10.2 Chemical Wood Pulping

10.2.1 General

Chemical wood pulping involves the extraction of cellulose from wood by dissolving the lignin that binds the cellulose fibers together. The 4 processes principally used in chemical pulping are kraft, sulfite, neutral sulfite semichemical (NSSC), and soda. The first 3 display the greatest potential for causing air pollution. The kraft process alone accounts for over 80 percent of the chemical pulp produced in the United States. The choice of pulping process is determined by the desired product, by the wood species available, and by economic considerations.

10.2.2 Kraft Pulping

10.2.2.1 Process Description[1] -

The kraft pulping process (see Figure 10.2-1) involves the digesting of wood chips at elevated temperature and pressure in "white liquor", which is a water solution of sodium sulfide and sodium hydroxide. The white liquor chemically dissolves the lignin that binds the cellulose fibers together.

There are 2 types of digester systems, batch and continuous. Most kraft pulping is done in batch digesters, although the more recent installations are of continuous digesters. In a batch digester, when cooking is complete, the contents of the digester are transferred to an atmospheric tank usually referred to as a blow tank. The entire contents of the blow tank are sent to pulp washers, where the spent cooking liquor is separated from the pulp. The pulp then proceeds through various stages of washing, and possibly bleaching, after which it is pressed and dried into the finished product. The "blow" of the digester does not apply to continuous digester systems.

The balance of the kraft process is designed to recover the cooking chemicals and heat. Spent cooking liquor and the pulp wash water are combined to form a weak black liquor which is concentrated in a multiple-effect evaporator system to about 55 percent solids. The black liquor is then further concentrated to 65 percent solids in a direct-contact evaporator, by bringing the liquor into contact with the flue gases from the recovery furnace, or in an indirect-contact concentrator. The strong black liquor is then fired in a recovery furnace. Combustion of the organics dissolved in the black liquor provides heat for generating process steam and for converting sodium sulfate to sodium sulfide. Inorganic chemicals present in the black liquor collect as a molten smelt at the bottom of the furnace.

The smelt is dissolved in water to form green liquor, which is transferred to a causticizing tank where quicklime (calcium oxide) is added to convert the solution back to white liquor for return to the digester system. A lime mud precipitates from the causticizing tank, after which it is calcined in a lime kiln to regenerate quicklime.

For process heating, for driving equipment, for providing electric power, etc., many mills need more steam than can be provided by the recovery furnace alone. Thus, conventional industrial boilers that burn coal, oil, natural gas, or bark and wood are commonly used.

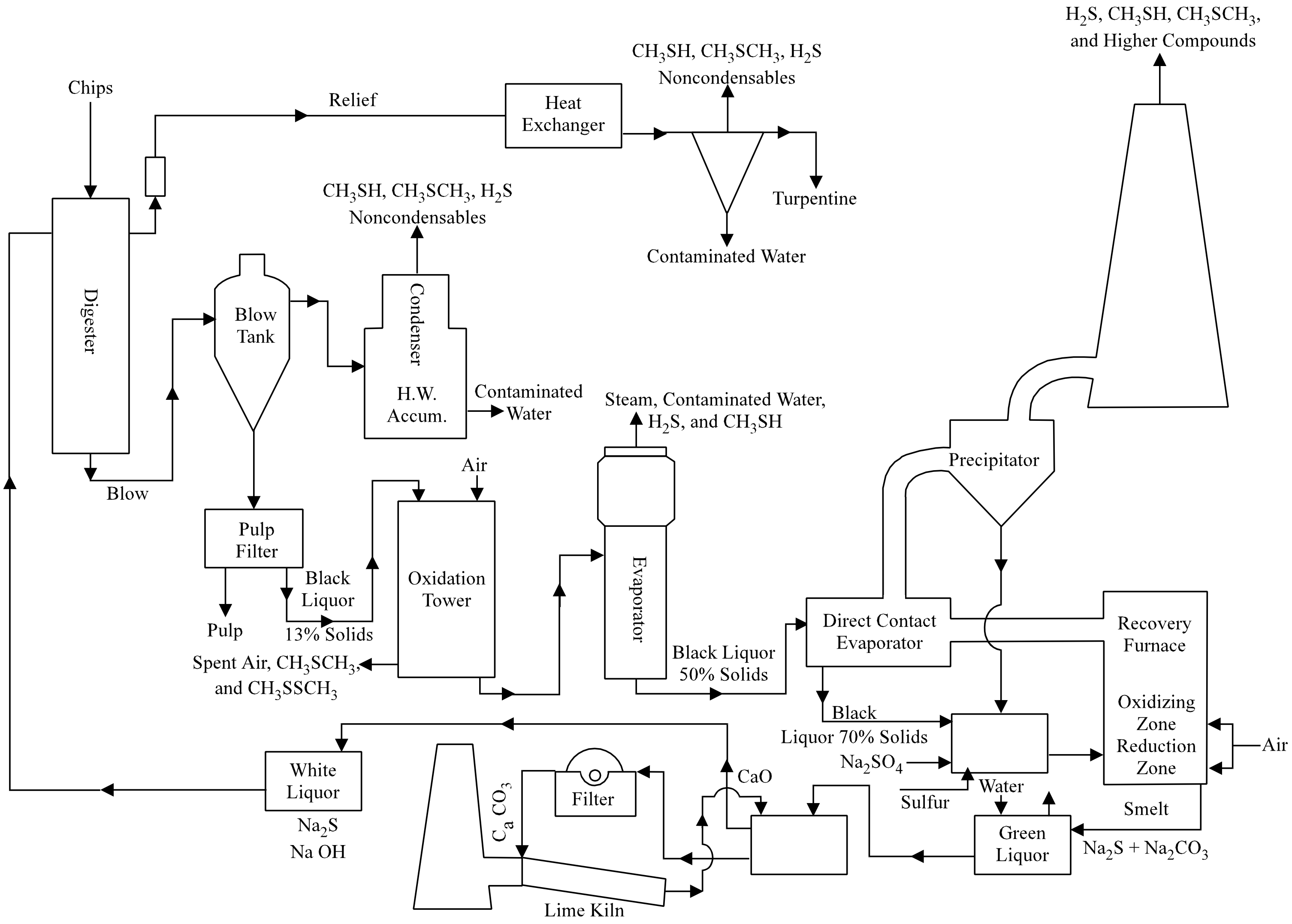

Figure 10.2-1. Typical kraft sulfate pulping and recovery process.

10.2.2.2 Emissions And Controls[1-7] -

Particulate emissions from the kraft process occur largely from the recovery furnace, the lime kiln and the smelt dissolving tank. These emissions are mainly sodium salts, with some calcium salts from the lime kiln. They are caused mostly by carryover of solids and sublimation and condensation of the inorganic chemicals.

Particulate control is provided on recovery furnaces in a variety of ways. In mills with either cyclonic scrubber or cascade evaporator as the direct-contact evaporator, further control is necessary, as these devices are generally only 20 to 50 percent efficient for particulates. Most often in these cases, an electrostatic precipitator (ESP) is employed after the direct-contact evaporator, for an overall particulate control efficiency of from 85 to more than 99 percent. Auxiliary scrubbers may be added at existing mills after a precipitator or a venturi scrubber to supplement older and less efficient primary particulate control devices.

Particulate control on lime kilns is generally accomplished by scrubbers. Electrostatic precipitators have been used in a few mills. Smelt dissolving tanks usually are controlled by mesh pads, but scrubbers can provide further control.

The characteristic odor of the kraft mill is caused by the emission of reduced sulfur compounds, the most common of which are hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide, all with extremely low odor thresholds. The major source of hydrogen sulfide is the direct contact evaporator, in which the sodium sulfide in the black liquor reacts with the carbon dioxide in the furnace exhaust. Indirect contact evaporators can significantly reduce the emission of hydrogen sulfide. The lime kiln can also be a potential source of odor, as a similar reaction occurs with residual sodium sulfide in the lime mud. Lesser amounts of hydrogen sulfide are emitted with the noncondensables of offgases from the digesters and multiple-effect evaporators.

Methyl mercaptan and dimethyl sulfide are formed in reactions with the wood component, lignin. Dimethyl disulfide is formed through the oxidation of mercaptan groups derived from the lignin. These compounds are emitted from many points within a mill, but the main sources are the digester/blow tank systems and the direct contact evaporator.

Although odor control devices, per se, are not generally found in kraft mills, emitted sulfur compounds can be reduced by process modifications and improved operating conditions. For example, black liquor oxidation systems, which oxidize sulfides into less reactive thiosulfates, can considerably reduce odorous sulfur emissions from the direct contact evaporator, although the vent gases from such systems become minor odor sources themselves. Also, noncondensable odorous gases vented from the digester/blow tank system and multiple effect evaporators can be destroyed by thermal oxidation, usually by passing them through the lime kiln. Efficient operation of the recovery furnace, by avoiding overloading and by maintaining sufficient oxygen, residence time, and turbulence, significantly reduces emissions of reduced sulfur compounds from this source as well. The use of fresh water instead of contaminated condensates in the scrubbers and pulp washers further reduces odorous emissions.

Several new mills have incorporated recovery systems that eliminate the conventional direct-contact evaporators. In one system, heated combustion air, rather than fuel gas, provides direct-contact evaporation. In another, the multiple-effect evaporator system is extended to replace the direct-contact evaporator altogether. In both systems, sulfur emissions from the recovery furnace/direct-contact evaporator can be reduced by more than 99 percent.

Sulfur dioxide is emitted mainly from oxidation of reduced sulfur compounds in the recovery furnace. It is reported that the direct contact evaporator absorbs about 75 percent of these emissions, and further scrubbing can provide additional control.

Potential sources of carbon monoxide emissions from the kraft process include the recovery furnace and lime kilns. The major cause of carbon monoxide emissions is furnace operation well above rated capacity, making it impossible to maintain oxidizing conditions.

Some nitrogen oxides also are emitted from the recovery furnace and lime kilns, although amounts are relatively small. Indications are that nitrogen oxide emissions are on the order of 0.5 to 1.0 kilograms per air-dried megagram (kg/Mg) (1 to 2 pounds per air-dried ton [lb/ton]) of pulp produced from the lime kiln and recovery furnace, respectively.[5-6]

A major source of emissions in a kraft mill is the boiler for generating auxiliary steam and power. The fuels are coal, oil, natural gas, or bark/wood waste. See Chapter 1, "External Combustion Sources", for emission factors for boilers.

Table 10.2-1 presents emission factors for a conventional kraft mill. The most widely used particulate control devices are shown, along with the odor reductions through black liquor oxidation and incineration of noncondensable offgases. Tables 10.2-2, 10.2-3, 10.2-4, 10.2-5, 10.2-6, and 10.2-7 present cumulative size distribution data and size-specific emission factors for particulate emissions from sources within a conventional kraft mill. Uncontrolled and controlled size-specific emission factors[7] are presented in Figure 10.2-2, Figure 10.2-3, Figure 10.2-4, Figure 10.2-5, Figure 10.2-6, and Figure 10.2-7. The particle sizes are expressed in terms of the aerodynamic diameter in micrometers (µm).

10.2.3 Acid Sulfite Pulping

10.2.3.1 Process Description -

The production of acid sulfite pulp proceeds similarly to kraft pulping, except that different chemicals are used in the cooking liquor. In place of the caustic solution used to dissolve the lignin in the wood, sulfurous acid is employed. To buffer the cooking solution, a bisulfite of sodium, magnesium, calcium, or ammonium is used. A diagram of a typical magnesium-base process is shown in Figure 10.2-8.

Digestion is carried out under high pressure and high temperature, in either batch mode or continuous digesters, and in the presence of a sulfurous acid/bisulfite cooking liquid. When cooking is completed, either the digester is discharged at high pressure into a blow pit, or its contents are pumped into a dump tank at lower pressure. The spent sulfite liquor (also called red liquor) then drains through the bottom of the tank and is treated and discarded, incinerated, or sent to a plant for recovery of heat and chemicals. The pulp is then washed and processed through screens and centrifuges to remove knots, bundles of fibers, and other material. It subsequently may be bleached, pressed, and dried in papermaking operations.

Because of the variety of cooking liquor bases used, numerous schemes have evolved for heat and/or chemical recovery. In calcium base systems, found mostly in older mills, chemical recovery is not practical, and the spent liquor is usually discharged or incinerated. In ammonium base operations, heat can be recovered by combusting the spent liquor, but the ammonium base is thereby consumed. In sodium or magnesium base operations, the heat, sulfur, and base all may be feasibly recovered.

Table 10.2-1 (Metric And English Units). EMISSION FACTORS FOR KRAFT PULPING[a]

EMISSION FACTOR RATING: A

Source	Type Of Control	Particulate		Sulfur Dioxide (SO_2)		Carbon Monoxide (CO)		Hydrogen Sulfide (S^m)		RSH, RSR, RSSR (S^m)	
		kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
Digester relief and blow tank	Untreated[b]	ND	ND	ND	ND	ND	ND	0.02	0.03	0.6	1.2
Brown stock washer	Untreated[b]	ND	ND	ND	ND	ND	ND	0.01	0.02	0.2[c]	0.4[c]
Multiple effect evaporator	Untreated[b]	ND	ND	ND	ND	ND	ND	0.55	1.1	0.05	0.1
Recovery boiler and direct evaporator	Untreated[d]	90	180	3.5	7	5.5	11	6[e]	12[e]	1.5[e]	3[e]
	Venturi scrubber[f]	24	48	3.5	7	5.5	11	6[e]	12[e]	1.5[e]	3[e]
	ESP	1	2	3.5	7	5.5	11	6[e]	12[e]	1.5[e]	3[e]
	Auxiliary scrubber	1.5 - 7.5[g]	3 - 15[g]					6[e]	12[e]	1.5[e]	3[e]
Noncontact recovery boiler without direct contact evaporator	Untreated	115	230	ND	ND	5.5	11	0.05[h]	0.1[h]	ND	ND
	ESP	1	2	ND	ND	5.5	11	0.05[h]	0.1[h]	ND	ND
Smelt dissolving tank	Untreated	3.5	7	0.1	0.2	ND	ND	0.1[j]	0.2[j]	0.15[j]	0.3[j]
	Mesh pad	0.5	1	0.1	0.2	ND	ND	0.1[j]	0.2[j]	0.15[j]	0.3[j]
	Scrubber	0.1	0.2	ND	ND	ND	ND	0.1[j]	0.2[j]	0.15[j]	0.3[j]
Lime kiln	Untreated	28	56	0.15	0.3	0.05	0.1	0.25[m]	0.5[m]	0.1[m]	0.2[m]
	Scrubber or ESP	0.25	0.5	ND	ND	0.05	0.1	0.25[m]	0.5[m]	0.1[m]	0.2[m]
Turpentine condenser	Untreated	ND	ND	ND	ND	ND	ND	0.005	0.01	0.25	0.5
Miscellaneous[n]	Untreated	ND	ND	ND	ND	ND	ND	ND	ND	0.25	0.5

Table 10.2-1 (cont.).

[a] References 8-10. Factors expressed in unit weight of air-dried unbleached pulp (ADP). RSH = Methyl mercaptan. RSR = Dimethyl sulfide. RSSR = Dimethyl disulfide. ESP = Electrostatic precipitator. ND = No data.

[b] If noncondensable gases from these sources are vented to lime kiln, recovery furnace, or equivalent, the reduced sulfur compounds are destroyed.

[c] Apply with system using condensate as washing medium. When using fresh water, emissions are 0.05 kg/Mg (0.1 lb/ton).

[d] Apply when cyclonic scrubber or cascade evaporator is used for direct contact evaporation, with no further controls.

[e] Usually reduced by 50% with black liquor oxidation and can be cut 95 - 99% when oxidation is complete and recovery furnace is operated optimally.

[f] Apply when venturi scrubber is used for direct contact evaporation, with no further controls.

[g] Use 7.5 kg/Mg (15 lb/ton) when auxiliary scrubber follows venturi scrubber, and 1.5 kg/Mg (3 lb/ton) when it follows ESP.

[h] Apply when recovery furnace is operated optimally to control total reduced sulfur (TRS) compounds.

[j] Usually reduced to 0.01 g/kg (0.02 lb/ton) ADP when water low in sulfides is used in smelt dissolving tank and associated scrubber.

[m] Usually reduced to 0.015 g/kg (0.03 lb/ton) ADP with efficient mud washing, optimal kiln operation and added caustic in scrubbing water. With only efficient mud washing and optimal process control, TRS compounds reduced to 0.04 g/kg (0.08 lb/ton) ADP.

[n] Includes knotter vents, brownstock seal tanks, etc. When black liquor oxidation is included, emissions are 0.3 kg/Mg (0.6 lb/ton).

Table 10.2-2 (Metric Units). CUMULATIVE PARTICLE SIZE DISTRIBUTION AND SIZE-SPECIFIC EMISSION FACTORS FOR A RECOVERY BOILER WITH A DIRECT-CONTACT EVAPORATOR AND AN ESP[a]

EMISSION FACTOR RATING: C

Particulate Size (µm)	Cumulative Mass % ≤ Stated Size		Cumulative Emission Factor (kg/Mg of Air-Dried Pulp)	
	Uncontrolled	Controlled	Uncontrolled	Controlled
15	95.0	ND	86	ND
10	93.5	ND	84	ND
6	92.2	68.2	83	0.7
2.5	83.5	53.8	75	0.5
1.25	56.5	40.5	51	0.4
1.00	45.3	34.2	41	0.3
0.625	26.5	22.2	24	0.2
Total	100	100	90	1.0

[a] Reference 7. ND = no data.

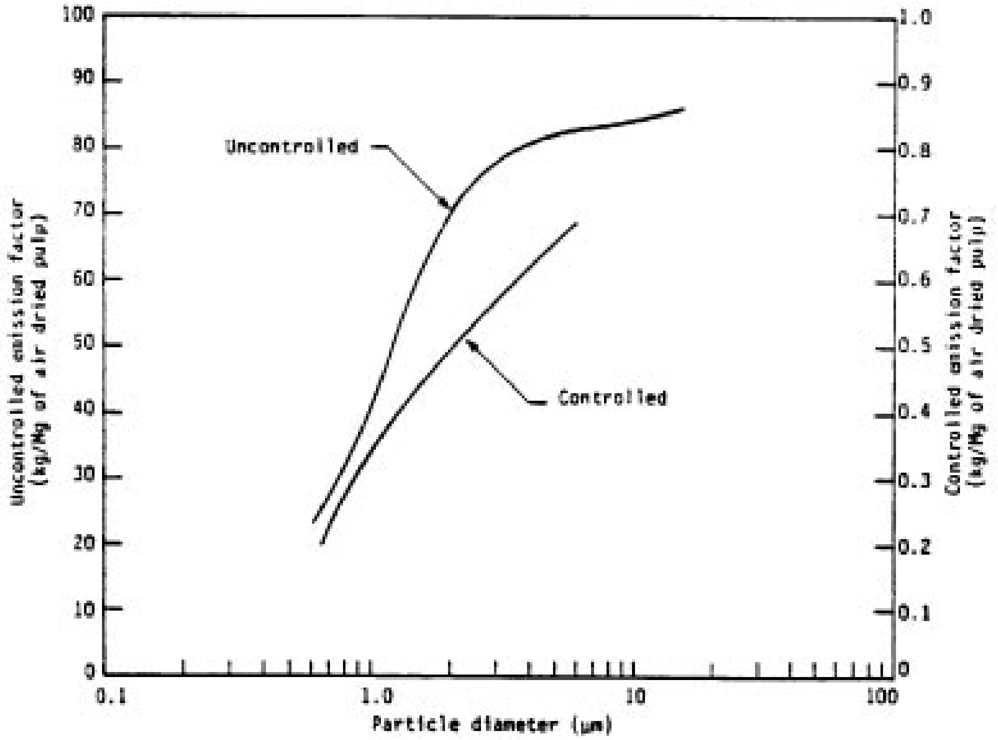

Figure 10.2-2. Cumulative particle size distribution and size-specific emission factors for recovery boiler with direct-contact evaporator and ESP.

Table 10.2-3 (Metric Units). CUMULATIVE PARTICLE SIZE DISTRIBUTION AND SIZE-SPECIFIC EMISSION FACTORS FOR A RECOVERY BOILER WITHOUT A DIRECT-CONTACT EVAPORATOR BUT WITH AN ESP[a]

EMISSION FACTOR RATING: C

Particulate Size (µm)	Cumulative Mass % ≤ Stated Size		Cumulative Emission Factor (kg/Mg of Air-Dried Pulp)	
	Uncontrolled	Controlled	Uncontrolled	Controlled
15	ND	78.8	ND	0.8
10	ND	74.8	ND	0.7
6	ND	71.9	ND	0.7
2.5	78.0	67.3	90	0.6
1.25	40.0	51.3	46	0.5
1.00	30.0	42.4	35	0.5
0.625	17.0	29.6	20	0.3
Total	100	100	115	1.0

[a] Reference 7. ND = no data.

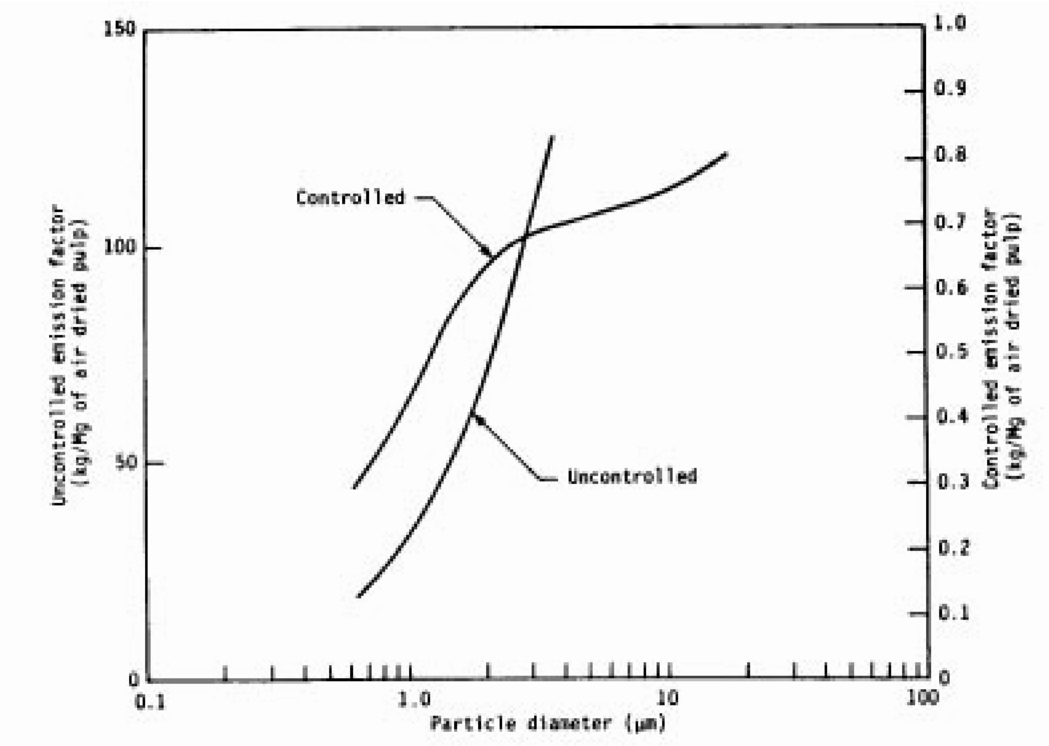

Figure 10.2-3. Cumulative particle size distribution and size-specific emission factors for recovery boiler without direct-contact evaporator but with ESP.

Table 10.2-4 (Metric Units). CUMULATIVE PARTICLE SIZE DISTRIBUTION AND SIZE-SPECIFIC EMISSION FACTORS FOR A LIME KILN WITH A VENTURI SCRUBBER[a]

EMISSION FACTOR RATING: C

Particulate Size (µm)	Cumulative Mass % ≤ Stated Size		Cumulative Emission Factor (kg/Mg of Air-Dried Pulp)	
	Uncontrolled	Controlled	Uncontrolled	Controlled
15	27.7	98.9	7.8	0.24
10	16.8	98.3	4.7	0.24
6	13.4	98.2	3.8	0.24
2.5	10.5	96.0	2.9	0.24
1.25	8.2	85.0	2.3	0.21
1.00	7.1	78.9	2.0	0.20
0.625	3.9	54.3	1.1	0.14
Total	100	100	28.0	0.25

[a] Reference 7.

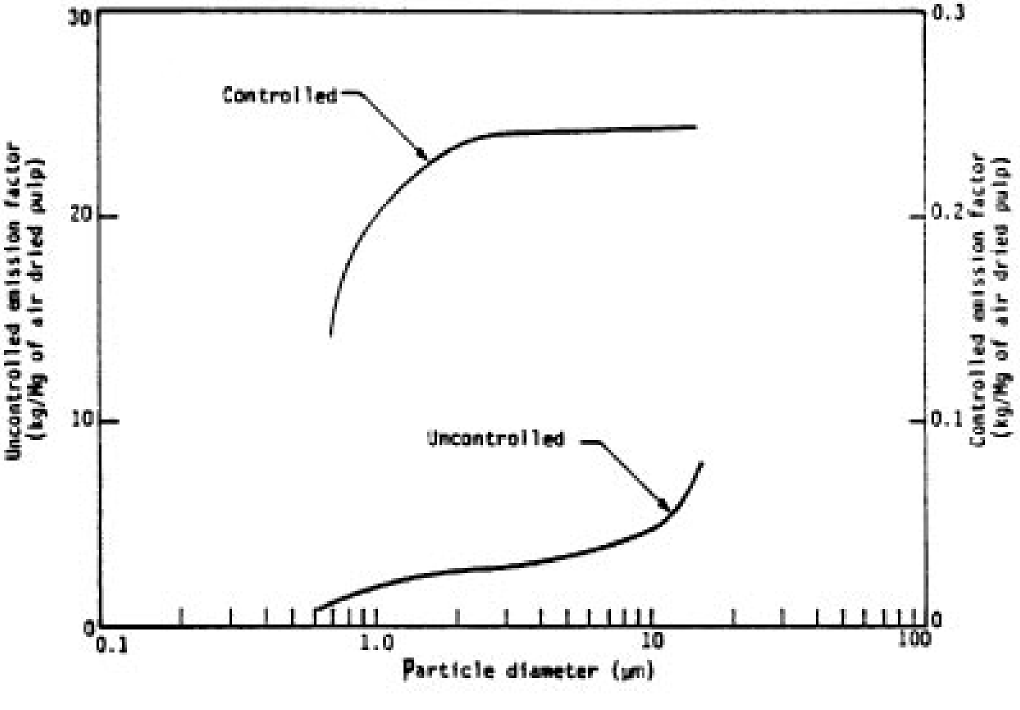

Figure 10.2-4. Cumulative particle size distribution and size-specific emission factors for lime kiln with venturi scrubber.

Table 10.2-5 (Metric Units). CUMULATIVE PARTICLE SIZE DISTRIBUTION AND SIZE-SPECIFIC EMISSION FACTORS FOR A LIME KILN WITH AN ESP[a]

EMISSION FACTOR RATING: C

Particulate Size (µm)	Cumulative Mass % ≤ Stated Size		Cumulative Emission Factor (kg/Mg of Air-Dried Pulp)	
	Uncontrolled	Controlled	Uncontrolled	Controlled
15	27.7	91.2	7.8	0.23
10	16.8	88.5	4.7	0.22
6	13.4	86.5	3.8	0.22
2.5	10.5	83.0	2.9	0.21
1.25	8.2	70.2	2.3	0.18
1.00	7.1	62.9	2.0	0.16
0.625	3.9	46.9	1.1	0.12
Total	100	100	28.0	0.25

[a] Reference 7.

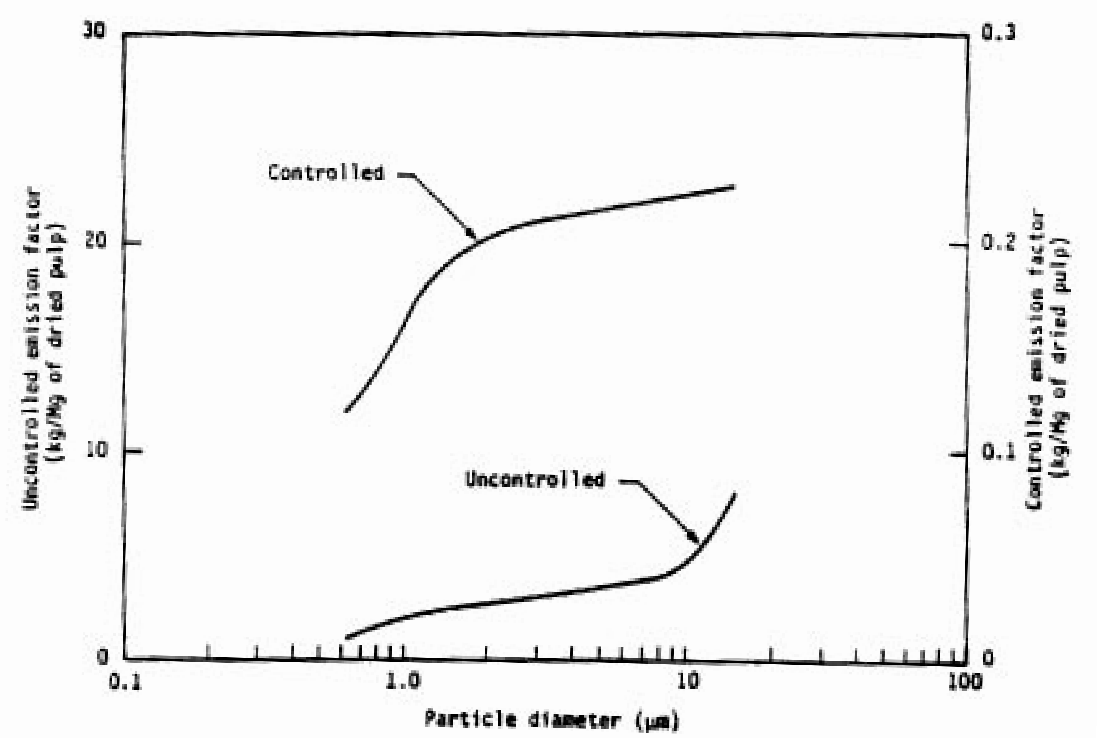

Figure 10.2-5. Cumulative particle size distribution and size-specific emission factors for lime kiln with ESP.

Table 10.2-6 (Metric Units). CUMULATIVE PARTICLE SIZE DISTRIBUTION AND SIZE-SPECIFIC EMISSION FACTORS FOR A SMELT DISSOLVING TANK WITH A PACKED TOWER[a]

EMISSION FACTOR RATING: C

Particulate Size (µm)	Cumulative Mass % ≤ Stated Size		Cumulative Emission Factor (kg/Mg of Air-Dried Pulp)	
	Uncontrolled	Controlled	Uncontrolled	Controlled
15	90.0	95.3	3.2	0.48
10	88.5	95.3	3.1	0.48
6	87.0	94.3	3.0	0.47
2.5	73.0	85.2	2.6	0.43
1.25	47.5	63.8	1.7	0.32
1.00	40.0	54.2	1.4	0.27
0.625	25.5	34.2	0.9	0.17
Total	100	100	3.5	0.50

[a] Reference 7.

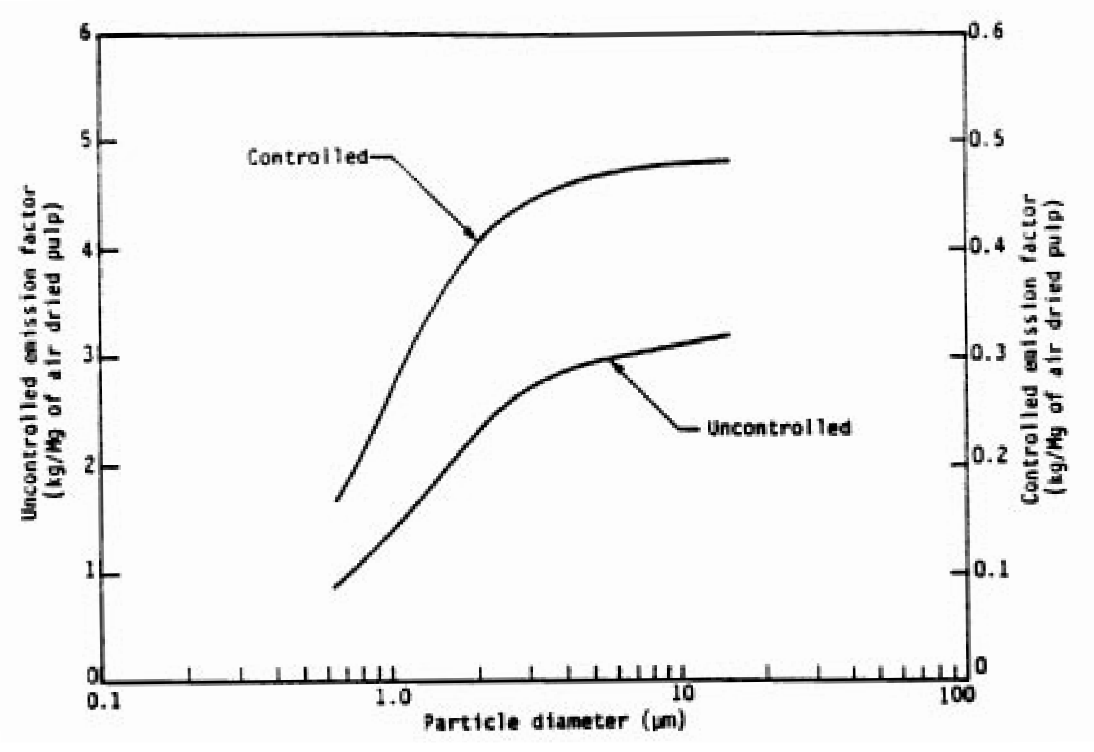

Figure 10.2-6. Cumulative particle size distribution and size-specific emission factors for smelt dissolving tank with packed tower.

Table 10.2-7 (Metric Units). CUMULATIVE PARTICLE SIZE DISTRIBUTION AND SIZE-SPECIFIC EMISSION FACTORS FOR A SMELT DISSOLVING TANK WITH A VENTURI SCRUBBER[a]

EMISSION FACTOR RATING: C

Particulate Size (µm)	Cumulative Mass % ≤ Stated Size		Cumulative Emission Factor (kg/Mg of Air-Dried Pulp)	
	Uncontrolled	Controlled	Uncontrolled	Controlled
15	90.0	89.9	3.2	0.09
10	88.5	89.5	3.1	0.09
6	87.0	88.4	3.0	0.09
2.5	73.0	81.3	2.6	0.08
1.25	47.5	63.5	1.7	0.06
1.00	40.0	54.7	1.4	0.06
0.625	25.5	38.7	0.9	0.04
Total	100	100	3.5	0.09

[a] Reference 7.

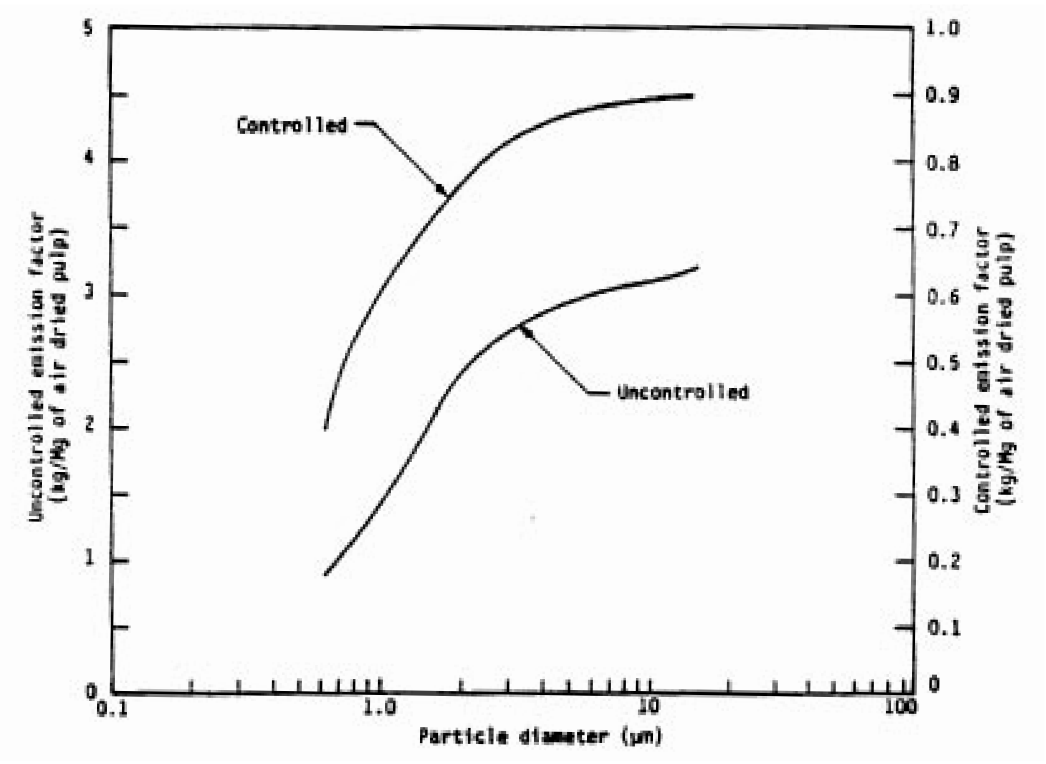

Figure 10.2-7. Cumulative particle size distribution and size-specific emission factors for smelt dissolving tank with venturi scrubber.

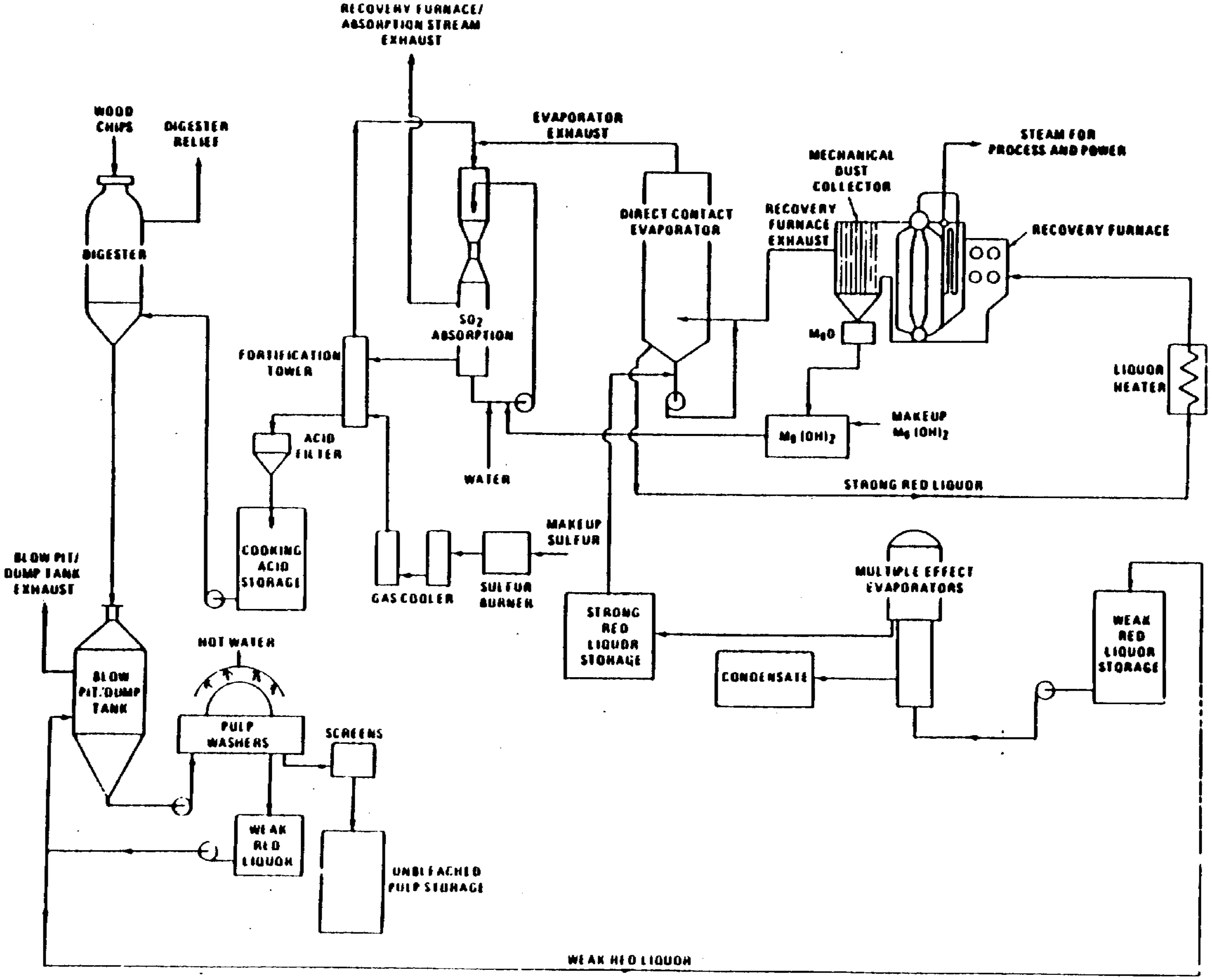

Figure 10.2-8. Simplified process flow diagram of magnesium-base process employing chemical and heat recovery.

If recovery is practiced, the spent (weak) red liquor (which contains more than half of the raw materials as dissolved organic solids) is concentrated in a multiple-effect evaporator and a direct-contact evaporator to 55 to 60 percent solids. This strong liquor is sprayed into a furnace and burned, producing steam to operate the digesters, evaporators, etc. and to meet other power requirements.

When magnesium base liquor is burned, a flue gas is produced from which magnesium oxide is recovered in a multiple cyclone as fine white power. The magnesium oxide is then water slaked and is used as circulating liquor in a series of venturi scrubbers, which are designed to absorb sulfur dioxide from the flue gas and to form a bisulfite solution for use in the cook cycle. When sodium base liquor is burned, the inorganic compounds are recovered as a molten smelt containing sodium sulfide and sodium carbonate. This smelt may be processed further and used to absorb sulfur dioxide from the flue gas and sulfur burner. In some sodium base mills, however, the smelt may be sold to a nearby kraft mill as raw material for producing green liquor.

If liquor recovery is not practiced, an acid plant is necessary of sufficient capacity to fulfill the mill’s total sulfite requirement. Normally, sulfur is burned in a rotary or spray burner. The gas produced is then cooled by heat exchangers and a water spray and is then absorbed in a variety of different scrubbers containing either limestone or a solution of the base chemical. Where recovery is practiced, fortification is accomplished similarly, although a much smaller amount of sulfur dioxide must be produced to make up for that lost in the process.

10.2.3.2 Emissions And Controls[11] -

Sulfur dioxide (SO_2) is generally considered the major pollutant of concern from sulfite pulp mills. The characteristic "kraft" odor is not emitted because volatile reduced sulfur compounds are not products of the lignin/bisulfite reaction.

A major SO_2 source is the digester and blow pit (dump tank) system. Sulfur dioxide is present in the intermittent digester relief gases, as well as in the gases given off at the end of the cook when the digester contents are discharged into the blow pit. The quantity of sulfur dioxide evolved and emitted to the atmosphere in these gas streams depends on the pH of the cooking liquor, the pressure at which the digester contents are discharged, and the effectiveness of the absorption systems employed for SO_2 recovery. Scrubbers can be installed that reduce SO_2 from this source by as much as 99 percent.

Another source of sulfur dioxide emissions is the recovery system. Since magnesium, sodium, and ammonium base recovery systems all use absorption systems to recover SO_2 generated in recovery furnaces, acid fortification towers, multiple effect evaporators, etc., the magnitude of SO_2 emissions depends on the desired efficiency of these systems. Generally, such absorption systems recover better than 95 percent of the sulfur so it can be reused.

The various pulp washing, screening, and cleaning operations are also potential sources of SO_2. These operations are numerous and may account for a significant fraction of a mill’s SO_2 emissions if not controlled.

The only significant particulate source in the pulping and recovery process is the absorption system handling the recovery furnace exhaust. Ammonium base systems generate less particulate than do magnesium or sodium base systems. The combustion productions are mostly nitrogen, water vapor, and sulfur dioxide.

Auxiliary power boilers also produce emissions in the sulfite pulp mill, and emission factors for these boilers are presented in Chapter 1, "External Combustion Sources". Table 10.2-8 contains emission factors for the various sulfite pulping operations.

10.2.4 Neutral Sulfite Semichemical (NSSC) Pulping

10.2.4.1 Process Description[9,12-14] -

In this method, wood chips are cooked in a neutral solution of sodium sulfite and sodium carbonate. Sulfite ions react with the lignin in wood, and the sodium bicarbonate acts as a buffer to maintain a neutral solution. The major difference between all semichemical techniques and those of kraft and acid sulfite processes is that only a portion of the lignin is removed during the cook, after which the pulp is further reduced by mechanical disintegration. This method achieves yields as high as 60 to 80 percent, as opposed to 50 to 55 percent for other chemical processes.

The NSSC process varies from mill to mill. Some mills dispose of their spent liquor, some mills recover the cooking chemicals, and some, when operated in conjunction with kraft mills, mix their spent liquor with the kraft liquor as a source of makeup chemicals. When recovery is practiced, the involved steps parallel those of the sulfite process.

10.2.4.2 Emissions And Controls[9,12-14] -

Particulate emissions are a potential problem only when recovery systems are involved. Mills that do practice recovery but are not operated in conjunction with kraft operations often utilize fluidized bed reactors to burn their spent liquor. Because the flue gas contains sodium sulfate and sodium carbonate dust, efficient particulate collection may be included for chemical recovery.

A potential gaseous pollutant is sulfur dioxide. Absorbing towers, digester/blower tank systems, and recovery furnaces are the main sources of SO_2, with amounts emitted dependent upon the capability of the scrubbing devices installed for control and recovery.

Hydrogen sulfide can also be emitted from NSSC mills which use kraft type recovery furnaces. The main potential source is the absorbing tower, where a significant quantity of hydrogen sulfite is liberated as the cooking liquor is made. Other possible sources, depending on the operating conditions, include the recovery furnace, and in mills where some green liquor is used in the cooking process, the digester/blow tank system. Where green liquor is used, it is also possible that significant quantities of mercaptans will be produced. Hydrogen sulfide emissions can be eliminated if burned to sulfur dioxide before the absorbing system.

Because the NSSC process differs greatly from mill to mill, and because of the scarcity of adequate data, no emission factors are presented for this process.

Table 10.2-8. (Metric And English Units). EMISSION FACTORS FOR SULFITE PULPING

Source	Base	Control	Emission Factor[b]				EMISSION FACTOR RATING
			Particulate		Sulfur Dioxide		
			kg/ADUMg	lb/ADUT	kg/ADUMg	lb/ADUT	
Digester/blow pit or dump tank[c]	All	None	Neg	Neg	5 to 35	10 to 70	C
	MgO	Process change[d]	Neg	Neg	1 to 3	2 to 6	C
	MgO	Scrubber	Neg	Neg	0.5	1	B
	MgO	Process change and scrubber	Neg	Neg	0.1	0.2	B
	MgO	All exhaust vented through recovery system	Neg	Neg	0	0	A
	NH_3	Process change	Neg	Neg	12.5	25	D
	NH_3	Process change and scrubber	Neg	Neg	0.2	0.4	B
	Na	Process change and scrubber	Neg	Neg	1	2	C
	Ca	Unknown	Neg	Neg	33.5	67	C
Recovery system[e]	MgO	Multicyclone and venturi scrubbers	1	2	4.5	9	A
	NH_3	Ammonia absorption and mist eliminator	0.35	0.7	3.5	7	B
	Na	Sodium carbonate scrubber	2	4	1	2	C
Acid plant[f]	NH_3	Scrubber	Neg	Neg	0.2	0.3	C
	Na	Unknown[g]	Neg	Neg	0.1	0.2	D
	Ca	Jensen scrubber	Neg	Neg	4	8	C
Other[h]	All	None	Neg	Neg	6	12	D

[a] Reference 11. All factors represent long term average emissions. ADUMg = Air-dried unbleached megagram. ADUT = Air-dried unbleached ton. Neg = negligible.

[b] Expressed as kg (lb) of pollutant/air dried unbleached Mg (ton) of pulp.

Table 10.2-8 (cont.).

[c] Factors represent emissions after cook is completed and when digester contents are discharged into blow pit or dump tank. Some relief gases are vented from digester during cook cycle, but these are usually transferred to pressure accumulators and SO_2 herein reabsorbed for use in cooking liquor. In some mills, actual emissions will be intermittent and for short periods.

[d] May include such measures as raising cooking liquor pH (thereby lowering free SO_2), relieving digester pressure before contents discharge, and pumping out digester contents instead of blowing out.

[e] Recovery system at most mills is closed and includes recovery furnace, direct contact evaporator, multiple effect evaporator, acid fortification tower, and SO_2 absorption scrubbers. Generally only one emission point for entire system. Factors include high SO_2 emissions during periodic purging of recovery systems.

[f] Necessary in mills with insufficient or nonexistent recovery systems.

[g] Control is practiced, but type of system is unknown.

[h] Includes miscellaneous pulping operations such as knotters, washers, screens, etc.

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