

Guidelines

For Handling and Treatment of Oil Contaminated Water In Thai Industries and Trades

Published by the PROTEKT team

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The guidelines have been developed by the following consortium, within the framework of the PROTEKT project – Handling and Treatment of Oil Contaminated Water in Thai Industries and Trades.

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Preface

Overview
Mixtures of oil and water are produced in the most diverse areas of industry, for example, in engineering, in automobile manufacture, in food processing, and in the fish industry. Even when the oil in question has different origins, the principles involved in treating it are similar. Oil contaminated water has a negative effect on a product's environmental properties. Since the production of internationally traded goods calls for increasing adherence to international environmental standards, trade can be impaired when such standards are not met.

What is PROTEKT?
PROTEKT, the eighteen-month project started in November 2006 and ended in April 2008, proposes building on the technical capacity of the SMEs in Thailand in respect to the management of oil-contaminated water (industrial oily waste and wastewater). The project intends to promote environmentally friendly production in Thai industries and trades by contributing to the effective and efficient managing of oil-contaminated water. To this aim, practice-oriented guidelines applicable to a wide range of industries, a training module and a distance-learning package are developed, along with trial consultancy, workshop and training course are organized in collaboration with scientists and those working in industry.

About the Handbook
These practice-oriented guidelines serve for professionals who are involved in environmentally friendly production, particularly in respect to managing mixtures of oil and water. The handbook represents the result of PROTEKT, which has been carrying out by an interdisciplinary and international consortium from Thailand, Germany, Estonia and the UK.

Funding of PROTEKT
The project is co-funded by the European Union and the Implementing Consortium, within the framework of the European Union's Asia-Invest Programme.

The European Union's Asia-Invest Programme
The Asia-Invest Programme was launched in 1997 as a European Union initiative designed to promote and support business co-operation between the European Union Member States and South Asia, South-East Asia and China. This five-year Programme with a total budget of €42 million, aims to facilitate opportunities for co-operation between European and Asian companies, in particular small and medium-sized enterprises (SMEs), and increase capacity for long-term strategic alliances by providing support to economic intermediary organizations. The Programme is under a period of review in 2002, pending the launch of a second phase for 2003-2007. For further information on the Programme, please see:http://ec.europa.eu/europeaid/projects/asia-invest/

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CHAPTER I

REASON TO ACT

-EXECUTIVE PART-

1 REASONS TO ACT

The benefits of adopting and implementing an effective approach to waste management is widely reported and well accepted by many leading industrial companies and organizations throughout the world. Small, medium and large-scale enterprises have found positive merit in developing an appropriate management system to deal with their various responsibilities, liabilities and operational procedures.

In the context of these Guidelines, management is defined as the functional organization necessary to deliver compliance with legislation, and cost-effective handling and treatment of oil-contaminated water to the highest standards of environmental quality.

A wide range of industries and trades throughout Thailand produce a variety of oil contaminated water as a result of their operations and activities. The handling and treatment of such waste has important implications both for the commercial success of the company and the quality of the environment affected by any impacts. It is also important to acknowledge that the industries and trades are highly significant to the socio-economic vitality of the country, and that SME*s in particular are highly valued locally for their role in generating and supporting jobs, and in the creation of wealth.

There is growing acceptance that there is mutual advantage between industry, community and environment in the implementation of effective handling and treatment of oily waste. Sustainability* lies at the heart of the business plan of pro-active industries and plants. A sustainable approach to the handling and treatment of waste set within an effective environmental management system* (EMS) can provide benefits to the company and improvements to the environment.

The challenge of dealing with oil-contaminated water affects managers in a wide range of plants and companies throughout Thailand. In many ways the basic issues are similar though the scale and resources available may be very different. However, comparison with similar industries and trades demonstrates that there are tangible benefits to be gained from a positive response to such waste material. The reasons to act can bring benefits and advantages from a pro-active response to the handling and treatment of oil-contaminated water as well as threats and costs if the challenge is ignored. Reasons to act include the following:

1.1 COST SAVING AND IMPROVED MANAGEMENT CONTROL

- Improved business systems and business management
- Identification of environmental (business) risks* associated with the production and disposal of oil contaminated water
- Recognition of potential cost savings
- Increased competitiveness and efficiency
- Reduced costs through waste minimization and energy efficiency
- Better cost control
- Risk* reduction

Notes: *Cost saving and cost reduction is widely seen as a critical driver for implementing effective waste management and control systems. Factoring-in the costs of raw materials, processing operations, waste management and environmental protection can provide a company with quantified and objective criteria necessary to justify investment in the most appropriate response option.*

1.2 COMPLIANCE WITH LEGISLATION

- Appropriate response to legislative and regulatory requirements
- Liability of Senior Managers/Directors/Chief Executive Officer
- Improved relationships and influence with regulators

Notes: *Compliance with legislation is acknowledged as being non-negotiable for companies and individuals mindful of their responsibilities and the integrity of their reputations. Compliance is a priority issue for all credible companies and a major component of their policy statement. This is demonstrated by increasing pressure from an ever-widening range of stakeholders, the threat of litigation and the necessity to retain a licence to operate.*

1.3 MEETING STAKEHOLDER EXPECTATIONS

- Meeting and pre-empting customer demands and expectations
- Improved public relations profile
- Marketing advantage
- Satisfying demands and expectations of investors, banks and insurers

Notes: *Industries and trades are increasingly under pressure and scrutiny from a wide range of stakeholders, all of whom may have a different perspective on the performance of the SME dealing with oily waste. It is to the advantage of the SME that it is aware of such interest (where justified) so that it can respond accordingly. Stakeholders may include Government Agencies, Shareholders, Employees (and their families), Trade Associations, Banks, Insurers, Certification Authorities and Local Communities amongst others.*

1.4 DEMONSTRATION OF COMMITMENT

- Acknowledgement of leadership by the company being pro-active
- Independent certification to demonstrate licence to operate
- Enhanced reputation of the company
- Improved stakeholder relationships
- Increased confidence of investors, banks and insurers
- Increased motivation of employees

Notes: *the development and implementation of an effective management system focussed on the safe handling and treatment of oil water demonstrates a pro-active approach and tends to build credibility of the company with regulators, inspectors and other stakeholders. It may be argued that these are value judgements that have little bearing on the harsh reality of investment, profit and loss, and market share. However, the demonstrable commitment of a company to its legislative and regulatory responsibilities is increasingly significant in terms of planning applications, marketing and investment.*

1.5 IMPROVED ENVIRONMENTAL PERFORMANCE

- Continual minimization of environmental impacts*
- Improved control of environmental aspects*
- Improved management of environmental issues*
- Raised staff awareness
- Support for planning and development applications
- Data and information for environmental management certification

Notes: *In dealing with environmental issues the company may well enhance its profitability because of the costs involved in waste reduction and waste disposal with all the attendant environmental considerations. The objective of all environmental systems is the continual improvement of environmental quality and there is increasing pressure for companies to declare their environmental performance.*

1.6 MOTIVATION TO IMPLEMENT EFFECTIVE ENVIRONMENTAL MANAGEMENT

- Confirmation of internal commitment
- Building of internal capacity and competence

Notes: *The adoption of a programme to deal effectively with oily waste may act as a catalyst to the plant, factory, industry or trade to implement EMS*. Many industrial sectors started by dealing with single issue problems such as dust, water quality or contaminated soil. It is widely recognized that the development of an appropriate EMS is more cost-effective because once the framework is established within the business culture of the company successive issues can be dealt with more efficiently because the expertise and system is already in place.*

1.7 INTEGRATED ENVIRONMENTAL MANAGEMENT*

- Better integration of environmental policy into all the company's functions
- Enhanced status of environmental quality within the company's management process
- More effective integration (and hence cost reduction) of safety, health, environment and security systems

Notes: *The management of oil contaminated water within a company's overall programme of activity is necessarily multidisciplinary in nature as it involves, amongst other considerations legislation, technology, processes, training and finance. An integrated approach reduces costs, increases efficiency and streamlines the management task.*

1.8 MONITORING*

- Promotes application of performance indicators to track efficiency and
- compliance
- Can provide an early warning system of potential problems or dangers
- Provides data and information for reporting of the company's
- performance. Increasing transparency of operational performance is a
- growing demand from regulators and stakeholders
- Provides positive evidence for purposes of internal review and external
- Auditing

Notes: *Monitoring of the process of handling and treatment of oil contaminated water can provide relevant data for the control of costs, risks, efficiency, safety, health and management itself. There is increasing pressure for companies to demonstrate competence and performance.*

1.9 LEGISLATION

As a newly emerging economy, Thailand has an intact environmental legislation framework. Compliaces with legislations are vital to companies existed in Thailand. The hierarchy of Thai laws is as follows:

- The Constitution, the most recent being the 1997 Constitution;
- "Acts" passed by the Parliament;
- "Regulations" and "Notifications" enacted by the respective Ministries.

The following list is laws and regulations related to the handling of oil contaminated water.

1.9.1 Law and Regulations related to Ministry of Industrial Works

- Factory of Act B.E.2535
- Hazardous Substance Act B.E. 2535
- Hazardous Substance Act (2nd Issue) B.E. 2544
- The Ministerial Regulation No. 15 (B.E. 2544) Issued Pursuant to the Factory Act B.E. 2535
- The Ministerial Regulation No. 11 (B.E. 2539) Issued Pursuant to the Factory Act B.E. 2535
- The Ministerial Regulation, No. 2 (B.E. 2535) Issued Pursuant to the Factory Act B.E. 2535
- The Ministry of Industry Notice Subject: The Support Measure for the Target Industries
- The Ministry of Industry Notice, Subject: Prescription of the Content Values of Contaminants in Air Emitted from the Factory in Case of Use of Processed Used-oiland Synthetic Fuel as Fuel in Industrial Furnaces B.E. 2548
- The Ministry of Industry Notice Subject: Prescription of the Content Values of Air Contaminants Emitted from the Factory B.E. 2548

1.9.2 Law and Regulations related to Ministry of Natural Resources and Environment

- Enhancement and Conservation of the National Environmental Quality Act 1992
- Notification of MOSTE on Types and Sizes of Projects or Activities of Government Agencies, State Enterprises or Private Persons Required to Prepare an Environmental Impact Assessment Report 1992 (24 August 1992)

- Groundwater Act 1977
- Groundwater Act (No. 2) 1992
- Regulations on Prevention and Combating of Oil Pollution

1.9.3 Law and Regulations related to Industrial Estates and Land Use and Planning

- Industrial Estate Authority of Thailand Act (No. 3) 1996
- Construction Building Control Act 1979
- City Planning Act 1975
- Land Reform for Agriculture Act 1975
- Investment Promotion Act 1977

CHAPTER II

DEFINITIONS AND CHARACTERIZATION OF OILS BY INDUSTRY

-TECHNICAL PART-

2 DEFINITIONS AND CHARACTERIZATION OF OILS BY INDUSTRY

2.1 OILY WASTEWATER

2.1.1 Introduction

Impact on human health and environment

Once released in the environment by the wastewater discharge, the oils and greases pose significant risks to human health due to the cocktail of chemicals they contain: heavy metals, PAHs, dioxins etc. People can be exposed to these chemicals by drinking water and eating contaminated food, as well as coming into contact with contaminated soil and breathing in contaminated dust.

The impact to the environment is the result of oily wastewater discharge into rivers and water bodies, as well as leakages into soil. In water, the oil is a visible pollutant affecting fish and water plants by stopping the sunlight and the oxygen from getting into water. It can kill the fish and other animals that breathe from the water's surface. Moreover, the contaminants contained in oil can be absorbed by plants and animals, harming and killing these organisms. A comprehensive understanding and characterization of wastewater containing oil products would help in assessing the risk posed to human health and environment and it will also lead to taking correct decisions for proper selection of cleaning technologies.

Problems to sewer system

The oily wastewater resulted from industries dealing with oil, fat and greases should be carefully evaluated and characterized in order to avoid damage or blockage to the collection system or safety hazards to the working personnel. Depending on certain parameters of oily wastewater, the metal and concrete conduits could be affected. Selecting the material and setting the general layout for the sewer system needs to be done only after an exact characterization of oily wastewater characteristics.

Difficulties in wastewater treatment

Beside the problems created by oily wastewater to the sewer system, high concentrations of oils and greases in the water to be purified can dramatically increase the costs of wastewater treatment. The available technologies should be accordingly adapted to specific levels of concentration and composition of oily wastewater. For a proper technology selection, detailed characterization of oily wastewater properties is required, and often this leads back to identification of all sources causing leakages or discharges of oily waste greases into wastewater stream (Fig 2-1).

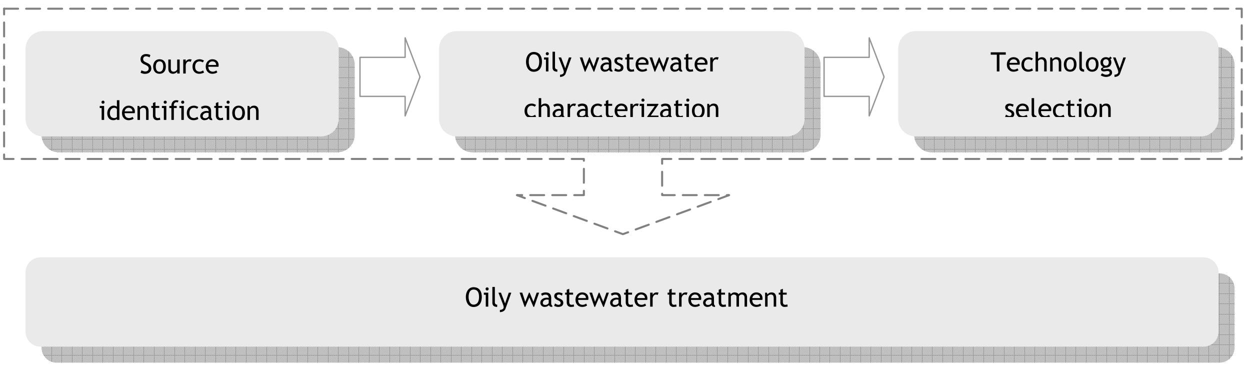


Fig 2-1 Oily wastewater treatment process

2.1.2 Source identification

The type and concentrations of contaminants in wastewater discharged from different sources vary greatly. The used oils from automotive industry may contain to a great extend heavy metals such as cadmium, chromium and lead, while oily wastewater from food industry is mostly loaded with oils and greases of animal and vegetal origin. A selection of representative Thai industry types was made based on particular objectives of the present study and for each of them was identified the major source of contamination with oils and greases (Table 2-1). A detailed characterization of each oil type is further presented in chapter 2, with emphasis on use within industry, general description and composition, parameters and external use.

Table 2-1 Classification of oils and greases by industry

Industry / oil type	Lubricant	Cooking	Fuel	Animal	Vegetable
Palm oil processing plants	■	–	■	–	■
Lubricant oil manufacturers	■	–	–	–	–
Reuse of used oil	■	–	■	–	–
Food processing industry	■	■	■	■	■

2.1.3 Oily wastewater characterization

General parameters

- Specific gravity of oil and greases to be separated
- Viscosity of oil and greases
- Free oil and greases concentration in wastewater
- Total oil and greases concentration in wastewater

Factors influencing oil/water separation

- Wastewater temperature
- Wastewater pH
- Total Suspended Solids (TSS) concentration
- Specific gravity of wastewater

Relevant oily wastewater constituents

Oil droplet size distribution is a critical information when evaluating the wastewater's behavior in a oil/water separator. Since oil droplets are not actually particle, it is widely accepted to treat them as spherical particles [King, 1999]. Figure 2-2 shows an oil droplet size distribution, according to drop's diameter in microns:

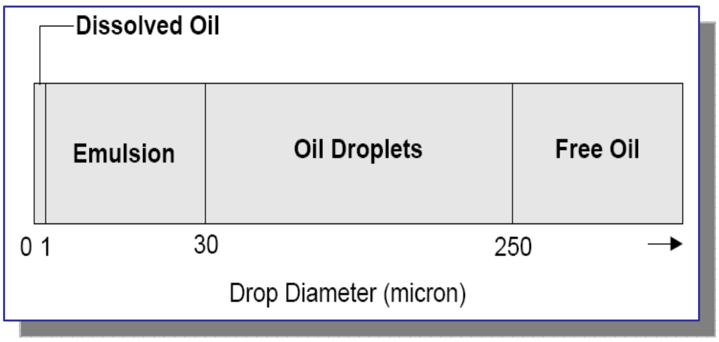


Fig 2-2 Oil droplet size ranges [King, 1999]

Above 250 microns, the oils are supposed to freely float on the water surface. Most of oil droplets are found having diameters between 30 and 250 microns and they are modeled as spherical particles able to rise towards the water surface during the oil/water separation process. Between 1 and 30 microns it is assumed that oil is under emulsion form and below 1 micron it is considered diluted.

But the oil drop size distribution is not identical for all kinds of oil. The Figure 2-3 a) shows a possible distribution of oil drops (in percent) versus their diameter, sampled from a oily wastewater discharge stream. The data suggest that most of the oil drops (about 45%) have diameters between 30 and 60 microns and the first tendency would be to focus the concern on this size range. In reality, the number of drops from a certain diameter interval does not reflect the total volume of oil contained by the respective drops, which is represented in Fig 2-3 b). Here we can notice that larger droplets contain significantly more oil than the small ones due to the fact that, for a spherical oil drop, the volume is a function of the cube of the drop's diameter.

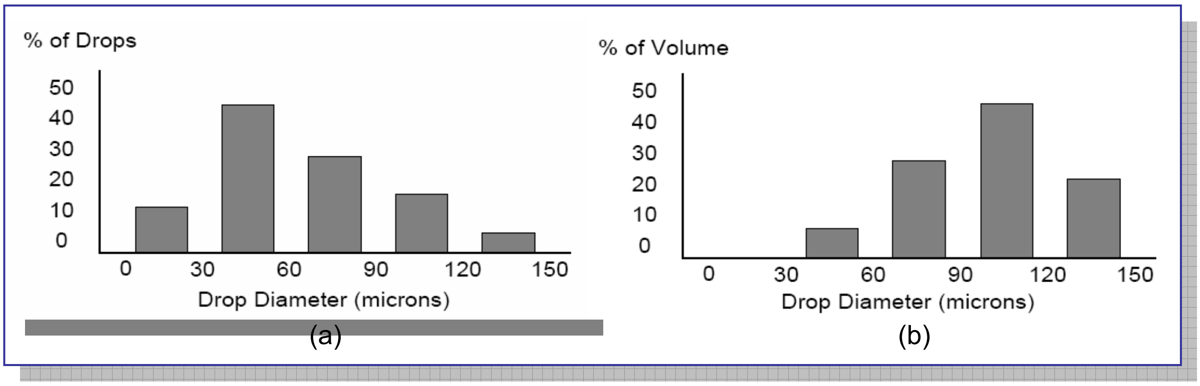


Fig 2-3 Numerical (a) and volumetric (b) percentage of oil droplets by diameter size ranges [King, 1999]

To find the volume of oil contained in the droplets of a particular size, the following formula can be used [King, 1999]:

$$\textit{volume of oil} = (\textit{number of droplets}) \cdot (\pi/6) \cdot (\textit{diameter of droplet})^3$$

As seen from Fig 2-3, the critical diameter range with most of the volume oil is situated between 90 and 120 microns. In practice, this should be the concerning oil droplet diameter taken in consideration when designing a oil/water separation system. Since usually the separation techniques do remove also bigger particles than those having a certain diameter, when choosing the proper technology it is recommended to focus only on a critical diameter (in this case 90 microns).

Before applying a separation technology based on oil droplets distribution, a exact diameter has to be firstly measured. King (1999) summarized three methods to determine the droplet size (in case a direct measurement is not possible, size distribution curves can be obtained also from literature):

- counter based on the electrical properties of a test solution;
- manually counting size and number of oil droplets under microscope;
- automatically counting using laser light (e.g. Coulter Counter).

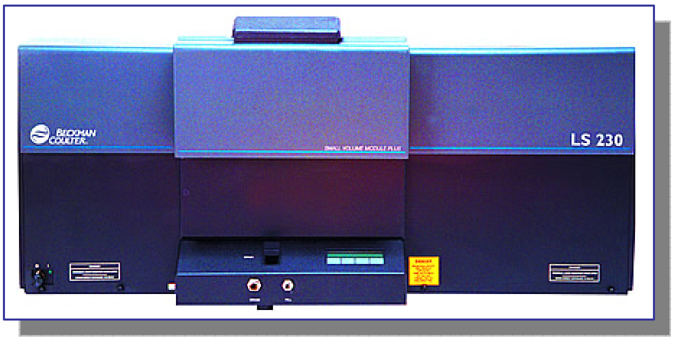
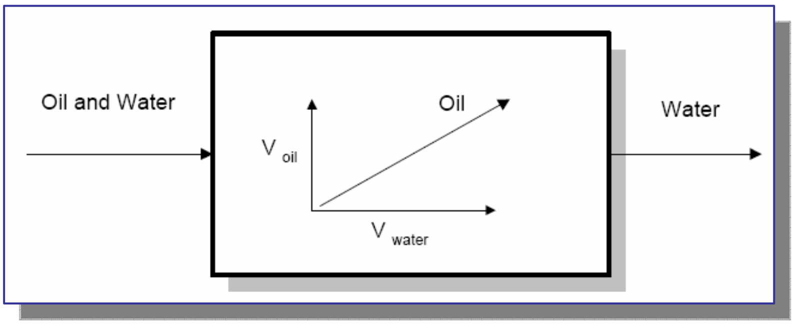


Fig 2-4 Coulter counter LS 230 using laser light

[www.beckmancoulter.com]

Oil droplet velocity is another important parameter for oil/water separation processes relying on gravitational forces (Fig 2-5). King (1999) distinguished between velocity of the rising oil to the water surface (v_{oil}) and the velocity of the oily wastewater during the separation process (v_{water}). Knowing and correlating both velocities we can estimate the time required by a drop of oil to rise to the water surface, obtaining thus the physical dimensions required for the separator in order to get an effective oil/water separation.



A condition for the successful oil droplets elimination is that the time for an oil droplet to rise to the surface of a gravitational oil/water separator must be *shorter* than the time needed by the wastewater to cover the total length.

Fig 2-5 Oil droplet trajectory in an idealized retention chamber [King, 1999]

Oil concentration in wastewater is actually the factor deciding the efficiency of an oil/water separation system and has to be measured both in influent and effluent. US Environmental Protection Agency (US EPA) recommends measuring the concentrations of oils in wastewater using *"Method 1664: N-Hexane Extractable Material (HEM; Oil and Grease) and Silica Gel Treated N-Hexane Extractable Material (SGTHEM; Non-polar Material) by Extraction and Gravimetry"*.

Emulsification represents a particular case in oily wastewater treatment and it is defined as mixing the two immiscible fluids (oil and water), with droplets of one fluid being distributed in the other fluid. In practice one can find the following types of emulsions:

- *mechanical dispersion* – apparent homogeneous mixture which could be separated by gravity but lasting a very long time;
- *chemical emulsion* – highly homogeneous mixture, very stable due to chemical interactions, it cannot be separated by gravity.

Since most of the emulsions are produced by high wastewater turbulences (e.g. caused by pumps and valves), their formation could be avoided by carefully controlling the wastewater flow before and inside the treatment plant.

2.1.4 Technology selection

The selection of proper technology for oil/water separation is a complex process which has to take in consideration, besides the oil properties described above, the "regular" wastewater footprints. Nevertheless, an important part of the decision is based on the overall influent oil concentration and the scheme presented in Fig 2-6 might serve for general orientation. A more detailed approach is presented further in chapter 3.

2.2 CHARACTERIZATION OF OILS BY INDUSTRY

As already introduced in chapter 2.1.2, a selection of industries was made in correlation with the particular objectives of this study. The following part is listing a brief characterization of oils by these industries, with focus on: palm oil processing plants, lubricant oil manufacturers, small companies dealing with used oil, and food processing industry (mainly poultry). For more information regarding a specific method of analysis or similar, the reader is directed to a regulatory international standard (e.g. ASTM).

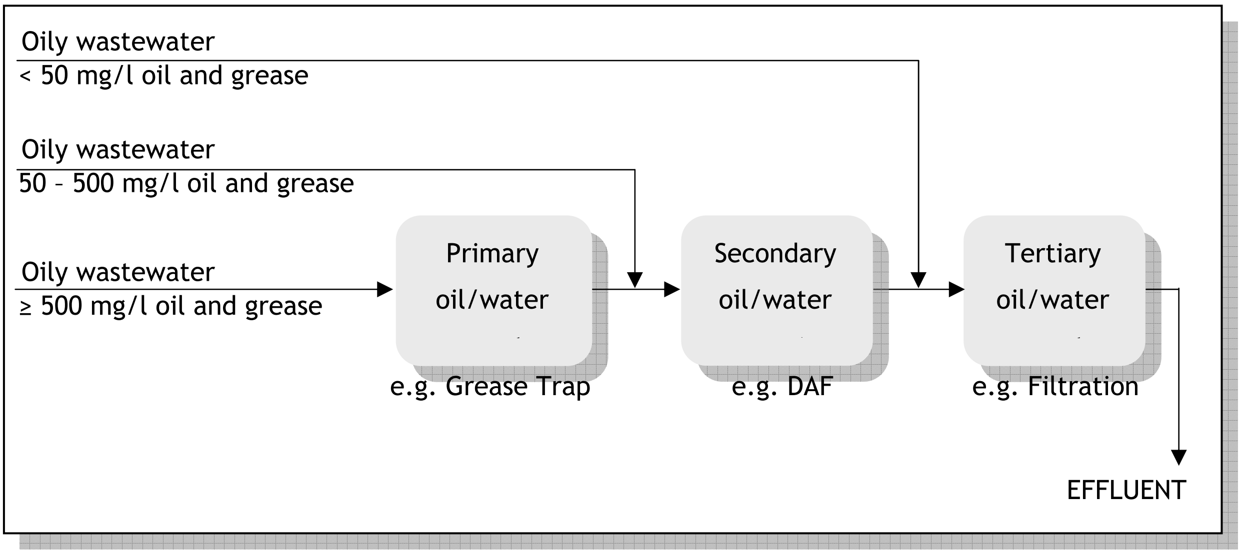


Fig 2-6 Selection of oil/water separation technology based on oil and grease concentration [Schultz, 1999]

2.2.1 Palm oil processing plants

Within palm oil industry, the following types of oil are found as row material, end product or used for various technological processes (Table 2-2):

Table 2-2 Types of oil in palm oil industry

Lubricant oil	Cooking oil	Fuel oil	Animal oil/fat	Vegetable oil
■	–	■	–	■

2.2.1.1 Vegetable oil

Use within industry

End product as palm oil (PO) and palm kern oil (PKO). PO is derived from the flesh of the fruit of the oil palm species Elaeis Guineensis [SCHULTES, 1990] and the PKO is obtained from the kernel of the oil palm fruit.

Description

Both semi-solids at room temperature (liquids at tropical temperatures), good resistance to oxidation and heat, bright orange-red color due to the high betacarotene content (the carotenoids are destroyed after a few minutes boiling, the oil getting a white color). Both palm oils are mainly composed by **palm olein** (fully liquid fraction of the palm oil) and **palm stearin** (more solid fraction), both obtained by fractionation of PO after crystallization at controlled temperatures.

Composition

Both PO and PKO contain fatty acids (FAs), esterified with glycerol like any other fats. Most of the FAs are saturated (especially in PKO) and their concentrations are presented in Table 2-3:

Table 2-3 Concentration of fatty acids in palm oil and palm kern oil [ANG ET AL., 1999]

	Palm oil			Palm kern oil		
Saturated	Palmitic Stearic Myristic	$C_{16}H_{32}O_2$ $C_{18}H_{36}O_2$ $C_{14}H_{28}O_2$	44.3% 4.6% 1.0%	Lauric Myristic Palmitic Capric Caprylic Stearic	$C_{12}H_{24}O_2$ $C_{14}H_{28}O_2$ $C_{16}H_{32}O_2$ $C_{10}H_{20}O_2$ $C_8H_{16}O_2$ $C_{18}H_{36}O_2$	48.2% 16.2% 8.4% 3.4% 3.3% 2.5%
	Total saturated FAs		49.9%	Total saturated FAs		82.0%
Monounsaturated	Oleic	$C_{18}H_{34}O_2$	38.7%	Oleic	$C_{18}H_{34}O_2$	15.3%
Polyunsaturated	Linoleic	$C_{18}H_{32}O_2$	10.5%	Linoleic	$C_{18}H_{32}O_2$	2.3%

Parameters

Iodine value

Iodine value is a measure of how strong a tendency the oil has to oxidation and thus to drying and represents the total number of unsaturated fatty acids in an oil. It can be obtained also by measuring how many grams of iodine will combine with 100 g of oil. In comparison with oils used for manufacturing of paints and inks (iodine values around 190), the iodine values for palm oil are between 43 – 58, thus characterizing PO as non-drying oil (it does not dry significantly on contact with atmospheric oxygen).

Standards:

- ASTM D1959-97 – Standard test method for iodine value of drying oils and fatty acids (withdrawn 2006)
- DIN 53241 - Determination of iodine value

External use

- Food industry: very reach in vitamin A and E, used as frying oil (stable at high temperatures), cooking oil, mayonnaise, dressings, margarine (palm kernel oil), cocoa butter replacement (palm oil stearin);
- Non-food industry: wide range of applications (see Figure 2-1)

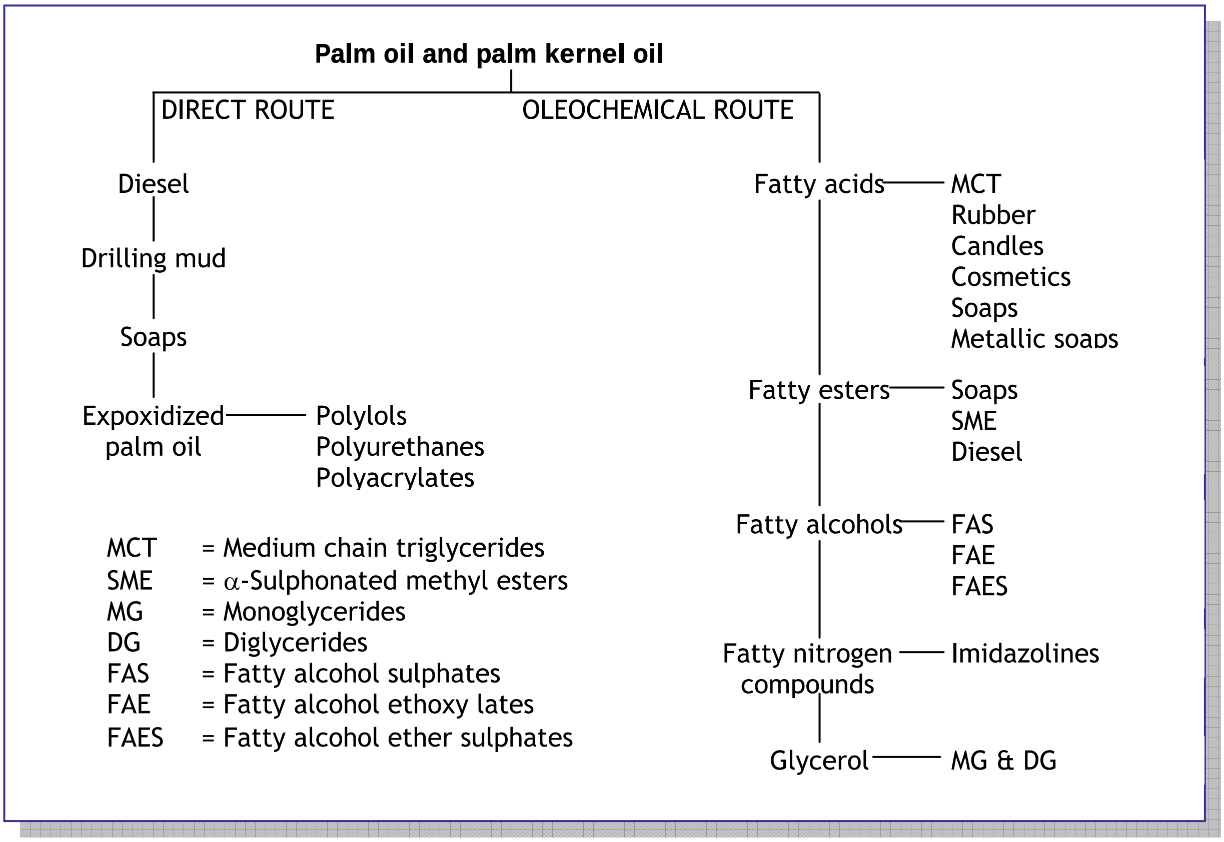


Figure 2-1 Non-food applications of palm oil and palm kernel oil [MPOC, 2007]

Waste oil

The waste oil is generated within industry by two factors: oil loss during the technological processes and the oil spills due to leakages and accidents. While the former can be quantified and precisely identified within the respective technological steps, directly dependent on the processing capacity in tones of fresh fruit bunch (FFB), the later is difficult to be evaluated but can play an important role in the overall efficiency.

According to [GTZ, 1997], a total oil loss of about 10% can be estimated from a mass balance of a standard wet oil mill process, representing about 17 kg/t fresh fruit bunch (FFB). This value may be considered for rough orientation, since efficiencies of processes can drastically differ from one example to another. About 56% of the total oil loss is fixed on the solid residues (mainly FFB and fiber) and 44% are discharged into the wastewater collection system together with the liquid residues. The Table 2-4 shows the distribution of oil loss within the standard processes in a palm oil mill:

2.2.1.2 Fuel oil

Use within industry

To fire the steam boilers used in different technological steps. In large-scale mills, the recovered fiber and nutshells are used but low quality oil can be used as fuel for the heating up the boilers for:

- Fruit bunch sterilization (or cooking) using hot water or pressurized steam.
- Fruit digestion (releasing the palm oil in the fruit through the rupture or breaking down of the oil-bearing cells), a steam-heated cylindrical vessel
- Wet pressing method (using hot water for leaching out the oil)

Table 2-4 Output balance of "standard wet processes" in a palm oil mill [GTZ, 1997]

Medium	Type of material	Individual mass	Individual oil content	Oil loss related to total loss
		kg/t FFB	kg/t FFB	%
Solids	- EFB - fiber - shell - kernel (incl. PK oil) - centrifuge cake (oil separation and purification)	230 145 60 60 0	4.5 5 0 0 0	26 30 0 0 0
Total		495	9.5	56
Liquids	raw oil PO Washing/cooling water (except indirect cooling water) sterilizer effluent underflow of settling tank after centrifugation (separator) with a suspended solid load of > 30 kg/t FFB	163 depending on local conditions 150 742	0 0.5 7	0 3 41
Total		1055	7.5	44
gas/vapor	water vapor	250	0	0
Total		250	0	0
Leakage	process instability, breakdowns inefficient equipment	depending on local conditions		
Total				
Summary total		1800		
Oil loss			**17**	**100**

2.2.2 Lubricant oil manufacturer

In case of a lubricant oil manufacturer, no vegetable or animal oil or fat is used (Table 2-5):

Table 2-5 Types of oils used by a manufacturer of lubricants

Lubricant oil	Cooking oil	Fuel oil	Animal oil/fat	Vegetable oil
■	–	–	–	–

2.2.2.1 Lubricant oil and greases

Use within industry

End product as lubricant oils and greases for a wide range of use in hydraulic processes employed in food processing industry, internal combustion engines from automotive industry etc. It consists of two groups of products:

- **Lubricating oils** - represented by engine oils, gear oils, hydraulic oils, food grade oils etc
- **Greases** – lubricants with higher initial viscosities than oil

Description

A lubricant is a substance which provides a protective film when is introduced between two surfaces, thus reducing friction and wear between them. The lubricants keep moving parts apart, reduce friction, transfer heat and can carry away contaminants. A lubricant usually consists of a base fluid, generally of petroleum origin, combined with additive chemicals that enhance the various desirable properties of the base fluid. According to the type of oil based on, most common lubricants can be characterized as mineral oils, synthetic oils, vegetable oils and greases.

Mineral based oils

Oil based lubricants derived from crude oil, classified by American Petroleum Institute (API) in five main groups [API 1509, 2007], depending on viscosity index and their sulfur and saturates content (see determination of these parameters in the next paragraph):

- **Group I** – obtained by solvent extraction, solvent or catalytic dewaxing. It contains less than 90% saturates and/or more than 0.03% sulfur. The viscosity index is comprised between 80 and 120
- **Group II** – obtained also by hydrocracking and solvent or catalytic processes but with higher anti-oxidant properties due to higher grade of saturation (≥ 90%). The sulfur content and viscosity index are the same like for group I.
- **Group III** – manufactured by isohydromerization, with a high saturation grade (≥ 90%), sulfur content less than 0.03% and viscosity index ≥ 120
- **Group IV** – represented by polyalphaolefins (PAO) and having good lubricating properties; see also [Tsvetkov et al., 1987]
- **Group V** – all other compounds not included in the previous groups (e.g. synthetic esters etc.)

Parameters

Viscosity

Viscosity can be generally defined as a fluid's resistance to flow (shear stress) at a given temperature. Viscosity can be kinematic or dynamic (absolute). Kinematic viscosity is defined as the resistance of an oil to flow and shear due to gravity [BARNES, 2002] and is measured by most laboratory methods. The relationship between kinematic and absolute viscosity is:

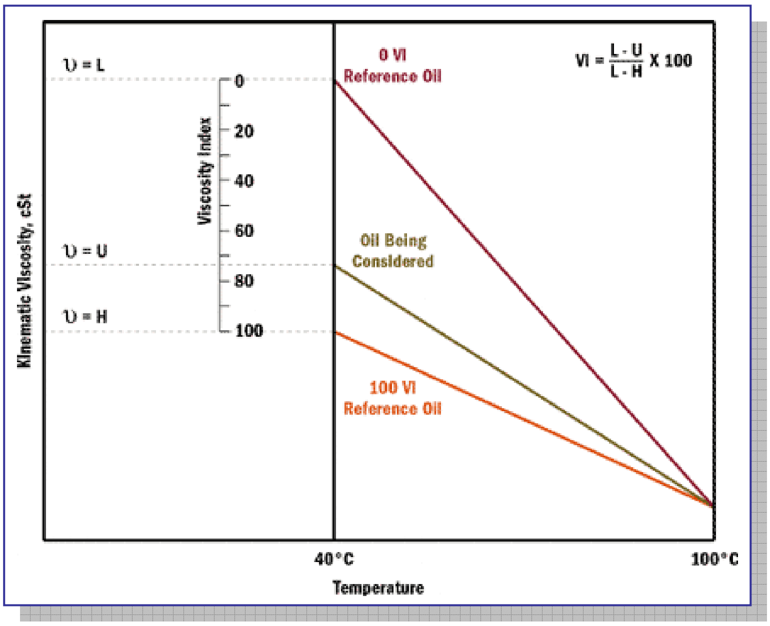
Absolute viscosity = kinematic viscosity x density

Figure 2-2 Rotary tube viscometer (left) and capillary tube viscometer (right) [BARNES, 2002]

For a detailed comparison of kinematic vs. dynamic (absolute) viscosity see also [TROYER, 2002]. The kinematic viscosity of oil is usually measured using a capillary tube viscometer (see Figure 2-2) and reported in *centistokes* (cSt), equivalent to mm^2/s in SI units. The viscosity is calculated from the time it takes oil to flow from the starting point to the stopping point using a calibration constant supplied for each tube [BARNES, 2002]. Another way to measure the viscosity of oil is using the rotary viscometer test method (also referred as "Brookfield method" – for more details see ASTM D2983 standard).

Viscosity Index

Viscosity Index (VI) is a unitless number describing the correlation between the temperature and the oil's kinematic viscosity. The principle of viscosity index determination is by comparison of kinematic viscosity of the test oil at 40°C with the kinematic viscosity of two reference oils; one of which has a VI of 0, the other with a VI of 100 (see also **Error! Reference source not found.**) - each having the same viscosity at 100ºC as the test oil.



Standards:

- **ASTM D445** – Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
- **ASTM D2983** – Standard Test Method for Low-Temperature Viscosity of Lubricants Measured by Brookfield Viscometer
- **ISO 3104** – Petroleum products -- Transparent and opaque liquids -- Determination of kinematic viscosity and calculation of dynamic viscosity
- **ISO 2909** – Petroleum products -- Calculation of viscosity index from kinematic viscosity

Figure 2-3 Determination of viscosity index, VI [BARNES, 2002]

Pour point

Pour point can be defined as the lowest temperature at which the lubricant oil will pour or flow under prescribed conditions.

Standards:

- **ASTM D97** - Standard Test Method for Pour Point of Petroleum Products
- **ISO 3016** – Petroleum products -- Determination of pour point

Flash point

Flash point represents the lowest temperature at which the oil gives vapors that can ignite (but does not burn further). The flash point can be used for determination of transport and storage temperature required for lubricants. The flash point can be also used as a method to determine the presence of contaminants in the oil (if the flash point is much lower than normal, this can be a sign for the presence of volatile contaminants).

Standards:

- **ASTM D92** – Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester
- **ASTM D93** – Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester

TBN – Total Base Number

TBN – Total Base Number represents the reserve alkalinity of an oil to neutralize acids and is measured in milligrams of potassium hydoxide per gram (mg KOH/g). In opposite, TAN – Total Acid Number represents the oil acidity. The TBN and TAN numbers are important for quality control monitoring of lubricant oils in regard to the corrosive effects of acids in the lubricated installations.

Standards:
(for new methods see also [Ball, 2002])

- **ASTM D2896** – Standard Test Method for Base Number of Petroleum Products by Potentiometric Perchloric Acid Titration
- **ASTM D974** – Standard Test Method for Acid and Base Number by Color-Indicator Titration
- **ASTM D664** – Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration

External use

Depending on the fluid type, the lubricants can be used by wide spectra of applications, starting with the engine oils from automotive industry but also many other industrial uses like hydraulic and air compressor oils, various pistons and circulating systems etc. A classification of lubricant oils can be done using different systems, the most common being those of SAE (Society for Automotive Engineers, website www.sae.org), AGMA (American Gear Manufacturers Association, website www.agma.org), as well as the well known standards from ASTM (American Society for Testing and Materials, website www.astm.org) and ISO (International Organization for Standardization, website www.iso.org).

Among all, the engine oils are by far the most representative class of lubricant oils with a worldwide spread demand. Starting with 1911, the classification of engine oils was done by viscosity after a system developed by SAE [API 1509, 2007]. Nowadays, the motor oils classification falls in what is called API EOLCS - Engine Oil Licensing and Certification System [API EOLCS, 2007].

2.2.3 Reuse of used oil

Lubricant oil and fuel oil are the two classes of oil processes by a used oil recycler (as raw material and end product, respectively) – see Table 2-6:

Table 2-6 Types of oils used by a manufacturer of lubricants

Lubricant oil	Cooking oil	Fuel oil	Animal oil/fat	Vegetable oil
■	–	■	–	–

2.2.4 Lubricant oil

2.2.4.1 Description

US Environmental Protection Agency (US EPA) issued a general definition for used oil and in order to meet this definition, a substance must meet all the following three criteria [US EPA, 1996]:

- **Origin** of the used oil must be synthetic materials or the refining of crude oil (vegetable and animal oils are excluded)
- **Use** is the second criterion and it refers to whether the oil has really been used or not. As used oils are considered lubricants, hydraulic fluids, heat transfer fluids and other oils used for similar purposes. Nevertheless, fuel oil recovered from a spill or the unused rest oil from a storage tank do not meet EPA's definition of used oil.
- **Contaminants** must be also present in oils in order to be considered used oils by EPA's definition. In this regard, the oils must be contaminated by residues and contaminants generated from handling, storing, and processing used oil. The physical contaminants could include metal shavings, sawdust, or dirt, while chemical contaminants could include solvents, halogens, or saltwater.

2.2.4.2 Composition

The US EPA has issued a criteria for determination whether an oil should be classified as used oil or as hazardous waste [US EPA, 2007], based on its content in total halogens:

> *"[…] Used oil containing more than 1,000 ppm total halogens is presumed to be a hazardous waste because it has been mixed with a halogenated hazardous waste […]. Persons may rebut this presumption by demonstrating that the used oil does not contain hazardous waste […]"*

The halogens are represented by compounds from the group VIIA of periodic table: fluorine, chlorine, bromine, and iodine. Chemicals containing one of this atoms and one atom of carbon are called organic halogens (e.g. short chain alkenes and short chain chlorinated paraffins) and those without the atom of carbon – inorganic halogens (e.g. sodium chlorine). Both organic and inorganic form the group of total halogens, whose high presence in the used oil can change its name into hazardous waste. The content in total halogens can be either tested (see ASTM D4057) or based on knowledge about type and concentration of halogen compounds in the oil [US EPA, 1995].

Apart from total halogens, the used oil may contain heavy metals in high concentrations, which can lead to important emissions to atmosphere if the used oil is further converted into fuel oil. An example of range and average values from used oils in Canada are presented in Table 2-7 [Boughton and Horvath, 2004]:

Table 2-7 Constituent concentrations in used oil in comparison with virgin fuel oil [Boughton & Horvath, 2004]

	Used oil		Virgin fuel oil
Element	Average (ppm)	Range (ppm)	Average (ppm)
Ba	18	12-26	< 1
Pb	33	18-38	< 10
Cd	1	< 1-2	< 0.25
Cr	1.4	< 1-2	< 2
Cu	40	28-64	Na
Ni	1	< 1-1.7	8.3
Zn	822	600-877	9

Parameters

Water content

Water content in oil can be easily determined with a crackle-test by heating a hot plate at 300°C and dropping a single drop of used oil. Interpretation of the bubbles formed gives a rough but satisfactory estimation of the water content (for details, see Troyer, 1998). Beside the visual crackle-test, following methods might be also taken into consideration:

- Dean and Stark Method: a classical distillation technique involving co-distillation of the oil sample
- Calcium Hydride Test Kits: simple and convenient way to determine water content in oil by reaction with solid calcium hydride to produce hydrogen gas
- Karl Fischer Moisture Test: accurate and precise method involving either a volumetric titration or colorimetric titration

In parallel with lab methods, inexpensive field tests can be run for quick estimation of water content in used oil. For this purpose, different hand-held devices are available on the market, as for example "Hydroscout", the portable test developed by Geneq, Inc. Canada [GENEQ, 2007]

Standards:

- **ASTM D95** – Standard Test Method for Water in Petroleum Products and Bituminous Materials by Distillation [ASTM D95]
- **ASTM D1744** – Standard Test Method for Determination of Water in Liquid Petroleum Products by Karl Fischer Reagent (Attention: withdrawn in 2000!!!)
- **ASTM D6304** – Standard Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fisher Titration
- **ASTM D1533** – Standard Test Method for Water in Insulating Liquids by Coulometric Karl Fischer Titration

- **ASTM D1401** – Standard Test Method for Water Separability of Petroleum Oils and Synthetic Fluids

Saponification number

Saponification number – is expressed in mg of KOH (or NaOH) required to saponify one mg of oil under specific conditions (saponification is the chemical process which describe the hydrolysis of an ester under basic conditions to form an alcohol and the salt of a carboxylic acid; saponifiable substances are those that can be converted into soap).

Standards (see also [VAN DE VOORT et al., 1992] for a rapid method of determination):

- **ASTM D94** – Standard Test Methods for Saponification Number of Petroleum Products
- **DIN 51559** – Testing of mineral oils; determination of saponification number; color-indicator titration, insulating oils

Total halogens

Standards:

- **ASTM D4057-95** (2000) Standard Practice for Manual Sampling of Petroleum and Petroleum Products

Density

Standards:

- **ASTM D1298** – Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method

Total chlorine

Standards:

- **DIN 51577** – Testing of mineral oil hydrocarbons and similar products; determination of chlorine and bromine content; analysis by energy dispersive X-ray spectrometry with low cost instruments
- **ASTM D6074** – Standard Guide for Characterizing Hydrocarbon Lubricant Base Oils

Viscosity

Sulfur content

Sulfur content in fuel oil must be reduced due to the hazard posed to the environment by sulfur emissions when fuel is burned. Sulfur content can be determined using a few methods: high-temperature method, X-ray fluorescence spectrometry (for sulfur concentrations from 0.001 to 2.50 % (m/m)); or UV fluorescence method (for sulfur in very low concentrations, from 0.0003 to 0.05 % (m/m) – see also).

Standards:

- **ASTM D1552** – Standard Test Method for Sulfur in Petroleum Products (High-Temperature Method)
- **ASTM D 4294** Standard Test Method for Sulfur in Petroleum and Petroleum Products by Energy-Dispersive X-Ray Fluorescence Spectrometry
- **ISO 20846** – Petroleum products -- Determination of sulfur content of automotive fuels -- Ultraviolet fluorescence method
- **ISO 14596** – Petroleum products -- Determination of sulfur content -- Wavelength-dispersive X-ray fluorescence spectrometry

Figure 2-4 Example of fluorescent UV sulfur analyzer (SLFA-2100/2800 developed by HORIBA, Ltd.) [HORIBA, 2007]

2.2.5 Food processing industry

In case of food processing industry (poultry processing plants and fishery processing plants, including slaughter houses and frozen sea food units), all five types of oil are being considered for the present guidelines (Table 2-8).

Table 2-8 Types of oils used within food processing industry

Lubricant oil	Cooking oil	Fuel oil	Animal oil/fat	Vegetable oil
■	■	■	■	■

2.2.5.1 Lubricant oil

Use within industry

For lubrication of machinery at different processing steps. According to the respective technological line, lubricant oils for food processing industry must meet specific requirements, e.g. working at extreme ambient conditions, but also an incidental contact with food during processing must be taken into consideration. Similar to industrial lubricants, the oils used in food industry must accomplish:

- Anti-wear and load carrying capabilities
- Rust and corrosion inhibition
- Oxidation stability
- Anti-foam and air release properties

In addition, they should provide a very good protection against rancidity and build up due to bacterial and fungal growth caused by food stacked in the moving parts of machineries.

Description

Lubricant oils for food processing industries are known as “food grade” oils and they should respect not only high technical and economical requirements but also avoid any food hazard caused by an eventual contact. Food grade oil must be therefore virtually non-toxic, colorless, odorless and tasteless and is engineered with customized additive technology to increase food plant productivity [LESINSKI and RAAB, 2003].

Composition

For food purposes, mineral base lubricant oils are usually made of liquid petrolatum or liquid paraffin, which consists basically of n-alkanes and some cyclic paraffins. They are chemically inert especially as regards the straight chain alkanes [INCHEM, 2007].

Parameters

In case of food processing industry, the pour point and flash point are important when choosing the proper lubricant oils due to specific conditions at which they must operate.

Pour point

Pour point is an important parameter especially for refrigerated and frozen food processors, since they require lubricant oils resistant at extremely low temperature conditions.

Flash point

Flash point represents the temperature at which the oil will vaporize and ignite when exposed to an open flame. The rate of oil vaporization is strictly related to the rate at which the lubricant must be replaced. High evaporation rates conduct to a high lubricant consumption and therefore an increased risk of food contact [RAAB and LESINSKI, 2005].

Figure 2-5 gives an example of a food grade lubricant with different constituents:

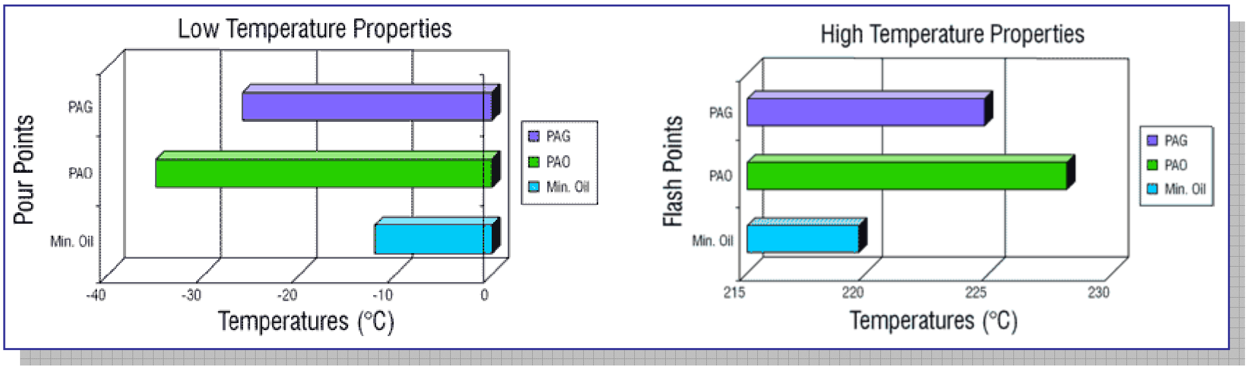


Figure 2-5 Properties of a food grade lubricant oil based on PAG (polyalkalene glycols), PAO (polyalphaolefins) and mineral oil [RAAB and LESINSKI, 2005]

2.2.5.2 Cooking oil

Use within industry

Used directly in frying step, involving direct contact between the oil and the raw food being cooked. During cooking, the oil is then absorbed by the food and contributes to its flavor and nutritional properties [BERGER, 2005].

Parameters

Smoke point

Smoke point represents the temperature at which the cooking oil starts to break down giving food an unpleasant taste. Depending to the oil's quality (refined, unrefined etc.), the smoke point can vary from 107 °C for the unrefined sunflower oil to 250 °C and more for other cooking oils (see a comprehensive list of smoke points for common fats at www.cookingforengineers.com/article/50/smoke-points-of-various-fats and at www.goodeatsfanpage.com/collectedInfo/oilsmokepoints.htm). For palm oil, the recommended smoke point must be above 215°C, preferably above 220°C [Berger, 2005].

Color and odor

Color and odor of the cooking oil are parameters that need to be analyzed in regard to each particular conditions of cooking process. Standard color comparator test kits can be used but they must be applied to same type of oil (the colors of cooking oils vary according to their origin). Moreover, the cooking oil must be free of rancidity or foreign flavors.

Free fatty acids

Free fatty acids (FFA) in cooking oil should be limited to a maximum of 0.1% [Brinkmann, 2000] since the presence of too much saturated fatty acid can lead to finished products with unpleasantly waxy mouth feel [Brinkmann, 2000].

Total polar materials

Total polar materials (TPM) are estimated based on dielectric constant of used oils and several methods have been developed for rapid determination of their presence [Gerde et al., 2007]. In Figure 2-6, a hand-held device developed by EBRO Electronics able to detect polar materials in used oil up to maximum 40%:

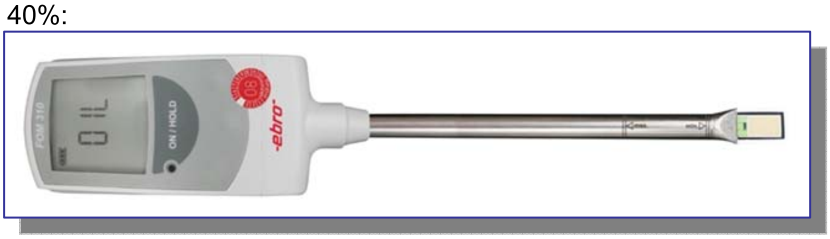


Figure 2-6 Example of hand-held food oil monitor - FOM 310 - developed by EBRO Electronics GmbH to measure polar compounds in cooking oil [EBRO, 2007]

2.3 BEST MANAGEMENT PRACTICES FOR USED OIL

In order to avoid wastewater contamination, a series of measures should be considered when handling used oils (Best Management Practices from Washington State, Department of Ecology: Used Oil Facts, 1995 - http://www.ecy.wa.gov/pubs/0204006.pdf):

- Use labels and signs to segregate used oil from other wastes at your business and train your
- employees in the importance of keeping wastes separate.
- Store used oil in a leak-proof, closed container.
- Drain and collect all oil on a covered and curbed, impermeable surface area away from drains.
- Do not open, handle, manage or store containers and tanks in a manner that may cause them to leak or rupture.
- Use tanks and containers that are inn good condition (no rust, structural defects or deterioration) to store used oil.
- Be prepared to stop, contain and clean up any releases of used oil.
- Take steps to prevent the accidental contamination of your used oil with even small amounts of solid or dangerous waste.
- Label containers, aboveground tanks, and fill pipes with the words “Used Oil.”
- Physically inspect all used oil storage containers and tanks on a regular basis.
- Know the on-spec/off-spec status of your used oil before it leaves your site.
- Know whether your used oil is prohibited from burning as used oil prior to it leaving your site.
- Know how your used oil will be recycled before it leaves your site.
- If possible, keep all containers stored inside or under cover.

2.4 LITERATURE

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CHAPTER III

ENVIRONMENTAL AND ECOLOGICAL IMPACT OF WATERS CONTAMINATATED WITH OIL

-TECHNICAL PART-

3 ENVIRONMENTAL AND ECOLOGICAL IMPACT OF WATERS CONTAMINATED WITH OIL

3.1 ENVIRONMENTAL ASPECTS AND IMPACTS OF MANUFACTURING VEGETABLE AND ANIMAL OILS, FATS AND GREASE

Food industry generates large amounts of oily wastes and wastewater. It is the biggest environmental problem faced by the industry and oils, fats and grease needs therefore proper handling. The losses of oil from edible oil industry can contribute by losses of the end product and by the waste oil generated during the technological processes and the oil spills if appropriate engineering requirements, managements systems, and controls are not implemented. Food processing activities that need to maintain certain level of hygiene, like scalding, meat washing, chilling, waste fluming, and cleaning and disinfecting equipment, results in high water usage and consequently high wastewater generation (The Edible…., 1999). The meat processing industry is usually heavily regulated and thus minimum amount of water required for specific operations, can be established. Due primarily to these regulations, water-use intensity (e.g. amount of water per animal or bird processed) can be very high and has, for example, actually increased during recent decade, like in the U.S since the late 1990s (Woodruff, 2000).

The food industry produces both solid and liquid oily wastes and byproducts, including oily wastewaters (Environmental…, 2006). Depending on the actual production type the content of different compounds in wastewater can vary a lot. However, most components in the wastewater are usually easily degradable and rather harmless but uncontrolled releases can result in significant environmental damage.

- **Palm oil industry**

Palm oil industry can contribute by losses of the end product as palm oil and palm kern oil that are mainly composed by palm olein (liquid fraction) and palm stearin (more solid fraction), and by the waste oil generated by oil loss during the technological processes and the oil spills due to leakages and accidents. Crude palm oil process does not need any added chemicals and therefore most of the oily wastes from the palm oil industry are not acutely toxic.

- **Poultry processing**

Oil and grease content in poultry processing wastewaters is depends on the amount of animal fats and oils lost during processing activities, but also may include lubricating oils and greases lost during the technological processes and the oil spills. The wastes from poultry industry include also blood, soft tissue, bone, feathers, viscera, and various cleaning compounds. Further processing and rendering can produce additional sources of animal fat, in addition to other substances such as cooking oils. The principal constituents of poultry processing wastewaters are a variety of readily biodegradable organic compounds, primarily fats and proteins, present in both particulate and dissolved forms.

3.1.1 Wastewater generation

An edible oil industry generates large quantities of wastewater. Wastewater from the food, including edible oil industries can be divided between

- process wastewater and
- non-process wastewater.

Process wastewater contributes to most of the pollution load in the effluent being drained by the industry; while non-process wastewater constitutes the major portion of total wastewater quantity (The Edible…., 1999).

3.1.1.1 Wastewater generated by palm oil industry

The waste from palm oil industry consists of a mix of water, crushed shells and fat residue and can be characterized as a suspension of 95-96% water, 0.6-0.7% oil and 4-5% total solids including 2-4% suspended solids (Ma, 2000). Chavalparit et al. (2006) provide estimation of the waste generation per ton of fresh fruit brunch (FFB) production from the crude palm oil industry in Thailand (Figure 3-1).

The average amount of waste water is 0.64 m^3/ton of FFB. All palm oil factories in Thailand have a more or less similar production process (Chavalparit et al., 2006), and thus the estimated amounts and consistency of wastes per unit of product is probably pretty similar. It is estimated that for one ton of crude palm oil produced 5-7.5 tons of water are required, and more than 50% of the water can end up as palm oil mill effluent (Ahmad et al., 2003). A study in Pakistan revealed that on an average, for every ton of oil produced, the discharge of wastewater is about 30 m^3 (The Edible…., 1999). Although a large portion of the water used by the industry could be reused or recycled, most of it becomes wastewater sooner or later.

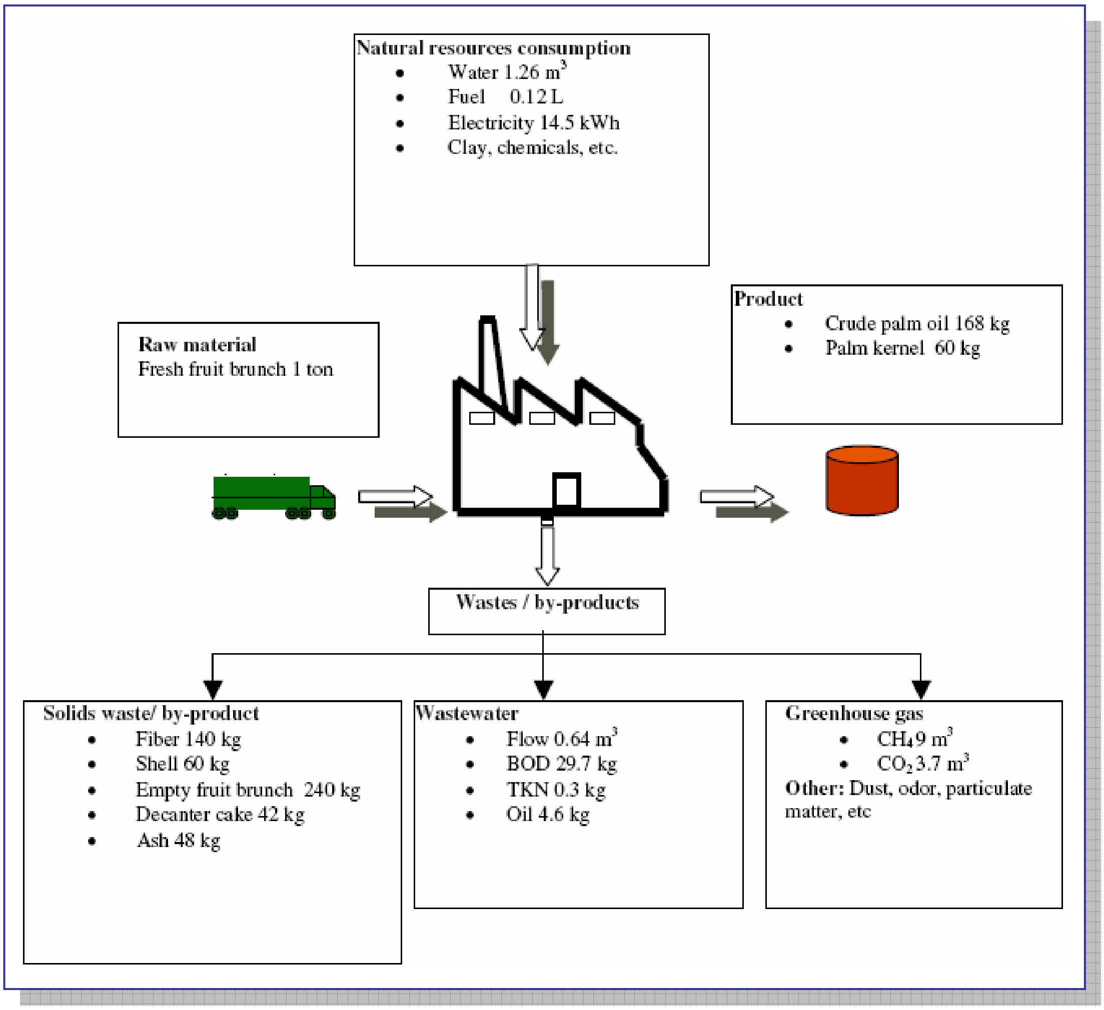

Figure 3-1 Average waste generation rate (per ton FFB) from five selected crude palm oil mills [Chavalparit et al., 2006].

3.1.1.2 Wastewater generated by poultry processing

The volume of water used and wastewater generated by poultry processing on a per unit of production basis can vary substantially among processing plants. Water is used primarily for scalding in the process of feather removal, bird washing before and after evisceration, chilling, cleaning and sanitizing of equipment and facilities, waste conveying and for cooling of mechanical equipment such as compressors and pumps. A study of 88 chicken processing plants found wastewater flows ranged from 15 to 85 liters per bird with a mean value of 35 liters per bird (USEPA, 1975). Using the mean live weight per bird of 2 kilos, 35 liters per bird translates into 17-18 liters per 1 kg live weight kilos (LWK).

In poultry rendering operations water is used for cooking and sterilization, condensing cooking vapors, cleanup, truck and barrel washing when materials from off-site locations are being processed, odor control, and steam generation (USEPA, 1975). Most of these activities generate wastewater. The major sources of wastewater at rendering plants are produced from raw material receiving operations condensing cooking vapors, drying, plant cleanup, and truck and barrel wash (USEPA, 1975). Rendering plants produce approximately one-half ton of water for each ton of rendered material (USEPA, 2002).

Condensates formed during raw material sterilization and drying are the largest contributors to the total wastewater in terms of volume and pollutant load (Metzner and Temper, 1990).

The variations in wastewater flow per unit of raw material processed are largely attributable to the type of condensers used for condensing. Based on a survey of National Rendering Association members, an average size rendering plant generates about of 800,000 liters/day process wastewater and an average of 130,000 liters/day from other sources (USEPA, 2002). The mean waste water generation is about 1400 liters per 1000 kg LWK.

Knowing that water use strongly affects the waste load from a plant even slight reduction of water use would result in a reduced pollution load as was demonstrated by Carawan et al.(1979b), when assessing the water use and load data from meat processing plants in the USA (Figure 3-2).

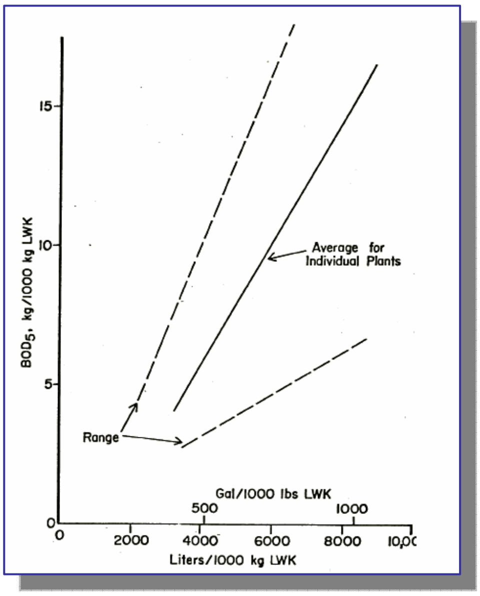

Figure 3-2 Effect of water use on wasteload (BOD_5) in meat processing plants in the USA [Carawan et al., 1979b]

3.1.2 Wastewater quality

3.1.2.1 Edible oil industry

Edible oil processing wastewater has a high content of organic material and, subsequently, a high biochemical oxygen demand (BOD) and chemical oxygen demand (COD). Wastewater may have a high content of suspended solids (SS), organic nitrogen, oil and fat and may contain pesticide residues from the treatment of the raw materials. A study carried out in Pakistan (The Edible…., 1999) to estimate the environmental impacts of edible oil industry provide assessment of mean daily pollution loads in kilograms per 100 tons of produced oil/ghee from three mills (Table 3-1)

Table 3-1 Mean daily pollution loads in kilograms per 100 tons of produced oil/ghee from three mills in Pakistan [The Edible…., 1999]

Parameters	Pollution load, Kg/100 tons of oil or ghee		
	Mill 1	Mill 2	Mill 3
BOD_5	60	230	1,600
COD	170	380	3,000
TSS	280	130	3,100
TDS	3,750	960	5,400
Oil and ghee	15	0.8	15
PO_4^{---}	4.2	-	-
SO_4	200	-	-
Cl^-	304	1,530	95,000

Source: The Netherlands Environmental Technology Program for Industry (ETPI) survey (modified)

3.1.2.2 Palm oil industry

For palm oil industry the BOD and COD of the wastewater is very high being on the level of 20,000–35,000 mg/l and of 30,000–60,000 mg/l, respectively (Pollution …, 1998). The total content of dissolved solids (TDS) can be on the level of 10,000 mg/l, oil and fat residues 5,000–10,000 mg/l, organic nitrogen 500–800 mg/l, and ash residues 4,000 to 5,000 mg/l. (Pollution …,1998). Main characteristics of palm oil effluent are described in Table 3-2.

It can be estimated that the total wastewater generation and BOD load resulting from palm oil mills in Thailand in 2003 was equal to 2.56 million m^3 and 118 million kg, respectively (Chavalparit et al., 2006). Thus, huge amounts of organic pollution, nutrients, and oil and fat residues reach the recipient water body. A study results from Pakistan (The Edible…., 1999) show that the process wastewater can have much higher pH, TDS and oil & grease content comparing to the non-process wastewater (Table 3-3).

Table 3-2 Main characteristics of palm oil effluent and respective standard discharge limits by Malaysian Department of the Environment [Ahmad et al., 2003]

Parameter	Concentration, mg l^{-1}	Standard limit, mg l^{-1}
pH	4.7	5-9
Oil and grease	4,000	50
BOD	25,000	100
COD	50,000	-
Total solids	40,500	-
Suspended solids	18,000	400
Total nitrogen	750	150

Table 3-3 Waste water characteristics of the edible oil industry in Pakistan (The Edible…., 1999, modified)

Parameter	Process wastewater	Cooling and vacuum wastewater
pH	11-12	6-8
BOD5, mg/l	450-700	-
COD, mg/l	1300-2100	-
TSS, mg/l	2000-16500	-
TDS, mg/l	3000-20000	350-10000
Oil and grease, mg/l	100-180	0-5
Phosphate, mg/l	10-20	-
Sulphate, mg/l	10000-15000	-
Total alcalinity, mg/l	6000-22200	-

3.1.2.3 Slaughterhouses

Slaughterhouse wastes are generally high in BOD, TSS and organic matter like grease. Untreated effluent may be as high as 8,000 mg/l BOD and 800 mg/l or greater with suspended solids (Environmental Impacts from Meat and Fish Processing). BOD production comes primarily from the butchering process and from general cleaning and can be on the level of one to 75 kilograms of BOD per ton of product. Nitrogen originates mainly from blood in the wastewater stream (Environmental Impacts from Meat and Fish Processing). Blood is rich also in BOD and chlorides, and BOD_5 ranges between 150,000 and 200,000 mg/l.

The slaughterhouse wastewater may also have pathogens, including Salmonella bacteria, parasite eggs and amoebic cysts. Pesticide residues may be present from treatment of animals or their feed. Chloride levels may be very high (up to 77,000 mg/l) from curing and pickling processes (Environmental Impacts from Meat and Fish Processing). Cooking activities also increase the fat and grease concentration in the effluent.

Slaughterhouse wastes, particularly where hard fats are involved, have resulted in serious decrease in the carrying capacity of sewers (Sawyer et al., 1994). Therefore regulations governing the discharge of greasy materials to sewer systems or receiving waters and installation of preliminary treatment facilities by many industries have been forced.

3.1.2.4 Fish processing plants

Wastewaters from fish processing plants are usually extremely high BOD content and can contain oils, grease, and nitrogen. Carawan et al (1979a) reported a BOD_5 of 100-24,000 mg/l, COD of 150-42,000 mg/l, TSS of 70-20,000 mg/l, and FOG of 20-5,000 mg/l in fish meal plants in the USA. Seafood processing wastewater was noted to sometimes contain also high concentrations of chlorides and organic nitrogen (0-300 mg/1).

3.1.2.5 Poultry processing

The wastes from poultry industry include feathers, blood, viscera, bone, soft tissue, and various cleaning compounds. Further processing and rendering can produce additional sources of animal fat, in addition to other substances such as cooking oils.

The principal constituents of poultry processing wastewaters are biodegradable organic compounds, primarily fats and proteins. Blood, soluble fat, and faeces are the main sources of BOD in poultry processing wastewaters. Therefore, the efficacy of blood collection and manure handling, especially from receiving areas, is a significant factor in determining BOD concentration in wastewaters. Additional sources of BOD in poultry processing wastewaters are feather and skin oils desorbed during scalding for feather removal.

Blood, urine and faeces, also are significant sources of nitrogen, primarily organic nitrogen, and ammonia nitrogen, in poultry processing wastewaters. The phosphorus in poultry processing wastewaters is primarily from blood, manure, and cleaning and sanitizing compounds in detergents.

To reduce wastewater treatment requirements, poultry processing wastewaters needs screening for partial removal of particulate matter before next treatment steps. Collected materials an be used as by-products.

Table 3-4 and Table 3-5, respectively, present typical wastewater characteristics and pollutants generated from broiler processing facilities provided by a study of the U.S. Environmental Protection Agency (USEPA, 2002).

Table 3-4 Typical characteristics of broiler first and further processing (per about one half ton of finished product) wastewaters (USEPA, 2002, modified).

Parameter	First processing	Further processing per about one half ton of finished product
BOD5	1662	3293
TSS	760	1657
Oil and grease	665	793
TKN	54	80
TP	12	72
Fecal coliform bacteria, Colony forming units/100mL	9.8×10^5	8.6×10^5

Table 3-5 Pollutant generation per unit of production in Broiler processing [USEPA, 2002, modified]

Parameter	First processing	Further processing per about one half ton of finished product
BOD5 (kg/1000 kg LWK)	13.84	52.94
TSS (kg/1000 kg LWK)	6.69	26.64
Oil and grease (kg/1000 kg LWK)	7.22	12.75
TKN (kg/1000 kg LWK)	0.44	1.29
TP (kg/1000 kg LWK)	0.10	0.65
Fecal coliform bacteria, Colony forming units/ per about one half ton of finished product	3.4×10^{10}	6.3×10^{10}

A study carried out by Merka (1989) revealed that the final effluent in a broiler slaughter plant had an average BOD of 2178 mg/l, 3772 mg/l COD, 1,446 mg/l TSS, 776 mg/l FOG, 129 mg/l TKN, and 13.0 mg/l ammonia. Another study (Rusten et al., 1998) of the wastewater that had passed through a 250 micron rotary screen and a grease trap found BOD levels ranged from 660 to 6400 mg/l (1940 mg/l average), FOG ranging from 55 to 3570 mg/l (970 mg/l), and total phosphorus from 14.1 to 18.5 mg/l (16.1 mg/l). Kiepper (2003) describes the results by Porges and Struzeski who revealed that blood from a broiler slaughter plant’s had a very high BOD level (92,000 mg/l), and that blood contributed about 40 percent of final effluent organic load.

Large amounts of raw materials commonly accumulate in receiving areas (i.e. on floors). Fluids from these raw materials drain off and enter the sewers contributing significantly to the total raw waste load. At rendering plants that process poultry, liquid drainage may account for approximately 20 percent of the original raw material weight (USEPA, 1975).

The other important source of wastewater from rendering operations is water used for cleaning equipment and facilities, the cleanup of spills, and trucks when materials are received from off-site locations for rendering. The wastewater generated during cleanup operations usually accounts for about 30 percent of total rendering plant wastewater flow and approximately 30 percent of the total raw BOD waste load originates in the cooking and drying process (USEPA, 1975). Although the water used in air scrubbers to control odor can contribute up to 75 percent of a plant’s total effluent volume, they contribute little to the final effluent discharge, since most of this air scrubber wastewater is usually recycled (USEPA, 1975). Other important sources of process wastewater include plant and truck washdown activities, and the cleanup of spills.

Hansen and West (1992) provide a data of the significance of various sources of wastewater from rendering operations before treatment in Columbus, Ohio (Table 3-6). Samples from blood, cooker condensate, and wash-up water were analyzed. The cooker condensate was mostly composed of condensed volatile fats and oils with some ammonia. The wash-up water consisted of plant cleanup water mixed with drainage from the raw product storage hopper. Although the blood accounted for only a small percentage of the total volume of wastewater, it clearly is a highly significant source of COD, TKN, ammonia nitrogen, and grease in rendering plant wastewater.

Table 3-6 Mean pollutant concentrations for poultry rendering plant [Hansen and West, 1992; modified]

Parameter	Raw blood, mg/l	Condensate batch 1, mg/l	Condensate batch 2, mg/l	Wash-up water, mg/l
Total COD	150,000	6,000	2,400	7,600
Soluble COD	136,000	6,000	2,400	3,200
TKN	16,500	740	430	270
Ammonia nitrogen	3,500	740	430	40
Total phosphorus	183	<4	<4	15.1
Oil and grease	620	260	110	35

Another study carried out by the US EPA provide characteristics for waste water generated from broiler rendering facilities (Table 3-7).

Table 3-7 Typical wastewater characteristics generated from broiler rendering facilities [USEPA, 2002, modified].

Parameter	Average value
Flow, Million liters per day	1.1
Raw product rendered, 1000 kg/day	787
BOD_5, mg/l	1,984
TSS, mg/l	3,248
Oil and grease, mg/l	1,615
TKN, mg/l	180
TP, mg/l	38
Fecal coliform bacteria, Colony forming units/100 mL	1.2×10^6

In 2000 U.S. National Rendering Organization collected data from its member organizations about waste water quality before treatment and discharged wastewater (USEPA, 2002, modified). The results of this survey are presented in Table 3-8.

Table 3-8 Typical wastewater characteristics of render plants [USEPA, 2002, Source NRA; modified]

Parameter	Generated wastewater, mg/l	Discharged wastewater, mg/l
COD	123,000	8,000
BOD	80,000	5,100
TSS	8,400	268
Fat and other greases	3,200	116
Fecal coliform bacteria, CFU/mL	2.5×10^8	4.5×10^4

3.1.3 Wastewater effluents

The most common disposal methods of treated oily wastewaters are discharge to public treatment works or by discharge to adjacent surface and surface water bodies. Any business that plans to discharge oily wastewater to the sewer must install, use, and maintain an oil/water separator (Figure 3-3 and Figure 3-4).

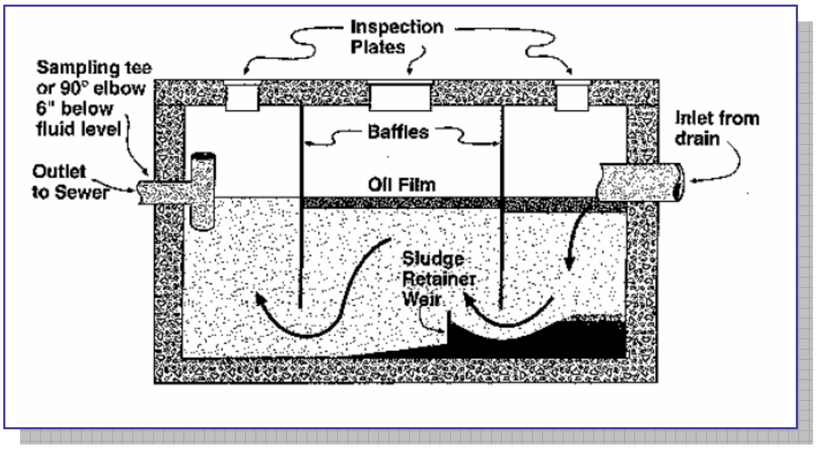

Figure 3-3 American Petroleum Institute Oil/Water Separator

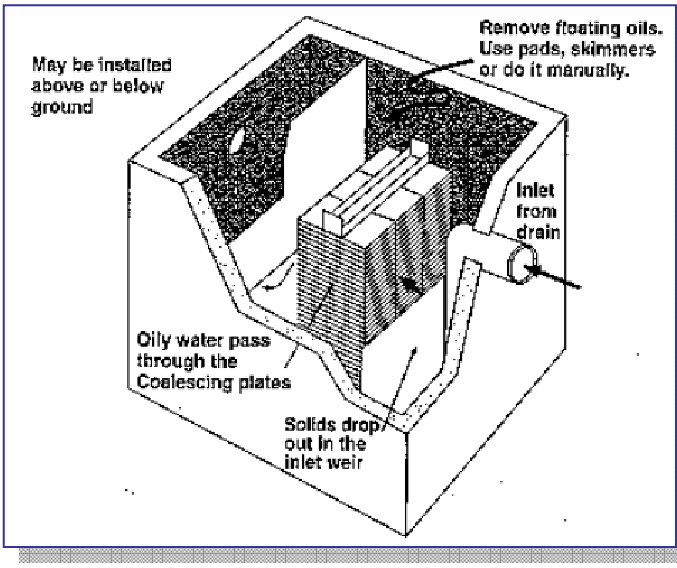

Figure 3-4 Coalescing Plate Separator (American Petroleum Institute)

Similarly in-site treatment, including oil trap, should be used when discharging to the water bodies. A catch basin, installed before the separator, can be used to trap solids before they wash into the separator (Figure 3-5). This can be very helpful to businesses cleaning oily equipment.

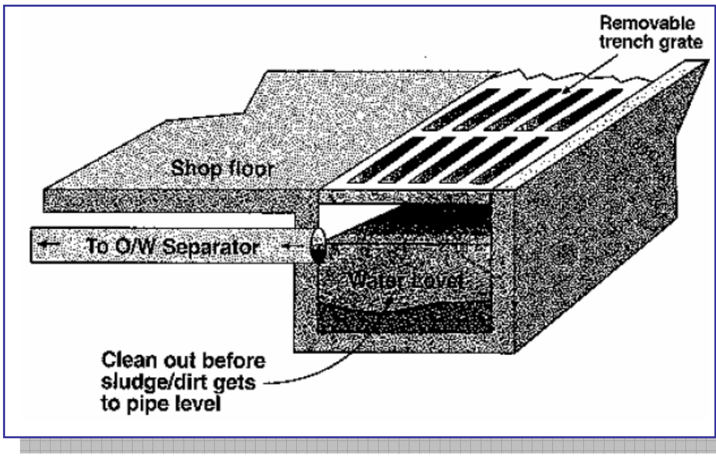

Figure 3-5 Catch basin for sludge discharges (American Petroleum Institute)

3.1.4 Wastewater treatment

As a rule sufficient wastewater treatment means three step handling of wastewaters including screening to remove or reduce coarse solids, followed by mechanical removal of grit, grease and other solids as a first step. Not all the oil and grease is removed from wastewater by this primary treatment. Appreciable amounts remain in the clarified wastewater in an emulsified form (Sawyer, 1994).

The second step usually involves biological treatment by activated sludge process, aerated lagoons, biological contactors or stabilization ponds to remove primarily organic substances. During this step the emulsifying agents are usually destroyed, and the finely divided oil and grease particles become free to coalesce into larger particles which separate from the water (Sawyer et al., 1994). Grease that can cover biological forms (e.g. activated sludge or biofilters) interferes with oxygen transfer from the liquid to the interior of the living forms.

The third step as the additional treatment is needed to remove suspended and dissolved substances, like inorganic ions (including phosphate and nitrate) and synthetic organic compounds, remaining after conventional secondary treatment.

Palm oil factories in Thailand can be divided into three categories depending on the existing oil recovery systems (Chavalparit et al., 2006):

- Factories using improved process that include use of decanter and separator for oil recovery (represent the best practice in clean technology in at the moment);
- Factories using standard processes: e.g. decanter for oil recovery;
- Factories using a separator for oil recovery.

3.1.5 Land application

Disposal by land application is a method that can eliminate the need for tertiary treatment of wastewater (Johns, 1995; Uhlman and Burgard, 2001). Spray and flood irrigation systems for wastewater disposal may be designed with the objective of either wastewater disposal or wastewater reuse. If disposal is the objective, application or hydraulic loading rate is not controlled by crop requirements, but by the limiting design parameter (e.g. nitrogen loading rate), soil permeability or constituent loading. (USEPA, 1974).

Land application by sprinkler or flood irrigation can be a feasible alternative to surface water discharge, if the appropriate land is available and other prerequisites can be satisfied. These prerequisites include soils with moderately rapid permeability and soils with the ability to collect any surface runoff that occurs (Uhlman and Burgard, 2001).

An analysis of palm oil mill effluent (Table 3-9) shows that wastewater is suitable for irrigation after anaerobic treatment because of its very high nutrient content (Chavalparit et al., 2006). Releases of these wastewaters to the environment will very likely increase the possibility for intensive eutrophication in the recipient water body.

Both crop uptake and nitrification-denitrification serve as mechanisms for nitrogen reduction. Crop uptake, chemical precipitation, and adsorption to soil particles are mechanisms of phosphorus reduction. (Uhlman and Burgard, 2001).

Table 3-9 Mean N and P content in the palm oil mill effluent (Chavalparit et al., 2006, modified).

Parameter	N	P
Raw wastewater, mg/l	1100	47
After anaerobic treatment, mg/l	340	28
After full anaerobic treatment, mg/l	30	3

Wastewater treatment systems using sprinkler or flood irrigation for wastewater disposal should provide a minimum of secondary treatment before use of wastewater for irrigation. Secondary treatment of wastewater reduces BOD and suspended solids loading rates and consequently, it reduces the potential of these parameters to act as limiting design factors. Secondary treatment also reduces the odor and vermin problems associated with flood irrigation or sprinkler application of lesser treated wastewater.

A holding basin is a necessary element to allow intermittent wastewater applications and to provide storage when climatic or soil conditions do not allow irrigation. Ideally, storage should be adequate to limit wastewater application to the active plant growth period of the year.

In the absence of proper system design and operation, land application as a method of wastewater disposal can adversely affect surface and ground water quality. Excessive organic loading rates can result in reduced soil permeability and the generation of noxious odors due to the development of anaerobic conditions. Excessive nitrogen application rates can lead to nitrate leaching to ground water. Excessive phosphorus application rates can lead to surface or ground water contamination, or both, if the irrigated soils become saturated with phosphorus (Tchobanoglous and Burton, 1991)

3.1.6 Impacts Associated with Wastewater

Depending on the nature of industry different undesirable constituents of waste waters need to be removed before discharge. The specific treatment requirements depend also on the projected use of the waters of the receiving water body. Main undesirable waste water characteristics of enterprises producing oily waste waters are:

3.1.6.1 Soluble organic compounds

that cause the depletion of dissolved oxygen and could cause adverse effects on biological activity in the receiving water body. Therefore the quantity of soluble organic compounds is usually restricted to the capacity of the receiving water body for assimilation.

Organic oil in wastewaters determines high BOD and COD levels. The microorganisms present in the naturally occurring microbial ecosystem decompose the organic matter contained therein. This decomposition of organic matter consumes oxygen and reduces the amount available for aquatic animals. Anaerobic conditions could be fatal to aerobic life and would also create odour problems. Severe reductions in dissolved oxygen concentrations can lead to fish kills. Even moderate decreases in dissolved oxygen concentrations can adversely affect water bodies through decreases in biodiversity, by the loss of some species of fish and other aquatic animals. Loss of biodiversity in aquatic plant communities due to anoxic conditions also can occur. Knowing that, for example, food production processes discharge often highly alkaline (pH >10) wastewater that increases the pH level in the vicinity of waste water effluent, it is an additional stressor changing environmental conditions for biological activities and reducing the biodegradation of organic pollutants.

3.1.6.2 Nutrients

primarily nitrogen and phosphorus, which enhances eutrophication and stimulates algae growth. Together with oily wastewaters a high load of nutrients, particularly phosphorus, if discharged into the surface water, can enhance eutrophication processes through excessive growth of phytoplankton and higher plant forms in the recipient water body. The nature of the process of eutrophication is natural, but wastewaters can contribute excess nutrients enhancing this process. A simple criterion is that algal blooms will tend to occur if the content of inorganic nitrogen and phosphorus exceed respective values of 0.3 mg/l and 0.01 mg/l (Sawyer, 1947). Eutrophication can cause changes in the stock of a species and in the balance between species. The oxygen level can be very low in recipient water body, especially in deep water due to the increased generation of biomass and heavier sedimentation and aerobic decomposition of dead organic material. Certain species of algae can cause direct toxic effects on higher organisms, including humans.

3.1.6.3 Suspended solids

that can result oxygen depletion in case organic solids are present, and impair the normal aquatic life in the water body.

Organic part of suspended solids decomposes aerobically or anaerobically, depending on the prevailing condition in recipient water body. During aerobic decomposition consumption of dissolved oxygen leads to the deficiency of oxygen in water, creating a potential for adverse effects on the ecological system. Anaerobic decomposition of organic compounds will generate odour. Suspended solids also reduce the aesthetic value of the receiving water body. Dissolved minerals and organic constituents may change colour, tastes and odour of water body that decreases the possibility of water use for others. Some dissolved solids may be toxic or carcinogens.

3.1.6.4 Oil and grease

that can have direct undesirable effect on the aquatic biota and adverse effects by decreased turbidity, smell, reduced absorption of oxygen by the receiving water body and natural re-aeration processes that decrease oxygen content in the receiving waters.

Oil and grease in discharges of edible oil industry and poultry processing wastewaters are of concern for several reasons. The concentration of oil and grease in the wastewater can be very high reducing absorption of oxygen by the receiving water body. Decreased dissolved oxygen levels may endanger aquatic biota. Oil films on the surface of water result in reduction of light transmission through surface water and reduce natural re-aeration processes. Furthermore, soluble and emulsified oil and grease can inhibit oxygen and other gas transport processes necessary for plant and animal survival, could be harmful for fish and other aquatic life, resulting in aquatic ecosystem disruption. Less light can result in reduced photosynthesis by plants.

Oil may adhere to the feathers and coats of birds and animals reducing their natural waterproofing and has toxic effects. It also contaminates drinking water supplies and water used for irrigation, stock watering and many industrial purposes and gives rise to problems in recreational waters.

3.2 ENVIRONMENTAL ASPECTS AND IMPACTS OF PETROLEUM OIL

Used petroleum oil creates a hazard in water because it contains a number of contaminants which have the potential to dissolve in water. Petroleum products contain thousands of different organic compounds. They range in structure from the simple compound, like methane, to highly complex compounds. Additionally petroleum products may also contain sulfur, nitrogen, chlorine, bromine, lead, zinc, chromium, other metals and heavy polycyclic aromatic hydrocarbons (PAHs) that would contribute to carcinogenicity mutagenicity and teratogenicity. Hydrocarbons from oil can move to atmosphere or settle through water to bottom sediments, where they may persist for years. Metals from oil may build up in various media.

Thus, the used petroleum oil is a cocktail of chemicals that include (Clancey, 1999):

- degraded oil chemicals
- heavy metals including lead, barium, chromium and zinc
- wear metals from the engine
- oil additives
- combustion by-products such as polycyclic aromatic hydrocarbon (PAH)

All of these are potentially harmful to the environment and human health (Clancey, 1999), especially PAH.

Petroleum oil spills are also objectionable aesthetically. Under certain conditions, oil slicks will form a water-in-oil emulsion that can contain up to 80 percent water. When an emulsion is formed, the volume of water contaminated by oil has increased by four to five times.

3.2.1 Impact of petroleum oil to species and ecosystems

The environmental risk from oil compounds is dependent on the oil type (Options …, 1994). Specific gravity determines whether the oil will sink in freshwater or not. Oil with a specific gravity of 0.95 or higher are also at risk of sinking once they become mixed with suspended sediments (Options …, 1994).

When these oils have stranded on a shoreline, sediment incorporated from the shoreline can cause sinking if it is eroded from the shoreline.

Low-viscosity oils spread rapidly into thin sheens, increasing the surface area. They readily penetrate into sediments and debris. Oil forms a film on the surface of rivers and lakes, which prevents or greatly reduces the rate at which atmospheric oxygen can be absorbed into water. This causes distress and even death to aquatic life. Oil may adhere to the feathers and coats of birds and animals reducing their natural waterproofing and has toxic effects. Viscous oils can be so thick that they do not spread.

Fish eggs and larvae, and young fish are sensitive to oil. Oil can affect wildlife and plants by covering them and reducing their ability to function and cause internal problems. Bottom dwelling fish exposed to oil may develop liver disease and reproductive and growth problems. Oil contamination of sediments can cause problems for years.

Naphthalene, a constituent in used motor oil, includes changes in the liver and harmful effects on the kidneys, heart, lungs, and nervous system (Upshall et al, 1993). Due to their relative persistence and potential for various chronic effects (like carcinogenicity), PAHs can contribute to chronic hazards of jet fuels in contaminated soils, sediments, and groundwaters.

A study carried out in the United States show that waste oil decreases in chlorophyll a and chlorophyll c concentrations (in this study, chlorophyll c in used as an indicator of diatom biomass). As a result, a shift in community structure (reduction in diversity and abundance) was observed after the exposure period (Mahaney, 1994). Invertebrates are have been detected as one of the most sensitive marine species to the water-soluble fraction of oil. (Mahaney, 1994).

Fish can be exposed to contaminants through their diet or skin, but the major route of exposure to water-soluble compounds is believed to be through the gills. According to Upshall et al. (1993) toxicity to aquatic life is seldom found in response to oil concentrations below 10 ppb. Exposure to used crankcase oil has been shown to produce an induction of EROD enzymes in the liver of fish. When studying egg hatching success, tadpole growth, and successful metamorphosis of green treefrog (*Hyla cinerea*) were measured in four concentrations of oil it was detected that tadpole and algae growth was negatively associated with the presence of oil (Mahaney, 1994). No tadpoles from the high concentration of oil treatments successfully metamorphosed.

In open waters oil can be rapidly diluted. Even though most organisms are mobile enough to move out of the area affected by the spill many adverse effects can occur. Oil spills can affect fish in the water column, with the early life stages at greatest risk. Also, many birds are highly vulnerable. Oil spills may restrict transportation, water intakes, or recreational activities. The plants without underground roots can regenerate oil after being oiled (Options …, 1994).

Larger rivers have usually extensive biological and human use. Recreational use of rivers can be high, and many are major transportation corridors. Drinking, industrial, and cooling water intakes are quite vulnerable to oil spills in this environment because of turbulent mixing, and they often shut down when slicks are present. Emulsified oil remain in the water column for a longer period. Oil can adsorb onto sediment particles, which then settle out in quiet backwaters, potentially contaminating these habitats (Options …, 1994).

Oil spills may have more of an impact on small rivers and streams due to lower flow conditions and lower dilution rates (Options …, 1994). Early life stages of fish spawning in smaller streams and the tributaries of larger rivers can be damaged. Fringing wetlands and adjacent floodplains of smaller rivers and its biodiversity can be damaged by oil spills for biological use. Fish kills are possible for spills. Many different kinds of mammals, birds, reptiles, and amphibians use the stream bank habitats, and there can be localized high mortality rates of these animals. Spills can cause closure of water intakes for drinking water, irrigation, or industrial use along small rivers.

Small lakes and ponds provide valuable habitat for migrating and nesting birds and mammals, and support important fisheries. Small lakes can be the focus of local recreational activities. Associated wetlands have higher sensitivities. Wind shifts can completely change the location of slicks, contaminating previously clean areas (Options …, 1994).

In mud habitats and shoreline sediments can be very slow natural removal rates, chronically exposing sensitive resources to the oil that may persist for years (Options …, 1994). The biological diversity in wetlands is significant. Oil spills affect both the habitat (vegetation and sediments) and the organisms that directly and indirectly rely on the habitat. Oil could possibly affect detritus-based food webs by slowing decomposition rates of plant material. Wetlands support populations of many species reliant upon wetlands for their reproduction and early life stages when they are most sensitive to oil. Many endangered animals and plants occur only in wetlands, and spills in such areas would be of particular conservation concern.

3.2.2 Handling of waste petroleum oils

Waste petroleum oils should be treated as hazardous wastes. To minimize possible environmental impacts the first priority should be given to the prevention or reduction of waste oil production and its harmfulness, particularly by the development of clean technologies. The development of appropriate techniques for the final disposal of dangerous substances contained in waste destined for recovery is the next step to minimise possible environmental impact.

On the top of the hierarchy for the specific management of waste oils should be regeneration (recycling and reuse) to extract secondary raw materials, instead of combustion, e.g. the use of waste oil as a source of energy. Any discharge of waste oils into internal surface waters, ground water, coastal waters and drainage systems should be prevented.

As a rule, the higher the concentration of used oil, the higher the likelihood of soil or water contamination due to oil spillage. Frequent dumping overloads the capacity of microbes to break down the soil. Compaction and high slope can increase dramatically the rate of oil run-off.

3.3 PRACTICES FOR MINIMIZATION OF OILY WASTEWATER AND ITS ENVIRONMENTAL IMPACTS

Minimization of wastewater flow and waste load reduction practices should be incorporated into normal business practices of every enterprise producing oily wastewaters. One of the main goals is reduction of production costs and maximization of profits. Excess consumption of water and the additional costs of wastewater treatment can mean losses of valuable resource and lower profitability.

There are two main ways on how to improve the water conservation by a plant:

- to improve water efficiency, using cleaner technology that includes process change, good housekeeping, reuse or recycling, or
- by replacing freshwater with reclaimed water.

The first option includes technological and behavioral solutions. Technological solutions could be reuse, recycling and reduction of water use to particular task where reuse and recycling are defined as reusing wastewater from one process either for a different process or for the same process, respectively. Behavioral improvement of water efficiency includes equipment modification for example, adjustment of watering, automatic control of bathing and washing waters, etc.

Most part of the World’s population reuses water in one way or another. For example, the intake water supply pipe of one municipality is often downstream from the discharge sewage pipe of another city. Therefore pollution abatement programs have usually classified waters according to use and thus has established standards of quality in accordance with these objectives. Reusing wastewater is basically also involves collecting the effluent from one or more unit processes, and then using that effluent as the influent for other unit processes (Carawan et al., 1979b). The key to wastewater reuse lies in matching the effluent from one unit process with the influent requirements of another unit process.

The share of water that can be cost-effectively re-used can be substantially increased by waste stream segregation system:

- Non-contaminated streams, e.g. stormwater and cooling water, that does not need any treatment, can be discharged directly to receiving water bodies or to the ground. Knowing that the storm water system should receive all storm runoff. the cost of installing separate collection systems may be high and by-passing the treatment plant becomes uneconomical
- Contaminated waste streams (sanitary and industrial) have to be treated.

Thus three water discharge systems are desirable when having a goal for increasing water reuse and minimizing further treatment costs:

- for storm and cooling water,
- for sanitary wastewater, and
- for industrial wastewater.

One option to increase the efficiency of water use is to install onsite advanced wastewater treatment systems which treat facility effluent allowing this water to be reused for some applications within the facility. Other option can be changed sanitation practices to reduce water use and effluence in general.

Reducing water use is important to reduce raw wastewater load. In addition, it has been demonstrated that substantial reductions in wastewater pollutant concentrations also can be achieved through implementation of waste load reduction practices. However, both goals can be achieved only when management recognizes that a reduction in processing costs and an increase in profitability can be realized by reducing the costs of potable water and wastewater treatment. Thus, a management commitment to water conservation logically depends on the cost of potable water, and a management commitment to waste load reduction depends on the cost of wastewater treatment (USEPA, 2002). If potable water is being obtained from private on-site wells, there obviously is a reduced economic incentive to conserve water than when water is being purchased from a public utility or private water purveyor (USEPA, 2002). Wastewater treatment costs can be less visible for direct dischargers and less sensitive to pollutant concentrations.

3.4 RECOMMENDATIONS FOR INDUSTRIAL WASTE WATER CONTROL PRACTICES

In order to minimize possible impact of oily wastes and wastewaters to the surface and ground waters, the following four key elements should be implemented:

- the provision of appropriate Engineering Requirements;
- the implementation of appropriate Managements Systems and Controls;
- the preparation of Environmental Risk Assessment and,
- the preparation of Emergency Plans and Procedures.

The general procedures in developing sustainable water use include:

- Understanding that waste is a pollution problem
- The development of water conservation and waste load reduction programs starting with the development of general profiles of water use and wastewater quality. It includes mapping of sites and magnitude of the anticipated waste water flows over one or preferably several periods to determine the relative significance of processing and cleanup activities. This step is accompanied or followed by selection of sites for possible monitoring stations, and sampling procedures to depending on the wastewaters
- Development of flow and material balances considering all significant sources of wastes and by measuring water use in individual phases of the processing process to identify opportunities for water use reduction. It includes for example measuring and regulating small flows such as from hand washing operations that also can significantly reduce water use and wastewater volume The daily cleanup and sanitation of processing facilities and equipment contributes substantially to water use and wastewater pollutant load and probably presents the greatest opportunity for reductions (USEPA, 2002).
- Statistical analyses of collected data due to high variability of some wastewater characteristics.
- A survey of in-plant major problem areas and sources for potential improvement and selecting the most cost-effective changes.
- Monitoring of the pollution reduction and water conservation efficiency.
- Implementation continuous employee training.

Both water use and wastewater load can be reduced substantially by dry cleaning of processing areas and equipment to collect waste material for disposal by rendering instead of the common practice of using water for cleaning. Gelman *et al.* (1989) have shown that biochemical oxygen demand (BOD) in cleanup wastewater in poultry processing can be reduced from 20 to 50 percent by initially dry cleaning processing areas and equipment. Dry cleaning of live animal holding areas also can reduce water required for the cleaning of these facilities and the pollutant load in the wastewater generated. It should be remembered that screening before wastewater treatment provides only recovery of larger particles, but fine particulate matter and soluble proteins, fats, and carbohydrates are not recovered and will need additional efforts and costs for removal. Similar approach is suitable for other enterprises producing oily wastewaters. Water reuse requires treatment as a prerequisite with the degree of treatment determining how water can be reused (USEPA, 2002).

3.4.1 Responsibilities of oily waste generator

3.4.1.1 Oily wastewaters

- The general rule is: use the lowest quality of water that will satisfy the needs of the process. Whenever possible reusable water should be made the water source for operations that may use other than potable water
- The mixing or diluting of different waste waters (i.e. mixing of treated process water with cooling water) for the purpose of compliance with the limit values for the effluent should be prevented.
- Control and minimization of freshwater flow at major outlets by installing properly sized spray nozzles and by regulating pressure on supply lines.
- Use minimum quantities of water in all process steps, e.g. the scalder and chillers in poultry industry. Consider the reuse of chiller water as makeup water for the scalder.
- Shut off all unnecessary flow during breaks.
- Use pretreated processing waste waters for condensing cooking vapors in onsite rendering operations.
- Control water use in gizzard splitting and washing equipment.
- Consider dry offal handling as an alternative to fluming

3.4.1.2 Other technological and behavioral solutions

- Provide for frequent and regular maintenance attention to byproduct screening and handling systems. A back-up screen may be required to prevent byproduct from entering municipal or private waste treatment systems.
- Dry clean all floors and tables in all other areas where there tend to be material spills prior to washdown to reduce the waste load.
- Use high-pressure, low-volume spray nozzles or steam-augmented systems for plant washdown.
- Minimize the amount of chemicals and detergents to prevent emulsification or solubilization of solids in the waste waters. Minimize the amount of chemicals and detergents to prevent emulsification or solubilization of solids in the waste waters.
- Treat offal truck drainage before sewering.
- In-plant primary systems—catch basins, skimming tanks, air flotation, etc.—should provide proper detention time of the waste water (at least 30-minutes).
- Recover all collectable blood and transport to rendering in tanks rather than by dumping on top of feathers or offal.
- The monitoring system should include both monitoring of physical-chemical parameters for wastewater as well as the recipient water body. Monitoring should ensure that the waste transported reaches the approved destination.
- Equipment should be frequently and regularly maintained.
- The overall improvement of management system and minimization of environmental impacts could be targeted by implementation and follow up of the ISO 14001 standards.
- All employees should be aware of good water management practices.
- Employees should be encouraged to apply these practices.
- Personal protective equipment should be made available for workers handling oily waste.

3.5 LITERATURE

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CHAPTER IV

RESPONSE OPTIONS

-TECHNICAL PART-

4 RESPONSE OPTIONS

4.1 TECHNICAL SOLUTIONS

This guideline can only provide general information and recommendations about available technical solutions for treatment of oil contaminated waters of different types of industries. To supply a company with detailed information about dimensioning or technical specific data is within the responsibility of the engineering consultant in the company. Furthermore the decision for or against one treatment technology should be based on the factory specific data, available space for a treatment plant or location of the next wastewater treatment plant, fixed and operating costs of treatment experience and so on.

The aim of this chapter is to help to find a systematic approach for developing a treatment concept for oily waste or wastewaters. Therefore different options are given, explained and the best suitable practices for different types of industry are summarized at the end of this chapter.

The first thing you should think about is: Is there a need for changing anything? Or is it even possible to ***DO NOTHING***? This is just an alternative for companies that meet all the limitations and regulations regarding sewer discharge etc.

Second option is to ***CHANGE THE PROCESS*** to eliminate the production of out-of-compliance wastewater. This is the most preferable option, because avoiding the production of waste has the highest priority in waste management. Besides changing the process that way, that less wastewater is produced you could also think about segregating the waste streams. Therewith the concentration of problematic components in the wastewater may decrease so that regulations regarding sewer discharge might be met. But then you have to think about option for treatment of the segregated waste stream.

In case you know, that you have to treat the generated oily wastewater there is also the possibility to collect all the wastewater and ***TREAT IT OFF-SITE***. The advantage is that you don't have to think about developing a treatment concept and that you don't have to operate the treatment plant, but depending on quality and quantity of generated wastewater more or less costs will result.

The fourth option is to install a wastewater treatment system and ***TREAT*** the generated wastewater ***ON-SITE***. But before you start installing a treatment system you should think about all options, list the alternatives and compare them based on the given data of your company.

The following scheme (Figure 4-1) summarizes the explained options of dealing with the production of wastewater and leads you to the further steps of proceeding.

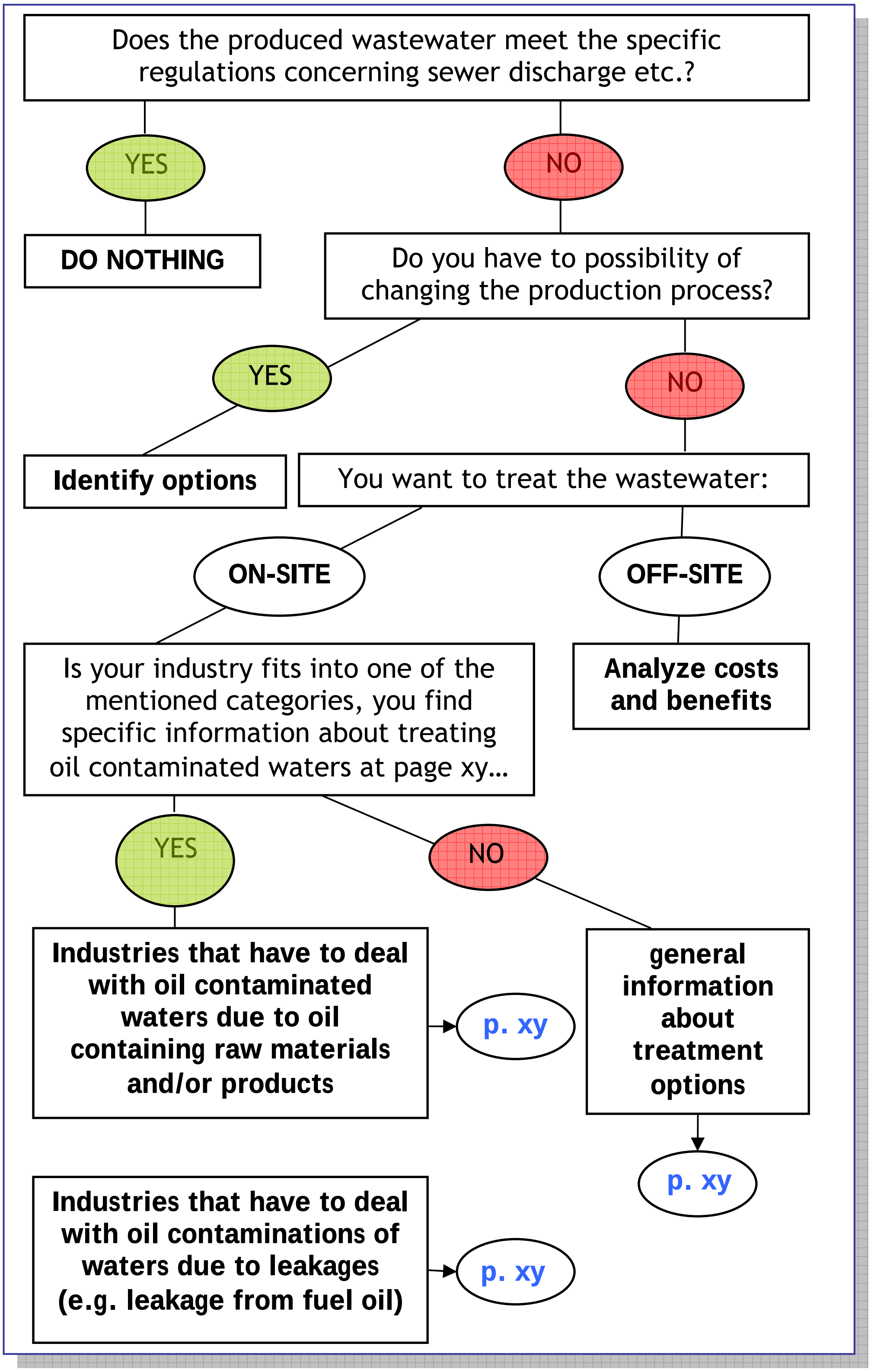

Figure 4-1 Options of dealing with the production of wastewater

4.1.1 Treatment Technologies - General Information

Due to different types of oil contaminated waters, several technologies are used for treatment of wastewaters (or emulsions). They can be divided into three important groups of processes: physical technologies (mechanical and thermal), chemical technologies and biological technologies. Additionally

the above mentioned processes can be combined. In general there are mostly two steps for treating oil-contaminated waters. The primary treatment step is to separate the floatable oils from the water and emulsified oils. For this treatment step often the advantage of different specific gravities of oil/grease/fat and water is used and therefore physical treatment concepts are preferred at this stage of treatment. In case the wastewater consists of emulsions a second treatment step has to be taken into consideration. Referring to this the secondary treatment is often operated with thermal, chemical or biological technologies. The following all types of technologies will be described.

4.1.2 Physical Treatment Technologies

Physical treatment technologies include mechanical and thermal technologies. Both will be explained in the following.

4.1.2.1 Mechanical Treatment Technologies

The right choice of mechanical treatment technologies depends on the substance you want to treat. In case you have a mixture of oil and water, which are in contrast to emulsions much easier to treat, you can consider technologies that base on differences in adhesion or density. One possible problem with dealing with this kind of wastewaters might occur regarding the volume flow that has to be treated. Because often oil/water mixtures come from cleaning processes, and therewith the volume flows can be very high.

Differences in density

These processes work according to the principle of gravity. Oil droplets with a lower density rise to the surface, aggregate at the surface to an oily phase and can be skimmed. Technical solutions for this treatment are for instance settling ponds (see Figure4-2).

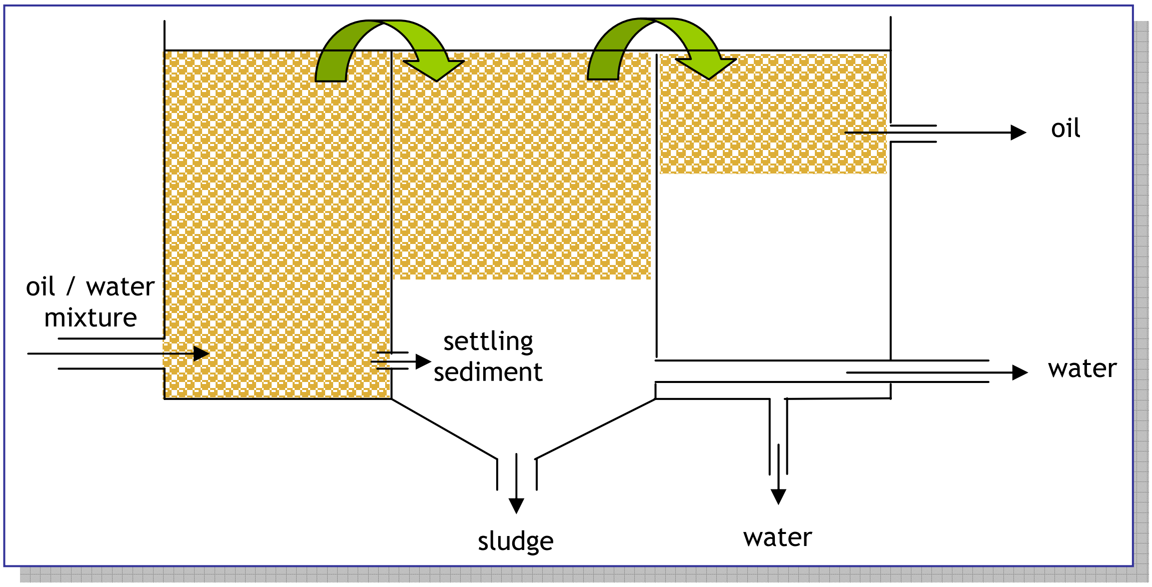

Figure 4-2 settling pond [Möller, 2004]

Similar to a settling pond is the functional principle of a fat trap (Figure 4-3). When the oily wastewater flows through a grease or fat trap, the grease and oils rise to the surface and are trapped inside the receptacle using a system of baffles. The captured grease and oils fill the trap from the top down, displacing "clean" water out of the bottom of the trap. When a significant layer of fat has accumulated, the trap must be cleaned.

Furthermore precipitators with fins or skimming units are technical solutions. Besides the gravity the centrifugal force can be used additionally to separate oil / water mixtures. Therefore centrifuges (Figure 4-4) or decanter (Figure 4-5) can be used.

Figure 4-3 fat trap [radio.weblogs.com]

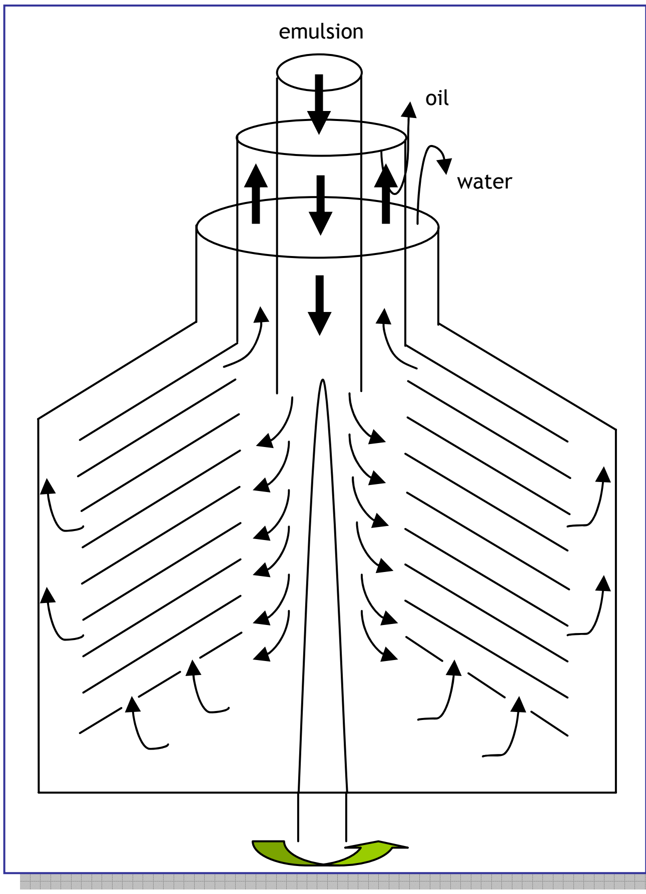

Figure 4-4 centrifuge [Möller, 2004]

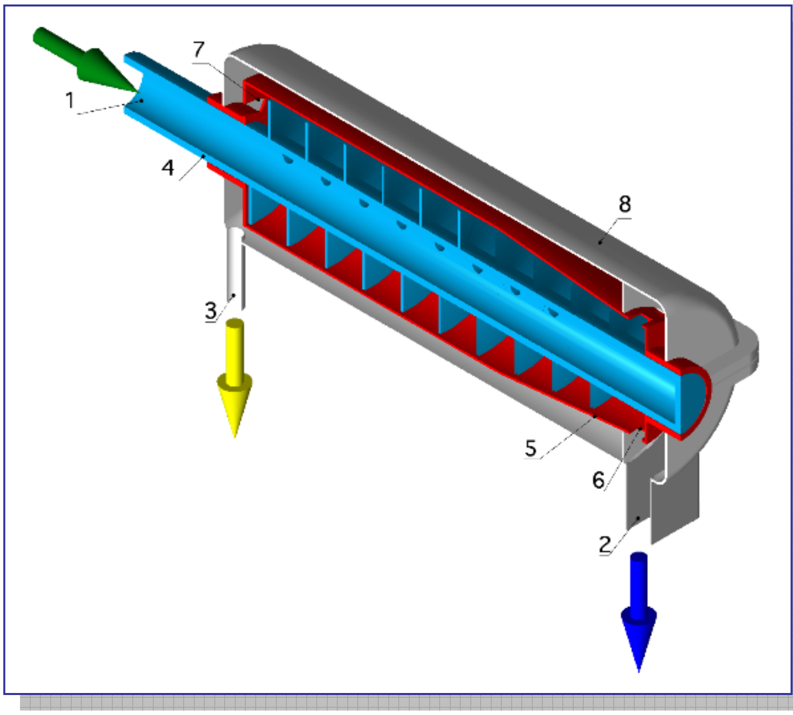

Figure 4-5 decanter separator [www.wikipedia.de]

Differences in adhesion

Figure 4-6 skimming device [www.unterkofler.de]

Adhesion can be described as the property of sticking together or the joining of surfaces of different composition. Possible treatment technologies using adhesion effects are for instance skimming devices like shown in Figure 4-6. This device uses rotating discs that dip into the oil/water mixture. The oil sticks on the disc due to adhesion effects and can be removed to surface.

Another kind of separation due to differences in adhesion is the flotation process. Flotation is a method for the separation of mixtures and often used water treatment. The technology bases on differences in surface properties of different particles. With small air bubbles that are conducted to the mixture, the dispersed particles agglomerate and rise because of lower density to surface and build a surface film. The particles that are to be floated are rendered hydrophobic by the addition of the appropriate chemicals. Air is then bubbled through the mixture and the desired particles become attached to the small air bubbles and move to the surface where they accumulate as a froth and are collected, or if the non-desired particles float to the surface they are collected and discarded (see also Figure 4-7). Coalescence separators (Figure 4-8) can also be taken into consideration for treatment of oil contaminated wastewaters. The mechanism of coalescence is that many smaller oil droplets colligate to one bigger drop (drop-drop-coalescence) or that many bigger drops colligate on an oily surface (drop-interface-coalescence). Used interface often are constituted of plastics (e.g. PP, PVC, PE, PTFE), steel, stainless steel or glass. The built oily phase goes to the top of the interfaces and can be removed manually or automatically.

Membrane filtration

Besides all this mentioned mechanical treatment technologies there is one important group of processes: membrane filtration [Figure 4-9]. In contrast to the foregoing technologies membrane processes are applicable for separation of emulsions. The separation process bases on the backing of particles greater than the pores of the filter. Membrane filtration processes are reverse osmosis, nanofiltration, microfiltration and ultrafiltration. Ultrafiltration is the most important technology with regard to separation of emulsions. The functional principle is to pressurize the solution flow (p = 3-10 bar), which is tangential to the surface of the supported membrane (cross-flow filtration). The solvent and other dissolved components that pass through the membrane (mostly plastics) are permeate and components that do not pass through are called retentate. Process parameters like difference in pressure, operating temperature, oil content in emulsion and flow velocity have big influence on effectiveness of the ultrafiltration process. But it is not useful, to rise the pressure endless, because in case of pressures higher than 4.5 bar, a coating will be build on the filter surface. The surface of the filter has to be cleaned continuously to keep the filtration process running optimal.

Figure 4-7 device for flotation [www.dafcorp.com]

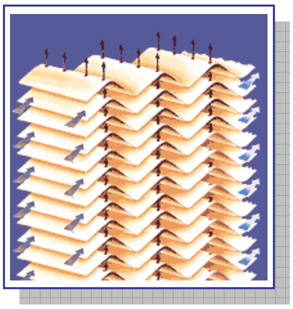

Figure 4-8 coalescence separator [www.3a-wassertechnik.de]

If the wastewater is recycled several times, the concentrate after filtration can reach 20 to 50% oil content. Most of the membranes are made from synthetic materials (e.g. polyolefines) due to their resistance against extremely high or low pH-values. [Möller, 2004]

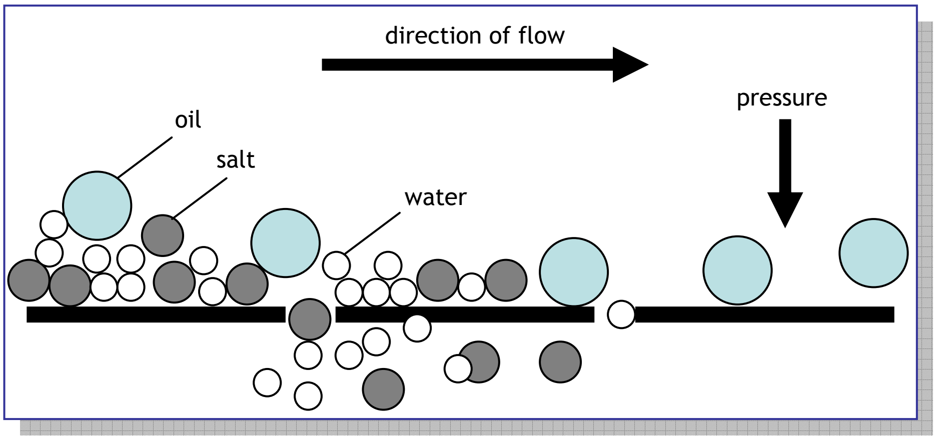

Figure 4-9 principle of separation with ultrafiltration

Figure 4-10 shows the limits of different membrane filtration processes with regard to particle size.

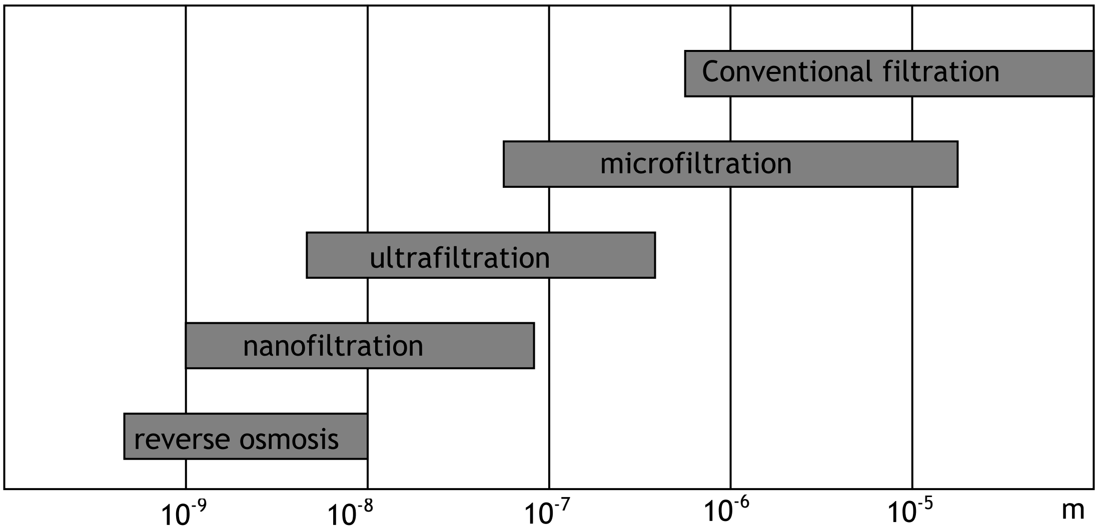

Figure 4-10 limits of filtration technologies regarding particle size [Möller, 2004]

4.1.2.2 Elecrochemical treatment technologies

Besides membrane filtration for treatment of emulsions electrochemical processes can be taken into consideration for treating of emulsions. Treating emulsions with electro-coagulation provides the opportunity of separation of emulsified particles with low demand on energy and without any addition of chemicals. The functional principle bases on discharge of dispersed particles in an electrochemical cell (see Figure 4-11). The electrochemical cell for coagulation consists of two electrodes, which are separated through a diaphragm, and that dip into the emulsion. Emulsions pass through the working electrode (anode or cathode) and the particles coagulate. Afterwards the oily phase can be removed.

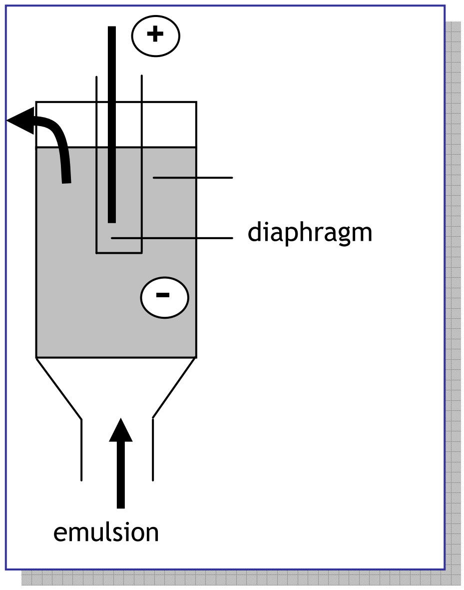

Figure 4-11 electrochemical cell for electro-coagulation [www.pius-info.de]

4.1.2.3 Thermal treatment technologies

The functional principle of thermal treatment methods for oil contaminated wastewaters is to vaporise the water phase of the oil water mixture or the emulsion respectively without using any chemicals. This treatment method is also useable for very stabile emulsions that can be difficult to separate with mechanical treatment technologies.

Most common is to use thermal technologies at a multiple-stage level. Optimal number of stages is between two and five stages [Möller, 2004]. An example for a thermal treatment technology is a thin-film evaporator (see Figure 4-12). This technology often is used for after treatment of retentae of ultrafiltration processes. The thickness of the film is between 0.5 and 2 mm.

The functional principle is basing on a distribution of the feed liquor by the rotor to the heating surface where a film of equal thickness is formed. The evaporated water phase often can be used for production of new emulsions because it contains just small amounts of pollutants. The oil that remains on the heating surface is removed via wipers and goes to waste oil treatment plants. A big disadvantage of thermal processes is both the demand on energy and the in comparison to for instance mechanical processes higher investment and operating costs. Just in case thermal energy can be provided in surplus thermal processes might be economical and ecological reasonable.

Figure 4-12 thin film evaporator [www.gigkarasek.at]

4.1.3 Chemical Treatment Technologies

Chemical treatment technologies are used for treatment of emulsion and base on the addition of salts or acids to break and separate the oily and the watery phase of the emulsions.

The use of acids for emulsion treatment is more common, nevertheless both technologies are going to be described the following.

4.1.3.1 Emulsion breaking with acids

Mostly used acids are hydrochloric acid or sulfuric acid. The hydrogen ions neutralize the surface loading of the colloidal oil droplets and therewith lead to a colligation of oil droplets. Oils that were emulsified into water are removed through acid splitting with flocculation, flotation or ultrafiltration.

4.1.3.2 Emulsion breaking with salt

The functional principle of emulsion breaking with salt bases on the addition of metals salts like calcium or magnesium chloride. Metallic ions are adsorbed on the surface of the oil droplets and neutralize the surface loading and therewith the repellent forces so that the droplets colligate. In case trivalent metallic salts like for instance aluminum or ferric(III)-salts are used besides the emulsion breaking flocculation processes of the hydroxides of metallic salts are forced. Often the emulsion breaking with salts doesn't lead to best effectiveness of breaking the emulsions. Besides that the resulting output flows are characterized by high salt concentrations and therewith difficult to handle.

Both emulsion breaking with acid and salt are technologies that use anorganic substances for treating. Besides breaking with acids or salts organic agents can be used. Organic agents are tertiary or quaternary polyamines like shown in Figure 4-13.

Main advantage of these organic agents is the avoidance of increasing salt contents in the output flows. Often the treatment with organic agents is used as a pretreatment method for before ultrafiltration processes. Reason is that in case of no pretreatment of the emulsions the filter will be blocked quite fast. Therefore pretreatment steps are inalienable to assure the optimal operation in the filtration unit.

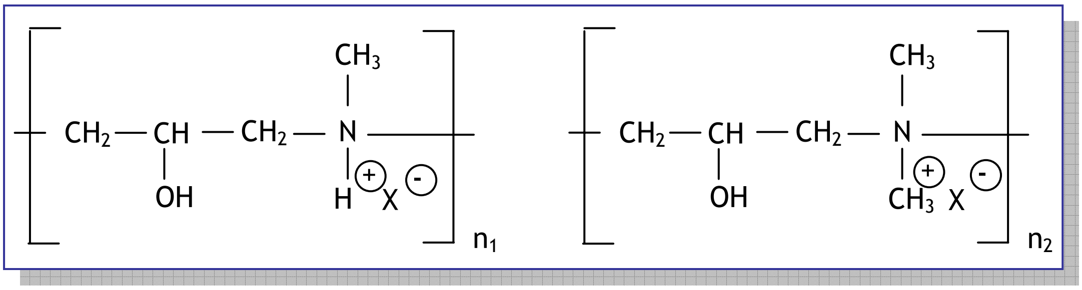

Figure 4-13 tertiary and quaternary polyamines [Möller, 2004]

4.1.4 Biological Treatment Technologies

In general biological treatment technologies can be divided into aerobic (in the presence of oxygen) and anaerobic (without presence of oxygen) processes. They are the main treatment technology for wastewaters with high organic load, like wastewaters from food processing industry.

Often a physical treatment step is prior to a biological treatment step for example through grease traps or dissolved air flotation processes. The reason is that the organic load would exceed the capacity of the biological system of the treatment reactors. The following the most important two groups of biological processes are going to be described briefly to give an overview about the technological background of the treatment processes.

4.1.4.1 Anaerobic biological treatment

This biological treatment method should be considered whenever wastewater with high BOD is encountered, like for instance wastewater from food industry. Anaerobic treatment can be used as a first stage biological unit to reduce high BOD (from >=600 → 200/300 ppm) [Stephenson & Blackburn, 1998]. For the technical handling of the anaerobic process there are two possibilities:

- anaerobic open pond system or
    - mostly consisting of several ponds
    - advantage: simple construction and operation
    - disadvantage: requires a huge area, production of sludge

- closed anaerobic systems
    - wide range of available systems: one stage reactors, two-stage reactors or with regard to type of mixing completely mixed reactors, fixed bed reactors, upflow anaerobic sludge blanket reactors (UASB), hybrid upflow anaerobic sludge blanket reactors, expanded granular sludge bed
    - advantage: requires less space, no air pollution, biogas utilization, no odour problems
    - disadvantage: higher demand on technical control and maintenance, more expensive (investment and operating costs)

Besides these two handling options the process can be divided into wet (3-15% TS) and dry (>30% TS) fermentation processes and into mesophilic (T=33-37°C) and thermophilic (T=50-58°C) processes.

The wastewater is conducted into vessels made of concrete or stainless steel and due to the anaerobic biological degradation process of biomass in the wastewater biogas (mixture of around 60% methane and 30% carbon dioxide) is produced. The stages of the anaerobic digestion are shown in Figure 4-14.

Besides the biogas production there is a formation of sludge (less than 0.3 kg TS/kg BOD5 removed [IP-Institut für Projektplanung GmbH] In some situations anaerobic treatment is a very cost effective treatment process and has a lower demand on energy than most of aerobic processes. But it can be mentioned disadvantageously that anaerobic organisms are very sensitive to certain chemicals, pH-values and temperatures. That means the process of anaerobic treatment requires a lot of operational intervention.

Another problem might occur due to the fact, that the oily phase builds a kind of lipid coat over the microbiological active surface and therewith disturbs substance transfer from aqueous phase to surface of bacteria, which again decreases the biodegradation process. Less biodegradation means less activity in the bioreactor, less COD-removal, less removal of oils, fats and grease and therewith wash-out effects of active biomass in the reactor.

According to [Cammarota & Freire, 2005] thermophilic conditions in the reactor can lead to improvements due to an increasing accessibility of oils and fats for the microorganisms. Therewith the efficiency can be enhanced and retention time is minimized, but this thermophilic operation is more expensive, requires much more energy for heating the reactor and leads to higher efforts for maintenance and temperature control.

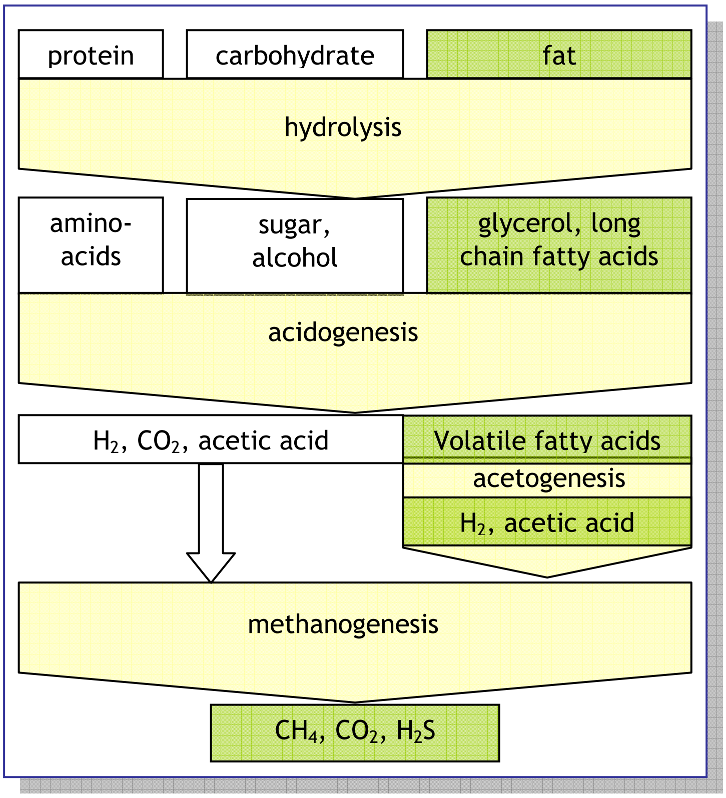

Figure 4-14 stages of anaerobic digestion

A possibility to avoid the above mentioned problems with anaerobic treatment of oil, fats and grease in wastewater, there are some research activities for pretreatment through hydrolytic enzymes, but they are still under development. [Cammarota & Freire, 2005]

4.1.4.2 Aerobic biological treatment

According to the IP-Institut für Projektplanung GmbH (1997) there is a wide range of possibilities for aerobic treatment of wastewaters in Thailand. The most applied system is the aerobic pond system and the activated sludge system and will be described the following.

Aerobic ponds are very simple treatment technologies and all the available systems only differ in the type of oxygen supply or the design loading rates [IP-Institut für Projektplanung GmbH]. You can divide between:

- facultative ponds (maturation ponds)
  - oxygen supply mainly from algae
  - upper aerobic zone and lower anaerobic zone
  - liquid depth from bottom sludge to pond surface: 1.5-2.5 m

- oxidation ponds
  - more flat than facultative ponds
  - oxygen supply through absorption of air
  - depth: 1.0-1.5 m
- aerated lagoons
  - oxygen supply with electrical power
  - require less space then the other types of aerobic treatment systems and have shorter retention times
- polishing ponds
  - oxygen supply from photosynthesis of algae and absorption from air
  - because of photosynthesis of algae high concentrations of solids in the effluent
  - therefore removal via e.g. stone/gravel embankment at the end of polishing pond

Besides the pond system the activated sludge process is a very long-time field-tested treatment process. The operational principle bases on biological activity of bacteria and other types of microorganisms (fungi,

algae and protozoa) [IP-Institut für Projektplanung GmbH, 1997]. Actually the activated sludge process is comparable to the aerobic pond processes. The most important difference is the controlling of the concentration of activated biomass in the aeration tank. Therefore the concentration of biomass is much higher than under natural conditions like you can find in aerobic ponds.

A plant that operates the activated sludge process consists of several operation units [IP-Institut für Projektplanung GmbH, 1997]:

- aeration tank
- sedimentation tank (to clarify the sludge and return the biomass into aeration tank
- return sludge pumping system
- excess sludge removal and treatment system

Figure 4-15 shows and overview of such an activated sludge system:

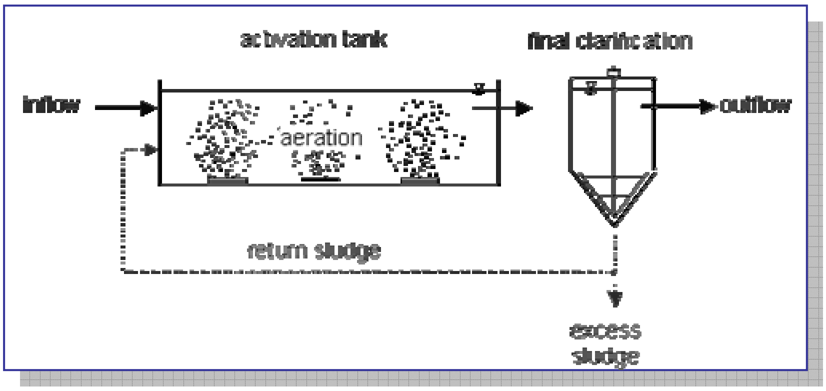

Figure 4-15 Conventional activated sludge process [Source: www.mebrane-bioreactor.com]

4.1.5 Combinations of technologies

In case only one treatment technology doesn't result in the wanted aim or it is not suitable for the wastewater that has to be treated, combinations of technologies have to be taken into consideration. Examples for combinations of different types of treatment technologies are flotation processes (chemical-physical treatment), pretreatment of emulsions with organic chemicals and afterwards treatment with membrane filtration or for instance using the membrane filtration and afterwards enrichment of the oily phase via thermal processes.

Another kind of combined technology might be constructed wetland as shown in Figure 4-16, because physical and biological effects are used for the treatment of wastewater.

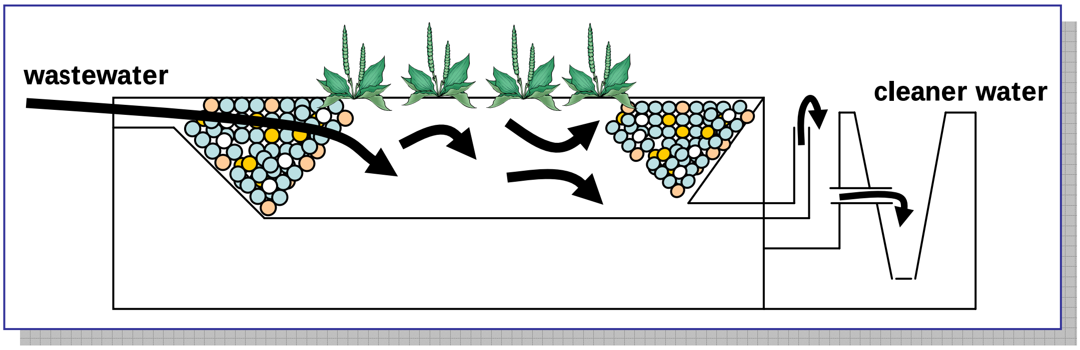

Figure 4-16 constructed wetland [source: www.unep.org; adopted]

The wastewater flows through the constructed wetland, is slowed down, and parts of the suspended solids are trapped by vegetation and settle out. Also processes of biochemical degradation through microorganisms take place, so that some pollutants are transformed to less soluble forms and are taken up by plants or become inactive.

4.1.6 Special information regarding type of industry

The following specific information was collected to describe the treatment options of oil contaminated waters in some types of industry, that belong to the most important industries in Thailand and which have to deal with oil contaminated waters.

Again it should be emphasized that this guideline can only provide general information and that the aim is not to go into many details. Nevertheless some specific information can be provided with regard to:

- food processing wastewaters which contain fat, grease and oil caused by the characteristics of the raw materials or products,
- wastewaters from other industries that use oil for lubrication or for boiling processes where wastewaters contain oil, fat or grease due to the operation of machines and possible leakages.

Besides the general aspects regarding the main treatment technologies in a specific type of industry, the provided information often refer to current research activities to develop treatment technologies that met the specific requirements of every type of industry.

4.1.6.1 Oil contaminated wastewaters from FOOD PROCESSING

Introduction

This chapter deals with treatment technologies for oil contaminated wastewaters that are generated because of used raw materials or products that contain oil, fat or grease. The aim is to put a focus on some types of food processing industry like slaughterhouses or palm oil mills and besides that to take into consideration industries like fuel oil or lubricants manufacture. Both types of industry have in common that they generate oily wastewaters because the processed materials contain oil, fat or grease and for example whenever facility units have to be cleaned the produced wastewater will contain oil contaminations. Nevertheless there are differences in treating these oily wastewaters. The following remarks are based on a comprehensive literature research and show the main treatment technologies in different types of industry. Additionally current research activities are mentioned to show the potential for further development and improvements of treating oil contaminated wastewaters.

Treatment technologies

FOOD PROCESSING

Wastewater from food processing industry is often very similar to domestic wastewater and therefore it is very harmful to the environment. Industries like seafood processing or slaughterhouses have a high demand on water due to hygienic reasons (10-40 m^3/tons for slaughterhouses [Sridanga et al, 2006] and therefore they produce large amounts of wastewater. Additional to the large quantities of wastewater also the quality of the produced wastewater is problematic.

Wastewater from this kind of production processes includes fat, grease, manure, grit, undigested feed and in case of slaughterhouses also hair and feathers. Therefore the wastewater is characterized by high organic loading rates and therewith by high chemical oxygen demand (COD), high concentrations of pollutants including suspended solids, organics and nutrients. Environmental impacts caused by discharging of slaughterhouse wastewaters are e.g. deoxygenation of rivers or contaminations of groundwater [Masse & Masse, 2000].

In general treatment of wastewater generated in food processing industry like slaughterhouses, chicken processing or seafood processing doesn't differ al lot, because all these wastewaters have high organic load and are therewith they should be easily biodegradable.

With respect to [Huynh, 2006] there are several studies that clearly show that the biological treatment technology is the most suitable treatment option for wastewaters with high organic loading. In the past most of this technologies were performed aerobic, but the ration between aerobic and anaerobic is changing due to the better effectiveness of energy production with anaerobic processes that can be achieved.

Besides biological treatment methods especially in current research activities other technologies like electrochemical methods are taken into consideration. This chapter provides mostly general information

about the most often used treatment processes for different types of industry within the food processing and gives a perspective about current research activities and the possibilities for further development of treating these kinds of wastewaters.

In case the generated wastewater in food processing is treated on-site primary, secondary and tertiary treatment processes can be taken into consideration. For removal of fat/grease oil only primary and secondary treatment technologies are used. Table 4-1 shows the possibilities of treatment technologies for wastewater from slaughterhouse according to [European Commission, 2005]. These suggestions can be adapted to other types of food processing industry as well.

Table 4-1 Possiblities of treatment technologies for wastewater from slaughterhouses

	Total Susp. Solids	Organics	**Fat/ oil/ grease**	Nitrates/ Ammonia	Phos-phorus
Primary treatment					
Mechanical screening	X	X			
Fat separation	X	X	X	X	X
Equalisation/balance tanks					
Dissolved air flotation Dsipersion flotation Mechanical flotation	X X X	X	X		
Coagulation/flocculation/precipitation		X	X	X	X
Sedimentation/filtration/flotation		X	X		
Secondary Treatment					
Anaerobic treatment, followed by anoxic step		X			
Activated sludge/aeration lagoons	X	X		X	X
Extended aeration		X		X	
Nitrification/denitrification				X	

Primary wastewater treatment processes are typically physical technologies that aim at minimization of organic loading for secondary or tertiary treatment steps. I case of palm oil industry primary treatment also aims at an improvement of production yield, because the removed oily phase can be recycled to production process.

Primary treatment technologies of wastewaters from food processing industries like seafood industry or poultry processing often include a screening process with static wedge screens inclined screw presses and rotary drum screens with typical mesh sizes of about 3 mm [European Commission, 2005] to remove organic residues (like hairs, feathers, some fats etc.) The removal efficiency of the organics through screnning devices normally is about 10-15%. Often the screening process is followed by a dissolved air floatation process (DAF) to meet the requirements for discharging the treated water to receiving water course directly. According to [European Commission, 2005] DAF can remove 15% of the BOD load and 70% of suspended solids without chemicals and 50-65% of BOD and 85-90% of suspended solids with chemicals. The removed (via skimming off) fat/oil/grease can be used for rendering or spread on land if nutrient content is high enough.

Primary treatment step of treatment for wastewaters from palm oil mills is a physical treatment in gravity separators (e.g. oil/fat trap) to remove most of the oil for recycling to production process. Such an oil/fat trap should be designed according to different criteria [IP-Institut für Projektplanung, 1997]:

- oil trap must be designed for maximum flow rate
- permissible surface loading
- installation of automatic skimming device for oil

According to [IP-Institut für Projektplanung GmbH, 1997] the maximum achievable efficiency of oil separation in palm oil industry in this physical step of treatment is about 70-90%. The skimmed and removed oil can be conducted back into the production process.

Besides the physical treatment via oil traps other physical methods or chemical processes could be taken into consideration. But according to [IP-Institut für Projektplanung GmbH, 1997] methods like filtration, air flotation or chemical coagulation cannot be done with great efficiencies due to a high suspended solid concentration and the building of stabile emulsions.

In case the water is considered to be treated further before discharging into the receiving water course secondary treatment of wastewaters from these types of industries is usually done by biological treatment processes.

With respect to the differences of characterizations of the wastewaters within the different food processing industry some notes must be given:

For example for slaughterhouse wastewaters aerobic processes cannot be suggested [Saddoud & Sayadi, 2007]. Reason is that on the one hand aeration requires a huge amount of energy. On the other hand due to the coating effects of the oily phase there are limitations in liquid phase oxygen transfer that reduce the degradation process and besides these facts large amounts of sludge are produced that inhibit the degradation process and lead to difficulties in operation.

Therefore anaerobic digestion of the wastewater are suggested for the main treatment technology (e.g. with a UASB) [Caixeta & Cammarota, 2000].

This process deals with the former mentioned difficulties of biomass washing out. To prevent the digestion process from this difficulty an anaerobic membrane bioreactor process (AMBR) is taken into consideration in reference [Saddoud & Sayadi, 2007]. Membrane bioreactor processes are membrane applications for advanced wastewater treatment. The technology is based on a combination of biological and physical pro¬cesses like micro- and ultrafiltration and consists mainly of an aerobic bioreactor, where a microfiltration device is submerged.

The AMBR-technology seems to be successful for treatment of e.g. slaughterhouse wastewaters when certain requirements are met concerning the organic loading rate, which should not be higher than 13.27 kg TCOD $m^{-3}d^{-1}$ [Saddoud & Sayadi, 2007].

For seafood processing water the AMBR technology seems to be in the lab scale testing phase. [Sridang et al, 2005] The first experimental results indicated the efficiency of the AMBR-technology for seafood processing wastewater. Figure 4-17 shows a schematic scheme of a membrane.

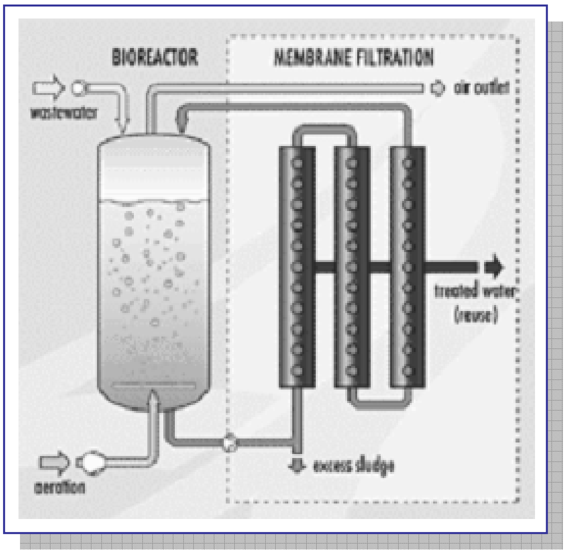

Figure 4-17 AMBR [www.membrane-bioreactor.com]

The AMBR technology is known for about twenty years but nevertheless there are some big problems in performance with these difficult to handle and high concentrated wastewaters from food processing industry. Problems are caused by fouling processes of the membrane units due to adsorption effects of organic materials, precipitated inorganic materials and the adhesion of microbial cells to membrane surface. In the built coating fouling process can occur and the membranes must be cleaned what is related to time consumption and costs. But more and more investigations are carried out to solve these problems so that the AMBR-technology definitely shows some promise for future.

Besides this way of biological-physical treatment constructed wetlands can be taken into consideration for seafood processing wastewater according to [Sohsalam et al, 2007].

In case of wastewaters from palm oil industry the secondary treatment is most often done by anaerobic processes. Aerobic treatment is nore suggested for treating palm oil industry wastewaters because due to the dark brown color of the wastewater would lead to insufficience for photosynthesis of the algae.

Another possibility for treatment of wastewater from food processing, especially from slaughterhouses, is reffering to [Kobya et al, 2005] the electrocoagulation. There is a current research program that investigates the electrocoagulation of poultry slaughterhouse wastewaters. Electrocoagulation seems to be a very effective method. With respect to [Kobya et al, 2005] this technology has certain advanatages in comparison to biological processes:

- simple equipment
- easy operation
- short reactive retention time
- decrease amount of precipitate and sludge

So far electrocoagulation was used successfully for example for treatment of textile wastewater, urban wastewater, landfill leachate or chemical fibers plant wastewater.

To achieve effective treatment results [Kobya et al, 2005] suggests the following conditions for the performance for the electrocoagulation:

- the anode material should be made from aluminum or iron
- initial pH values should be low (2-3)
- current density of 150 A/m^2

With respect to these conditions COD removal efficiencies up to 98% can be reached in the lab scale. Further developments include the building of a pilot plant scale. [Kobya et al, 2005]

LUBRICANTS MANUFACTURE

In general the nature of problem in treating oil contaminated wastewaters from lubricants or fuel oil manufacture is equal to treatment of oily wastewaters from food processing: the primary treatment is performed with mechanical technologies to reduce the oily charge for the following treatment step. But especially the secondary treatment is different from treatment of food processing wastewaters. The preferred treatment technology for food processing wastewaters is biological, due to the high organic loadings of the generated wastewaters. For oily wastewaters from lubricant or fuel oil manufacture biological treatment cannot be suggested at all. Reason is that lubricants or fuel oils consist of either synthetic oils or mineral oils (see chapter 2). These types of oils are due to the length of the chains hardly biodegradable or the degradation processes take a long time. (Key word: natural attenuation processes). In comparison to synthetic or mineral oils the wastewater from food processing industry contains animal or vegetable fats and oils that are easily biodegradable and therefore the wastewater from food processing has optimal initial conditions for biological treatment technologies.

For secondary treatment of wastewaters from lubricants industry all treatment technologies except biological treatment can be recommended. To suggest on specific technology is impossible, because that depends on the quality and quantity of generated wastewater and is a single-case decision with regard to costs and benefits for the specific company.

4.1.6.2 Oil contaminated wastewaters from LEAKAGES

Oil contaminations due to leakages have to be taken into account for every industry that has contact to oils / fat and grease in any possible way. That are not only industries that deal with oils, fats or grease within the production process directly, but also industries that need oils e.g. for heating or lubrication of facilities. In case accidents happen or leakages appear (for instance in storage areas of fuel oils), the wastewater will definitely be oil contaminated.

Treatment of oil contaminated wastewaters due to leakages or accidents is not included in this guideline, because quality and quantity of the wastewater is not predictable so no general advice for treatment can be given.

The responsibility for minimizing the risk of oil contaminations of water through leakages etc. lies within the management of every company.

MANAGEMENT RESPONSE OPTION

Businesses and individuals are responsible for complying with environmental regulations and for preventing pollution of air, land and water. Many thousands of pollution incidents occur each year, originating from factories, farms, transport activities and even homes. Each incident is an offence and can result in prosecution as well as environmental damage. However, most cases are avoidable, given careful planning of operations, responsible waste management and suitable facilities to reduce the risk of spillage - along with simple precautions to deal with any spillages, in case they occur.

Responsible waste management can ensure that you comply with the relevant regulations, while minimizing waste can reduce the amount of waste produced, which in turn cuts the risk of environmental damage and the costs of waste disposal. Waste is a good major environmental issue for businesses. Good waste management policies means good company image.

The handbook provides practical advice on environmentally friendly production that aims to help you to avoid causing pollution, to minimize waste and to comply with the requirements of the regulations. Often the necessary measures cost little, especially if you think about them early on, for example at the design stage, and can save you money, too. In contrast, the fines for failing to comply with the relevant regulations or the costs of cleaning up pollution (which are recovered from the polluter wherever possible) can be very high.

Every organization, whether public or private, large or small, has an impact on the environment and an interest in achieving good management practices. That helps explain why a growing number of organizations are using Environmental Management Systems (EMSs) to achieve process, resource, labor, and material efficiencies that translate into meaningful environmental improvements, safer and healthier work places, and improved competitiveness.

An EMS is a formal set of policies and procedures that define how an organization will evaluate, manage, and track its environmental impacts. In practice, the specific structure of environmental management systems can vary widely, but most systems follow a basic “Plan-Do-Check-Act-Maintain” model (Figure 4-18) that facilitates cost-effective environmental performance by defining and continuously improving the processes and actions that an organization undertakes to meet its business and environmental goals.

Typically, EMS development starts with a policy statement that communicates an organization’s environmental priorities to employees, stockholders, and customers. Management endorsement of the policy statement demonstrates the organization’s commitment to the effort and willingness to allocate resources for implementation. Once a policy statement is in place, the organization implements it following the “Plan-Do-Check-Act-Maintain” model, which facilitates ongoing environmental improvement.

Plan

During the “Plan” phase, an organization identifies all of its environmental aspects - any environmental or health and safety impacts resulting from its products, activities, and services. The organization then evaluates each aspect according to a variety of criteria (e.g., environmental and health effects, economic impacts, liabilities) to determine which should be treated as significant aspects. After establishing a complete list of significant aspects, the organization sets its environmental goals and develops a plan to achieve those goals.

Do

The “Do” phase of the model involves implementation of the environmental plan through employee training and establishment of operational controls. For a management system to be effective, each employee must be trained on his or her role in addressing the significant aspects identified by the plan, and procedures must exist for orienting new employees into the system. Operational controls are procedures that provide direction for employees conducting specific activities, and can also include investments in technologies that conserve resources or prevent pollution.

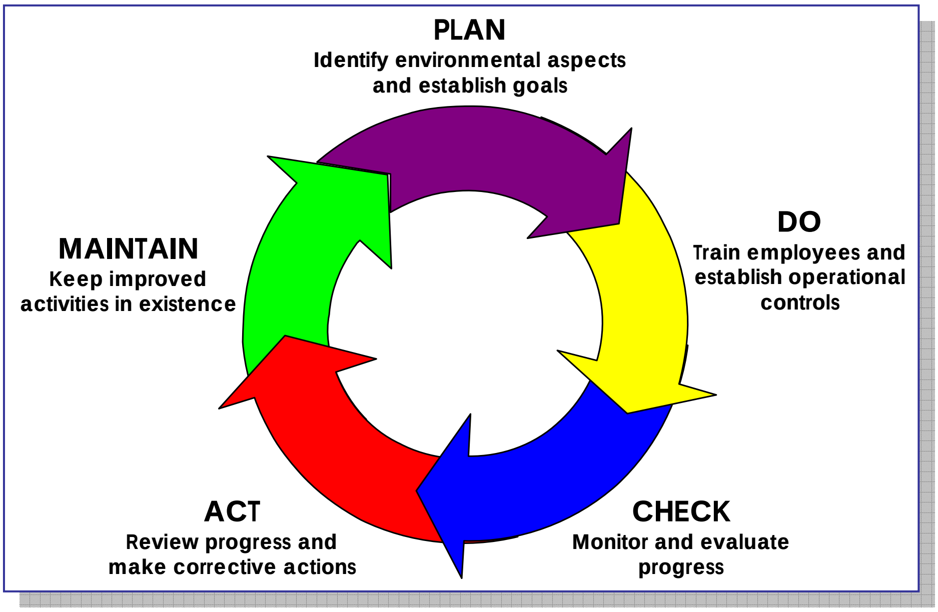

Figure 4-18 PDCAM Chart

Check

During the “Check” phase, an organization evaluates its progress toward meeting its program goals through ongoing monitoring and measuring and periodic internal management system audits. The success of this phase depends on the organization’s ability to accurately monitor and measure key activities and track progress by maintaining a usable recordkeeping system. Tracking environmental progress allows the organization to quantify successful components of its environmental program and identify areas that need improvement.

Act
The "Act" phase involves taking corrective action to update and improve the environmental plan. For example, if an organization makes significant progress on one environmental aspect, another environmental aspect might replace it on the priority list.

Maintain
The "Maintain" phase of the model involves keeping improved plan, procedures and activities in existence. The process of reevaluating and developing procedures to address the organization's most significant environmental aspects brings the organization to the "Plan" stage of the process.

4.1.7 Why Should My Organization Adopt an EMS?

An EMS serves as an excellent tool for achieving cost effective environmental improvements through methods spurred by an organization's initiative rather than government regulation. Many organizations – large corporations, small businesses, local governments, state and federal agencies, schools, and non profits- use EMSs to systematically manage their environmental, health, and safety matters and produce a variety of benefits, including:

4.1.7.1 Improved environmental performance

An EMS can help monitor energy and water conservation, resource efficiencies, and pollution prevention. By tracking the reductions in emissions that result from these activities, and EMS helps demonstrate an organization's commitment to reducing the risk of climate change. Process improvements that lead to resource conservation and pollution prevention can also translate into reduced purchasing and disposal costs.

4.1.7.2 Certification and recognition

EMS implementation can enhance an organization's image and improve public and community relations. As consumers place an increasing value on environmental performance, they will favor organizations that show a commitment to demonstrable environmental management. An effective EMS can also improve access to capital by satisfying investor and lender criteria, and increase sales by helping a company meet vendor certification criteria. By reducing the risk of injury to workers through process changes and additional training, employers can also enhance recruitment and employee morale.

4.1.8 Waste Management

All waste must be handled, stored and disposed of correctly to avoid pollution. A useful model when dealing with a waste stream originating from any source is the "waste hierarchy" (Figure 4-19). This concept uses principles of waste avoidance, reduction, reuse, recycling and recovery to minimize the amount of waste produced, thus reducing environmental and economic costs and ensuring that legislative requirements are met. It provides a tool for structuring a waste management strategy and can be used as a model for all operations.

4.2 TRAINING AND EDUCATION

In general, company personnel should be trained depending on their level and responsibilities as well as their experiences on the job. The common subjects they need to know are, for example, company goal and missions, policy and strategy, along with its procedure. These are base all staff should be informed; therefore, they are able to effectively support a company to reach its goal. Training is namely an indirect tool to enhance staff's moral, loyalty and motivation. It brings well interaction between top and bottom as well as between similar hierarchy.

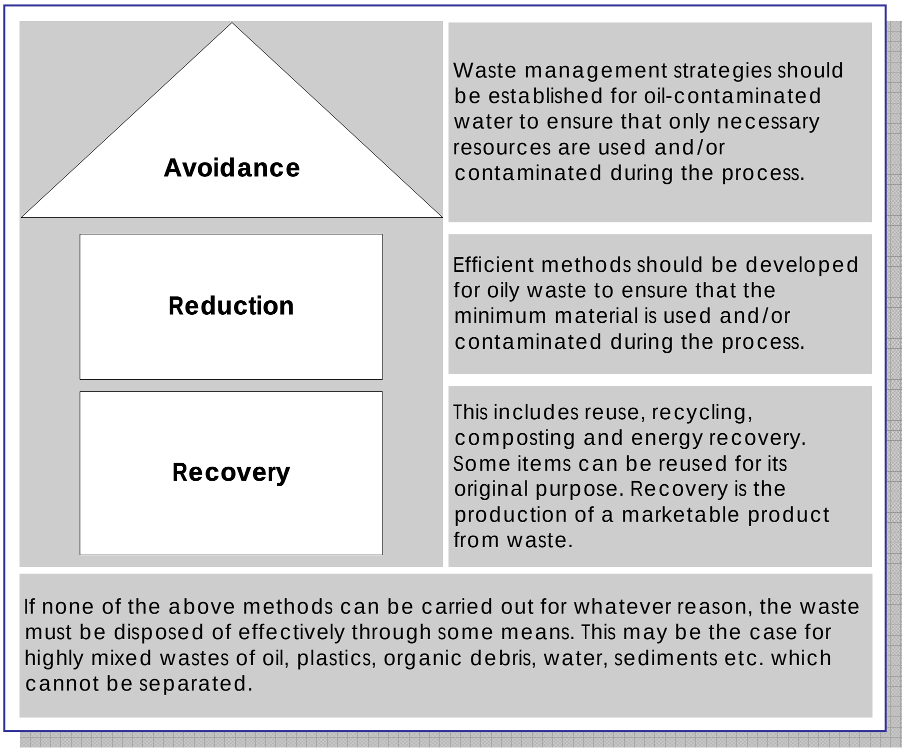

Figure 4-19 Figure Waste Hierarchy

All relevant staff and new coming staff who using a facility for the first time, should be trained in the purpose and should be educated about the environmental management policy and its procedure. In case that staff is in charge of environment, safety, health and related activities, they should obtain on intensive training on both theory and practice. On the job training is also a smart method to enhance staff's capacity together with their awareness on the environment. All relevant staff should undergo revision training on the operation of the waste management system and the facility, as part of a formal training schedule.

A general environmental awareness of all associated with a facility, should be undertaken by staff, including being made aware of the penalties for infringement imposed by the facility or regulating authorities. An environmental awareness may not be easy to build-up immediately at the first time in some case due to complex factors. However, this should be emphasized for the sake of sustainability in the long run.

All contractors coming onto the plant need to be made aware of management and safety requirements while on the site. It prevents a company paying a claim for an accident or environmental damage in any case even unintentionally. Assistance should be sought especially in relation to updating knowledge base with new developments from environment protection authorities, transport departments and associations. Technical personnel should be made very aware of hazards related to oily waste.

4.3 LITERATURE

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CHAPTER V

APPENDICES

-TECHNICAL PART-

5 APPENDICES

5.1 BEST PRACTICES

5.1.1 Industry

5.1.1.1 Lubricant Oil

Company profile

- *Nature of activity*
  - Production of oil grease lubricant
  - 400-450 Mio. L per year
  - First production line: 200.000 l/d lubricant oil, grease 1.5 Mio. L/d
  - Second line: last one biodegradable oil
- *Scale of operation (volume)*
  - Exporting countries: Australia, Singapore, Malaysia (20% total)

Overview

Technological steps

Production Process

- *Product:*
  Industrial, food, marine and textile lubricants as well as for automobiles.
- *Raw material / Resources (water, energy):*
  Base fluid (from petroleum origin) and additive chemicals
- *Process details:*
  Product Development Manufacturing Co. Ltd. researches its own lubricant oil formulas. The ratios of base oil to additives vary according to the lubricant function. Most of the production process involves mixing different ingredients in mixing tanks.

Oils/Greases

Process details

Impacts / issues

- *Waste products produced / amount of waste water*
  Waste water 40m^3/month, waste water from scrubber
- *Waste treatment system / waste management*
  Waste water treatment system with oil trap
- *Waste disposal / options / prices*
  Solids from the oil trap: send it to GENCO
- *Impact on the environment*
  (water / soil / sediment / air)
  Treated water discharge to the river (discharge is under the standard regulations, 2 times/month)
- *Problems with oil spills / Nature of problems*
  Oil spill during transportation inside the factory, rain water


Waste water treatment


Fat separator

Best Practice / observations

- *Ongoing projects with regard to environmental issues (waste programs etc.)*
  According to ISO 9000
- *Quality management / assurance*
  Accredited with ISO 9000 – 2000
  Laboratory accredited with ISO/IEC 17025

Good Manufacturing Practice

- **In general**
  - Quality Management System (QMS) based on ISO 9001:2000
  - Audit every month / quality assurance
  - Environmental management system (part of quality management)
    - Appointment of a conservation representative
    - Ecologically careful utilization of resources
    - Thrifty expenditure of auxiliary and work materials
      - Careful storage and production regarding to environment and resources
      - Responsible handling of waste and sewage water
      - Controlling via indices (e.g. pH)
  - QMS is a dynamic / process orientated process → permanent improvement via:
      - Audits (internal, external)
      - Measures of correction and prevention

- **In particular (examples)**
  - Policies existing for quality, costs, delivery, safety, moral, environment
  - Awards for safety
  - Information centre for employees (books, brochures etc.)
  - Full, careful manual clean-up when changing the sort of base oil;
  - Wastewater collection and treatment system
  - Good training of employees (special skills and experience required);

5.1.1.2 Tapioca Starch

Company profile

- A manufacture of native tapioca starch.
- Mid-sized facility with 180 employees.
- Production capacity of 150 - 200 tons of native tapioca starches a day and produces 240 days a year.

Technological steps

Policy / strategy

- *Strategy for future (improvement of quality / quantity)*
  - Building another biogas plant
  - Continuing improvement of product and process
  - Emphasizing on quality control, product development and process improvement
- *Any monitoring?*
  - Yes (product quality and quantity, wastewater)
- *Certification for management / safety / environment*
  - Operation of biogas plant under the EU standard for safety
- *Any quality control / quality assurance*
  - Yes
- *Safety / health*
  - Machinery guard, safety sign
  - No personal safety equipments applied etc.
- *Company policies (target / company strategy)*
  - Decrease S and cyanide content in starch product to be able to export to Japan

Impacts / issues

- *Waste products produced / amount of waste water*
  - 2,000 m^3 a day (200 tons of product) of wastewater, 200 L of waste oil from 500 KW generator every 1,000 operating hour; 400 L of waste oil from 1MW generator
- *Waste treatment system / waste management*
  - Biogas and opened pond
- *Waste disposal / options / prices*
  - Biogas, currently storage area, plan to filter waste oil and reuse in burner
- *Impact on the environment (water / soil / sediment / air)*
  - Storage of fuel oil outside building – spilling on the ground and able to mix with rainwater
- *Problems with oil spills / Nature of problems*
  - See analysis and recommendations below

Best Practice / observations

- *Ongoing projects with regard to environmental issues (waste programs etc.)*
  - The project "Research and Development on the Tapioca Starch Production Process to Increase Efficiency and Optimize the Utilization of Natural Resources, Water, and Energy: A Near-Zero Discharge Starch Factory" researches 4 major topics that are (1) water resource utilization and management, (2) extraction unit, (3) separation unit, and (4) drying unit in order to enhance our understanding on the native tapioca production process.
  - In the year 2002, the company was one of the 12 factories participating in the demonstration project for the Development of High Rate Anaerobic Hybrid Reactors for Biogas Production from Tapioca Starch Wastewater funded by the Energy Policy and Planning Office. The twelve biogas systems treating tapioca starch wastewater would produce approximately 36 million m3 biogas a year, which can replace all of the consumption of fuel oil in the factory approximately 22 million liters (equivalent to 308 million baht a year at the fuel oil price of 14 baht/liter) or produce electricity of 44 million kWh per year. Further, this project would reduce the methane emission of 9 million kilogram a year; reduce the polluted wastewater approximately 3 million m3 to the environment.

5.1.1.3 Frozen Chicken

Company profile

- production and distribution of animal feed
- Started its business with its first mill in Prapradaeng, Samutprakarn Province
- Production of processed frozen and fresh chicken for export
- Other products are also manufactured upon customer orders such as ready-to-eat food products, yakitori, etc.

Process

The company has a range of products that include steamed, fried, and roasted chicken for both domestic and export.
0.7% of the whole chicken is fat. 2,2-2,4 kg per chicken.

Steamed Chicken Process

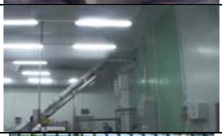
- *Preparing*
Defrost frozen chickens from slaughterhouse and then cut and trim the chicken

- *Tumbling*
At a pressure of -0.8 to –0.9 bar, 10 rpm, 75 minutes, controlled temperature of 4-6 °C

- *Holding*
For 4-8 hours

- *Steaming*
Chicken pieces are steamed in a spiral oven

- *Pre-cooling*
Temperature of products is reduced to 10 °C in a chiller for 30-45 minutes



- *Cutting*
Cut and trim using both cutting machines and workers

- *Freezing*
Individual quick freezing; IQF and then packaging

- *Packing*

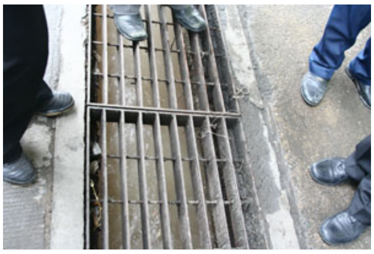
- *Metal detecting*

- *Packaging*

- *Distributing*

Other further processes, such as roasting and frying processes, uses similar steps with a little alteration of equipments from steamer to be roaster and fryer, respectively.

Impacts / issues



- *Waste products produced / amount of waste water*
  - Wastewater of 5,400 m^3/day for slaughterhouse, 1,600 m^3 a day from further processing house, 1,000 m^3 a day from Ajinomoto factory
  - (36% of whole chicken is meat)
- *Waste treatment system / waste management*
  - Grease trap, EQ, AS, clarifier, polishing pond
  - Sludge used as fertilizer
- *Waste disposal / options / prices*
  - Outside contractor
- *Impact on the environment (water / soil / sediment / air)*
  - Discharge is monitored twice a week, if exceeds standard, retreat
  - There might be impact on receiving canal
- *Problems with oil spills / Nature of problems*
  - Used cooking oil (measure AV) – storage and dispose by outside contractor

Organization (personnel / training)

- *Human resources*
  - Several operational tools utilized in the company:
    - TQM - Every staff is encouraged to partake in the organizational management by improving their work through the use of Total Quality Management
    - PIP - The Productivity Improvement Program is set up to enhance efficiency, yet reduced cost, in the manufacturing
    - KAIZEN - applied to maximize the effectiveness and well-being of our workforce
    - Training programs - perpetually provided both inside and outside of the Betagro Group
    - scholarships granted for Masters study

Best Practice / observations

- *Ongoing projects with regard to environmental issues (waste programs etc.)*
  - Biogas
  - Reduction of cooking oil and wastewater

5.1.1.4 Palm Oil

Company profile

The factory is a medium-size palm oil mill with 43 employees working in 3 shifts a day. The object of activity is producing of crude palm oils) for industry and international trade. Main process is based on pressing of fresh fruit bunches (FFB).

The company has a production capacity of 45 tons of FFB an hour. The actual capacity is approximately 40-42 tons FFB an hour. Peak period for production is between February and July. The production yield is approximately 17-19% of FFB with an oil loss of approximately 2.6% of total oil. The company owns palm plantation of 3,000 – 4,000 rai (1 rai = 1,600 m^2), which is 10% of total raw material. Processed water comes from surface water and rainwater.

Technological steps

Policy / strategy

- *Strategy for future (improvement of quality / quantity)*
  - Reduction of oil loss. Currently the company has the oil loss of 2.6%. If reduce 0.6%, the factory would recover 18 million baht a year. The benchmark from the palm oil association is 1.79% of oil loss.
  - Additional biogas system. The existing biogas system produces 500 kW of electricity (x24 units a day). The electricity is sold back to the grid at 80% (3.3 baht/kWh).
  - Buying more land for irrigation to prevent overflow from rainwater.

- *Any monitoring?*
  - Product quality/quantity (yield/loss): Crude palm oil (FFA, moisture, impurity – hourly and composite sample in 1 shift)
  - Wastewater: BOD, pH, SS, TVA, TS, TVS, %oil – every day
- *Certification for management / safety / environment*
  - ISO 9000 (not interested in ISO14000 because it brings pressure to the company)

- *Any quality control / quality assurance*
  - Yes
- *Safety / health*
  - No safety guarding, signs, personal safety equipment
- *Company policies (target / company strategy)*
  - 5M (man, method, machine, management, money)
  - Improve worker skills and awareness

Process

- *Fruit bunch sterilization*

Fresh fruit arrives from the field as bunches or loose fruit. Large installations use weighbridges to weigh materials in trucks. Sterilization or cooking means the use of high-temperature wet-heat treatment of loose fruit. Cooking normally uses hot water; sterilization uses pressurized steam at 3 bar, 130-150 °C for 70-90 minutes. Each batch is 20 tons.

- *Bunch threshing*

The fresh fruit bunch consists of fruit embedded in spike lets growing on a main stem. In a mechanized system a rotating drum or fixed drum equipped with rotary beater bars detach the fruit from the bunch, leaving the spike lets on the stem. In larger mills, the bunch waste is incinerated and the ash, a rich source of potassium, is returned to the plantation as fertilizer.

- *Fruit digestion*

Digestion is the process of releasing the palm oil in the fruit through the rupture or breaking down of the oil-bearing cells. The digester commonly used consists of a steam-heated cylindrical vessel fitted with a central rotating shaft carrying a number of beater (stirring) arms. Through the action of the rotating beater arms the fruit is pounded. Pounding, or digesting the fruit at high temperature, helps to reduce the viscosity of the oil, destroys the fruits' outer covering (exocarp), and completes the disruption of the oil cells already begun in the sterilization phase. Temperature in this step is 80-90 °C and processing time is 15 minutes.

- *Pressing*

There are two distinct methods of extracting oil from the digested material. One system uses mechanical presses and is called the 'dry' method. The other called the 'wet' method uses hot water to leach out the oil. In the 'dry' method, the objective of the extraction stage is to squeeze the oil out of a mixture of oil, moisture, fiber and nuts by applying mechanical pressure on the digested mash. The presses may be designed for batch (small amounts of material operated upon for a time period) or continuous operations.

- *Clarification and centrifugation*

The main point of clarification is to separate the oil from its entrained impurities. The fluid coming out of the press is a mixture of palm oil, water, cell debris, fibrous material and 'non-oily solids'. Because of the non-oily solids, the mixture is very thick (viscous). Hot water is therefore added to the press output mixture to thin it. The dilution (addition of water) provides a barrier causing the heavy solids to fall to the bottom of the container while the lighter oil droplets flow through the watery mixture to the top when heat is applied to break the emulsion (oil suspended in water with the aid of gums and resins).

The diluted mixture is passed through a screen to remove coarse fiber. The screened mixture is boiled from one or two hours and then allowed to settle by gravity in the large tank so that the palm oil, being lighter than water, will separate and rise to the top. The clear oil is decanted into a reception tank. This clarified oil still contains traces of water and dirt.

To prevent increasing FFA through autocatalytic hydrolysis of the oil, the moisture content of the oil must be reduced to 0.15 to 0.25 percent. Re-heating the decanted oil in a cooking pot and carefully skimming off the dried oil from any engrained dirt removes any residual moisture. Continuous clarifiers consist of three compartments to treat the crude mixture, dry decanted oil and hold finished oil in an outer shell as a heat exchanger.

- *Kernel recovery*

Large-scale mills use the recovered fiber and nutshells to fire the steam boilers. The super-heated steam is then used to drive turbines to generate electricity for the mill. For this reason it makes economic sense to recover the fiber and to shell the palm nuts.

In the large-scale kernel recovery process, the nuts contained in the press cake are separated from the fiber in a depericarper. They are then dried and cracked in centrifugal crackers to release the kernels. The kernels are normally separated from the shells using a combination of winnowing and hydro cyclones. The kernels are then dried in silos to moisture content of about 7 percent before packing.

Impacts / issues

- *Waste products produced / amount of waste water*
  - 50 m^3 of wastewater per 100 tons of FFB
  - Shells, fibers, empty fruit bunches, decanter cake, ashes
  - Air emission

- *Waste treatment system / waste management*
  - Biogas system generating electricity to sell back to the grid (80%). The biogas technology is completely stirred tank reactor (CSTR) with a liquid volume of 4,600 m^3 and a headspace of 250 m^3. The designed parameters are HRT of 10 days and inlet BOD of 25,000 mg/L. The BOD removal of the system is 95%.
- *Waste disposal / options / prices*

- *Impact on the environment (water / soil / sediment / air)*
  - Oil spills
  - Odor
  - Wastewater
  - Air emissions

- *Problems with oil spills / Nature of problems*

Palm shells are sold at a price of 1,400 baht per ton, while 90% of fibers are used in boiler and 10% is sent to palm orchards.

Organization (personnel / training)

- *Skill of the workers / training*
  - Poor labor skill
  - High competition in neighboring area

5.1.2 Plant Specific

5.1.2.1 Experience From Germany

Company profile

Build in 1925, the company started as a family business led by Mr. Henry Lamotte. The object of activity is producing of oils and foodstuffs for industry and international trade. Henry Lamotte GmbH (later divided into Lamotte Oils and Lamotte Food) is a mid-sized company with 96 employees delivering oil products for food, pharmaceuticals and cosmetics industry. Main process is based on cold pressing of different oil containing seeds: sunflower, almonds, hazelnut, jojoba, linseed, pumpkins, sesame, rapeseed etc.

Technological steps

- Counter unit for raw products (storage area for seeds); includes sighting of the raw products plus physical, chemical and microbiological tests

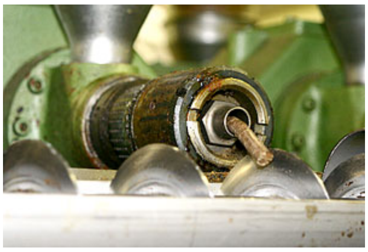
- Small testing unit

- Cleaning facility
  (sieving process)

- Transportation to pressing unit

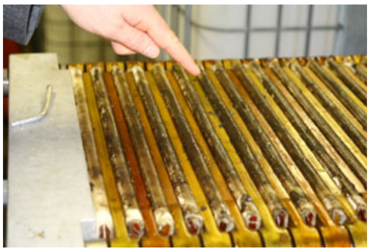
- Cold pressing
  (mechanical screw)

- Crude oil – pellets separation



- Transportation to filtration unit

- Filter press
  (filtration on cloth membranes)



- Transportation to storage tanks and distribution to clients

Good Manufacturing Practice

→ in general:

- Quality Management System (QMS) based on ISO 9001:2000 and correspondences to certain certifications:
    - International Food Standard (IFS)
    - Quality and Safety (Q&S)
    - Identity Preserved (IP)
    - Hazard Analysis and Critical Control Points certification (HACCP)

        - "BIO-certified" company
        - Kosher certified
        - Etc

- Environmental management system (part of quality management):
    - Appointment of a conservation representative
    - Ecologically careful utilization of resources
    - Thrifty expenditure of auxiliary and work materials
        - Careful storage and production regarding to environment and resources
        - Responsible handling of waste and sewage water
        - Controlling via indices
        - Determining the behavior regarding to environmental aspects of the dealer in the seeds producing country

- QMS is a dynamic / process orientated process → permanent improvement via:
        - Audits (internal, external)
        - Measures of correction and prevention

→ in particular (examples):

- Careful selection of seeds;

- Proper storage of seeds and products (good ventilation, protection from humidity, smells, temperature variation, pests etc.)
- Cold pressing system (no refinery);
- Reuse of pellets (delivered to organic food industry);

- Reuse of filter membranes (washed in washing machine);
- Reuse of old clothes for clean-up of devices;

- Full, careful manual clean-up when changing the sort of seeds;

- Integrated waste water collection system (disposal by authorized operator);

- Harmful substances analysis (PAHs, pesticides etc.)
- Good training of employees (special skills and experience required);

- Further planned measures for phosphor-lipids recover out of the filter cake;

- General processes optimization by future plant up-grade.

5.1.2.2 Experience From Estonia

Company profile

- 20 branches in northern Germany
- Car repairing garage (AUDI, VW, SKODA, Porsche)

Technological steps

- Sewage system with sludge separation unit (car park)…taken away once a week by NEHLSEN Plump (treatment)

- Car maintenance
  - Wastewater handled by an emulsion splitting unit (DYWIDAG Aquaschutz);
  - Chemical treatment: flocculation – sedimentation based, Al-based compounds added and some polymers (concentrations calculated, no lab data available);
  - Sludge collected and sent for further handling;
  - Samples taken two times per year and chemicals concentration adjusted if needed; focus on hydrocarbons.

- Hand wash unit

  (Special cleansing agents - automatically de-graded after a certain time)

- Garage (Porsche)

  Special place for repairing cars, cleaning the floor with water every day and discharged into the sewage system

Good Manufacturing Practice

- Waste separation and recycling ("Green Dot", metals etc.)


- Garage: special care by oil changing (collection in special container) – waste oil treatment

- Reuse of old clothes for clean-up of devices


- ISO 9001:2000 since 2000 and ISO 14000
- GVÖ – oil cans go back to the producing industry

5.1.2.3 Experience From Germany

Company profile

The company is a leading producer of the rapeseed oil in Estonia that started manufacturing in 1999. The company uses about 72,000 tons of rape seed as a raw material for production of refined rapeseed oil (34% of production), rapeseed expeller (63% of production) and feed oil (1% of production).

Main environmental issue has been very high load of wastewaters to the nearby river, and accompanied high pollution charges for releases of particularly phosphorus.

Another problem has been prevention of possible leakage of oil and formation of oil-water mixtures in all steps of production of the company.

Technological steps

According to the legislation a water permit (from local environmental authority) is obligatory because:

- consumption of ground water is more than 5 m3/day and;
- waste water needs treatment before discharged back to the nature.

Maximum allowed annual discharge and maximum concentrations of BOD, COD, suspended solids and total phosphorus of wastewaters in the outlet of the WWTP are determined by authorities.

According to the legislation the company is obliged to use additional phophorus removal step at the WWTP because wastewaters are discharged to the sensitive to pollution water body as designated by the Minister of Environment.

Additionally the company is obliged to carry out monitoring of the recipient water body 100 meters downstream of the wastewater outlet.

Air pollution permit specifies

- Maximum yearly emissions
- Maximum emissions for every step of production
- Purification efficiency (90%) for cyclones

The main environmental problem has been very high phosphorus loading accompanied by high BOD loading that led to enhanced eutrophication of the recipient water body.

High pollution load caused substantial expenses for the company by environmental pollution charges and negative image.

Technical solutions

1. Redesign of production chain to minimize the amount of wastewaters released to the environment
2. Implementation of a system for reuse of technological water
3. Implementation of a system to collect and reuse all solid wastes

Procedural solutions

1. Implementation of ISO quality management systems
2. Permanent monitoring of leak detection systems
3. Implementation of proper reporting system in case of larger oil spills
4. Ensuring that containment systems are functional

Financial solutions

1. Part of solid wastes are sold out for bio-energy production

Handling of the waste water treatment facility, monitoring of pollution sources and chemical analyses are handed over to another company to save costs.

Technical solutions

1. Redesign of technological process to minimize the amount of wastewater released to the environment

- Installation of equipment fulfilling BAT requirements;
- Oil-water separators are used for oil collection, including two separators inside and outside the buildings that are used in case of accidental oil spills;
- Main storage and production areas where oil spills can occur are covered by roofs to minimize possibility for spreading increased amounts of oily waters to different direction bypassing existing collection systems;

- Small spillages are collected permanently

- For accidental larger spillages an empty container (volume about one tonne), special pump and cleaning tools are available
- Collected oil is added to the raw oil (if more or less clean) and partly to the feed oil

2. Implementation of a system for reuse of technological water
    - All technological water is either reused or inserted to oil cake;
    - Some process waters that needs treatment before inserted to oil cake are treated;
    - Thus the WWTP treats only sanitary wastewaters, and washing and cleaning waters and treatment costs are substantially reduced;

3. Implementation of a system to collect and reuse all solid wastes
    - Rape seed cleaning residues are used for energy production and sold for a boiler house;
    - Bleaching soil, e.g. product of oil bleaching is transported to the waste deposit where used in compost;

Procedural solutions
1. Implementation of ISO 9001 and ISO 22000 certificates. ISO 14001 certification not yet implemented;
2. Permanent monitoring of leak detection systems. Wherever leakage can occur –some storage vessels, containers are used. Automatic monitoring and detectors for larger oil spillage were established;
3. Implementation of proper reporting system in case of larger oil spills. Obligation to report about larger oil spills to local environmental authority, municipality, environmental inspection and if needed to rescue board;
4. Ensuring that containment systems are functional is achieved by permanent check. The personnel are trained for carrying out this task.

Financial solutions
1. Part of solid wastes are sold out for energy production that save money for waste deposit
2. Handling of the waste water treatment facility, monitoring of pollution sources and chemical analyses are handed over to another company to save costs

Effectiveness / effects

The actual discharges of waste water during recent years is about two times lower than allowed by the water permit. The technological improvement with regard of the water re-use minimized wastewater impact and accompanied expenses.

The wastewater quality is in agreement with the requirements except too high concentration of phosphorus.

Mean phosphorus concentrations in the outlet of the WWTP are still nearly two times higher than maximum levels set up by the water permit, probably, due to used detergents for cleaning the production area.

Costs

All technical solutions were provided and the new technological scheme developed by engineers of the company. Therefore, the costs were rather low.

Implementation of the new system did not require any interruption to economic activity, because the company is closed for two weeks every summer for maintenance and proper cleaning of the production and storage area.

Only one third of the capacity of the WWTP is used at the moment. Underused treatment facility needs some extra expenses for maintenance. The real waste water discharge is about two times lower comparing to the level allowed by the water permit

Benefits

Environmental quality: reduced P load, suppressed eutrophication,
Financial savings: annual pollution charges are negligible: less than 1000 EUR per year.
Monitoring system is set up according to the legislation and specific requirements set up by the environmental permits. The system includes both monitoring of physical-chemical parameters for waste water as well as the recipient water body