

9.10.1.2 Sugarbeet Processing

9.10.1.2.1 General¹⁻²

Sugarbeet processing is the production of sugar (sucrose) from sugarbeets. Byproducts of sugarbeet processing include pulp and molasses. Most of the molasses produced is processed further to remove the remaining sucrose. The pulp and most of the remaining molasses are mixed together, dried, and sold as livestock feed.

9.10.1.2.2 Process Description¹⁻⁴

Figures 9.10.1.2-1 and 9.10.1.2-2 are flow diagrams for a typical sugarbeet processing plant. Figure 9.10.1.2-1 shows preprocessing and livestock feed production operations, and Figure 9.10.1.2-2 shows the beet sugar production operations. Mechanically harvested sugarbeets are shipped to processing plants, where they are typically received by high-speed conveying and screening systems. The screening systems remove loose dirt from the beets and pinch the beet tops and leaves from the beet roots. The conveyors transport the beets to storage areas and then to the final cleaning and trash removal operations that precede the processing operations. The beets are usually conveyed to the final cleaning phase using flumes, which use water to both move and clean the beets. Although most plants use flumes, some plants use dry conveyors in the final cleaning stage. The disadvantage of flume conveying is that some sugar leaches into the flume water from damaged surfaces of the beets. The flumes carry the beets to the beet feeder, which regulates the flow of beets through the system and prevents stoppages in the system. From the feeder, the flumes carry the beets through several cleaning devices, which may include rock catchers, sand separators, magnetic metal separators, water spray nozzles, and trash catchers. After cleaning, the beets are separated from the water, usually with a beet wheel, and are transported by drag chain, chain and bucket elevator, inclined belt conveyor, or beet pump to the processing operations.

Sugarbeet processing operations comprise several steps, including diffusion, juice purification, evaporation, crystallization, dried-pulp manufacture, and sugar recovery from molasses. Descriptions of these operations are presented in the following paragraphs.

Prior to removal of the sucrose from the beet by diffusion, the cleaned and washed beets are sliced into long, thin strips, called cossettes. The cossettes are conveyed to continuous diffusers, in which hot water is used to extract sucrose from the cossettes. In one diffuser design, the diffuser is slanted upwards and conveys the cossettes up the slope as water is introduced at the top of the diffuser and flows countercurrent to the cossettes. The water temperature in the diffuser is typically maintained between 50° and 80°C (122° and 176°F). This temperature is dependant on several factors, including the denaturation temperature of the cossettes, the thermal behavior of the beet cell wall, potential enzymatic reactions, bacterial activity, and pressability of the beet pulp. Formalin, a 40 percent solution of formaldehyde, was sometimes added to the diffuser water as a disinfectant but is not used at the present time. Sulfur dioxide, chlorine, ammonium bisulfite, or commercial FDA-approved biocides are used as disinfectants. The sugar-enriched water that flows from the outlet of the diffuser is called raw juice and contains between 10 and 15 percent sugar. This raw juice proceeds to the juice purification operations. The processed cossettes, or pulp, leaving the diffuser are conveyed to the dried-pulp manufacture operations.

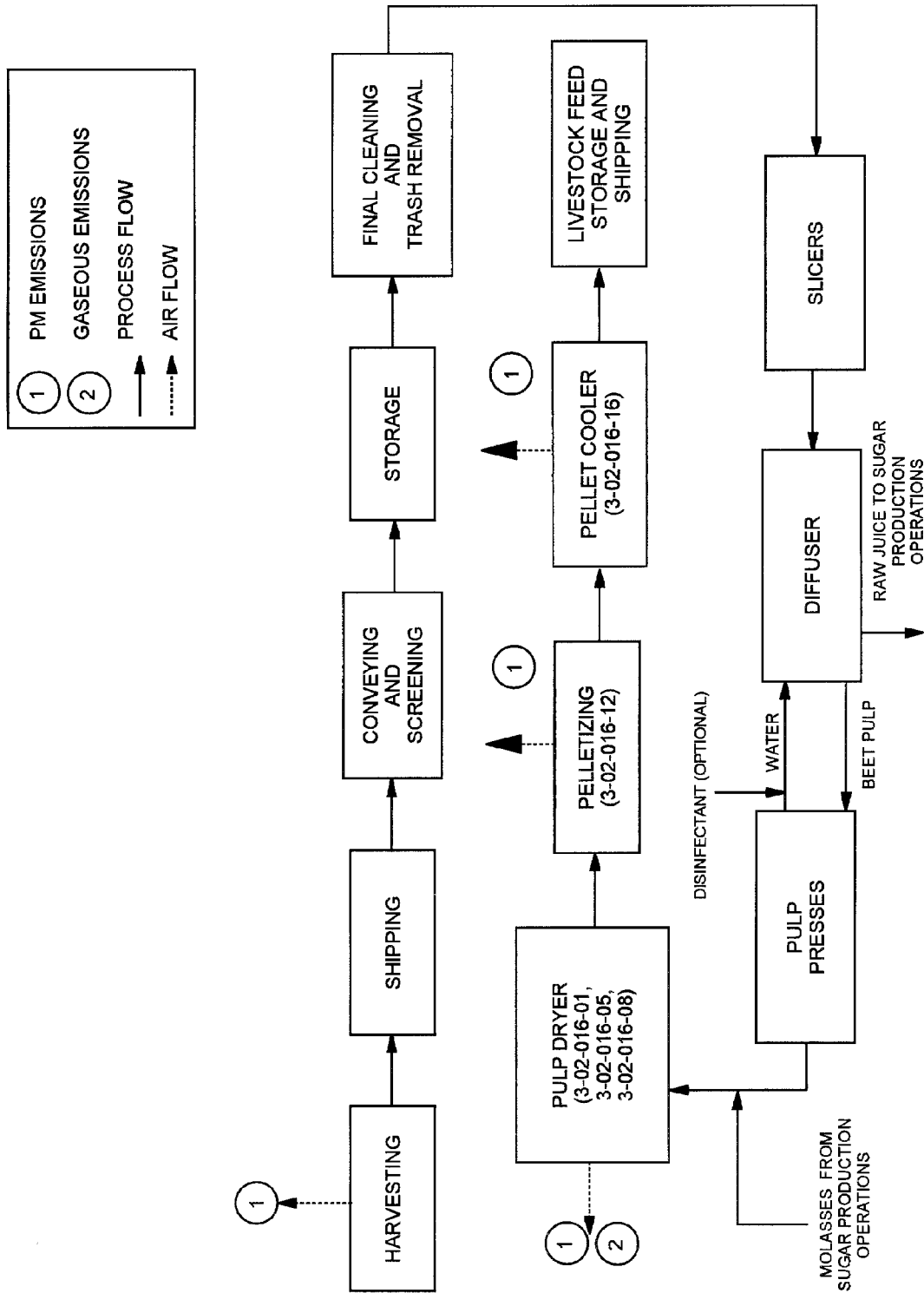


Figure 9.10.1.2-1. Preprocessing and livestock feed production operations at a sugarbeet processing plant. (Source Classification Code in parentheses.)

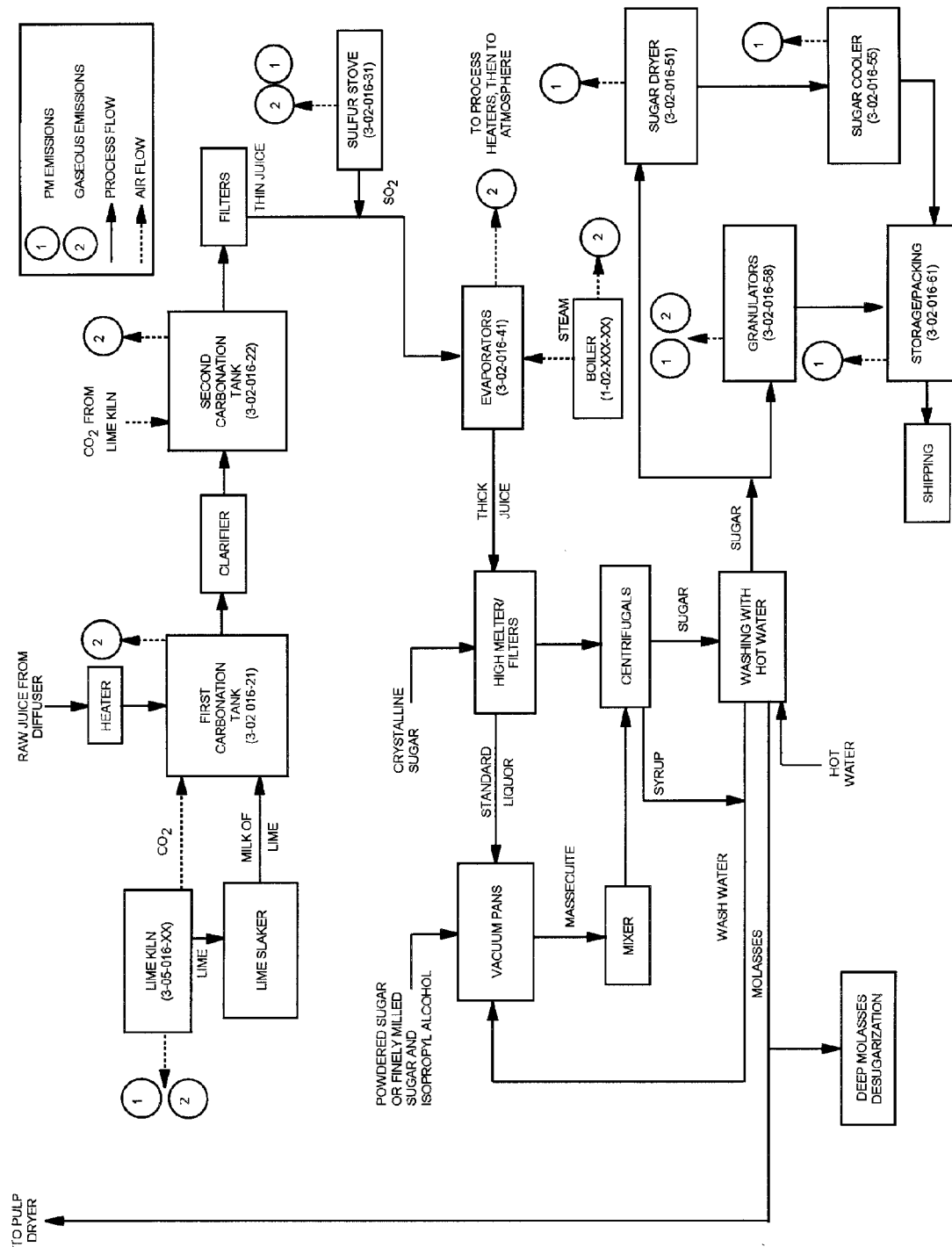


Figure 9.10.1.2-2. Sugar production operations at a sugarbeet processing plant.
(Source Classification Code in parentheses.)

In the juice purification stage, non-sucrose impurities in the raw juice are removed so that the pure sucrose can be crystallized. First, the juice passes through screens to remove any small cossette particles. Then the mixture is heated to 80° to 85°C (176° to 185°F) and proceeds to the first carbonation tank. In some processes, the juice from the screen passes through a pre-limer, heater, and main limer prior to the first carbonation tank. In the first carbonation tank, milk of lime [Ca(OH)₂] is added to the mixture to adsorb or adhere to the impurities in the mixture, and carbon dioxide (CO₂) gas is bubbled through the mixture to precipitate the lime as insoluble calcium carbonate crystals. Lime kilns are used to produce the CO₂ and lime used in carbonation; the lime is converted to milk of lime in a lime slaker. The small, insoluble crystals (produced during carbonation) settle out in a clarifier, after which the juice is again treated with CO₂ (in the second carbonation tank) to remove the remaining lime and impurities. The pH of the juice is lower during this second carbonation, causing large, easily filterable, calcium carbonate crystals to form. After filtration, a small amount of sulfur dioxide (SO₂) is added to the juice to inhibit reactions that lead to darkening of the juice. Most facilities purchase SO₂ as a liquid but a few facilities produce SO₂ by burning elemental sulfur in a sulfur stove. Following the addition of SO₂, the juice (known as thin juice) proceeds to the evaporators.

The evaporation process, which increases the sucrose concentration in the juice by removing water, is typically performed in a series of five evaporators. Steam from large boilers is used to heat the first evaporator, and the steam from the water evaporated in the first evaporator is used to heat the second evaporator. This transfer of heat continues through the five evaporators, and as the temperature decreases (due to heat loss) from evaporator to evaporator, the pressure inside each evaporator is also decreased, allowing the juice to boil at the lower temperatures provided in each subsequent evaporator. Some steam is released from the first three evaporators, and this steam is used as a heat source for various process heaters throughout the plant. After evaporation, the percentage of sucrose in the "thick juice" is 50-65 percent. Crystalline sugars, produced later in the process, are added to the juice and dissolved in the high melter. This mixture is then filtered, yielding a clear liquid known as standard liquor, which proceeds to the crystallization operation.

Sugar is crystallized by low-temperature pan boiling. The standard liquor is boiled in vacuum pans until it becomes supersaturated. To begin crystal formation, the liquor is either "shocked" using a small quantity of powdered sugar or is "seeded" by adding a mixture of finely milled sugar and isopropyl alcohol. The seed crystals are carefully grown through control of the vacuum, temperature, feed-liquor additions, and steam. When the crystals reach the desired size, the mixture of liquor and crystals, known as massecuite or fillmass, is discharged to the mixer. From the mixer, the massecuite is poured into high-speed centrifugals, in which the liquid is centrifuged into the outer shell, and the crystals are left in the inner centrifugal basket. The sugar crystals are then washed with pure hot water and are sent to the granulator, which is a combination rotary drum dryer and cooler. Some facilities have separate sugar dryers and coolers, which are collectively called granulators. The wash water, which contains a small quantity of sucrose, is pumped to the vacuum pans for processing. After cooling, the sugar is screened and then either packaged or stored in large bins for future packaging.

The liquid that was separated from the sugar crystals in the centrifugals is called syrup. This syrup serves as feed liquor for the "second boiling" and is introduced back into the vacuum pans along with standard liquor and recycled wash water. The process is repeated once again, resulting in the production of molasses, which can be further desugarized using an ion exchange process called deep molasses desugarization. Molasses that is not desugarized can be used in the production of livestock feed or for other purposes.

Wet pulp from the diffusion process is another product of sugarbeet processing. The pulp is first pressed, typically in horizontal double-screw presses, to reduce the moisture content from about 95 percent

to about 75 percent. The water removed by the presses is collected and used as diffusion water. After pressing, molasses is added to the pulp, which is then dried in a direct-fired horizontal rotating drum known as a pulp dryer. The pulp dryer, which can be fired by oil, natural gas, or coal, typically provides entrance temperatures between 482° and 927°C (900° and 1700°F). As the pulp is dried, the gas temperature decreases and the pulp temperature increases. The exit temperature of the flue gas is typically between 88° and 138°C (190° and 280°F). The resulting product is usually pelletized, cooled, and sold as livestock feed.

9.10.1.2.3 Emissions And Controls^{1,3-4}

Particulate matter (PM), combustion products, and volatile organic compounds (VOC) are the primary pollutants emitted from the sugarbeet processing industry. The pulp dryers, sugar granulators and coolers, sugar conveying and sacking equipment, lime kilns and handling equipment, carbonation tanks, sulfur stoves, evaporators, and boilers, as well as several fugitive sources are potential emission sources. Potential emissions from boilers are addressed in AP-42 Sections 1.1 through 1.4 (Combustion) and those from lime kilns are addressed in AP-42 Section 11.17, Lime Manufacturing. Potential sources of PM emissions include the pulp dryer, sugar granulators and coolers, sugar conveying and sacking equipment, sulfur stove, and fugitive sources. Fugitive sources include unpaved roads, coal handling, and pulp loading operations. Although most facilities purchase SO₂, a few facilities still use sulfur stoves. The sulfur stove is a potential source of SO₂ emissions, and the pulp dryers may be a potential source of nitrogen oxides (NO_x), SO₂, CO₂, carbon monoxide (CO), and VOC. Evaporators may be a potential source of CO₂, ammonia (NH₃), SO₂, and VOC emissions from the juice. However, only the first three of five evaporators (in a typical five-stage system) release exhaust gases, and the gases are used as a heat source for various process heaters before release to the atmosphere. Emissions from carbonation tanks are primarily water vapor but contain small quantities of NH₃, VOC, and may also include CO₂ and other combustion gases from the lime kiln. There are no emission test data available for ammonia emissions from carbonation tanks.

Particulate matter emissions from pulp dryers are typically controlled by a cyclone or multiclone system, sometimes followed by a secondary device such as a wet scrubber or fabric filter. Particulate matter emissions from granulators are typically controlled with wet scrubbers, and PM emissions from sugar conveying and sacking as well as lime dust handling operations are controlled by hood systems that duct the emissions to fabric filtration systems. Emissions from carbonation tanks and evaporators are not typically controlled.

Table 9.10.1.2-1 presents emission factors for filterable PM, PM-10, and condensable PM emissions from sugarbeet processing operations. Table 9.10.1.2-2 presents emission factors for volatile organic compounds (VOC), methane, NO_x, SO₂, CO, and CO₂ emissions from sugarbeet processing operations, and Tables 9.10.1.2-3 and 9.10.1.2-4 present emission factors for organic pollutants emitted from coal-fired dryers, carbonation tanks, and first evaporators.

Table 9.10.1.2-1. PARTICULATE MATTER EMISSION FACTORS FOR SUGARBEET PROCESSING OPERATIONS^a

Source	Type of Control	Filterable PM				Condensable PM					
		PM	EMISSION FACTOR RATING	PM-10	EMISSION FACTOR RATING	Inorganic	EMISSION FACTOR RATING	Organic	EMISSION FACTOR RATING	Total	EMISSION FACTOR RATING
Coal-fired pulp dryer ^b (SCC 3-02-016-01)	None	4.4	D	ND		ND		ND		ND	
	Multiclone	0.66 ^c	B	ND		ND		0.084 ^d	C	ND	
	Wet scrubber	0.49	D	ND		0.050 ^f	D	0.35 ^e	D	0.40 ^g	D
Natural gas-fired pulp dryer (SCC 3-02-016-08)	Multiclone ^h	0.69	D	ND		ND		ND		ND	
	Wet scrubber	0.19	D	ND		0.018 ^k	D	ND		ND	
Fuel oil-fired pulp dryer (SCC 3-02-016-05)	Cyclone	1.4	C	ND		0.24 ⁿ	C	0.076 ^m	C	0.32 ⁿ	C
	Dry scrubber and cyclone	1.1	D	0.83 ^p	D	0.24 ⁿ	C	ND		ND	
	Multiclone ^q	0.60	D	ND		ND		ND		ND	
Sugar granulator (SCC 3-02-016-58)	Mechanical centrifugal separator with water sprays ^r	0.064	D	ND		ND		0.0037	D	ND	
	Mechanical centrifugal separator with water sprays ^r	0.13	D	ND		ND		0.0043	D	ND	
Sugar cooler (SCC 3-02-016-55)	Venturi scrubber ^s	0.065	D	ND		0.0047	D	0.0042	D	0.0089	D
	Fabric filter	ND		ND		ND		ND		ND	
Sugar conveying and sacking (SCC 3-02-016-61)											
Sulfur stove (SCC 3-02-016-31)	None	ND		ND		ND		ND		ND	
Pellet Cooler (SCC 3-02-016-16)	None	ND		ND		ND		ND		ND	
Sugar Dryer (SCC 3-02-016-51)	None	ND		ND		ND		ND		ND	

Table 9.10.1.2-1 (cont.).

Source	Type of Control	Filterable PM				Condensable PM					
		PM	EMISSION FACTOR RATING	PM-10	EMISSION FACTOR RATING	Inorganic	EMISSION FACTOR RATING	Organic	EMISSION FACTOR RATING	Total	EMISSION FACTOR RATING
Pelletizer (SCC 3-02-016-12)	None	ND		ND		ND		ND		ND	

^a Emission factor units are lb/ton of pressed wet pulp to the dryer, unless noted. Factors represent uncontrolled emissions unless noted. To convert from lb/ton to kg/Mg, multiply by 0.5. SCC = Source Classification Code. ND = no data.

^b Reference 17.

^c References 7,16-17,19,21.

^d References 16-17,19,21.

^e References 3,13.

^f Reference 13.

^g Reference 3.

^h References 22-23; both of these facilities utilize gas recirculation systems operating at different rates.

^j References 8-12.

^k References 11-12,25.

^m References 4-6.

ⁿ References 4-6,14. Includes condensable organic PM data from dryers controlled by cyclones and dryers controlled by a dry scrubber and cyclone combination.

^p Reference 14.

^q References 15,24; fuel gas aspiration systems used at both facilities.

^r Reference 20. Emission factor units are lb/ton of sugar output.

^s Reference 18. Emission factor units are lb/ton of sugar output.

Table 9.10.1.2-2. EMISSION FACTORS FOR VOC, METHANE, AND INORGANIC POLLUTANT EMISSIONS FROM SUGARBEET PROCESSING OPERATIONS^a

EMISSION FACTOR RATING: D

Source	lb/ton					
	VOC ^b	Methane	NO _x	SO ₂	CO	CO ₂
Coal-fired pulp dryer ^c (SCC 3-02-016-01)	1.2 ^d	ND	0.66 ^e	0.79 ^f	2.3 ^d	370 ^g
Natural gas-fired pulp dryer ^c (SCC 3-02-016-08)	ND	ND	ND	ND	ND	156 ^h
Fuel oil-fired pulp dryer ^c (SCC 3-02-016-05)	0.11 ^j	0.028 ^j	0.60 ^j	1.0 ^k	1.0 ^j	430 ^m
First evaporator (SCC 3-02-016-41)	ND	ND	ND	ND	ND	ND
Sulfur stove (SCC 3-02-016-31)	ND	ND	ND	ND	ND	ND
First carbonation tank (SCC 3-02-016-21)	ND	ND	ND	ND	ND	ND
Second carbonation tank (SCC 3-02-016-22)	ND	ND	ND	ND	ND	ND

^a Emission factor units are lb/ton of pressed wet pulp to the dryer, unless noted. Factors represent uncontrolled emissions unless noted. To convert from lb/ton to kg/Mg, multiply by 0.5.

SCC = Source Classification Code. ND = no data.

^b Volatile organic compounds as methane.

^c Data for pulp dryers equipped with cyclones, multiclones, wet scrubbers, or a combination of these control technologies are averaged together because these control technologies are not specifically designed to control VOC, methane, NO_x, SO₂, CO, or CO₂ emissions.

^d Reference 19.

^e References 16,19.

^f References 7,19.

^g References 7,13,16-17,19,21. EMISSION FACTOR RATING: B.

^h References 8-12,22-23,25. EMISSION FACTOR RATING: C.

^j Reference 4.

^k References 14-15.

^m References 4-6,14,24. EMISSION FACTOR RATING: C.

Table 9.10.1.2-3. EMISSION FACTORS FOR ORGANIC POLLUTANT EMISSIONS FROM PULP DRYERS^a

EMISSION FACTOR RATING: E

Source	Pollutant		Emission Factor, lb/ton
	CASRN	Name	
Coal-fired pulp dryer with wet scrubber (SCC 3-02-016-01)	75-07-0	Acetaldehyde	0.015
	107-02-8	Acrolein	0.0076
	123-73-9	Crotonaldehyde	0.0020
	50-00-0	Formaldehyde	0.0071
	91-57-6	2-methylnaphthalene	1.7x10 ⁻⁵
	88-75-5	2-nitrophenol	0.00018
	95-48-7	2-methylphenol	3.4x10 ⁻⁵
	105-67-9	2,4-dimethylphenol	2.5x10 ⁻⁵
	106-44-5	4-methylphenol	0.00013
	100-02-7	4-nitrophenol	0.00014
	208-96-8	Acenaphthylene	1.7x10 ⁻⁶
	100-52-7	Benzaldehyde	0.0014
	65-85-0	Benzoic acid	0.0028
	100-51-6	Benzyl alcohol	7.1x10 ⁻⁵
	117-81-7	Bis(2-ethylhexyl)phthalate	0.0015
	84-74-2	Di-n-butylphthalate	5.2x10 ⁻⁵
	132-64-9	Dibenzofuran	1.1x10 ⁻⁵
	84-66-2	Diethylphthalate	9.8x10 ⁻⁶
	91-20-3	Naphthalene	0.00011
	98-95-3	Nitrobenzene	1.9x10 ⁻⁵
85-01-8	Phenanthrene	1.2x10 ⁻⁵	
108-95-2	Phenol	0.00032	

^a Reference 3. Emission factor units are lb/ton of pressed wet pulp to the dryer. To convert from lb/ton to kg/Mg, multiply by 0.5. SCC = Source Classification Code. CASRN = Chemical Abstracts Service Registry Number.

Table 9.10.1.2-4. EMISSION FACTORS FOR ORGANIC POLLUTANT EMISSIONS FROM CARBONATION TANKS AND EVAPORATORS^a

Source	Pollutant		Emission Factor, lb/1,000 gal	EMISSION FACTOR RATING
	CASRN	Name		
First carbonation tank ^b (SCC 3-02-016-21)	91-57-6	2-methylnaphthalene	5.1×10^{-7}	D
	51-28-5	2,4-dinitrophenol	ND	D
	106-44-5	4-methylphenol	6.6×10^{-7}	D
	83-32-9	Acenaphthene	ND	D
	100-52-7	Benzaldehyde	1.1×10^{-4}	D
	65-85-0	Benzoic acid	8.4×10^{-6}	D
	100-51-6	Benzyl alcohol	5.0×10^{-6}	D
	117-81-7	Bis(2-ethylhexyl)phthalate	1.2×10^{-5}	D
	91-20-3	Naphthalene	2.0×10^{-6}	D
	85-01-8	Phenanthrene	1.4×10^{-6}	D
	108-95-2	Phenol	1.3×10^{-6}	D
Second carbonation tank ^b (SCC 3-02-016-22)	75-07-0	Acetaldehyde	0.0043	E
	107-02-8	Acrolein	2.4×10^{-4}	E
	123-73-9	Crotonaldehyde	3.0×10^{-5}	E
	50-00-0	Formaldehyde	1.6×10^{-5}	E
First evaporator ^c (SCC 3-02-016-41)	75-07-0	Acetaldehyde	6.7×10^{-5}	E
	107-02-8	Acrolein	4.2×10^{-7}	E
	123-73-9	Crotonaldehyde	1.4×10^{-7}	E
	50-00-0	Formaldehyde	7.0×10^{-7}	E
	106-44-5	4-methylphenol	ND	E
	100-52-7	Benzaldehyde	2.2×10^{-6}	E
	65-85-0	Benzoic acid	ND	E
	100-51-6	Benzyl alcohol	1.8×10^{-7}	E
	117-81-7	Bis(2-ethylhexyl)phthalate	3.7×10^{-7}	E
	84-74-2	Di-n-butylphthalate	1.1×10^{-9}	E
	132-64-9	Dibenzofuran	ND	E
	84-66-2	Diethylphthalate	ND	E
	78-59-1	Isophorone	ND	E
	91-20-3	Naphthalene	2.5×10^{-8}	E
85-01-8	Phenanthrene	1.6×10^{-8}	E	
108-95-2	Phenol	1.2×10^{-8}	E	
110-86-1	Pyridine	3.4×10^{-8}	E	

^a Reference 3. SCC = Source Classification Code. CASRN = Chemical Abstracts Service Registry Number. ND = no data.

^b Emission factor units are lb per 1,000 gallons of raw juice produced.

^c Emission factor units are lb per 1,000 gallons of thin juice produced.

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