

Environmental, Health, and Safety Guidelines for Sugar Manufacturing

Introduction

The Environmental, Health, and Safety (EHS) Guidelines are reference documents designed to provide project developers, financiers, facility managers, and other decision makers with relevant industry background and technical information. This information supports actions aimed at avoiding, minimizing, and controlling EHS impacts during the construction, operation, and decommissioning phases of a project or facility.*

How to Use This Document

The EHS Guidelines for sugar manufacturing provide information that is specific to facilities in this industry sector. They are organized according to the following sections.

Section 1.0 — Industry-Specific Impacts and Management
Section 2.0 — Performance Indicators and Monitoring
Section 3.0 — References and Further Information
Annex A — General Description of Industry Activities

They are designed to be jointly used with the **General EHS Guidelines** document, which provides the user with guidance on common EHS issues potentially applicable to all industry sectors. On complex projects, multiple industry-sector guidelines may be useful. A complete list of industry-sector guidelines can be found at www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines

* **Note:** Attribution of all references, including verification for completeness and accuracy, to be completed for final draft.

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. The applicability of the EHS Guidelines may need to be 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.

Applicability

This document includes information relevant to sugar manufacturing projects and facilities. **Annex A contains a full description of industry activities for this sector.** This document does not include agriculture and field activities, which are included in the EHS Guidelines for Plantation Crop Production.

1.0 Industry-Specific Impacts and Management

The following section provides a summary of EHS issues associated with sugar manufacturing that occur during the operational 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

Environmental issues in sugar manufacturing projects primarily include the following:

- Solid waste and by-products
- Wastewater effluent
- Emissions to air
- Water consumption
- Energy consumption

Solid Waste and By-Products

Sugar industry activities generate large quantities of organic solid waste and by-products, such as leaves from cane or beet, molasses from the final crystallization, press mud or cachaza, bagasse fiber from the cane, mud and soil arriving at the plant with the raw material, and lime solids from the juice clarification. Generated mainly from the primary treatment of raw materials, these waste materials may also present a risk from pesticide residues. The amount of waste generated depends on the quality of the raw materials themselves and on the initial cleaning in the field. The generation of higher quality waste can provide opportunities for reprocessing of otherwise discarded

raw materials into commercially viable by-products such as paper making and particle board manufacturing, providing a potential additional source of revenue. Other solid wastes from the sugar manufacturing process include spent filter material such as active carbon, resins from the ion exchange process, acids from chemical cleaning of equipment, vinasse or spent wash from the distillation of fermented molasses-sugar juice, and ashes from the steam boiler plant.

The recommended techniques for prevention and control of solid waste from sugar cane and beets include the following:

- Avoid burning cane leaves in the field before harvest; the trimmings from the sugar cane should be spread in the field to biodegrade;
- Use bagasse (waste fiber) from the cane as fuel for steam and power generation; depending on production capacity and raw material input volumes, using bagasse as a fuel can meet the plant energy demand and may generate excess electrical energy for sale;
- Use molasses beneficially as a feedstock for
 - Fermentation and organic chemical manufacturing
 - Production of citric acid and yeast
 - Distillation industries
 - Organic chemical manufacturing (for example, ethanol)
- Use beet leaves and roots, which enter the plant as part of the raw material and accumulate during the washing process, as an energy-rich feed for ruminants;
- Collect waste products, such as beet tops from the washing process, for use in by-products or as animal feed;
- Convert beet pulp into cattle feed—during the processing season it can be sent as return loads on empty beet lorries;

- Separate stones from the beet during the washing process and reuse in other industrial applications, including road building and construction industries;
- Remove soil and earth from the beet while in the field and before transport to reduce the risk of spreading pesticide residues;
- Use organic material in the wastewater and the spent wash from distillation to produce biogas;
- Use filter and dry lime from the juice clarification process to make a soil-conditioning product for agricultural land;
- Compost organic solids from press mud (cane laundry) to make high-quality organic manure for agricultural production;
- Use uncontaminated sludge from on-site wastewater treatment as fertilizer in agriculture.

Sludge Treatment and Disposal

Recommended methods for the treatment of sludge from wastewater treatment include the following:

- Aerobic stabilization or anaerobic digestion; anaerobic stabilization improves the sludge applicability to agriculture;
- Gravity thickening;
- Sludge dewatering on drying beds for small-scale facilities and dewatering using belt presses and decanter centrifuges for medium- and large-scale facilities;
- Using sludge from concentrated sugar juice prior to evaporation and crystallization, known as cane mud or cachaza, to produce organic manure and soil for agricultural applications.

Wastewater

Sugar processing wastewater has a high content of organic material and subsequently a high biochemical oxygen demand (BOD₅), particularly because of the presence of sugars and

organic material arriving with the beet or cane. Wastewater resulting from the washing of incoming raw materials may also contain crop pests, pesticide residues, and pathogens.

Wastewater Management

Recommended wastewater management includes the following prevention strategies:

- Reduce the organic load of liquid waste by preventing the entry of solid wastes and concentrated liquids into the wastewater stream:
 - Prioritize the removal of waste in its solid form; implement dry precleaning of raw material, equipment, and production areas before wet cleaning;
 - Fit and use floor drains and collection channels with grids and screens or traps to reduce the amount of solids entering the wastewater;
 - Avoid direct runoff to watercourses, especially from tank overflows.

Wastewater Treatment

Wastewater from sugar manufacturing facilities has a high organic load and should be treated on site before discharge to municipal sewers or directly to a recipient water body. Typical levels of biochemical oxygen demand (BOD₅) are 1,700-6,600 milligrams per liter (mg/L) in untreated effluent from cane processing and 4,000-7,000 mg/L for beet processing, while COD ranges are 2,300-8,000 mg/L from cane processing and up to 10,000 mg/L in beet processing. Wastewater sludge from sugar manufacturing should be, to the extent feasible, returned to agricultural fields, as it is a good source of basic plant nutrients and provides carbon for soils. The sugar manufacturing industry typically employs a primary treatment involving filtering, sedimentation, and skimming of fat and floating sludge. Use of secondary and advanced treatment will

depend on site-specific discharge requirements for receiving water body use and may include further treatment at municipal or other off-site wastewater treatment facilities before discharge. A more detailed discussion of wastewater treatment and discharge approaches is discussed in the **General EHS Guidelines**.

Emissions to Air

Air emissions in sugar manufacturing are primarily related to particulate matter generated from bagasse-fired steam boilers, dust from unpaved access roads and areas, and sugar drying or packing activities. In addition, odor emissions are generated from beet processing activities and storage facilities. Beet factory juice clarification produces a sweet odor, which can be irritating. Inadequate cleaning of the raw material may result in fermented juice, which will also create a foul smell.

Particulate Matter and Dust

Recommended measures to prevent or control particulate matter include the following:

- Operate bagasse-fired steam boilers while targeting emissions guidelines applicable to the combustion of solid fuels presented in the **General EHS Guidelines**. Typical control methods include boiler modifications or add-on controls, such as flue gas cyclones and wet scrubbers and local recirculation systems to capture the ash and recycle the water to prevent the emission of particulate;¹
- Reduce fugitive dust from roads and areas by cleaning and maintaining a sufficient level of humidity;
- Install ventilation systems with filters on transport systems for dry sugar and on sugar packing equipment.

¹ The appropriate level of control for bagasse-fired boilers may need to be evaluated on a case-by-case basis as determined by model-predicted impacts on ambient quality.

Odor

Recommended measures to prevent or control odor in beet processing facilities include the following:

- Keep beet processing and storage facilities clean to avoid the accumulation and fermentation of juice;
- Use wet scrubbers to remove odors with a high affinity to water, for example, the ammonia emitted from the drying of beet pulp;
- Ensure that vapor from the carbonation section is emitted from a stack of sufficient height.

Water Consumption and Management

Sugar manufacturing requires considerable quantities of high-quality water for raw material cleaning, sugar extraction, final sugar washing, and cooling and cleaning equipment. Water vapor is essential to the evaporation and heating of the various process steps in sugar processing. Beet and cane raw materials also contain high percentages of water, which can be recovered and reused during processing. General water conservation and management is covered in the **General EHS Guidelines**. Additional industry-specific measures applicable to sugar manufacturing include:

- Recycle process water and apply to the washing of incoming raw material;
- Use closed loops for intensive solid generating washings, such as cane and beet wash, and flue gas scrubbers.

Energy Consumption and Management

Sugar manufacturing facilities use energy to heat water and produce steam for process applications and cleaning purposes. Reducing energy consumption will have a positive effect on air emissions. General energy conservation and management is

covered in the **General EHS Guideline**. Additional industry-specific recommendations include:

- Install steam turbine-based combined heat and power technology, enabling the plant to generate its own process steam and electricity requirements and sell excess electricity to other consumers on the national grid;
- Use waste fiber or bagasse from the cane as fuel for steam and power generation. Ensure that bagasse moisture level is below 50 percent before it is used as boiler fuel to improve its calorific value and overall efficiency for steam generation and avoid the need for supplemental fuels. Depending on production capacity and raw material input volumes, using bagasse as a fuel can meet the plant energy demand, even generating excess electrical energy for sale;
- Anaerobically digest high-strength organic wastes such as vinasse or spent wash from distillery and organic chemical manufacturing to produce biogas. Use biogas to fire distillery boilers or to operate combined heat and power systems generating electric energy and hot water or steam;
- Keep heating surfaces clean by adding chemicals to prevent incrustations. Incrustations are generated by mineral salts that are not removed in during clarification and may be prevented or reduced by adding special polymers to the thin juice;
- Ensure even energy consumption by management of batch processes (centrifuges, vacuum pans) to schedule energy demand and equalize steam demand on the boilers;
- Reuse vapor from vacuum pans for heating juice or water;
- Use an evaporator with at least five effects; and
- Combine drying of beet pulp with the main energy system in the factory to achieve an overall energy system.

- Select the operating conditions of the boiler and steam turbine system to match the heat-power ratio of the utility system to that of the plant. If, despite selection of a high pressure boiler, the plant needs to pass more steam through the turbine than it uses in process to generate sufficient electricity, then it should condense rather than vent this steam.

1.2 Occupational Health and Safety

Occupational health and safety hazards for sugar manufacturing facilities are similar to those of other industrial facilities.

Recommendations for the management of these issues can be found in the **General EHS Guidelines**. In addition, occupational health and safety issues that may be specifically associated with sugar manufacturing operations include the following:

- Physical hazards
- Exposure to dust and biological hazards
- Exposure to chemicals (including gases and vapors)
- Exposure to heat and cold and radiation
- Exposure to noise and vibrations

Physical Hazards

The most common risks for accidents in sugar manufacturing are trips and falls caused by slippery floors, stairs, and elevated platforms, the incorrect use of equipment (for example, packaging and transport equipment), contact with sharp edges on process equipment (for example, replacing worn beet slicing knives in the slicing machines), and explosions (for example, sugar drying and storing, gas, fuels, boilers).

Recommendations for the management of these issues can be found in the **General EHS Guidelines**.

Repetitive Work Injuries

Sugar manufacturing activities may include a variety of situations in which workers can be exposed to lifting, carrying, repetitive work, and work posture injuries. Recommended management approaches to reduce these injuries are discussed in the **General EHS Guidelines**.

Dust and Biological Hazards

Workers are exposed to dust (including biological and microbiological agents) during the sugar drying and packing processes. Recommendations for the management of these issues can be found in the **General EHS Guidelines**.

Heat, Cold, and Radiation

Workers can be exposed to heat, cold, and radiation from changes in the internal climatic conditions caused by cold and warm areas or activities and exposure to heat (for example, from boilers or hot equipment). Recommended measures to prevent and control exposure to heat, cold, and radiation are discussed in the **General EHS Guidelines**.

Noise and Vibrations

Noise and vibrations result from a variety of sources, including internal and external transportation, flow in pipelines, lime milling, rotating machinery ventilators, turbines, and compressors. Recommended measures to prevent and control exposure to noise are discussed in the **General EHS Guidelines**.

1.3 Community Health and Safety

Community health and safety impacts during the construction, operation, and decommissioning of sugar manufacturing plants are common to those of other industrial facilities, and are discussed in the **General EHS Guidelines**.

2.0 Performance Indicators and Monitoring

2.1 Environment

Emissions Guidelines

Combustion source emissions guidelines associated with steam and power generation activities from sources with a capacity equal to or lower than 50 thermal megawatts are addressed in the **General EHS Guidelines**; larger power source emissions are addressed in the thermal power EHS Guidelines. Guidance on ambient considerations based on the total load of emissions is provided in the **General EHS Guidelines**.

Effluent Guidelines

Table 1 presents effluent guidelines for this sector. These guidelines are achievable under normal operating conditions in appropriately designed and operated facilities through the application of 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 that 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.

Effluent guidelines are applicable for 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, on the receiving water use classification as described in the **General EHS Guidelines**.

Table 1. Effluent levels for sugar manufacturing

Pollutant	Unit	Guideline Value
pH	pH	6–9
BOD	mg/L	50
COD	mg/L	250
Total nitrogen	mg/L	15 ^a
Total phosphorus	mg/L	5 ^a
Oils, and grease	mg/L	10
Biocides	mg/L	0.05
Total suspended solids	mg/L	50

^a Nitrogen and phosphorus play important roles in the eutrophication of freshwater and marine environments, so discharge of these nutrients to surface waters needs to be limited. Maximum levels for discharge may need to be modified from the representative numbers given here, in order to reflect specific characteristics of the receiving environment.

Environmental Monitoring

Environmental monitoring programs for this sector should be implemented to address all activities that have been identified to have potentially significant impacts on the environment, during normal operations and upset conditions. Environmental monitoring activities should be based on direct or indirect indicators of emissions, effluents, and resource use applicable to the particular project.

Monitoring frequency should be sufficient to provide representative data for the parameter being monitored. Monitoring should be conducted by trained individuals following monitoring and record-keeping procedures and using properly calibrated and maintained equipment. Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Additional guidance on applicable sampling and analytical methods for emissions and effluents is provided in the **General EHS Guidelines**.

Resource Use

Table 2 provides examples of resource consumption indicators in this sector. Industry benchmark values are provided for comparative purposes only and individual projects should target continual improvement in these areas.

Table 2. Resource and energy consumption

Input per unit of product	Mass load unit	Industry benchmark
Energy (fuel and electricity) consumption in beet industry	kWh/ton beet	300 ^a
	MJ/ton beet	819 ^b
Additional fuel consumption in cane industry	L fuel/ton cane	0
Water consumption per unit of production	m ³ /ton cane	0.5
	m ³ /ton beet raw materials	0.5 ^a

^a EC (2005)
^b CEFS (2003)

2.2 Occupational Health and Safety

Occupational Health and Safety Guidelines

Occupational health and safety performance should be evaluated against internationally published exposure guidelines, of which examples include the Threshold Limit Value (TLV[®]) occupational exposure guidelines and Biological Exposure Indices (BEIs[®]) published by American Conference of Governmental Industrial Hygienists (ACGIH),² the United States National Institute for Occupational Health and Safety (NIOSH),³ Permissible Exposure Limits (PELs) published by the Occupational Safety and Health Administration of the United States (OSHA),⁴ Indicative Occupational Exposure Limit Values published by European Union member states,⁵ or other similar sources.

Accident and Fatality Rates

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 of facilities in this sector in developed countries through consultation with published sources (e.g. US Bureau of Labor Statistics and UK Health and Safety Executive)⁶.

Occupational Health and Safety Monitoring

The working environment should be occupational hazards relevant to the specific project. Monitoring should be designed and implemented by credentialed professionals⁷ as part of an

occupational health and safety monitoring program. Facilities should also maintain a record of occupational accidents and diseases and dangerous occurrences and accidents. Additional guidance on occupational health and safety monitoring programs is provided in the **General EHS Guidelines**.

² <http://www.acgih.org/TLV/>
³ <http://www.cdc.gov/niosh/npg/>

⁴ http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992

⁵ http://europe.osha.eu.int/good_practice/risks/ds/oe/

⁶ <http://www.bls.gov/iif/> and <http://www.hse.gov.uk/statistics/index.htm>

⁷ Credentialed professionals may include Certified Industrial Hygienists, Registered Occupational Hygienists, or Certified Safety Professionals or their equivalent.

3.0 References

- Arbejdstilsynet. 2005. Anmeldte arbejdsbetingede lidelser 1999–2000. Årsopgørelse 2004. Copenhagen: Arbejdstilsynet. (Reported accumulated occupational disease 1999–2004. Annual report 2004). Available at <http://www.at.dk/graphics/at/07-Arbejdsmiljoe-i-tal/02-Arbejdsskader/Aarsopgoerelser/Anmeldte-arbejdsbetingede-lidelser-2004.pdf>
- BLS (US Bureau of Labor Statistics). 2004a. Industry Injury and Illness Data – 2004. Supplemental News Release Tables. Table SNR05: Incident rate and number of nonfatal occupational injuries by industry, 2004. Available at <http://www.bls.gov/iif/home.htm>, and <http://www.bls.gov/iif/oshwc/osh/os/ostb1479.pdf>
- BLS (US Bureau of Labor Statistics). 2004b. Census of Fatal Occupational Injuries Charts, 1992–2004. Table (p.10): Number and rate of fatal occupational injuries by private industry sector, 2004. (). Available at <http://www.bls.gov/iif/oshwc/cfoi/cfch0003.pdf>
- CEFS (European Committee of Sugar Manufacturers). 2001. Guide to Establishing BAT in the Sugar Industry. CEFS.
- CEFS (European Committee of Sugar Manufacturers). 2003. Environmental Report Beet Growing and Sugar Production in Europe. CEFS. Available at <http://www.comitesucre.org/www/pdf/environ.pdf>
- EC (European Commission). 2005. Integrated Pollution Prevention and Control, Reference Document on Best Available Techniques in the Food, Drink and Milk Industries. Adopted final draft. EC. Available at <http://eippcb.jrc.es/pages/FActivities.htm>
- EC (European Communities). 1996. Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control (IPPC). EC. Available at http://europa.eu.int/eur-lex/en/consleg/pdf/1996/en_1996L0061_do_001.pdf
- Exposure to Endotoxins and Microbes in the Treatment of Waste Water and in the Industrial Debarking of Wood. Available at http://europe.osha.eu.int/OSHA/index.html/newsboard_view
- FAO and WHO (Food and Agriculture Organization of the United Nations and World Health Organization). 1962–2005. Codex Alimentarius. Geneva: FAO and WHO. Available at http://www.codexalimentarius.net/web/index_en.jsp
- Harrison, Tom, et al. 1999. Investing in Sugar in Emerging Markets. International Sugar Journal 101.: Commonwealth Development Corporation.
- HSE (Health and Safety Executive UK). United Kingdom, Food and Drink Manufacture. London: HSE. Available at <http://www.hse.gov.uk/food/index.htm>
- ICIDCA (Instituto Cubano de Derivados de la Caña de Azúcar). Manual de los Derivados de la Caña de Azúcar. Havana: ICIDCA. Available at <http://www.icidca.cu/Publicaciones/Manual.htm>
- NSW . Sugar Milling, Waste Minimization and Energy Efficiency. NSW. Available at <http://www.deh.gov.au/settlements/industry/corporate/eecp/case-studies/nswsugar.html>
- Queensland Government. HS Codes for Sugar Industry. Queensland. Available at <http://www.dir.qld.gov.au/workplace/law/codes/sugar/index.htm>
- hailand MOSTE (Ministry of Science, Technology and Environment). 1996. Industrial Effluent Standard. Source: Notification the Ministry of Science, Technology and Environment, No. 3, B.E.2539 (1996) issued under the Enhancement and Conservation of the National Environmental Quality Act B.E.2535 (1992). MOSTE. Available at http://www.pcd.go.th/info_serv/en_reg_std_water04.html#s1

Annex A: General Description of Industry Activities

Sugar Manufacturing facilities have traditionally processed beet and cane into crystalline sugar and limited byproducts such as ethanol and other organic chemicals. The model modern sugar mill may be an electric power plant providing electrical energy to the local grid and organic chemicals operations; and, can be highly sustainable as all wastes can be reused beneficially. In fact many can be used to generate additional energy.

Additionally factories process the beet and cane into other sucrose products such as liquid sugar, organic sugar, and organic syrup. Crystalline sugar is packed and distributed to industry or consumers. The liquid sugar is distributed in bulk to industries. In some industries, the process is split up by sending raw sugar to a different facility for final refinement. In some sugar factories, sugar juice and/or molasses are rendered into by-products, mainly alcohol.

Sugar processing facilities are typically located outside of, or on the outskirts of, urban centers, which allows proximity to raw material supply and reduces potential disturbance to neighbors. Cane processing factories are located in tropical or subtropical areas because cane is not frost tolerant. Traditionally, beet factories have been located in colder climates, but attempts are being made to develop new varieties of tropical beet, because it consumes less water in the field than cane. Factories receiving beet or cane are highly seasonal—the season length for beets is 6 to 18 weeks and for cane is 20 to 32 weeks.

Factory size is related to logistics, such as transport volume and the weight of the raw material. Rapid processing of the raw material is important for product quality and process efficiency. Beet may be stored for longer periods in colder climates, allowing a relatively long operational season. Typical cane processing installations can process between 500 tons cane/24 hrs to 10,000 tons cane/24 hrs, and some installations have a

production capacity of 20,000 tons cane/day. Typical beet processing installations can process between 2,000 tons beet/24 hrs to 15,000 tons beet/24 hrs. More than 70 percent of the world's sugar production is based on sugar cane, with the remainder based on sugar beet. Approximately 10 percent of the raw material can be processed to commercial sugar, and this percentage varies according to geographic and operational conditions. Sugar cane contains 70 percent water, 14 percent fiber, 13.3 percent saccharose (about 10 to 15 percent sucrose), and 2.7 percent soluble impurities. Sugar beet has a water content of 75 percent, and the saccharose concentration is approximately 17 percent. Trends in the sector and market are toward larger units, increased focus on product safety, improved product quality, increased level of processing, and better working conditions. The main environmental, health, and safety impacts and risks associated with sugar processing occur during the operational phase of the project life cycle, which is the focus of the following general description of industry activities.

Beet and cane sugar production processes are similar. Both involve reception, cleaning, extraction, juice clarification, evaporation, crystallization centrifugation, drying, storing, and packing as illustrated in figures A-1 and A-2. Beet and cane sugar manufacturing are typically located adjacent to the sources of raw materials to reduce costs and transportation time to ensure fresh raw material (the latter factor is most relevant in warm climates). If possible, plants are also distributed in proximity to product markets. Sugar can be economically distributed by trucks in a radius of around 500 km from the plant, but competition and market demand are important factors to be assessed. If the plant is located near a harbor, products can be distributed at a very long distance. A sugar factory (beet with 1,000 tons/day white sugar production capacity) typically needs around 400,000 square meters (m²) in a flat area, plus some

additional area (for example, 250,000 m²) available for future expansion. A typical project lifespan is at least 40–50 years, because the investment involved is around US\$1,500–2,500 per ton sugar produced per year.⁸

As the simplified process diagrams illustrate, various operations are performed in cane and beet sugar manufacture.

The most important by-product of the sugar production is molasses, which is the liquor generated by the process of separating the crystals in the centrifuges. In the process, the molasses is recirculated a number of times to improve the yield of crystalline sugar, but the final molasses still contains some sugar with noncrystalline sugars, minerals, and color particles. The molasses can be used as cattle fodder or as raw material in the fermentation industry. To facilitate the use of the molasses, which is generated in relatively high volumes, and take advantage of the combined process facilities, sugar factories can be combined with distillation plants. The basis for the distillery can be sugar juice, molasses, or a combination of these. Beet and cane processing differ mainly with respect to the treatment of the raw material from factory reception to the extraction of sugar.

Reception of Beet and Cane

Sugar beet and cane are generally unloaded from the transportation vehicle after a sample has been taken for assessment of sugar and dirt content. The beet production line runs continuously at full capacity, whereas the sugar cane production line usually has to stop every 14 days to facilitate removal of encrustations on heating surfaces. Because there may be some restrictions on night transport of raw materials, the cane and beet processing facilities should have big enough areas to stockpile enough raw materials to facilitate continuous production.

⁸ From Commonwealth Development Corporation (1999).

Figure A-1. Sugar Manufacture from Beet
Source: Adapted from CEFS (2003).

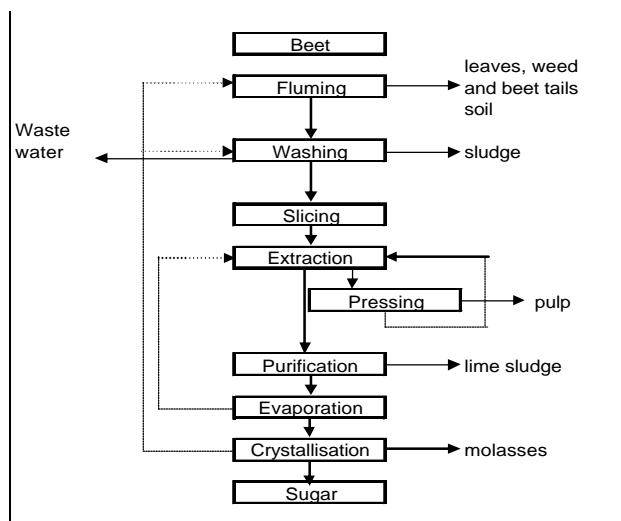
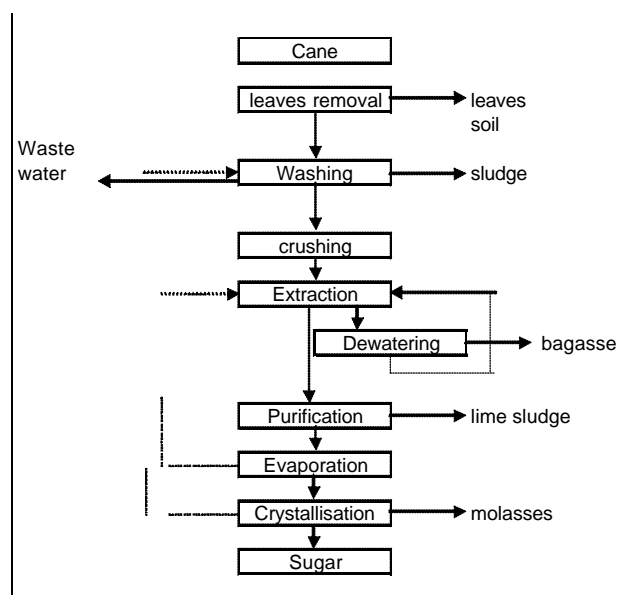


Figure A-2. Sugar Manufacture from Cane
Source: Adapted from CEFS (2003).



Washing and Extraction of Cane

Traditionally, cane has been burned in the field before transport to processing facilities to remove any leaves from the cane stalk. The current trend is to harvest green unburned cane, returning leaves to the field where the crop residue promotes soil conservation. Cane factories may have washing operations followed by disintegration of the raw material by knives and hammer mills. Extraction of the sugar juice is traditionally done by roller mills, which press out the juice. The remains of the cane stalk are called “bagasse,” which contains cellulose fiber. This is mostly used in the process facility as fuel for energy supply. Where fuel is available from another source, the bagasse may be used for derivative processing in the cellulose industry. In some places (for example, South Africa), cane juice extraction is performed by a diffusion leaching process, which can give higher rates of extraction with roughly 50% less energy consumption than a mechanical mill. An additional benefit is reduced operating and maintenance costs. This approach is beginning to take hold in Latin America as companies refit and reconstruct old mills.

Washing and Extraction of Beet

Washing of sugar beet is water intensive, so recirculation of wash water should be ensured. In the washing stage soil, stone and leaves are separated from the beet and left as a by-product. Because of the intensive washing and grading of materials, the stone that outputs from the washing process will be available in a well-controlled size that is readily useable in other industries, for example, as gravel for the construction industry. Disintegration of the beet is done by cutting into slices, called “cossettes,” and the juice is extracted by a diffuser extractor where the slices are mixed with hot extraction water to form a roughly 15 percent sugar solution, also known as diffusion juice. The exhausted beet

cossettes in the beet pulp are then pressed and dried to produce a high-energy and top-quality animal feed. If the remaining beet pulp is dried, storage capability is increased, and transport over a longer distance is viable. Drying used to be done with fuel burners, but new methods use steam integrated in the factory steam supply, thus reducing overall energy consumption.

Clarification, Evaporation, and Crystallization

The juice resulting from the extraction process is clarified by mixing it with milk of lime and then filtered or clarified to remove the mud. In beet-based sugar production, the lime is produced from limestone, which is combusted in a specially designed lime kiln. The main outputs are burnt limestone and carbon dioxide (CO₂). The burnt limestone is used to generate milk of lime and the CO₂ is also added to the liquid in a process called carbonation. Because large quantities of milk of lime and gas are needed, this is a continuous process. These substances are added to the juice and, in the process of carbonation, bind other components such as protein to the lime particles. The lime is then filtered, resulting in lime sludge and dried for use as a soil conditioning agent in agriculture. The resultant clear solution of juice is called “thin juice.”

The carbonation process gives good results, but it is rarely used in the cane industry because of the investment required and a general lack of the main raw material, limestone. Cane processing facilities typically purchase ready-made burnt limestone powder and use this to generate milk of lime. Solids are removed by settling.

After clarification, the thin juice has a sugar content of 15 percent. It has to reach concentrations greater than 68 percent to allow sugar crystallization, and this is achieved through evaporation. At the evaporation station, the water is

removed by evaporation from the thin juice in a series of evaporating vessels until a syrup with a dry matter content of 68–72 percent is obtained. This thick juice is further evaporated until sugar crystals form, and the crystals and the accompanying syrup are then centrifuged to separate the two components. The final syrup, which contains 50 percent sugar, is called molasses. Sugar crystals are then dried and stored. Storing is done in silos in more developed facilities. Crystals may be further refined before bagging for shipment. Refining of the raw sugar may also take place in a different location from the initial processing and can thus be done year-round.

Refinery Operation

Refining of sugar involves removal of impurities and decolorization. The steps generally followed include affination (mingling and centrifugation), melting, clarification, decolorization, evaporation, crystallization, and finishing. Decolorization methods use granular activated carbon, powdered activated carbon, ion exchange resins, and other materials.

Distillery

A sugar-based distillery may employ batch or continuous fermentation followed by the distillation, which may produce ethanol with a purity of 95 percent. This ethanol can be used in other industries or further processed to be blended with gasoline. Waste from the distillation process known as vinasse or spent wash has a BOD concentration of ~60,000 ppm. Anaerobic digestion of this waste is used to produce biogas and can be utilized for the production of boiler fuel for the distillery or to fuel CHP engines. After removing the energy from this waste it can be returned to agricultural fields and/or used in composting of organic solids emanating from processing. After concentration of sugar juice and crystallization molasses remains. It makes excellent feedstock for organic chemical and a host of other manufacturing products. In some applications in Latin America it is used for soil solidification to promote land claiming and cane rearing.