

ENVIRONMENTAL, HEALTH, AND SAFETY GUIDELINES FOR VEGETABLE OIL PRODUCTION AND PROCESSING

INTRODUCTION

1. The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP).¹ When one or more members of the World Bank Group are involved in a project, these EHS Guidelines are applied as required by their respective policies and standards. These industry sector EHS Guidelines are designed to be used together with the **General EHS Guidelines** document, which provides guidance to users on common EHS issues potentially applicable to all industry sectors. For complex projects, use of multiple industry-sector guidelines may be necessary. A complete list of industry-sector guidelines can be found at www.ifc.org/ehsguidelines.

2. The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. Application of the EHS Guidelines to existing facilities may involve the establishment of site-specific targets, with an appropriate timetable for achieving them.

3. The applicability of the EHS Guidelines should be tailored to the hazards and risks established for each project on the basis of the results of an environmental assessment in which site-specific variables, such as host country context, assimilative capacity of the environment, and other project factors, are taken into account. The applicability of specific technical recommendations should be based on the professional opinion of qualified and experienced persons.

4. When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures than those provided in these EHS Guidelines are appropriate, in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment.

APPLICABILITY

5. The **EHS Guidelines for Vegetable Oil Production and Processing** are applicable to facilities that extract and process oils and fats from a variety of seeds, grains, and nuts; these include canola, castor, cottonseed, mustard, olive, palm, palm-kernel, peanut (groundnut), rapeseed, safflower, sesame, soybean, and sunflower. Additionally covered are crude oil production and refining processes, from the preparation of raw materials to the bottling and packaging of final products for human or animal

¹ Defined as the exercise of professional skill, diligence, prudence, and foresight that would be reasonably expected from skilled and experienced professionals engaged in the same type of undertaking, under the same or similar circumstances globally. The circumstances that skilled and experienced professionals may find when evaluating the range of pollution prevention and control techniques available to a project may include, but are not limited to, varying levels of environmental degradation and environmental assimilative capacity, as well as varying levels of financial and technical feasibility.

consumption. These EHS Guidelines do not however apply to the production of biofuels. Annex A contains a full description of industry activities for this sector. The production of oilseeds, beans, and oil palm fresh fruit bunches is covered by the **EHS Guidelines for Annual Crop Production** and the **EHS Guidelines for Perennial Crop Production**.

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1. INDUSTRY-SPECIFIC IMPACTS AND MANAGEMENT

6. The following section provides a summary of EHS issues associated with vegetable oil production and processing that arise during the operations phase, along with recommendations for their management. Recommendations for the management of EHS issues common to most large industrial facilities during the construction and decommissioning phases are provided in the **General EHS Guidelines**.

1.1 Environment

7. Environmental issues associated with the operational phase of vegetable oil production and processing primarily include the following:

- Solid waste and by-products
- Water consumption and management
- Energy consumption and management
- Atmospheric emissions
- Greenhouse gas emissions
- Hazardous materials

1.1.1 Solid Waste and By-Products

8. Vegetable oil processing activities generate significant quantities of organic solid waste, residues and by-products, such as empty fruit bunches (EFBs) and waste palm kernels from palm oil processing or olive oil cake and pulp from olive processing. The amount of waste generated depends on the quality of the raw materials and on process efficiency. Wastes, residues, and by-products may be used for producing commercially viable by-products or for energy generation. Other solid wastes from the vegetable oil manufacturing process include soap stock and spent acids from chemical refining of crude

oil; spent bleaching earth containing gums, metals, and pigments; deodorizer distillate from the steam distillation of refined edible oils; mucilage from degumming; and spent catalysts and filtering aid from the hardening process.

9. Recommended techniques for minimizing the volume of solid waste and by-products for disposal include the following:

- Reduce product losses through better production/storage control (e.g., monitor and adjust air humidity to prevent product losses caused by the formation of molds on edible materials).
- Collect residues from the raw material preparation phase for conditioning (drying) and reprocessing (grinding) to yield by-products (e.g., animal feed).
- Return waste and residues to fields to assist in soil nutrient management; for example, EFBs from oil palm plantations with tree trimmings are a valuable soil amendment and/or can be composted with vegetable oil wastewater effluent.
- Use waste and residues for energy generation in the project plant's boiler(s). Note, however, that relatively high atmospheric emissions (such as particulate emissions (PM)) are possible when burning crop residues, and potential fire risks (e.g., from combustible dust) may arise from handling, storing, and processing crop residues; as such, expert advice on fuel characteristics and boiler design should be solicited when planning to use biofuels in this manner.
- Investigate the following options for the responsible disposal of spent bleaching earth:
 - Use as fertilizer, if not contaminated with heavy metals such as nickel, pesticide residues, or other contaminants.
 - Recover non-food-grade oils from spent bleaching earth that could be used in other applications (feedstock for conversion to biodiesel or in bio-lubricants).
 - Avoid direct recycling on agricultural land. Add spent earth to other organic waste and compost to avoid contact with air and risk of spontaneous combustion of spent bleaching earth.
 - If contaminated, manage according to the waste management guidance presented in the **General EHS Guidelines**.
 - Consider use as a feedstock for brick, block, and cement manufacturing.
- Investigate the following options for the use of distillates (e.g., free fatty acids and volatile organic compounds (VOCs)), depending on the level of contaminants (pesticides and/or residues):
 - Use free fatty acid as animal feed if uncontaminated.
 - Apply as a feedstock for chemical industry processes (e.g., antioxidants).
 - Use as fuel for energy production.
- The nickel catalyst from hydrogenation should be either:
 - recycled and recovered for reuse as a nickel catalyst or as nickel metal, salt, or other application, or
 - stored and disposed of according to the hazardous waste management guidance presented in the **General EHS Guidelines**.

- Manage filtering aid mixed with nickel in accordance with the recommendations for nickel catalyst.
- Use uncontaminated sludge and effluent from on-site wastewater treatment as fertilizer in agricultural applications or as a supplemental boiler fuel. Recommendations for the management of EHS issues common to sludge and effluent are provided in the **General EHS Guidelines** and in the **Water and Sanitation EHS Guidelines**. Dispose of contaminated sludge from wastewater treatment at a sanitary landfill or by incineration. Incineration should only be conducted in permitted facilities operating under internationally recognized standards for pollution prevention and control.²

1.1.2 Water Consumption and Management

10. Vegetable oil facilities require significant amounts of water for crude oil production (cooling water), chemical neutralization processes, and subsequent washing and deodorization. General recommendations to reduce water consumption, especially where it may be a limited natural resource, are provided in the **General EHS Guidelines**. Sector-specific recommendations to reduce water consumption, optimize water use efficiency, and reduce subsequent wastewater volumes include the following:

- When economically viable, consider the use of physical refining instead of chemical refining to reduce water consumption.
- Replace water-based conveyor systems by mechanical systems (augers or conveyors).
- Apply Cleaning-in-Place (CIP) procedures to help reduce chemical, water, and energy consumption in cleaning operations.
- Recover and reuse condensate from heating processes.
- Upgrade equipment water sprays (e.g., to include jets or nozzles).
- Use dry cleanup techniques before rinsing floors.
- Manually clean vessels before rinsing to remove solids for recovery or disposal.
- Use high-pressure, low-volume washing systems, and auto shut-off valves.
- Vegetable oil processing wastewater generated during oil washing and neutralization may have a high content of organic material and, subsequently, a high biochemical oxygen demand (BOD) and chemical oxygen demand (COD). Wastewater may also have a high content of suspended solids, organic nitrogen, and oil and fat, and may contain pesticide residues from the treatment of the raw materials. Recommended measures to reduce contaminant loading include the following: install spill collection trays to collect solids at appropriate places in the production line; use emulsion breaking techniques, (e.g., dissolved air flotation (DAF)), to segregate high BOD and COD oils from wastewater.
- Use grids to cover drains in the production area to prevent solid wastes and concentrated liquids from entering the wastewater stream.

² Examples of key environmental issues associated with incineration facilities are available in the IFC's EHS Guidelines for Waste Management Facilities.

- Select disinfection chemicals to match the cleaning operation being applied on the process equipment to the type of problem. Caustics (e.g., lye) are typically used for polymerized fat, and acids are used for lime deposit acids.
- Apply cleaning chemicals using the correct dose and application method.
- Properly treat and discharge cleaning solutions (e.g., through a soap-splitting process) to separate oil and fatty acids from the water phase and then pass through a fat trap.
- When appropriate and feasible, reduce phosphoric acid in degumming operations through the use of improved neutralization processes or alternative methods, such as enzymatic degumming (this reduces the phosphorus load in the wastewater and also brings about a slight reduction in sludge quantities).

Process Wastewater Treatment

11. Techniques for treating industrial process wastewater in this sector include: grease traps, skimmers, or oil water separators for the removal of floatable solids; flow and load equalization; sedimentation for suspended solids reduction using clarifiers; biological treatment—typically anaerobic, followed by aerobic treatment—for the reduction of soluble organic matter (BOD); biological nutrient removal for reduction in nitrogen and phosphorus; chlorination of effluent when disinfection is required; and dewatering and disposal of residuals. In some instances, composting or land application of wastewater treatment residuals of acceptable quality may be possible. Additional engineering controls may be required to contain and neutralize nuisance odors.

12. The management of industrial wastewater and examples of treatment approaches are discussed in the **General EHS Guidelines**. By employing these technologies and good practice techniques for wastewater management, including a regular program of maintenance, facilities should meet the Guideline Values for wastewater discharge as indicated in the relevant table of Section 2 of this industry sector document.

Other Wastewater Streams

13. Guidance on the management of non-contaminated wastewater from utility operations, non-contaminated stormwater, and sanitary sewage is provided in the **General EHS Guidelines**. Contaminated streams should be routed to the treatment system for industrial process wastewater.

1.1.3 Energy Consumption and Management

14. Vegetable oil processing facilities use energy to heat water and produce steam both for process applications (especially for soap splitting and deodorization) and cleaning processes. Other common energy consumption systems include refrigeration and compressed air. In addition to the energy conservation recommendations provided in the **General EHS Guidelines**, sector-specific recommendations include the following:

- Improve uniformity of feed to stabilize and reduce energy requirements.
- Increase efficiency of air removal in sterilization vessels to improve heat transfer.

- Identify and implement opportunities for process heat exchange; e.g., optimized oil-oil heat exchangers in continuous deodorization.
- Reduce stripping steam consumption by improving process efficiency; e.g., improve stripping tray design. Where possible, consider technologies such as dry ice condensing systems that may lower energy consumption.
- Consider co-generation (combined heat and power (CHP)) to improve energy efficiency.
- Consider more advanced approaches—such as the use of enzymes—for processes such as degumming and oil recovery.
- Where feasible, use anaerobic digestion for wastewater treatment and capture methane for heat and / or power production.

1.1.4 Atmospheric Emissions

Process Emissions

15. Particulate matter (dust) and VOCs are the principal emissions from vegetable oil production and processing. Dust results from the processing, including cleaning, screening, and crushing, of raw materials, whereas VOC emissions are caused by the use of oil-extraction solvents, normally hexane.³ Several sources within vegetable oil processing plants generate solvent emissions, including the solvent-recovery unit, the meal dryer and cooler, leaks in piping and vents, and product storage. Additional emissions will result from the refining process if a fractionation method is used. Small quantities of solvent may be present in the crude vegetable oil if the oil has been extracted by a solvent and will volatilize during the oil refining process, particularly during deodorization. Odor emissions are produced by multiple sources (e.g., cookers, soap splitting, and vacuum generation).

16. Recommended management techniques to prevent and control VOCs include the following:

- Process improvements, for example:
 - Optimize recovery of solvents by distilling the oil from the extractor.
 - Back-vent to the solvent delivery tanks during bulk storage tank filling.
 - Improve exhaust air collection systems.
 - Implement leak prevention systems.
- Adoption of abatement technologies:
 - Recover solvent vapors where feasible, primarily through the use of countercurrent flow desolventizer–toaster in vegetable oil extraction.
 - Use a condenser, a reboiler, and a gravity separator to treat condensates with high solvent content, to reduce both solvent emissions and the risk of explosions in the sewer.
 - Treat hexane-laden air from the condenser/reboiler process with a mineral oil scrubber.
 - Consider cryogenic condensation in the solvent fractionation process. Best practice approaches use a closed loop process in which 99.9 percent of the solvent input is reused.

³ Hexane is classified as a hazardous air pollutant in some jurisdictions.

- Additional recommendations for the prevention and control of VOC emissions are presented in the **General EHS Guidelines**.

17. The recommended management techniques to prevent and control dust and odors include the following:

- Ensure proper maintenance of cleaning, screening, and crushing equipment—including in any ventilation and air handling systems—to reduce emissions of fugitive dust, and avoid the use of compressed air or steam for cleaning.
- Install cyclones and/or fabric filters or electrostatic precipitators on selected vents—including meal dryers, coolers, and grinders—to remove odor emissions.
- Reduce odor emissions (e.g., from soap splitting, cookers in the extraction process, vacuum systems, and pressurized systems) with a caustic, alkaline, or ozone scrubber system, or incinerate the gas in a boiler plant or in separate incinerator systems.

Combustion Products

18. Vegetable oil processing plants are large energy consumers, making use of auxiliary boilers for the generation of steam energy. Emissions related to the operation of these steam energy sources typically consist of combustion by-products, such as NO_x, SO_x, PM, VOCs, and greenhouse gases (CO₂). Recommended management strategies include adoption of a combined strategy, which involves a reduction in energy demand, use of cleaner fuels, and the application of emissions controls, where required. Recommendations on energy efficiency are addressed in the **General EHS Guidelines**.

19. Guidance for the management of small combustion source emissions with a capacity of up to 50 megawatt thermal (MWth), including exhaust emission guidelines, is provided in the **General EHS Guidelines**. Guidance applicable to combustion sources with a capacity greater than 50 MWth is presented in the **EHS Guidelines for Thermal Power**.

1.1.5 Greenhouse Gas Emissions (GHG)

20. Vegetable oil processing produces GHG emissions through the use of fossil energy. Projects should manage energy use in accordance with the **General EHS Guidelines**.

21. The high nutrient loading of wastewater can be a source of methane (CH₄) when treated or disposed of anaerobically. It can also be a source of nitrous oxide (N₂O) emissions associated with the degradation of nitrogen components in the wastewater (e.g., urea, nitrate, and protein). Recommended measures to prevent and control non-fossil-fuel-related GHG emissions include:

- Avoid open anaerobic conditions for wastewater treatment by ensuring a regular program of operational maintenance in the wastewater treatment system.
- Consider biological methods of wastewater treatment, such as anaerobic digestion and methane capture; use of waste effluent for irrigation; co-composting of by-products, where appropriate (e.g., oil palm empty fruit bunches with palm oil mill effluent nutrient waste or olive mill waste residue with wastewater); and detoxification by nitrogen fixation.

1.1.6 Hazardous Materials

22. Vegetable oil processing involves the transport, storage, and use of bulk quantities of acids, alkalis, solvents, and hydrogen during extraction and refining. Their transport, storage, and handling provide opportunities for spills or other types of releases with potentially negative impacts on soil and water resources. Their flammability and other potentially hazardous characteristics also present a risk of fire and explosions. Hazardous materials should be managed according to the guidance presented in the **General EHS Guidelines**.

1.2 Occupational Health and Safety

23. Occupational health and safety impacts during the construction and decommissioning of vegetable oil processing plants are common to those of most large industrial facilities and their prevention and control are discussed in the **General EHS Guidelines**. Occupational health and safety issues during the operational phase include:

- Chemical hazards
- Physical hazards
 - Confined space entry
 - Electrical hazards
 - Risk of fire and explosion
 - Noise

1.2.1 Chemical Hazards

24. Operators in vegetable oil facilities may be exposed to hazardous substances via, inhalation of hexane or other solvents used for extraction; inhalation of toxic chemicals (e.g., sodium methylate can cause burns on the skin and lung tissue if inhaled); eye or skin exposure to acids or bases; inhalation of dust from the transportation of raw materials (e.g., seeds and beans to the crushing plant); inhalation of dust from meal treatment and shipment; inhalation of dust from bleaching earth, filter aid, and nickel catalyst; and inhalation of aflatoxins present in raw materials. The **General EHS Guidelines** provide guidance on the management of chemical hazards in the workplace.

25. Additional industry-related recommendations include the following:

- In oil extraction areas, ensure that there is adequate air circulation to reduce the concentration of solvents.
- Provide ventilation, especially at workstations devoted to raw-material handling, milling, handling of bleaching earth, and use of solvents.
- Maintain air concentrations of VOCs below 10 percent of lower explosive limits. For hexane, the lower explosive limit is 1.1 percent volume per volume (v/v) and the upper explosive limit is 7.5 percent v/v.
- Ensure proper distillation of oil after extraction for effective solvent removal.
- Prevent leaks and spills of oils in the extraction plant.

- Control the flash-point temperature of the incoming extracted oils and use temperature control for all facilities receiving solvent-extracted oils.
- When feasible, use hot water, rather than solvents, to facilitate cleaning.

1.2.2 Physical Hazards

26. Physical hazards in vegetable oil production and processing facilities are similar to those present in other industry sectors and include the potential for falls caused by slippery floors and stairs; injuries caused by unprotected machinery or moving parts; hazards associated with potential collisions with internal transport, such as trucks; and accidental contact with conveyor systems, such as those used in crushing plants and in the removal of spent earth. The **General EHS Guidelines** provide guidance on the prevention and control of physical hazards.

Confined Space Entry

27. Grain silos present a significant risk of death from asphyxia. Extremely toxic nitrogen oxides and CO₂ begin to accumulate in the head space of the silo within hours of its filling. Tank cars may also represent asphyxia risks if, for example, a tanker is flushed with nitrogen prior to loading. Recommendations for the management of occupational health and safety (OHS) risks associated with confined spaces are provided in the **General EHS Guidelines**.

Electrical Hazards

28. Electrical systems are a source of danger for workers that can lead to injuries or fatalities. The **General EHS Guidelines** provide guidance on hazard prevention and control of electrical systems. Sector-specific recommendations applicable to silo safety are identified below.

Risk of Fire and Explosion

29. Risks of fire and explosion occur at different stages of vegetable oil production and processing and can lead to loss of property, as well as possible injury or fatalities among project workers. General fire safety management should be handled according to the **General EHS Guidelines**. Sector-specific risks are related to the combustibility of vegetable oil and the high volumes of combustible dust present both in grain and oil-seeds handling and in storage facilities. The control and removal of this dust and the control or removal of potential ignition sources are key to eliminating the explosion hazard. The storage of grains and seeds represents a combustion risk, owing to the potential for self-heating and ignition. Silo safety for these products, as well as for oil storage, is critical. Vegetable oil facilities also present the risk of explosions resulting from the volatilization of solvent dissolved in the oil (e.g., hexane), along with the risk of fire from spent bleaching earth with a high iodine-value oil, high ambient temperature, and high circulation-draft of air.

Combustible Dust and Silo Safety

30. The following measures are recommended as a means of preventing and controlling fires and explosions from combustible dust:⁴

- Use recognized international standards in design and operation.⁵
- Classify areas according to respective hazard classes following practices and requirements found in recognized international standards⁶ and deploy intrinsically safe electrical circuits and anti-explosion electrical devices (including lighting).
- Develop and implement a comprehensive maintenance program to avoid dust build-up. Compressed air should not be used for cleaning dust due to the risk of raising the dust level in the atmosphere; all maintenance equipment, especially welding sets and other electrically driven tools, should be regularly inspected and approved for use.
- Avoid heat sources from friction by adopting appropriate practices or technologies.
- Control static electricity. For example, elevator belts should be constructed of anti-static material or have anti-static properties; during pneumatic transfer of combustible substance, ensure electrical bonding and grounding of tanker vehicles to prevent static electricity.
- Provide proper grounding and lightning protection for silos following internationally recognized standards.
- Control access to areas with a high risk of explosion, e.g., limit access to qualified personnel only.
- Ensure the tipping area is completely enclosed and that the design and maintenance of the grid in the tipping area prevent stones and metal from entering.
- Separate heating systems and surfaces from dust.
- Deploy dust suppression/control systems in silo elevators and conveyor belts to avoid dust accumulation in grain transferring areas; e.g., in tipping areas, a dust control system should be used, ideally installed below the grid and above the receiving hopper.
- Ensure that emergency plans and procedures are developed and understood by staff. Install suitable detection equipment in silos, such as temperature sensor cables and gas detectors. Spark/heat detectors should be connected to an extinguishing system installed in transport systems (belt conveyors, dust extraction systems, etc.) to reduce the risk of ignition.

⁴ Persson (2013); Krause (2009); France, MEDDAT (2008).

⁵ E.g., EN 1127-1 Explosive Atmospheres - Explosion Prevention and Protection; EN 13463-1 Non-Electrical Equipment for Potentially Explosive Atmospheres; NFPA 61: Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities, 2013 Edition; NFPA 654 Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids; OSHA 29 CFR 1910.272 Grain Handling Facilities Standard.

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9874; Directive 94/9/EC on Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres (ATEX) <http://ec.europa.eu/enterprise/sectors/mechanical/documents/legislation/atex/>; Arrêté du 29/03/04 relatif à la prévention des risques présentés par les silos de céréales, de grains, de produits alimentaires ou de tout autre produit organique dégageant des poussières inflammables, http://www.ineris.fr/aida/consultation_document/5163.

⁶ US National Electrical Code.

- Establish a suitable extinguishing operation (e.g., water, foam, inert gas, powder) based on the silo construction and bulk material stored. The silo should be prepared with connections or openings suitable for the planned method and silo construction; e.g., pipe systems and connections should be located at the top of the silo wall if the roof is not considered sufficiently strong to withstand an explosion.
- Consider a separate emergency discharge system (i.e., a separate conveyor at the silo outlet) to a safe place outside the silo to reduce risk of fire spreading inside the plant and ensure firefighting equipment is present. If ordinary transport systems are to be used for emergency discharge, consider chain and screw conveyors to avoid generating heat from friction.
- Consider a fixed gas fire extinguishing system, adapted to the diameter and construction of the silo, to enable a quick and appropriate response to fire.
- Ensure vessels or tanks have sufficient emergency venting capacity to relieve excessive internal pressure in the event of fire; if the silo is contained within a plant, evacuate gases outside

Processing Risks

31. Other fire and explosion risks in vegetable oil processing include flammable atmospheres produced from hexane leakage,⁷ air entrained in the deodorizer at high temperatures, and the potential for auto-ignition of spent bleaching earth. Where further modification of the processed oil takes place, risks such as explosions from hydrogen leaks (in the hydrogenation stage) or the production of flammable substances may be present. The following measures are recommended to prevent and control these risks:⁸

- Ensure regular and proper maintenance of equipment to avoid leaks.
- Establish procedures for startup, shutdown, and maintenance, and train personnel to identify air leaks and react to the outbreak of fires.
- Connect a nitrogen supply line to the deodorizer so that the oxygen level can be decreased in the event of fire.
- The deodorizer should be protected from overpressure by a bursting disc and a pressure relief valve combination.
- Store catalyst drums in enclosed, dry areas with grounded electrical connections. Transport bags from the drum to the dosing system within a container to avoid contact with moisture. Use the complete contents of bags; do not leave contents unused, as this could also cause contact with moisture.

Noise

32. Operators in vegetable oil plants are also exposed to noise from internal transport, conveyors, boilers, pumps, fans, and various steam and air leaks. The **General EHS Guidelines** provide guidance on the prevention and control of exposure to noise.

⁷ E.g., Fediol (2006); Directive 94/9/EC on Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres (ATEX) <http://ec.europa.eu/enterprise/sectors/mechanical/documents/legislation/atex/>; NFPA-36 Solvent Extraction Plants.

⁸ Hamm, W., R. J. Hamilton, and G. Calliauw (Eds) 2013.

1.3 Community Health and Safety

33. Community health and safety impacts during the operation phase of vegetable oil processing are common to most industry sectors—including those related to traffic safety during transport of raw materials and finished products—and are discussed in the **General EHS Guidelines**. Industry-specific issues that could affect the community or the public at large may include the potential presence of pathogens and contaminants in processed oil (e.g., pesticide residues).

1.3.1 Food Safety Impacts and Management

34. Food safety is an industry-specific risk relevant to vegetable oil processing. For example, a product recall caused by contaminated or adulterated products found in commerce that is attributable to a specific company can damage a viable business. If a company can trace its products back to specific lot numbers, then a recall is a matter of removing all non-conforming products associated with the specific lot numbers.

35. With a food safety management system in place, the company can protect itself against product adulteration, contamination, and the impacts of product recalls. Vegetable oil processing should therefore be performed according to internationally recognized food safety standards consistent with the principles of Hazard Analysis Critical Control Points (HACCP),⁹ Food and Agriculture Organization (FAO)/World Health Organization (WHO) *Codex Alimentarius*, and *ISO 22000*. Recommended product safety principles include the following:

- Fully institutionalize HACCP prerequisites, including: sanitation, good management practices, implementation of integrated pest and vector management programs, and maximization control through mechanical means (e.g., traps and mesh on doors and windows), chemical control, allergen control, and the establishment of a customer complaints mechanism.
- Consider enhanced monitoring schemes for dioxin and dioxin-like polychlorinated biphenyls (PCBs).¹⁰
- All personnel should receive training to ensure they are aware of potential microbiological contamination and growth during processing, material handling, storage and maintenance (e.g., salmonella contamination).
- Food grade-quality fresh bleaching earth should be used for processing food and feed-grade products to avoid risks to public health from food and feed contamination.¹¹

⁹ ISO 2005.

¹⁰ Fediol 2006.

¹¹ Available at: <http://www.acgih.org/TLV/> and <http://www.acgih.org/store/>

2. PERFORMANCE INDICATORS MONITORING

2.1 Environment

2.1.1 Emissions and Effluent Guidelines

36. Tables 1 and 2 present emissions and effluent guidelines for this sector. Guideline values for process emissions and effluents in this sector are indicative of good international industry practice as reflected in relevant standards of countries with recognized regulatory frameworks. Effluent guidelines are applicable to direct discharges of treated effluents to surface waters for general use. Site-specific discharge levels may be established based on the availability and conditions in use of publicly operated sewage collection and treatment systems or, if discharged directly to surface waters, based on the receiving water use classification, as described in the **General EHS Guidelines**.

TABLE 1. EFFLUENT GUIDELINES FOR VEGETABLE OIL PROCESSING		
POLLUTANTS	UNITS	GUIDELINE VALUE
pH	pH	6–9
BOD ₅	mg/l	50
COD	mg/l	250
Total nitrogen	mg/l	10
Total phosphorus	mg/l	2
Oil and grease	mg/l	10
Total suspended solids	mg/l	50
Temperature increase	°C	<3 ^b
Total coliform bacteria	MPN ^a / 100 ml	400
Active Ingredients / Antibiotics	To be determined on a case-specific basis	
Notes:		
^a MPN = Most Probable Number.		
^b At the edge of a scientifically established mixing zone that takes into account ambient water quality, receiving water use, potential receptors, and assimilative capacity.		

TABLE 2. AIR EMISSIONS GUIDELINES FOR VEGETABLE OIL PROCESSING		
POLLUTANTS	UNITS	GUIDELINE VALUE
Dust ^a	mg/Nm ³	10 (dry dust) 40 (wet dust)
Hexane ^b	mg/Nm ³	100
VOCs ^c	kg solvent loss/t feedstock	Animal fat: 1.5 Castor: 3 Rape seed: 1 Sunflower seed:1 Soya beans (normal crush): 0.8 Soya beans (white flakes):1.2 Other seeds and other vegetable matter: 1.5 (fractionation excluding degumming) 4 (degumming)
Notes:		
^a Dust level of 10 mg/Nm ³ for dry dust can be achieved by applying cyclones and bag filters on selected vents, e.g. from meal dryers, coolers, and grinders. A dust level of 40 mg/Nm ³ for wet dust can be achieved by applying cyclones and/or multicyclones.		
^b Applies to the solvent plant and can be achieved by application of cyclones.		
^c Refers to total solvent loss, European Solvent Directive 1999 (Council Directive 1999/13/EC of 11 March 1999. on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations).		

37. These guidelines are achievable under normal operating conditions in appropriately designed, operated, and maintained facilities through the application of the pollution prevention and control techniques discussed in the preceding sections of this document. These levels should be achieved, without dilution, at least 95 percent of the time during which the plant or unit is operating, to be calculated as a proportion of annual operating hours. Deviation from these levels in consideration of specific, local project conditions should be justified in the environmental assessment.

38. Emissions guidelines are applicable to process emissions. Combustion source emissions guidelines associated with systems designed to deliver electrical or mechanical power, steam, heat, or any combination of these, regardless of the fuel type, with a total, rated heat input capacity of between three Megawatt thermal (MWth) and 50 MWth are addressed in the **General EHS Guidelines**, with larger power source emissions covered by the **EHS Guidelines for Thermal Power**. Guidance on ambient considerations based on the total load of emissions is provided in the **General EHS Guidelines**.

2.1.2 Resource Use and Waste

39. Table 3 presents information on resource use and waste generation in the vegetable oil processing sector that can be considered as indicators of this sector's efficiency and may be used to track performance changes over time. Industry benchmark values are provided for comparative purposes only; individual projects should target continual improvement in these areas. Note that the volume of wastewater produced depends highly on the raw material processed and its quality, as well as the processing technology applied.

2.2 Occupational Health and Safety

2.2.1 Occupational Health and Safety Guidelines

40. Occupational health and safety performance should be evaluated against internationally published exposure guidelines, examples of which include the Threshold Limit Value (TLV®) occupational exposure guidelines and Biological Exposure Indices (BEIs®), published by the American Conference of Governmental Industrial Hygienists (ACGIH);¹² the Pocket Guide to Chemical Hazards, published by the United States National Institute for Occupational Health and Safety (NIOSH);¹³ Permissible Exposure Limits (PELs), published by the Occupational Safety and Health Administration of the United States (OSHA);¹⁴ Indicative Occupational Exposure Limit Values, published by European Union member states;¹⁵ or other similar sources.

2.2.2 Accident and Fatality Rate

41. Projects should try to reduce the number of accidents among project workers (whether directly employed or subcontracted) to a rate of zero, especially accidents that could result in lost work time, different levels of disability, or even fatalities. Facility rates may be benchmarked against the performance

¹² Available at: <http://www.acgih.org/TLV/> and <http://www.acgih.org/store/>

¹³ Available at: <http://www.cdc.gov/niosh/npg/>

¹⁴ Available at: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992

¹⁵ Available at: http://europe.osha.eu.int/good_practice/risks/ds/oel/

of facilities in this sector in developed countries through consultation with published sources (e.g., U.S. Bureau of Labor Statistics and U.K. Health and Safety Executive).¹⁶

TABLE 3. RESOURCE AND ENERGY CONSUMPTION			
INPUTS PER UNIT OF PRODUCT	UNIT	BENCHMARK	
Water Use^a			
Crude oil production – wastewater	m ³ /t raw material	0.2–0.5	
Crude oil production – cooling water	m ³ /t raw material	2–14	
Chemical neutralization	m ³ /t product	1–1.5	
Deodorization	m ³ /t product	10–30	
Hardening	m ³ /t product	2.2–7	
Chemical consumption^a			
Caustic soda	kg/t crude oil	1–6*	
Phosphoric acid	kg/t crude oil	0.1–2.0	
Citric acid	kg/t crude oil	0.1–1.0	
Sulfuric acid	kg/t soap	100–250	
ENERGY USE	STEAM ^b (MJ/t FINAL PRODUCT)	ELECTRICITY (MJ/t FINAL PRODUCT)	TOTAL ENERGY (MJ/t FINAL PRODUCT)
Neutralization	112–280	22–44	145–330
Soap splitting ^c	560–2800 ^c	11–36 ^c	620–2850 ^c
Deodorization ^d			
Batch	420–1120 ^e	60–150	510–1350
Semi-continuous			
Continuous			
Source: EC 2006.			
^a Range depends on the free fatty acid content.			
^b Calculated using 2.8 x kg steam/t = MJ/t (EC 2006).			
^c MJ/t soap.			
^d Batch and semi-continuous deodorization can achieve the lowest steam consumption figures in the ranges quoted and at the low end of the range for total energy use.			
^e Substantially lower steam consumption figures are possible with the use of dry condensing technology, which can achieve as low as around 70MJ steam/t final product for dry condensing units in continuous and semi-continuous deodorization (Hamm et al. 2013).			

¹⁶ Available at: <http://www.bls.gov/iif/> and <http://www.hse.gov.uk/statistics/index.htm>

2.2.3 Occupational Health and Safety Monitoring

42. The working environment and workers' health should be monitored for occupational hazards and diseases relevant to the specific project. Monitoring should be designed and implemented by accredited professionals,¹⁷ as well as applicable prevention or protection measures, as part of an occupational health and safety monitoring and prevention program. Facilities should also maintain a record of occupational accidents, diseases, and dangerous occurrences and other accidents. The **General EHS Guidelines** provide additional guidance on occupational health and safety monitoring programs.

¹⁷ Accredited professionals may include certified industrial hygienists, registered occupational hygienists, or certified safety professionals or their equivalent.

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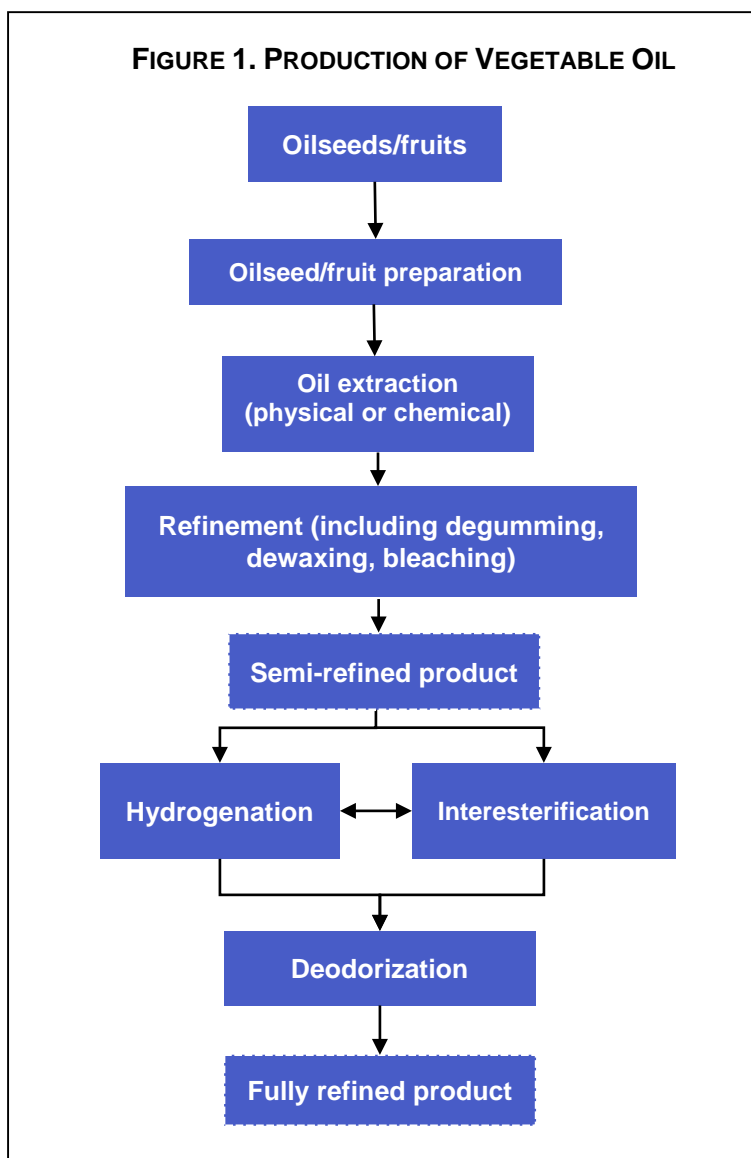
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ANNEX A. GENERAL DESCRIPTION OF INDUSTRY ACTIVITIES

43. The vegetable oil processing industry extracts and processes oils and fats from vegetable sources. Vegetable oils and fats are principally used for human consumption, but they are also used in animal feed, for medicinal purposes, and for certain technical applications. In developing countries, the production of crude palm oil (CPO) is typically carried out in CPO mills associated with the plantations. CPO is then transported to refineries all around the world. A significant part of the CPO, however, is processed locally and exported as Refined, Bleached, and Deodorized (RBD) quality oil.

44. Figure 1 presents a simplified flow diagram of vegetable oil production. The main steps in vegetable oil processing are extraction, refinement, other modification, and deodorization.



A.1 Extraction

45. Oil is extracted from beans, grains, seeds, nuts, and fruits. The raw materials are received and weighed at the facility, cleaned to remove stalks, stones, and other matter, then weighed and stored before initial processing. The type of storage depends on the raw material, (e.g. soybeans are stored in grain elevators). The critical factor in determining the storage life of seed material is its moisture content; the higher the moisture and the hotter the climate, the shorter the secure storage time. The raw materials are prepared using a variety of processes, including husking or hulling, flaking, cleaning, drying, crushing, conditioning, and pressing. Environmental, health, and safety issues from the raw material preparation phase include particulate emissions (e.g., from cleaning and drying), and solid waste (e.g., empty fruit bunches EFB) resulting from threshing operations, as well as sticks, stems, pods, sand, and dirt.

46. Oil extraction can be performed mechanically (e.g., by boiling fruits and pressing seeds and nuts) or in combination with a chemical extraction process using solvents (usually hexane). Most large-scale commercial facilities use chemical extraction (with hexane), owing to a better process efficiency in producing the meal and oil. During solvent extraction, hexane is used to wash the processed raw materials, typically in a countercurrent extractor. The extraction is normally followed by skimming (boiled oils) or filtration (pressed fats), and separation of the crude oil from the solvent-oil mixture (miscella). Hexane is removed from the oil through distillation, and from the flakes through steam vapor in a desolventizer, and recovered for reuse after condensation and separation from water. The recovery processes for flakes that are intended for animal consumption typically use conventional distillation to remove hexane in a desolventizer-toaster. The desolventized flakes are then ground for use as meal (e.g., soybean meal). The process for flakes that are intended for human consumption uses specialty or “flash” distillation, in which superheated hexane is used in a vacuum, followed by steam stripping. Flash distillation removes more residual hexane from the flakes, but it uses more energy and generates more emissions than the conventional process.¹⁸

Examples:

Palm Oil Extraction¹⁹

47. Palm fruit is processed to produce crude palm fruit oil and crude palm kernel oil. The fruit grows in clusters on a central, branched stalk rather similar to grapes and consists of oily pulp surrounded by a tough outer skin containing seeds (or kernels) in the pulp. Palm fruit oil is extracted from the pulp and palm kernel oil is extracted from the seed. During harvest, the bunches are loaded into trucks or railway cars and taken to the extraction facility. The sterilizing cars are rolled into cylindrical sterilizing chambers and steam is sparged into the chamber. The heat sterilizes the fruit to prevent bacterial or enzymatic activity from attacking the oil. The length of time in the sterilization chamber depends on the size and maturity of the fruit.

48. After sterilization, the fruits are removed from the stems in threshing equipment and then washed before being transported to a twin-screw press that squeezes out the palm fruit oil. The extracted palm fruit oil is clarified in a continuous decanter or settling tank to remove water and solid matter. The cake from the screw press consists of moist pulp solids, kernels (or seeds), and the outer skin of the fruit. The

¹⁸ MOEA.

¹⁹ Shahidi & Bailey 2005.

kernels are separated from the fiber and cellular debris and conditioned by lowering their moisture level, so that the meat shrinks loose from the shell. The kernels are then cracked and the meats are separated from the shells, either by mixing them into an aqueous slurry of clay or salt so that the kernels float and the shells sink or by mixing them with water and passing the mixture through a liquid cyclone (the heavier shells pass out of the bottom and the lighter meat floats to the top). The meats are then dried and sent for storage before being pressed in screw presses to produce palm kernel oil.

Olive Oil Extraction²⁰

49. Olives are ground into a paste through milling, which is followed by mashing, possibly with the addition of salt. The pulp is then pressed and the press oil is clarified by sedimentation or centrifugation. Traditional open-cage presses are now being replaced by continuous screw expellers. The mashed pulp can also be separated in a horizontal decanter, in which case the crude oil is re-centrifuged after the addition of wash-water. Alternatively, machines can be used to remove the kernels from the pulp and the residue is then separated using self-discharging centrifuges. Cold pressing, which yields virgin grades, is generally followed by a warm pressing at approximately 40 °C.

50. A two-phase centrifuge generates a paste-like waste, whereas the traditional and the three-phase systems produce a liquid phase, i.e. olive mill wastewater, or alpechin and a press cake known as pomace. This latter product may be further treated as husk or pomace oil. The remaining solid husk is dried to 3 to 6 percent humidity and used as fuel. Olive kernel oil is obtained by pressing and solvent extraction of cleaned kernels. In some countries, warm-pressed olive oil with a high acidity is refined by neutralization, bleaching, and deodorization, and flavored by blending with cold-pressed oil. The press cake contains 8 to 15 percent of a relatively dark oil that can be extracted with hexane and is used for technical purposes. After refining, it is also fit for edible consumption.

A.2 Refinement

51. The crude oil is refined to remove undesired impurities, such as gums, free fatty acids (FFA), traces of metals, coloring components, and volatile components. During refining, the FFA are removed to the level of less than 0.1 percent in the refined oil, either by chemical or physical refining. Physical refining generally has a lower environmental impact than chemical refining. Conversely, chemical refining results in a better product quality in terms of lower FFA levels, longer shelf life, and a more reliable process.²¹

52. Crude oil contains free fatty acids and gums that must be removed before the oils can be used in foods. Before refining occurs, degumming may be applied to the crude oil. Degumming is an essential step of the physical refining process because the oil entering the final deodorization has to have a low content of phosphatide. Degumming is also used in conjunction with chemical refining. Degumming methods can either be acidic or enzymatic. In acidic degumming, phosphoric acid is added to remove phosphatides, phospholipids, and lecithins. Degummed oil has a phosphorus content of less than 30 parts per million (ppm). Citric acid may be used instead of phosphoric acid, which brings a range of advantages, including reduced phosphorus load in the wastewater and a slight reduction in the amount of sludge. Enzymatic degumming uses enzymatic hydrolysis of the phosphatides. Environmental benefits

²⁰ EC 2006.

²¹ Ibid.

from this approach include reduced consumption of phosphoric and sulfuric acid, as well as caustic soda, water, and energy.

Chemical Refining

53. Conventional chemical refining involves degumming (for the removal of phospholipids), neutralization (for the removal of FFA), bleaching (for decolorization) and deodorization. Hydratable phospholipids can be removed by water degumming. The mixture is then centrifuged for separation. Nonhydratable phospholipids are removed during so-called acid degumming before water is added and separation takes place in a centrifuge. This is usually the first stage of physical refining and can be considered the equivalent process to alkali neutralization in chemical refining. Enzymatic degumming uses enzymes to degrade the phospholipids. The first step is acid conditioning/pH adjustment of the crude or water-degummed oil before the enzyme is added. A short reaction time and higher dosage is generally preferred over long reaction time with lower enzyme dosage.

54. During degumming, caustic soda is added to the oil, which has been preheated to between 75°C and 110°C to saponify the FFA. This process gives rise to two main outputs, namely semirefined oil and soap stock. The soap stock is removed by precipitation, followed by sedimentation or centrifugation, and may be further processed into acid oils by splitting. The soap stock is heated to between 70°C and 100°C and reacts with sulfuric acid to reform the fatty acids. The resulting by-products can be sold to the paints and cosmetics sector, as well as to the animal feed industry. The neutralized oil is bleached to remove coloring matter and other minor constituents prior to deodorization. Spent bleaching earth is the main solid waste arising from this stage.

Physical Refining

55. Physical refining is a more simple process in which the crude oil is degummed and bleached, and then steam-stripped to remove FFA, odor, and VOCs all in one step. A physical pretreatment can be used to achieve a low phospholipid content by degumming and using bleaching earth. Following this, FFA can be stripped from the physically pretreated oil using steam in a vacuum at temperatures of around 250°C and refined by the oil flowing over a series of trays countercurrent to the flow of the stripping steam. Previous neutralization stages are not necessary because the neutralization and deodorization are combined. A scrubber is then used to condense the greater part of the fat from the vapors as a water-free product.²²

A.3 Other Modification

Hydrogenation

56. Most installations carry out hydrogenation to produce fats with superior retention qualities and higher melting points. Before entering the reactor and mixing with hydrogen, the fresh oil is deaerated and dried in a buffer tank kept under reduced pressure. Hydrogenation is usually carried out by dispersing hydrogen gas in the oil in the presence of a finely divided catalyst (usually nickel), supported on diatomaceous earth. Other catalysts (palladium, rhodium, platinum) are being explored in light of their potential to reduce the formation of trans-fatty acids during hydrogenation. The resultant hydrogenated fats are

²² EC 2006.

filtered to remove the hydrogenation catalyst, subjected to a light earth bleach, and deodorized before they can be used for edible purposes. After hardening, the oil is mixed with an aqueous solution to produce an emulsion. The emulsified mixture is then pasteurized, cooled, and crystallized to obtain the final product.²³

Interesterification

57. Interesterification involves the separation of triglycerides into fatty acids and glycerol, followed by recombination. The reaction is carried out using phosphoric or citric acid with a catalyst, typically sodium methoxide. Interesterification modifies the functional properties of the treated oil and may be carried out after neutralization or deodorization.

A.4 Deodorization

58. During deodorization, the bleached oil is steam-distilled at low pressure to remove volatile impurities, including undesirable odors, flavors, and pigments. Volatile components are removed from the feedstock using steam in a process that may last from 15 minutes to five hours. The vapors from the deodorizer contain air, water vapor, fatty acids, and other variables. Before entering the vessel, the vapors pass through a scrubber and a scrubbing liquid is sprayed into the vapor stream. Fatty acids and volatiles partly condense on the scrubbing droplets or alternatively on the packing material. The deodorization process produces the fully refined, edible oils and fats.²⁴

A.5 Resource Consumption

59. Vegetable oil processing facilities use energy to heat water and produce steam for process applications (especially for soap splitting and deodorization) and for cleaning processes. Energy consumption will vary according to the oil type (e.g., the energy needed for cold-pressing unconditioned olive oil is twice as great as the energy needed for pressing heat-conditioned oilseeds) and the process technology. Recent developments in the deodorization process that use dry (ammonia) condensing units have reduced energy consumption significantly.

60. Water is mainly used for neutralization and deodorization, and both processes produce wastewater with a high organic load. Typically, used chemicals include alkalis such as caustic soda and sodium carbonate; acids, including phosphoric acid, citric acid, and sulfuric acid; Ni-catalysts; and methylates. Solvents such as acetone, ethanol, and methanol are sometimes used instead of, or to supplement, hexane in the extraction process. Hexane can cause health problems in relatively low concentrations and other dangerous chemicals, including strong acids and bases, present significant health and safety hazards.

61. In parallel with the primary production of vegetable oil, some by-products—such as oils for animal feed or pharmaceutical products—are often produced by further processing of residues. This processing can reduce volumes of solid waste, including fractions like spent bleaching earth that can be reused for energy production through direct incineration or biogas production, either on-site or at another location. Citric acid and phosphoric acid are used in degumming operations.

²³ Ibid.

²⁴ EC 2006.