solids and solvent extractables in EO wastewater originate mainly from emulsified fats and oils, and soaps, and are therefore predominantly organic. The BOD/COD ratio of some EO wastewater before and after physicochemical treatment suggests that it is comprised of readily biodegradable organic matter, and therefore lends itself to secondary biological treatment if the COD has not been reduced sufficiently during primary treatment. However, secondary treatment is not widely applied in SA.

New technologies are starting to look at waste as a resource, and a biorefinery approach to the management of many waste streams is being sought. For example, it has been shown that some fungal species grow readily in EO wastewater. Not only can they reduce COD, but some fungal strains produce valuable chemicals.

5.2.1.3 Tertiary treatment

Tertiary treatment includes selective crystallisation of impurities (e.g. toxic metals), reverse osmosis, ion exchange, chlorination, and dewatering of sludge. These methodologies are not applied in SA at present. The information contained in the questionnaires, together with anecdotal evidence suggest that most SA EO industries use gravity separation with or without pH adjustment and/or DAF to treat their effluent.

Some of the advantages and disadvantages of commonly employed technologies for the treatment of EO wastewater are given in Table 17.

Table 17: Major advantages and disadvantages of common edible oil wastewater treatment technologies

	Major advantage/s	Major disadvantage/s
Primary treatment		
Coagulation/ flocculation	Reduces concentration of suspended solids	Production of large volumes of toxic sludge
Gravity separation and skimming	Simple Significant reduction in oil content Can downscale secondary and tertiary treatment	Dissolved or highly emulsified oils are not removed without additional physicochemical treatment
Dissolved air flotation	Efficiency of gravity separation can be greatly increased Soapstock can be easily recovered	Relatively high energy requirements
Electrocoagulation	Simple infrastructure Low sludge production and reduced retention time when compared to conventional coagulation/flocculation	Requires tight pH control Addition of coagulant aid and supporting electrolyte may be required Production of toxic sludge

Table 17: Major advantages and disadvantages of common edible oil wastewater treatment technologies

...continued	Major advantage/s	Major disadvantage/s
Secondary treatment		
Activated sludge	Can significantly reduce COD	EO wastewater results in selection of undesirable microorganisms, leading to poor floc formation and bulking
Anaerobic digestion and other anaerobic processes	Can significantly reduce COD Biogas can be harnessed for energy	High capital costs, process instability, requires skilled operation
Tertiary treatment		
Membrane technology	Can re-use water Low sludge production	Large capital outlay Membranes prone to fouling

5.3 Impact of edible oil effluent on wastewater treatment facilities

5.3.1 Introduction

Domestic (and some industrial) wastewaters contain 'nutrients', the most important being organic carbon, nitrogen and phosphorus. If high quantities of these enter the aquatic environment, bacteria and/or algae proliferate as they use the nutrients for growth in a process termed 'eutrophication'. As the microorganisms grow, they utilise oxygen. In turn, when the nutrients are expended, they die and degrade, providing more nutrients for more growth, and more oxygen consumption. The result is that the aquatic systems become oxygen-starved, culminating in severe adverse effects such as the death of fish and other organisms. The role of the wastewater treatment plants (WWTPs) is to reduce nutrients, pathogens, and, in some cases, to remove other toxic substances such as heavy metals.

The majority of WWTPs in the larger metropolitan areas of SA treat wastewater using primary (physical), secondary (biological) and tertiary treatments (polishing and sterilization) (Figure 17). The wastewater entering the facilities always contains domestic sewage and household grey water. Depending on the location, various percentages of industrial wastewater, in some instances, wastewater from EO processing, may also be present. In addition, storm-water is discharged to some facilities.

The primary treatment consists of mechanical removal of larger solids in screens, generally followed by settling out of larger particulates in gravitational primary settling tanks. In SA, the most utilised secondary treatment is the **activated sludge process**, where bacteria living in the wastewater utilize the organic fraction under aerated (activated) conditions, thereby 'treating' the wastewater. Some plants are also designed to remove other 'nutrients', especially nitrogen, and in some cases, phosphorus. The operators of each plant try to ensure that the process is stable, and adjust the inflow and outflow rates and the concentration of microorganisms present so that the food to microorganism (F/M) ratio falls within a certain range. This is a simplistic explanation, and in reality there is usually more than one bioreactor, each bioreactor favouring the growth of microbial populations capable of utilising different fractions of the wastewater. Recycling of microorganisms and wastewater is employed to create desirable conditions.

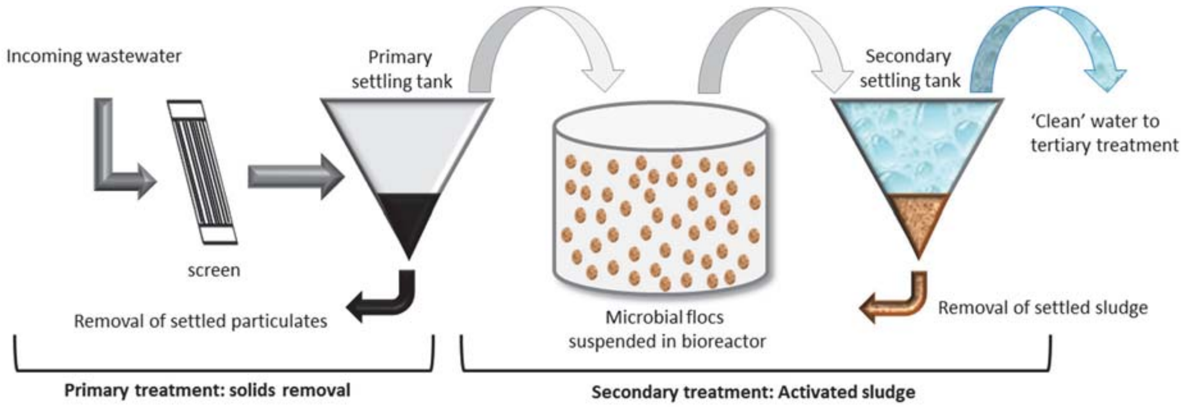


Figure 17: Simplistic schematic diagram showing the principle of how a typical activated sludge wastewater treatment facility operates

In the bioreactor, it is essential that the microorganisms grow together with suspended organic and inorganic matter in small assemblages called **flocs**. When the wastewater is transferred from a more turbulent system in the bioreactors to a static settling tank, the flocs settle to the bottom, leaving 'clean' water on top. This water is removed and may undergo further, tertiary treatment.

5.3.2 Adverse effects of fats and oils on the activated sludge treatment process

The sources of vegetable and fruit oils and fats are domestic households, restaurants and industries. Edible oils and fats in sewers and WWTPs can clog the systems, especially during cold weather (Figure 18).

Fats and oils in bioreactors can interfere with the process by retarding the mass transfer of oxygen and nutrients to the microorganisms within the flocs. In addition, overgrowth of bacteria that form long filaments can hamper settling of flocs, a phenomenon known as bulking. Some bacteria float selectively on the surface of the bioreactor and/or secondary settling tank, causing scum (foam) formation (Figure 18). Bulking and foaming are serious issues, which lead to poor quality treated effluent.

The presence of high concentrations of fatty acids in the wastewater can favour the growth of the 'nuisance' microorganisms, *Microthrix parvicella* and other actinomycetes. In addition to forming long filaments, these organisms have hydrophobic (water-hating) cell walls, causing them to form scum. Wastewater with high concentrations of 'higher' fatty acids, e.g. oleic acid, are utilized selectively by *M. parvicella* and it has been postulated that surface enzymes that break down fats and oils (lipases) allow *M. parvicella* to take up and store long chain fatty acids, providing the filament with a competitive advantage. Like *M. parvicella*, some species of Gram positive brancing bacilli can utilize the fat fraction of wastewater for growth and their hydrophobic/lipophilic cell wall causes them to float and form scum. These organisms were the most common cause of bulking and foaming in the United States in the 1980s.

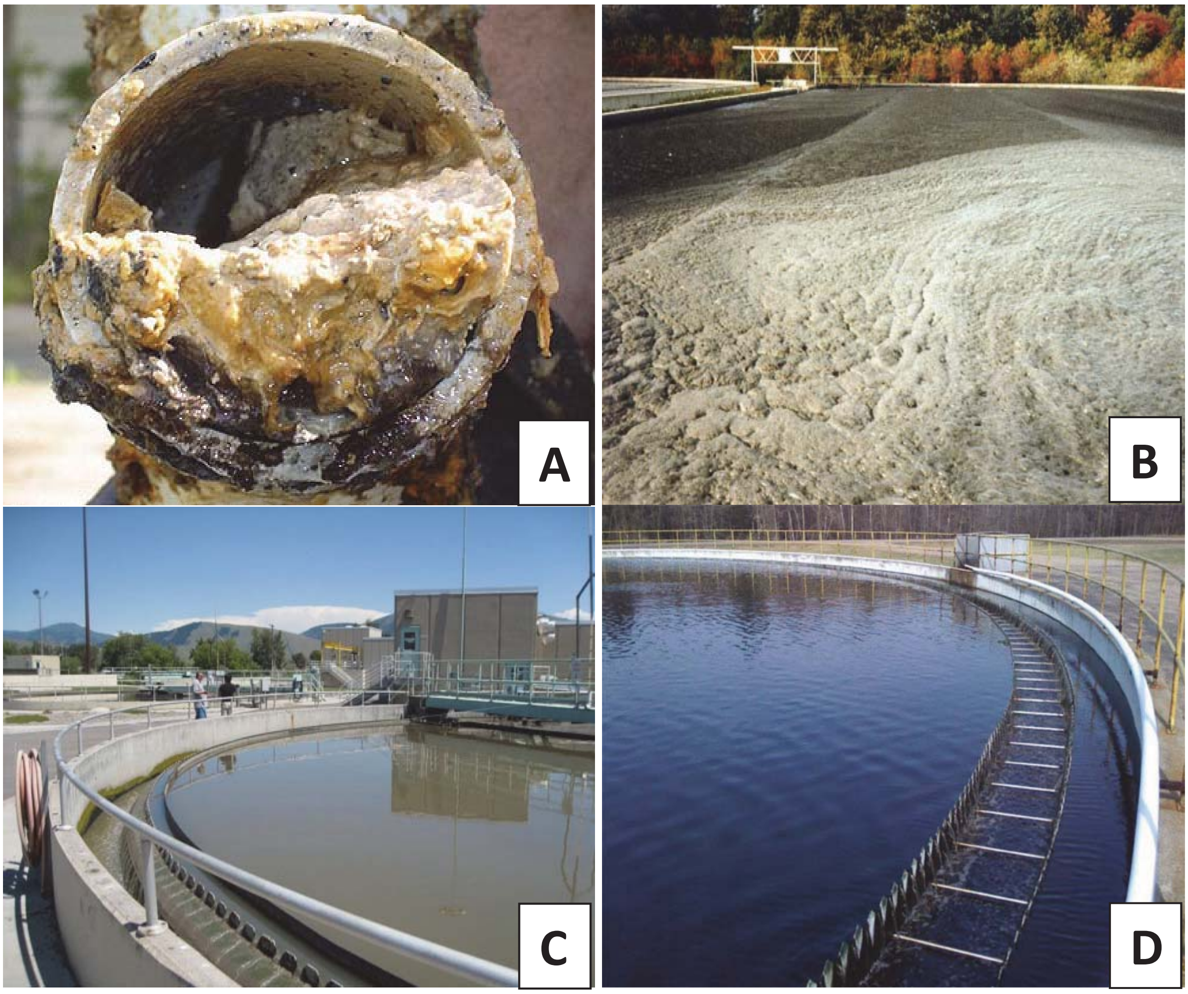


Figure 18: Problems caused by discharging oils and fats into sewers: (A) A sewer pipe blocked with fat, (B) Scum formation caused by overgrowth of *Microthrix parvicella* on the surface of a bioreactor, (C) A secondary settling tank filled with bulking activated sludge, which can be compared to (D), An example of a secondary settling tank from a bioreactor with good floc formation.

5.3.3 Wastewater generation and management: Best practice

5.3.3.1 Pollution prevention

Minimising the amount of product and/or process consumables in the wastewater has both economic and environmental benefits: decreased losses directly contribute to increased oil production, and 'better' quality wastewater requires less intensive treatment and is more likely to conform to regulatory requirements. This in turn saves on treatment costs and/or government fines for non-compliance.

A thorough audit to identify sites where losses are occurring should be conducted and where possible, measures should be implemented to prevent or minimise these. This approach has proven to be highly beneficial. For example, in a waste-minimisation exercise conducted at an EO facility in Egypt, annual savings on energy, water, and product loss were 2.5 times the initial capital outlay for the upgrades. In addition, the proposed expenditure for the commissioning of a wastewater treatment facility was reduced by almost two thirds (SEAM project, 1999). This clearly demonstrates the financial advantages that can be gained by minimising waste.

Suggested measures to improve wastewater quality and/or reduce the volume of wastewater generated include:

- **Leakages:** Regularly fix leakages in storage units and pipes.
- **Spillages**: Institute measures to reduce spillages and/or collect product from spillages for reprocessing; for example, install spill collection trays at appropriate sites.
- **Solids**: Install grids over drains to prevent solids from entering the wash-water.
- **Disinfection:** Use the correct disinfection chemicals, e.g. caustic soda in areas contaminated with fats, and acids for lime deposits.
- **Cleaning agents**: Use cleaning agents in the correct concentrations and apply according to manufacturers' instructions.
- **Degumming**: If possible, reduce the amount of phosphoric acid used in degumming by improving the neutralisation process or by using alternatives such as enzymes.
- **Maintenance**: Institute a preventative maintenance protocol: regular servicing of expellers and other mechanical equipment, etc.
- **Educate staff:** Make staff aware why it is important to reduce the amount of wastewater generated and improve the quality of the wastewater. Train staff how to implement appropriate measures, and provide refresher instructions at timely intervals.
- **Chemical audits**: Consider substituting different chemicals and/or materials; for example caustic soda in solution may be cheaper than the solid form and results in less loss of consumables, reduced corrosion and improved soap-stock quality.
- **Caustic soda usage**: Monitor caustic soda addition carefully to prevent saponification of neutral oil.
- **Soap splitting**: Use continuous soap splitting rather than batch to reduce the volume of acid water.
- **Detergents**: Minimise the use of detergent in cleaning operations to prevent emulsification of oil in wastewater.
- **Fat traps**: Use fat traps judiciously to prevent oil from entering the wash-down water.
- **Measure and monitor**: Measure and monitor the volume of effluent produced from each area. Monitor the quality of effluent produced from different processes to identify areas where product and/or consumables are being lost.
- **Product recovery**: Recover fat from effluent to increase soap-stock production and improve wastewater quality.

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Section 6: Energy Use and Management

The main energy requirements in the EO industry are for: (i) The generation of open steam for deodorising, (ii) The creation of a vacuum for drying prior to deodorising, and during bleaching, for degassing, and to enhance deodorisation, (iv) The running of other high energy-demanding electrical equipment including mills, expellers, presses, centrifuges, cooling compressors, cooling water circulation pumps, and cooling towers, and (v) Heating, for various stages in extraction and refining. Table 18 gives some estimated steam and electricity consumption figures for various refining processes.

Table 18: Estimated energy consumption of various edible oil refining processes per ton of oil produced

Process	Steam (kg)	LFO (kg)	Electricity (kWh)	Tot. energy (MJ)
Deep degumming	55	-	15	175
Centrifuge neutralisation and soap splitting	100	-	10	256
Batch neutralisation	150	-	6	352
Bleaching	60	-	6	154
Dewaxing/winterising	30	-	15	120
Batch deodorisation	280	-	20	688
Semi continuous deodorisation with alkaline circulation	140	8	18	709
Semi continuous deodorisation with dry condensing	30	8	20	474
Continuous deodorisation with dry condensing	25	3	17	242
Refining (NATSURV, 2016)	200			

Adapted from Hamm, 2013 LFO = light fuel oil

Not surprisingly, information provided by the SA respondents showed those facilities that store, mill, extract and refine have the highest energy requirements. Coal is the cheapest form of energy, but some facilities rely on electricity alone for all their energy requirements (Table 19).

Table 19: Breakdown of energy usage and costs provided by respondents

Annual production	Sources	Energy (% or MJ)	Cost (R/MJ)	Annual cost
Seed oil	Coal	79.4%	0.045	R12 768 300
50 000 MT crude	Paraffin	8.2%	0.211	(2013/2014)
30 000 MT refined	Electricity	12.4%	0.276	
24 000 tons refined	Coal	NG	NG	NG
	Electricity	4 399 920 MJ	0.211	R960 000
125 000 MT crude seed oil	Coal and sunflower husks	NG	NG	NG
Variable refined	Electricity			
150 000 crude	Electricity	100%	NG	NG
Variable refined				
36 000 MT refined seed oil	Coal – 200 kg steam/MT oil	NG	NG	NG
	Paraffin for heat 7 L/MT oil			
52 000 tons crude	Electricity	NG	NG	R2 040 000
100 tons avocado	Coal	100%	R0.80/unit	R144 000
12 tons olive	Electricity	NG	NG	
2.2 tons olive	Electricity	NG	NG	

Conversion factors: 1kWh = 3.6 MJ 1 MT coal = 29308 MJ 1 ton paraffin = 41868 MJ

Of seven respondents, only one had no plans to introduce alternative energy sources (Figure 19). One facility already burns husks as boiler feed, while another intends introducing this. One facility indicated that they were going to start producing biodiesel from reject seeds and other waste materials, as well as introduce solar energy to offset their use of fossil fuel and electricity. Others intend to use wind power and generate biogas from waste material. One mill was exploring the option of using solar power for most of their energy requirements. The facility owner indicated that the return of investment for this was only four years at current electricity rates.

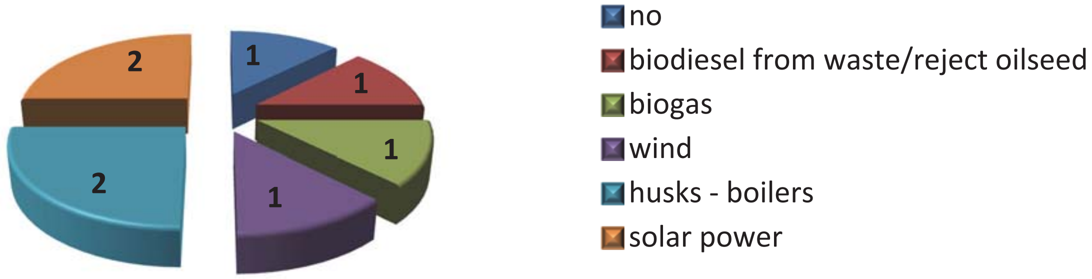

Figure 19: Chart depicting the intentions of respondents to use alternative energy

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7. Appendices

Appendix 1: Introductory letter from the Water Research Commission

Water Research Commission
Marumati Building,
491 18th Avenue, Rietfontein, Pretoria

Private Bag X03, Gezina, 0031, South Africa

Tel: +27 (0)12 330 0340
Fax: +27 (0)12 331 2565
Email: info@wrc.org.za
Web: www.wrc.org.za

03 October 2014

Dear Sir/Madam

Re: National Survey (Natsurv) of Water and Wastewater Management of Industries

In 1985 the Water Research Commission, in collaboration with the Department of Water Affairs and Forestry (now the Department of Water and Sanitation), commissioned a national industrial water and wastewater survey of all classes of industry in order to ascertain the minimum water requirements (specific water intake) of particular industries, as a blanket restriction in times of drought would be grossly unfair. Furthermore, the study also surveyed the wastewater and typical pollutant loads generated which allowed regulators to manage discharge to sewers thus protecting infrastructure and the downstream treatment processes. These surveys resulted in the publication of a series of 19 NATSURV guidelines on water and wastewater management for the different industrial categories between 1987 and 2005 (see list below). The Natsurv reports for different industries have been used extensively by the sector since they were developed. Most of the guides have been incorporated in courses presented by universities and universities of technology and are widely used by the sector to make informed decisions regarding industries.

There is increasing consensus that South Africa is a water stressed country and some areas could even be defined as water scarce. As the demands on water systems increase, the impact on the social, environmental and economic systems they support become more stressed and the responses become more uncertain and unpredictable. For economic development, a major dimension is the relationship between water management by government, the manner in which water is used, and water-associated risks dealt with by the private sector which forms the engine of the economy.

South Africa and its industrial sectors have either grown or in some cases shrunk considerably since the 1980's. Thus, the landscape has changed. New technologies and systems have been adopted by some of the industries, and therefore, certain information contained in the national surveys can be regarded as obsolete. Furthermore, initiatives like the UN CEO mandate, water stewardship, water allocation and equity dialogues, amongst others suggests growing awareness by industry related to: water use, water security, and waste production. Thus, it is considered an opportune time to review the water and wastewater management practices of the different industrial sectors and make firm recommendations.

Supporting sustainable development through research funding, knowledge creation and dissemination

The WRC is currently revising all 19 Natsurvs and have included a new national survey for the Steel industry. This is a process that commenced in 2013 with 4 studies supported per year and the aim is to complete all current revisions by 2019. The revision has the support of the Department of Water and Sanitation.

We therefore encourage industries that are approached by the researchers for data and information to support this process as this will ensure that right information is captured. In addition, your support is important for the following reasons:
a) The report can be used by industries to benchmark their practices
b) The report will introduce to industry new concepts of water and wastewater management
c) The report will allow regulators and industries to engage in informed discussions as it will provide a national overview.

Yours sincerely

____

Dr Valerie Naidoo
Research Manager

WRC Natsurv Reports:

1. Malt Brewing
2. Metal Finishing
3. Soft Drink
4. Dairy
5. Sorghum Malt and Beer
6. Edible Oil
7. Red Meat
8. Laundry
9. Poultry
10. Tanning and Leather Finishing
11. Sugar
12. Pulp and Paper
13. Textile
14. Wine
15. Oil Refining and Re-refining
16. Power Generating
17. Fruit and Vegetable Processing
18. Pelagic Fishing
19. Fish Processing
20. Steel (NEW!)

Note: These report can be downloaded from the WRC website fee of charge: www.wrc.org.za

Appendix 2: Questions included in questionnaire to seed oil facilities

1. Type, quantity and quality of oil
If applicable, what raw material/s is/are used for pressing/extraction?
What crude oils are refined?
Approximately how many tons of oil is produced each year? Stipulate if crude or refined.
Is it possible to obtain long-term production statistics? If so, kindly provide.
2. Seasonality
Is any particular oil production seasonal? If so, over which months does the season extend?
3. Production processes
What extraction process(es) are used?
Is physical or chemical refining used? What method is used from degumming?
4. Water usage
What volume(s) and source(s) of water are employed (monthly or yearly)? Can you estimate the fraction of water used for different processes?
Water re-use: How much of the cooling water and process steam water is re-cycled?
Can you please provide a holistic cost estimate for the provision of water for your oil production process. What are the municipal water tariffs in your area?
Are water usage targets in place? If so, to what extent are these being met?
5. Wastewater generation and management
What volume of wastewater is generated during the production process? Can you estimate what fraction comes from each specific process? Can you provide an overall estimate of the volume of wastewater generated per litre of oil produced?
If available, can you please provide us with historical quality data on the final effluent? This may be provided in a separate document.
Is the wastewater being treated before discharge? If so, what methods are being used? Have you tried other methods in the past, and if so, how do these compare to your current practices?
Are wastewater quality and quantity targets in place? If so, to what extent are these being met? How do the targets compare to statutory requirements?
Is any of the wastewater being re-used? If so, please explain. Do you have automated CIP equipment (cleaning-in-place). Please give some detail.
Do you think that there is scope to re-use or gain benefit from any of the effluent streams?
6. Solid waste/slurry generation
What is the type and quantity of solid waste or slurry (e.g. husks, spent clays, wastewater sludge) generated?
How is the solid waste disposed of currently? (e.g. sold for fodder, fertiliser, to landfill, etc.)
Do you think that there is scope for further beneficial use of any of the solid waste?
Emissions
Are gaseous emissions generated during the production processes? (e.g. coal-fired boilers)
Are plans in place to mitigate the production of these emissions?
Energy usage
What type(s) of energy are used in the oil production processes?
How much energy is used in the oil production processes? (details or estimates)
What is the cost (kWh) of energy used?
Do you already make use of, or have plans to explore the use of alternative, green energy resources (e.g. production of biodiesel from waste)? If so, please provide details.

Appendix 3: Questions included in questionnaire to olive oil facilities

1. Type, quantity and quality of oil
What raw material or crude substrate is used?
Approximately how many tons of oil is produced (per annum)?
Is it possible to obtain long-term production statistics? If so, kindly provide.
2. Seasonality
Over which months does your production season extend?
3. Production processes
What extraction process(es) are used?
4. Water usage
What volume(s) and source(s) of water are employed? Can you estimate how much water is used for each ton of oil produced (excluding irrigation water).
Can you please provide a holistic cost estimate for the provision of water for your oil production process. If applicable, what are the municipal water tariffs in your area?
Are water usage targets in place? If so, to what extent are these being met?
5. Wastewater generation and management
What volume of wastewater is generated during the production process? Can you provide an overall estimate of the volume of wastewater generated per litre of oil produced?
Do you monitor the quality of the wastewater? If so, are you willing to provide data? Can be given on a separate sheet.
Is the wastewater being treated before discharge? If so, what methods are being used? Have you tried other methods in the past, and if so, how do these compare to your current practices?
Are wastewater quality and quantity targets in place? If so, to what extent are these being met? How do the targets compare to statutory requirements?
Is any of the wastewater being re-used? If so, please explain. Do you have automated CIP equipment (cleaning-in-place).
Do you think that there is scope to re-use or gain benefit from any of the effluent streams?
6. Solid waste/slurry generation
Approximately what quantity of pomace and slurry is generated per ton of oil produced?
How is the solid waste disposed of currently (e.g. sold for fodder, fertiliser, to landfill, etc.)?
Do you think that there is scope for further beneficial use of any of the solid waste?
7. Energy usage
What type(s) of energy are used in the oil production processes? e.g. municipal, solar, etc.
How much energy is used in the oil production processes? (details or estimates).
What is the cost (kWh) of energy used?
Do you already make use of, or have plans to explore the use of alternative, green energy resources (e.g. production of biodiesel from waste)? If so, please provide details.

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