Organic waste treatment technologies

Characteristics of organic wastes

Almost all kinds of organic wastes can be recycled into valuable products according to the technologies outlined in Chapter 1. In designing facilities for the handling, treatment, and disposal/reuse of these wastes, knowledge of their nature and characteristics is essential for proper sizing and selecting of a suitable technology. This chapter will describe characteristics of organic wastes generated from human, animal and some agro-industrial activities. Pollution caused by these organic wastes, and possible diseases associated with the handling and recycling of both human and animal wastes are described. A section on cleaner production is presented to emphasize the current trend of waste management. The analysis of physical, chemical and biological characteristics of the organic wastes can be done following the procedures outlined in "Standard Methods for the Examination of Water and Wastewater (APHA, AWWA, WEF 2005) and Official Methods of Analysis of the Association of Official Analytical Chemists (AOAC 2000); while the significance of these characteristics for waste treatment and recycling can be found in Chemistry for Environmental Engineering and Science (Sawyer *et al.* 2003) and Wastewater Engineering: Treatment, Disposal and Reuse (Metcalf and Eddy Inc. 2003).

2.1 HUMAN WASTES

Excreta is a combination of feces and urine, normally of human origin. When diluted with flushing water or other grey water (such as from washing, bathing and cleansing activities), it becomes domestic sewage or wastewater. Another type of human wastes, called solid wastes, refers to the solid or semi-solid forms of wastes that are discarded as useless or unwanted. It includes food wastes, rubbish, ashes and residues, etc.; in this case, the food wastes which are mostly organic are suitable to be recycled.

The quantity and composition of human excreta, wastewater and solid wastes vary widely from location to location depending upon, for example, food diet, socio-economic factors, weather and water availability. Therefore, generalized data from the literature may not be readily applicable to a specific case and, wherever possible, field investigation at the actual site is recommended prior to the start of facility design.

2.1.1 Human excreta

Literature surveys by Feachem *et al.* (1983) found the quantity of feces production in some European and North American cities to be between 100 to 200 g (wet weight) per capita daily, while those in developing countries are between 130-520 g (wet weight) per capita daily. Most adults produce between 1 to 1.3 kg urine depending on how much they drink and the local climate. The water content of feces varies with the fecal quantity generated, being between 70-85%. The composition of human feces and urine is shown in Table 2.1. The solid matter of feces is mostly organic, but its carbon/nitrogen (C/N) ratio is only 6-10 which is lower than the optimum C/N ratio of 20-30 required for effective biological treatment. If such processes as composting and/or anaerobic digestion are to be employed for excreta treatment, other organic matters high in C content are needed to be added to raise the C/N ratio. Garbage (food wastes), rice straw, water hyacinth, and leaves are some easily available C compounds used to mix with excreta. A person normally produces from 25 to 30 g of BOD_5 daily through excreta excretion.

In areas where sewerage systems are not available, excreta is commonly treated by on-site methods such as septic tanks, cesspools, or pit latrines. Periodically (about once in every 1-5 years), septage or the sludge produced in septic tanks and cesspools needs to be removed so that it does not overflow from the tanks to clog the soakage pits (Figure 2.1) or the drainage trenches (soakage pit and/or drainage trench is a unit where septic tank/cesspool overflow flows into and from where it seeps into the surrounding soil where the soil microorganisms will biodegrade its organic content). The most satisfactory method of septage removal is to use a vacuum tanker (size about 3-10 m^3) equipped with a pump and a flexible suction hose (Figure 2.1). If vacuum tankers are not available, the septage has to be manually collected by shovel and buckets; in this case the laborer who does the septage emptying can be subjected to disease contamination from the septage, and the practice is considered to be unaesthetic and unhygienic.

Table 2.1 Composition of human feces and urine[a]

	Feces	Urine
Quanity (wet) per person per day	100-400 g	1 - 1.31 kg
Quanity (dry solids) per person per day	30 - 60 g	50 -70 g
Moisture content	70 -85 %	93 - 96 %
Approximate composition (percent dry weight)		
Organic matter	88 - 97	65 - 85
Nitrogen (N)	5.0- 7.0	15 – 19
Phosphorus (as P_2O_5)	3.0 - 5.4	2.5 - 5.0
Potassium (as K_2O)	1.0 - 2.5	3.0 - 4.5
Carbon (C)	44 - 55	11.0 - 17.0
Calcium (as CaO)	4.5	4.5 -6.0
C/N ratio	~ 6 -10	1
BOD_5 content per person per day	15 - 20 g	10 g

[a] Adapted from Gotaas (1996) and Feachem *et al.* (1983)

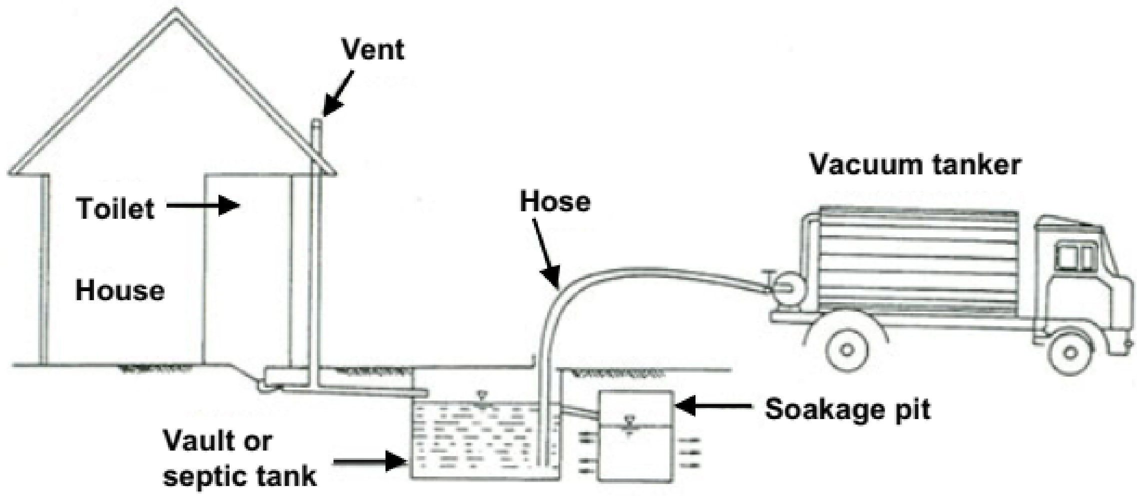


Figure 2.1 Vacuum tanker removing septage

Septage is characterized by high solid and organic contents, large quantity of grit and grease, great capacity to foam upon agitation, and poor settling and dewatering characteristics. A highly offensive odor is often associated with brown to black septage. The composition of septage is highly variable from one location to another. This variation is due to several factors including: the number of people utilizing the septic tank and their cooking and water use habits, tank size and design, climatic conditions, septage pumping frequency, and the use of tributary appliances such as kitchen waste grinders and washing machines.

Table 2.2 summarizes the septage characteristics in the U.S.A. and Europe/Canada as reported in the literature. The last column of this table shows the suggested design values of the septage characteristics for use as guidelines in the design and operation of septage handling and treatment facilities. Characteristics of some septage in Asia are shown in Table 2.3.

Brandes (1978) reported that longer detention time of septage in the tanks contributed to better decomposition of organic materials and, consequently, to lower amounts of septage pumped out per year. He found the septage accumulation rate for the residents of Ontario, Canada, which is applicable for septage disposal and treatment planning, to be approximately 200 L per capita yearly. Septage accumulation rates under Japanese conditions were estimated to be 1-1.1 L per capita daily (or 365-400 L per capita yearly) (Pradt 1971). However, field investigations at the actual site are strongly recommended prior to the inception of detailed planning and design of septage treatment facilities. Because of its concentrated characteristics, septage needs to be properly collected and treated prior to disposal. On the other hand, its concentrated form would be advantageous for reclaiming the valuable nutrients contained in it.

Human excreta that is deposited in pit latrines normally stay there under anaerobic conditions for 1-3 years prior to being dug out for possible reuse as a soil conditioner or fertilizer. The rather long period of anaerobic decomposition in pit latrines will cause the excreta to be well stabilized and most pathogens inactivated.

2.1.2 Wastewater

Urban cities in developed countries and many cities in developing countries have sewerage systems to carry wastewater from households and buildings to central treatment plants. This wastewater is a combination of excreta, flushing water and other grey water or sullage, and is much diluted depending on the per capita water uses. According to White (1977), the volume of water used ranges from a daily mean consumption per person of a few L to about 25 L for rural consumers without tap connections or standpipes. The consumption is 15-90 L for those with a single tap in the household, and 30-300 L for those with multiple taps in the house.

Table 2.2 Physical and chemical characteristics of septage, as found in the literature, with suggested design values[a,b] (adapted from U.S. EPA 1994)

Parameters	United States				Europe/Canada				EPA mean	Suggested design value
	Average	Minimum	Maximum	Variance	Average	Minimum	Maximum	Variance		
TS	34,100	1,130	130,475	115	33,800	200	123,860	619	38800	40,000
VSS	9030	95	51500	542	29900	4000	52,370	13	8,720	10,000
BOD_5	6480	440	78600	179	8340	700	25000	36	5,000	7,000
COD	31900	1500	703000	469	28975	1300	114870	88	42,850	15,000
TKN	550	66	1060	16	1070	150	2570	17	680	700
Total P	210	20	760	38	155	20	640	32	250	250
Grease	5600	210	23370	112	-	-	-	-	9,090	8,000
pH	-	1.5	12.6	8	-	5.3	9	-	6.9	6.0
LAS[c]	-	110	200	2	-	-	-	-	157	150
Total coliforms	-	10^7	10^9	-	-	-	-	-	-	-
Fecal coliforms	-	10^6	10^8	-	-	-	-	-	-	-

[a] Values expressed as mg/L, except for pH, which is unitless and total and fecal coliforms which are no./100 mL
[b] The data presented in this table were complied from many sources. The inconsistency of individual date sets results in some skewing of the data and discrepancies when individual parameters are compared. This is taken into account in offering suggested design value
[c]LAS = linear alkylbenzene sulfonate, used in making detergents

Table 2.3 Characteristics of septage in Asia[a]

	Japan[b]	**Bangkok, Thailand[c]**
pH	7-9	7-8
TS	25,000-32,000	5,000-25,400
TVS		3,300-19,300
TSS	18,000-24,000	3,700-24,100
VSS	3,500-7,500	-
BOD_5	4,000-12,000	800-4,000
COD	8,000-15,000	5,000-32,000
NH_3-N	-	250-340
Total P	800-1,200	-
Total coliforms, no/100mL	10^6-10^7	10^6-10^8
Fecal coliforms, no/100mL	-	10^5-10^7
Bacteriophages, no/100 mL	-	10^3-10^4
Grit (%)	0.2-0.5	-

[a] Values expressed as mg/L, except for pH and those specified
[b] Date from Magara *et al.* (1980)
[c] Data from Arifin (1982) and Liu (1986)

It should be noted that households with per capita water consumption less than 100 L per day may produce wastewater containing very high solids content which could possibly cause sewer blockage. The strength of a wastewater depends mainly on the degree of water dilution which can be categorized as strong, medium, or weak as shown in Table 2.4. These wastewater characteristics can vary widely with local conditions, hour of the day, day of the week, seasons, and types of sewers (either separate or combined sewers where storm water is included). It is seen from Table 2.4 that domestic wastewaters generally contain sufficient amounts of nutrients (based on BOD_5: N: P ratio) suitable for biological waste treatment and recycling, where microbial activities are employed.

In sewerless areas where septic tanks or cesspools are employed for wastewater treatment, the hydraulic retention time (HRT) designed for these units are only about 1-3 days to remove the settleable solids and retain the scum. Because of short HRT, the effluent from a septic tank or septic tank overflow is still obnoxious liquor, containing high concentrations of organic matter, nutrients, and enteric microorganisms. The septic tank effluent is normally treated through a subsurface soil absorption system or soakage pits (as shown in Figure 2.1) (Polprasert and Rajput 1982). Where land is not available for the treatment of septic tank effluent, the effluent can be transported, via small-bore sewers, to a central wastewater treatment/recycling plant (small-bore sewers have diameters smaller than conventional sewers and carrying only liquid effluents from septic tanks or aqua privies). The characteristics of septic tank effluent are more or less similar to those of the wastewater (Table 2.4), but contain less solid content.

Table 2.4 Typical characteristics of domestic wastewater (all values are expressed in mg/L)

Parameters	Concentration		
	Strong	**Medium**	**Weak**
BOD_5	400	200	100
COD	800	400	250
Org.-N	25	15	8
NH_3	50	25	12
Total-N	70	40	20
Total-P	15	8	4
Total solids	1200	720	350
Suspended solids	400	200	100

Data adapted from Metcalf and Eddy Inc.(2003)

2.1.3 Solid wastes

Solid wastes generated from human activities include those from residential, commercial, street sweepings, institutional and industrial categories. Table 2.5 is a comparative analysis of solid waste characteristics of some developing and developed countries. The percentages of food wastes (organic matter) were 60 -70 for the developing countries (Thailand and Egypt) which were a few folds higher than those of the developed countries (U.K. and U.S.A.). On the other hand, paper and cardboard were found to be higher in the solid wastes of the developed countries. The quantity of solid waste generation is generally correlated with the per capita income and affluence, i.e. the higher the income the greater the amount of solid wastes generated. The global range of solid waste generation is 0.2-3 kg per capita daily (Pickford 1977). Solid waste generation rates of less than 0.4 kg per capita daily can be applied to some cities of developing countries and a range of 1.0 – 1.5 kg per capita daily for major cities and tourism areas. Generation rates greater than 2 kg per capita daily are applicable to several cities in the U.S.A. (Cook and Kalbermatten 1982; and Pickford 1977).

Since the food waste portion of the solid wastes is suitable for recycling (e.g. through composting and anaerobic digestion), it should be ideally stored and collected separately for this purpose. However, for convenient and practical reasons, food waste is normally collected together with other kinds of wastes to be processed and treated at a solid waste treatment plant. If composting is to be employed as a means to stabilize and produce fertilizer from the solid wastes, several methods of solid waste processing have to be utilized to separate out the food waste.

2.2 ANIMAL WASTES

The amount and composition of animal wastes (feces and urine) excreted per unit of time also vary widely. They depend on various factors such as the total live weight of the animal (TLW), animal species, animal size and age, feed and water intake, climate, and management practices, etc. For design of facilities for animal waste collection and treatment, measurements and samples should be taken at the farm site or (if the farm is not built) at similar sites. For planning purpose, Taiganides (1978) suggests that the general guideline values given in Table 2.6 may be used. Young animals excrete more waste per unit of TLW than mature animals. The quantities of wastewater or wastes to be handled would, in general, be larger than those given in Table 2.6, due to the addition of dilution water, washwater, moisture absorbing materials and litter, etc.

Table 2.7 shows the approximate weights of animals, the quantity of waste produced and their BOD_5 values. The annual production of nutrients from animal wastes is given in Table 2.8. During storage of animal wastes, a considerable portion of N which exists in the form of ammonia (NH_3) is lost through NH_3 volatilization.

Table 2.6 Bioengineering parameters of animal wastes (Taiganides 1978)

Parameters	Symbol	Units	Pork pigs	Laying hens	Feedlot beef	Feedlot sheep	Dairy cattle
Wet waste	TWW	%TLW/day	5.1	6.6	4.6	3.6	9.4
Total solids	TS	%TWW	13.5	25.3	17.2	29.7	9.3
		%TLW/day	0.69	1.68	0.7	1.07	0.89
Volatile solids	TVS	%TS	82.4	72.8	82.8	84.7	80.3
		%TLW/day	0.57	1.22	0.65	0.91	0.72
Biochemical oxygen demand	BOD_5	%TS	31.8	21.4	16.2	8.8	20.4
		%TVS	38.6	29.4	19.6	10.4	25.4
		%TLW/day	0.22	0.36	0.13	0.09	0.18
COD/BOD_5 ratio	COD/BOD_5	ratio	3.3	4.3	5.7	12.8	7.2
Total nitrogen	N	%TS	5.6	5.9	7.8	4.0	4.0
		%TLW/day	0.039	0.099	0.055	0.043	0.043
Phosphate	P_2O_5	%TS	2.5	4.6	1.2	1.4	1.1
		%TLW/day	0.017	0.077	0.008	0.015	0.010
Potash	K_2O	%TS	1.4	2.1	1.8	2.9	1.7
		%TLW/day	0.01	0.035	0.013	0.031	0.015

TLW = Total live weight of animal

For systems handling animal wastes as solids (>30%TS), N losses will range from 20% in deep lagoons to 55% for open feedlots. For animal waste liquid handling systems (<12%TS), N loses can range from about 25 % in anaerobic lagoons to 80 % for aerated systems (Taiganides 1978). P and K are physically and chemically less mobile than N. However, when applied to land the actual amounts of nutrients available to crops can be much less than those shown in Table 2.8 because of nutrient loss through soil leaching and the inability of crops to utilize the nutrients effectively, etc.

2.3 AGRO-INDUSTRIAL WASTEWATERS

This section will describe six types of agro-industries namely tapioca, palm oil, sugar cane, brewery, slaughter house, and fruit and vegetables. The general processes of the above industries and the quantity and characteristics of waste generation are presented. The processing diagrams of each agro-industry will include the sources of waste generation which should be useful for the environmental engineers and scientists to understand the waste characteristics and to investigate means to reduce waste generation at the industries.

2.3.1 Tapioca industry

Tapioca, also known as cassava or manioc, is grown in most tropical areas of the world. The root of the plant contains approximately 20 percent starch in a cellulose matrix. Tapioca starch is in particular demand for sizing paper or fibres and is also used in food industry.

Tapioca products include pellets, chips and flour. The production of pellets has been increasing steadily, due to increase in demands of pellets as animal feeds from European countries (Unkulvasapaul 1975).

Production of pellets and chips are not water-using processes and hence are not causes of pollution. On the other hand, the production of tapioca flour requires large quantities of water and the resulting wastewaters are highly polluting. About 5 to 10 m^3 of water is used to process one ton of input root, or about 30 to 50 m^3 of water is used per ton of starch produced. The wastewaters produced are organic in nature and highly variable in quantity and quality. They are characterized by high BOD_5 and SS values, with low pH and few nutrients (Jesuitas 1966).

Tapioca processing

The main products of tapioca roots are pellets, chips and flour. Most of these (about 90% by weight) are marketed / exported in the form of pellets.

The manufacture of tapioca products is seasonal: plants begin processing in June and thereon production increases steadily to a peak production period between September and January, then production falls off gradually and comes to a halt in April. A few larger plants operate throughout the year.

Chip and pellet production

Chips are manufactured by chopping the tapioca roots and then spreading them out on large concrete pads for drying. They are either transported directly to market or are pelletized before shipping overseas.

Pellets are produced by pressing chips into a cylindrical shape under high pressure and raised temperature; a small quantity of waste pulp from the starch plant is also added for adhesive purposes. Sometimes, an even smaller quantity of rice bran is added to improve the nutritional value of the pellets.

Flour production

Tapioca starch is produced in two grades by two types of processes. The final quality of starch is, however, similar.

First grade tapioca processes

A typical flow diagram of the first-grade starch plant is illustrated in Figure 2.2. Roots, transported to the plant, should be processed within 24 hours to avoid degradation of the starch. The sand on the roots is first removed by dry rasping in a revolving drum and the peel is then removed by mechanical tumbling in a wash basin, from which the root washwater is derived. The roots are then mechanically crushed, releasing the starch granules from their surrounding cellulose matrix. Most of the cellulose material is removed by centrifugal means in a jet extractor and then by continuous centrifugation. The cellulose material or pulp is sold as poultry feed, provided it is fresh; or dewatered, dried and sold as animal feed. After primary centrifugation, the starch milk is sieved through a series of three sieves decreasing in pore size to assist in separating the starch from the small amount of pulp remaining. The recovered pulp is recycled to the jet extractor and the processed starch milk is led to a second centrifuge, from which wastewater is derived and by which a more concentrated starch is produced. After dewatering to a paste-like substance in a basket centrifuge, the product is spray dried and packed.

As shown in Figure 2.2, there are three main sources of wastewaters, namely that from the root washer, centrifuge 1 and centrifuge 2. These wastewaters are normally combined and treated prior for discharge or reuse. The wastewaters from centrifuge 1 and centrifuge 2 are sometimes called separator wastewater.

Second grade tapioca process

Second-grade tapioca plants are labour intensive, employing simple processes with little mechanization, and are mostly small private-enterprise operations. A typical process flow diagram is shown in Figure 2.3. The roots are washed in a wooden tank with revolving paddles; sand and clay particles as well as some peel are removed at this step. The washed roots are conveyed to the rasper, followed by filtration through nylon mesh supported by a large cylindrical drum. The starch is sprayed through and the pulp is slowly drawn off and collected for dewatering. The starch milk is then released into large concrete settling basins. After 24 hours settlement, the supernatant is removed by decantation. The surface of the starch cake on the bottom is washed; the starch is then resuspended and pumped to a second sedimentation basin. After 24 hours the supernatant is decanted and the surface is then washed again. The starch is then removed in large cakey chunks and spread on a heated concrete pad to dry.

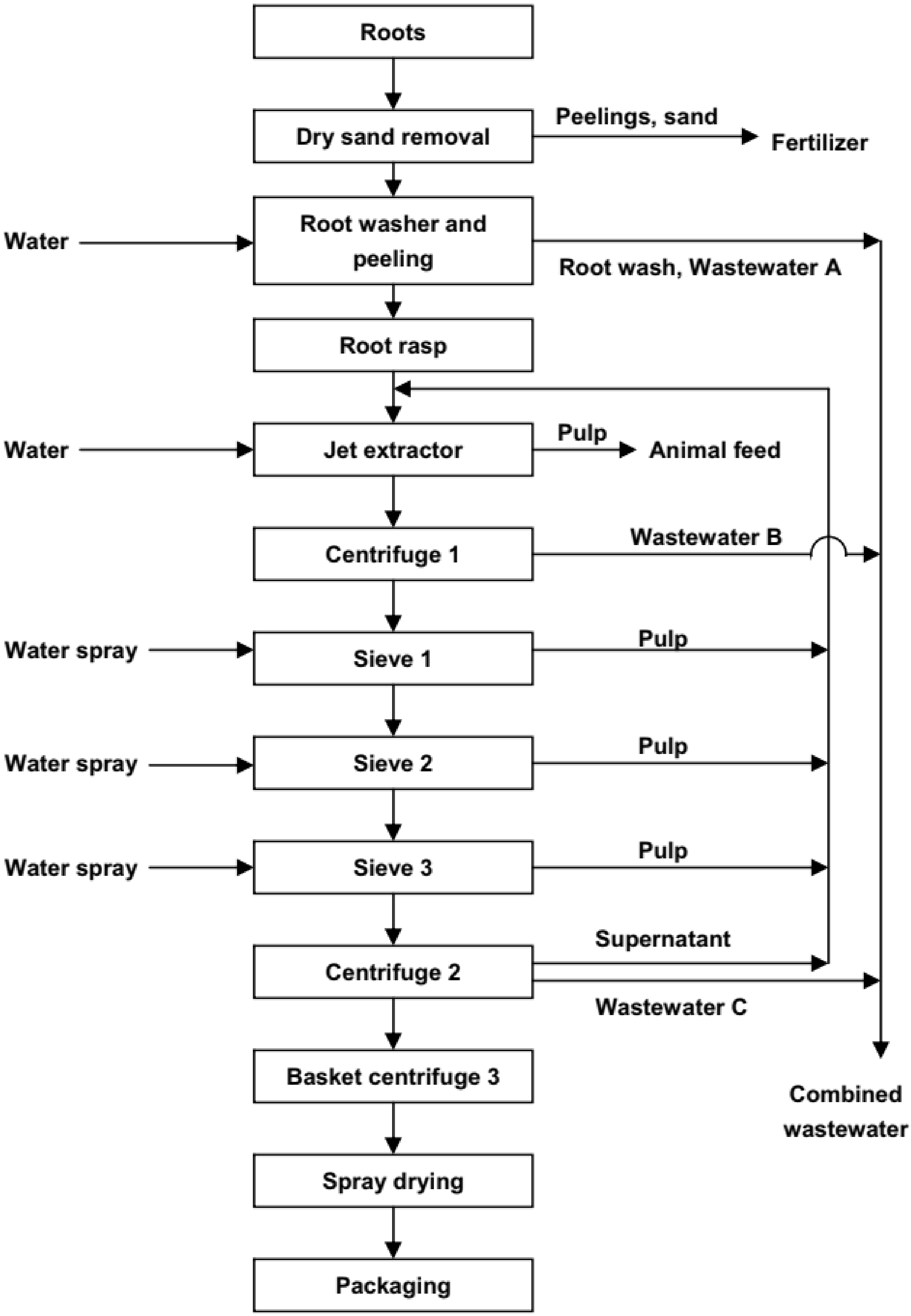
After drying, the starch is packed. The supernatant and surface washwaters from the first and second settling basins are discharged or directed to a third settling basin. In the case where a third settling basin is available, the supernatant and the surface washwaters are allowed to settle for 24 hours before the supernatant is decanted and discharged. The bottom sediment is dredged about once every two months; the sediment is resuspended two times again as mentioned above, and the starch thus recovered is sold as a lower-grade starch.

Tapioca starch wastewater characteristics

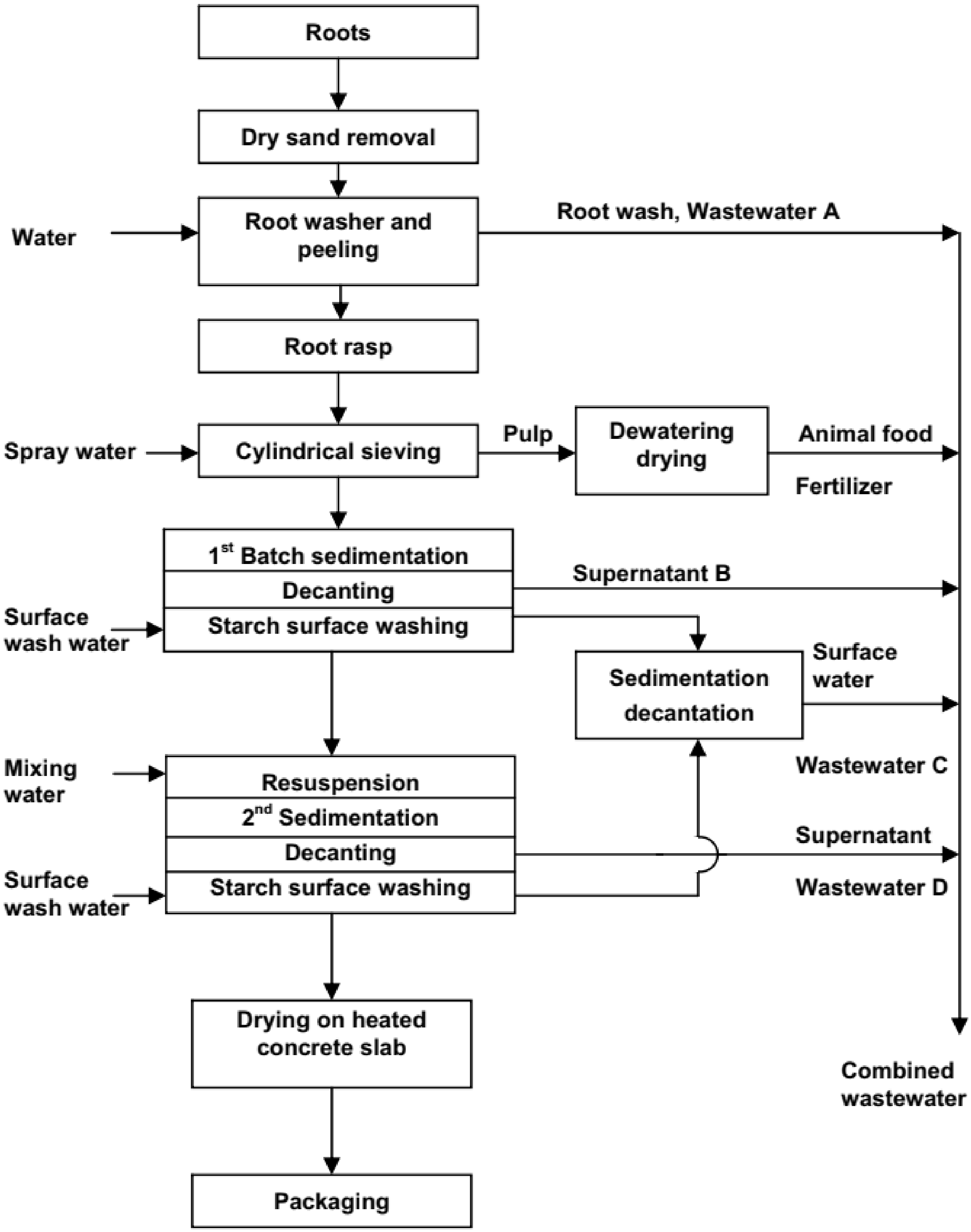
The combined wastewater from tapioca starch production is composed mainly of root washwater and either the starch supernatant decanted from sedimentation basins or the separator wastewater, depending upon whether a second-grade or first-grade starch factory is being considered. First-grade and second-grade factories in Thailand commonly process in the order of 200 and 30 tons of tapioca root per day, respectively, and release wastewaters with unit mass emission rates (UMER values) as shown in Table 2.9. Designations A, B, C and D refer to wastewater sources shown in Figures 2.2 and 2.3.

The characteristics of tapioca starch wastewaters are summarized in Table 2.10. Root washwater contains high settleable solids, mainly sand and clay particles from the raw roots. The combined waste is acidic in nature, its pH ranging from 3.8 to 5.2, resulting from the addition of sulphuric acid in the extraction process and also from the release of some prussic acid by the tapioca root.

Tapioca starch wastewaters are highly organic but have relatively low nitrogen and phosphorus concentrations. The ratio of soluble BOD_5 to soluble COD in the settled separator waste is 0.6 - 0.8, indicating that the waste is biologically degradable. It is likely that biological treatment methods will be most economical for this organic waste.



Roots
Dry sand removal
Peelings, sand
Fertilizer
Water
Root washer and peeling
Root wash, Wastewater A
Root rasp
Water
Jet extractor
Pulp
Animal feed
Centrifuge 1
Wastewater B
Water spray
Sieve 1
Pulp
Water spray
Sieve 2
Pulp
Water spray
Sieve 3
Pulp
Centrifuge 2
Supernatant
Wastewater C
Basket centrifuge 3
Combined wastewater
Spray drying
Packaging



2.3.2 Palm oil industry

Palm oil is basically a vegetable oil used mainly for human consumption. It is semi-solid, edible oil, extracted from the pulpy portion of the fruit wall of the palm fruit. The palm plants seem to have originated in the Guinea coast of West Africa and are now Malaysia's second most important crop. Almost all the palm oil produced in Malaysia and Thailand is used for margarine and other edible purposes. Due to the high oil prices, there has been increased use of palm oil to produce bio diesel in those countries that have oil palm plantation.

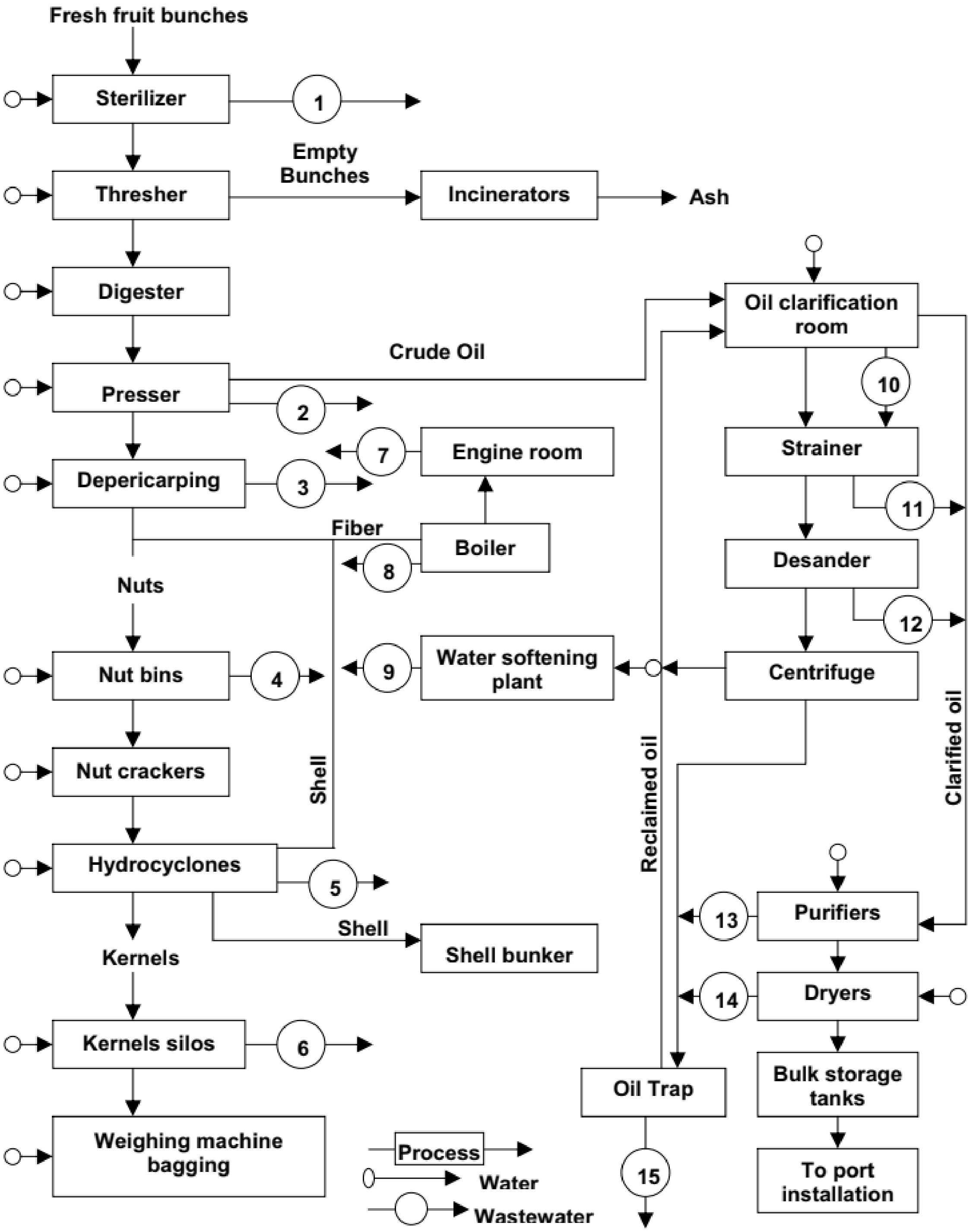
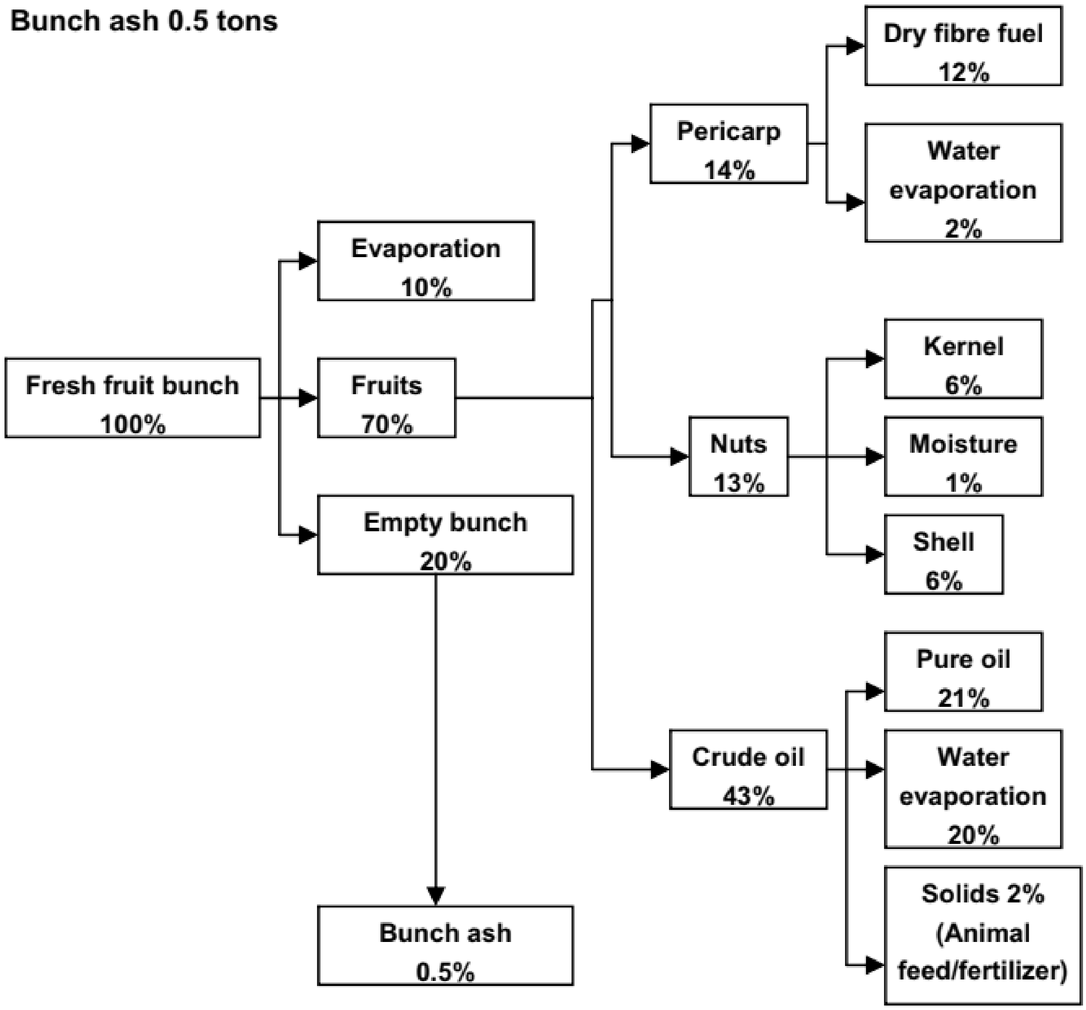


Figure 2.4 General process diagram of a palm oil mill

From 100-ton FFB products obtained are:
Pure oil 21 tons
Palm kernel 6 tons
Bunch ash 0.5 tons

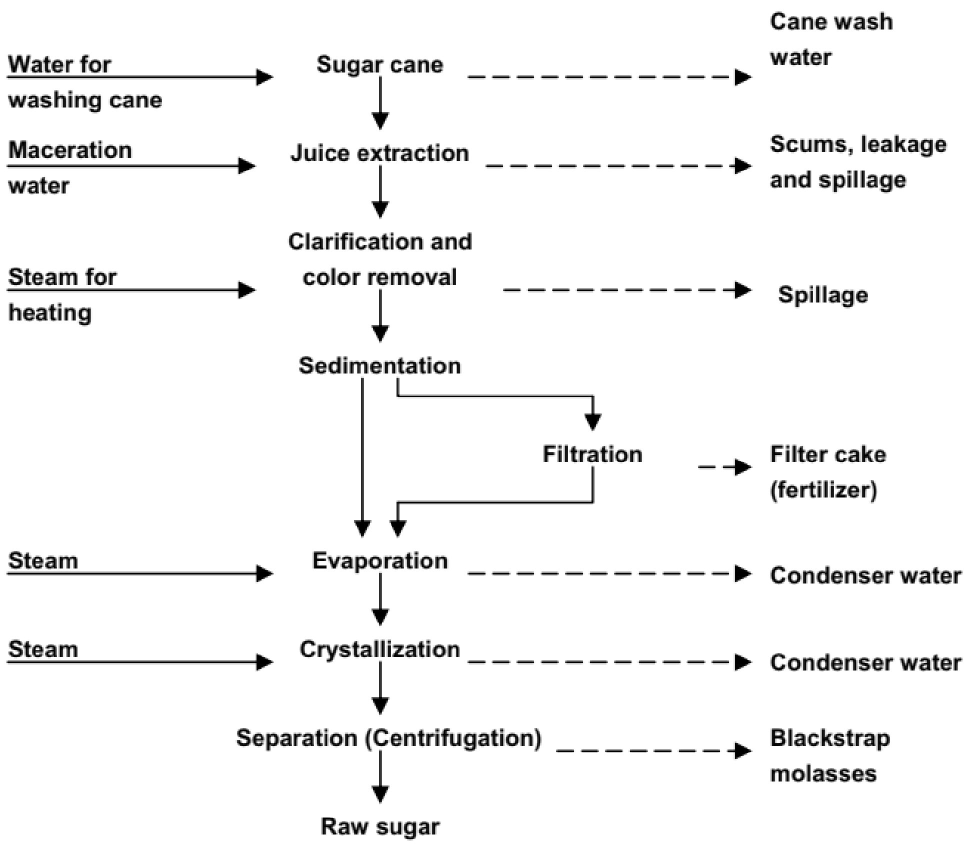


2.3.3 Sugar cane industry

Raw sugar cane manufacturing process

A flow diagram of the sugar cane manufacturing process is shown in Figure 2.6. The first step in raw sugar processing is juice extraction carried out by crushing the cane between a series of rollers under pressure. To aid in the extraction of the juice, sprays of water or thin juice are directed on the blanket of bagasse (fibrous part of the cane) as it emerges from each mill unit to leach out sugar. The final bagasse from the last roller contains the unextracted sugar, the woody fiber, and 40-50% water. This is used as fuel or as material for wallboard and paper manufacture.

The extracted juice is acidic, turbid, and dark green in color. It is treated with chemicals, such as lime, sulfur dioxide, carbon dioxide and phosphate, and heated for clarification. This treatment has the effect of precipitating suspended solids and some impurities and color removal, which are allowed to settle, and the clear juice is then filtered through vacuum filters. The filter press juice returns to the clarification process or goes directly to clarified juice. The press cake is discarded or returned to the fields as fertilizer.



2.3.4 Brewing industry

The brewing process

The principal stages in brewing are mashing, boiling and fermentation with subsequent packaging into bottles and casks followed by cooling, clarification and pasteurization.

Parameter	Units	Value
Total nitrogen (N)	mg/L	16.4
Chlorides	mg/L	400[a]
Sulfate	mg/L	210
Alkalinity ($CaCO_3$)	mg/L	538.0[b]
Phosphate (P)	mg/L	3.4
Potassium	mg/L	88.0[c]
BOD_5 (unfiltered)	mg/L	930
COD (unfiltered)	mg/L	1600
Suspended solids	mg/L	1015
Dissolved solids	mg/L	2209
Total solids	mg/L	3224
Sugar	mg/L	1.25
Dissolved oxygen	mg/L	0
pH	-	7.1

[a] Based on specific conductivity, [b] By difference, [c] Single values

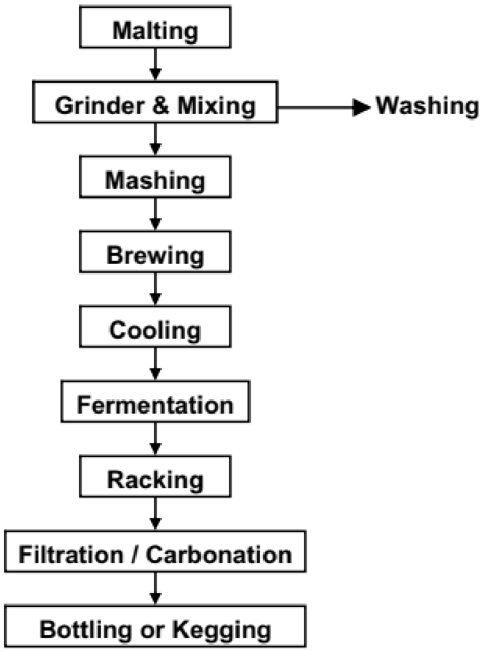


Figure 2.7 Brewing process

During mashing, the mixture of finely ground malt and hot water undergoes enzymatic changes whereby the starch is converted into sugar and dextrins and the protein into amino acids and polypeptides. The soluble product from mashing is known as sweet wort and this is subsequently boiled with hops in a metal vessel. Boiling destroys the enzymes and, at the same time, extracts resins from the hops to give bittering effect. The wort then goes to a cooling process in the cool-ship, yeast is added and during the resultant fermentation, the sugars present are converted into alcohol and CO_2. The nitrogenous material and phosphates in the wort are also utilised by the yeast for growth and fermentation. The beer is stored in lager tanks for some period and filtered and pasteurized before being bottled or canned. A schematic diagram of this brewing process is given in Figure 2.7.

Sources of wastewaters and characteristics

The sources of wastewaters that contain very high amounts of suspended and dissolved solids are: washing from cool ships, lager tanks and fermentation tanks. These wastewaters contain excessive amounts of beer, malt and yeast which possess a very high COD, sometimes as high as 20,000 mg/L, amounting to about 10% of the total waste discharged. Brewery wastewaters normally have an amber color and a rich grainy smell of malt.

Brewery wastewaters have been found to be highly contaminated with soluble organics, low in nutrients and pH, and they have a high temperature (Table 2.15). The COD content can vary from as much as 24,000 mg/L to as little as 6,000 mg/L. The ratio of BOD_5: COD varies between 0.2 and 0.9.

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