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Brief presented to the British Columbia Pollution Control Board Inquiry into the Food Processing, Agriculturally Orientated and other Miscellaneous Industries

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FOREWORD

In keeping with the intent of this Inquiry to consider only technical matters for the control of discharges from the food processing, and agriculturally oriented industries as well as those remaining industrial sectors not covered at previous Inquiries, to prevent pollution of the water and of land and/or air, Environment Canada, in this brief, has assembled technical information and other relevant data which it is hoped will be useful to the Pollution Control Branch to carry out its mandate. For the most part, the technical information presented in this brief is the direct result of data gathered through investigations and studies conducted by Environment Canada personnel; in particular, the data presented on waste characterization and treatment of fish processing plant effluents and on toxicity of various waste parameters on fish.

The brief is divided into three technical sections: Section I deals with Water Pollution; Section II with Toxicity and Section III with Air Pollution.

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SECTION I
WATER POLLUTION: FISH PROCESSING INDUSTRY

1. FISH PROCESSING INDUSTRY

In 1970 approximately 240 million pounds of fish and shellfish were landed in the Province of British Columbia, with a landed value of 60 million dollars. Table 1, below, gives the major species in weight and value landed in 1970.

Table 1: Landings and Landed Value of Fish in British Columbia. (1970).

	<u>Landings</u> <u>'000 pounds</u>	<u>Landed Value</u> <u>'000 dollars</u>
Cod	12,063	1,241
Halibut	29,525	10,588
Total Groundfish	58,536	12,823
Salmon	154,486	45,076
Total Pelagic and Estuarial	167,493	45,810
Oyster	5,977	530
Crab	2,548	460
Total Shellfish	12,472	1,622
Total Landings	238,501	60,255

Salmon landings represent approximately 65 percent by volume of total fish landings, but the landed value is approximately 75 percent of the total value. In contrast landings of halibut, the second most important commercial species, represent approximately 12 percent by volume of total fish landings with a value of approximately 17 percent of total value. Thus, 92 percent of value and 77 percent of volume is made up of the two species, salmon and halibut.

While the total landings in B.C. are declining the landed and marketed value of the fish is increasing (Table 2).

Table 2: Summary of Total Landings and Values of all Species for B.C. (1970)

	<u>Landings</u>	<u>Landed</u>	<u>Marketed</u>
	<u>millions of lbs.</u>	<u>Value</u>	<u>Value</u>
		<u>millions of dollars</u>	
1955	497.2	28.3	61.5
1963	772.7	40.5	80.1
1970	238.5	60.2	123.3

Table 3 gives the landings and values for salmon.

Table 3: Summary of Salmon Landings and Values for B.C. (1970)

	<u>Landings</u>	<u>Landed</u>	<u>Marketed</u>
	<u>millions of lbs.</u>	<u>Value</u>	<u>Value</u>
		<u>millions of dollars</u>	
1955	131.0	18.4	42.6
1963	119.3	22.7	48.9
1970	154.5	45.1	99.5

In 1970 the fishing industry supported a commercial fleet of 7,000 boats with a value of \$105 million. This fleet generated \$31 million of gross sales in supporting service industries. The industry employs some 12,000 fishermen, with a further 4,000 shore workers.

The industry provides necessary employment for a number of remote communities on the B.C. coast. These communities are dependent to a significant degree, if not wholly, on the fishing industry for their livelihood. The industry has also played a significant role in the life of B.C.'s native peoples, both as a source of food and a means of commercial livelihood.

2. PROCESSING BY SPECIES

2.1 Groundfish

The most important groundfish species in B.C. is halibut, followed by cod, sole and rockfish.

2.1.1 Halibut

Halibut, is a large fish; the commercially landed sizes vary from 20 to over 200 pounds. They are caught near the sea bottom using baited longlines. The commercial season extends from April or May through to October and is dependent on quota set by the Halibut Commission.

After being landed on the vessel, the halibut are dressed by removing the viscera and cutting away the gills. The halibut are then packed in ice in the hold. Halibut are ordinarily processed in relatively small plants. The fishermen usually unload and behead the fish before sale to the processor.

If the fish are not processed immediately, they are re-iced in the fish plant. The majority of halibut are filleted and marketed frozen, however, some are frozen whole or sold fresh.

Prior to whole freezing, a continuous belt washer sprays the fish. The fish are frozen with a glaze protection at approximately -20°F. The filleting and freezing operations are diagrammed in figures 1 and 2.

Halibut are cut in fletches (boneless and skinless pieces produced from fresh fish). This process divides the halibut into four or more trimmed meaty portions weighing from 5 to 20 pounds. The fletches are frozen and either glazed or packaged in moisture proof wrapping. Other forms of fresh or frozen halibut include packaged fillets, steaks, and breaded fillets.

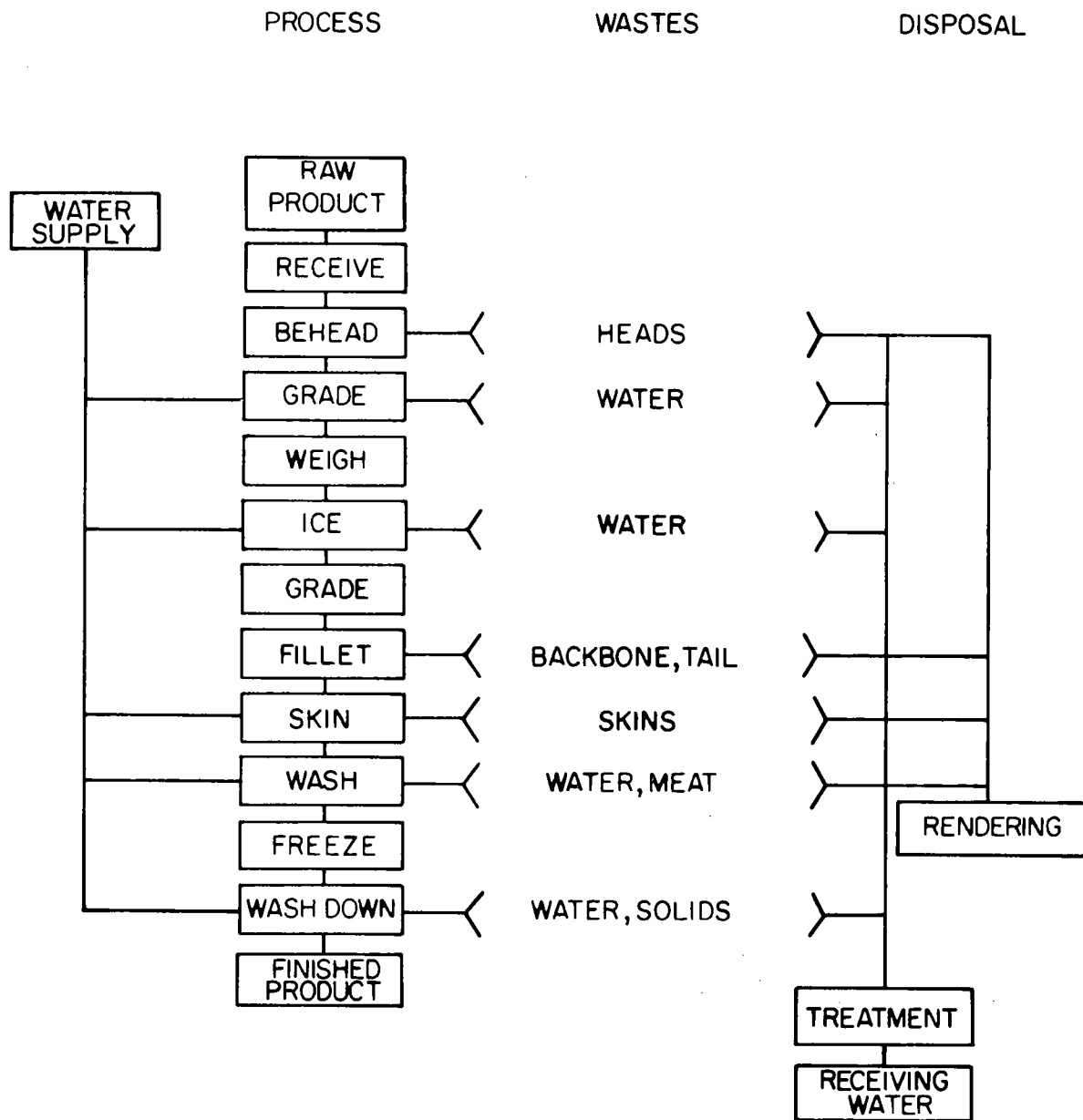


FIGURE 1. HALIBUT FILLET FREEZING

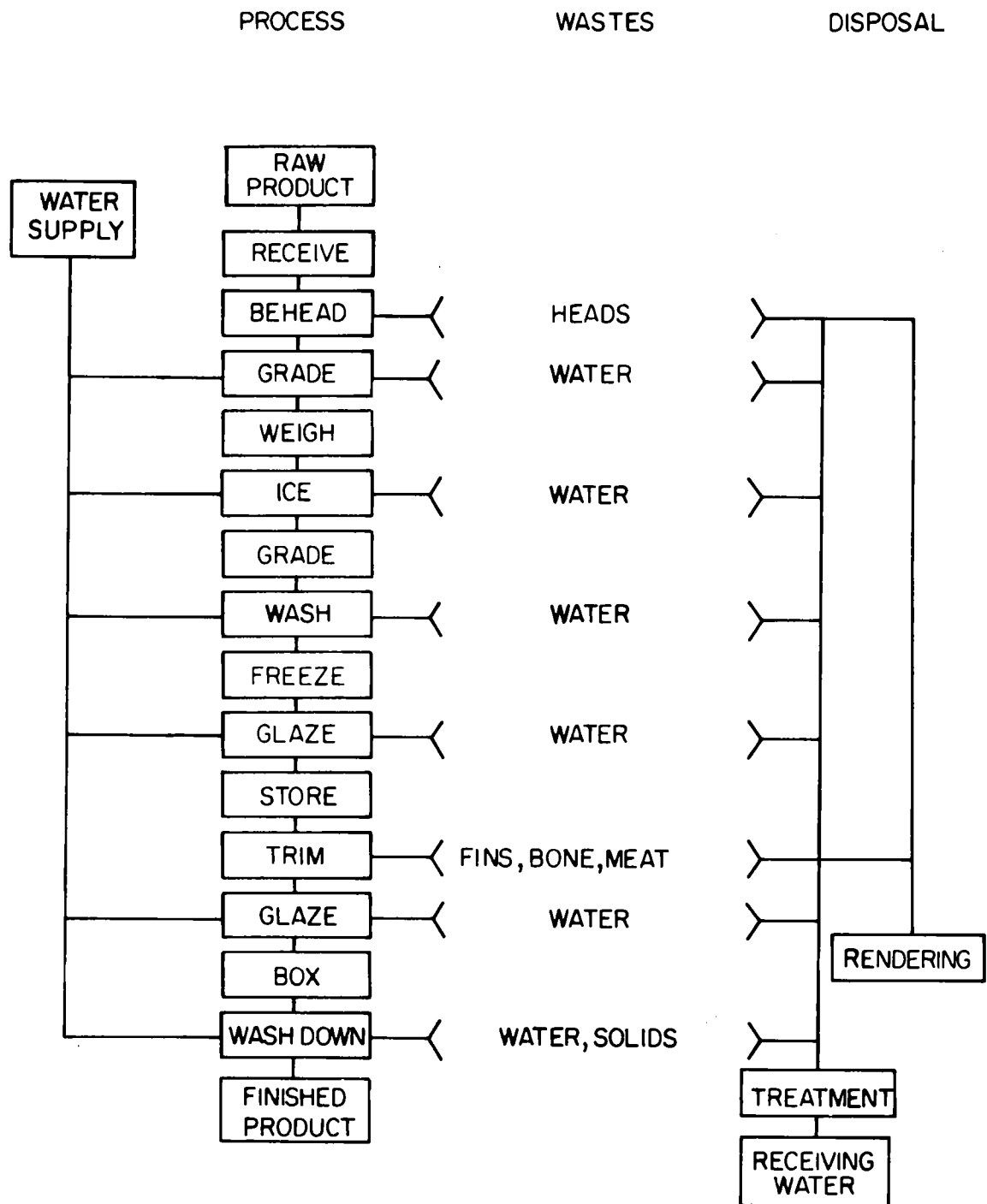


FIGURE 2. WHOLE HALIBUT FREEZING

2.1.2 Cod, Sole and Rockfish

The fish are either stored whole in the ship or are eviscerated prior to storage, the viscera and blood being washed overboard. At the wharf, unloading is usually accomplished by pitching the fish into a basket that has been lowered into the hold. The fish are then weighed, washed and iced in tote boxes. In some larger plants, mechanized unloading methods are used to minimize manual handling.

In small plants, the fish are processed by hand. The fillets are cut on a wooden board next to a sink, washed and immediately iced in boxes for distribution.

Most plants processing fillets use mechanized equipment. First, the fish are washed in large wash tanks or by water sprays in large rotating tumblers. Next the fish pass to filleting machines or hand filleting tables. Filleting machines only operate on certain fish sizes and shapes, but considerably reduce labor costs and increase yields, over hand-filleting. The skin is removed from fillet by hand or machine. The solid wastes from filleting and skinning operations are usually rendered for pet food or animal meal. Figure 3 outlines a typical groundfish filleting operation.

The skinned fillets are transported by conveyor belt through a washing tank and, in some cases, a brining tank. After inspection the fillets are packed into containers by hand or frozen and then packed. Steaks are produced from the eviscerated fish by cuts made at right angles to the backbone. These steaks are marketed frozen or fresh. Fillets are marketed frozen (fresh or breaded), chilled, or fresh.

2.2. Pelagic and Estuarial

The most important pelagic and estuarial species in B.C. is salmon followed by herring and tuna. Herring and tuna represent only 5 percent and 1 percent by weight of catch respectively, the remaining 94 percent being salmon.

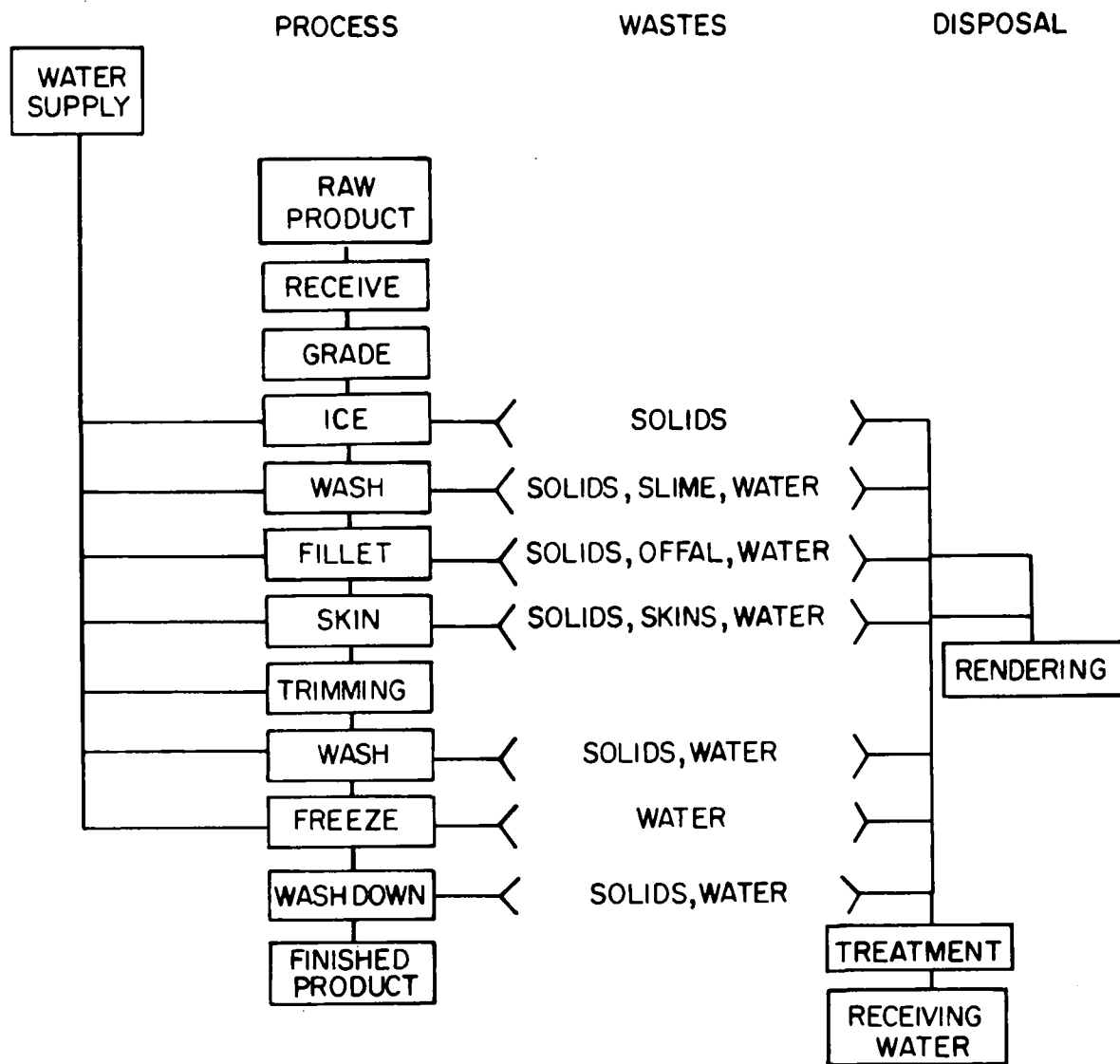


FIGURE 3. GROUND FISH FILLETING

2.2.1 Salmon

The five main species of salmon found in B.C. are spring, sockeye, coho, pink and chum. The major portion of the catch (approximately 80%) is canned.

Spring, coho and some sockeye salmon are caught using a trolling technique whereas the remaining species of salmon are netted. Troll caught salmon are gutted at sea and subsequently stored in ice. Following unloading a small portion are usually sold fresh while the balance is frozen and glazed for sale in this form or as steaks cut from the frozen fish.

Net caught fish are usually taken close to the canneries and are often held for short periods in the boats without refrigeration. Canning operations are conducted for the most part employing standard cannery equipment in a conventional manner. The principal exception is the use of the "iron chink". The iron chink performs several functions in one operation by mechanically removing heads, fins, and viscera. During all the steps a strong stream of water continuously washes the blood away. The remaining canning operations are somewhat standard, as shown in figure 4. The fish are washed, inspected and cut into controlled-length pieces. These pieces are cut into can-length portions and the cans are filled mechanically. Finally, the cans are automatically sealed under vacuum and then retorted.

2.2.2 Herring

There has recently been a marked increase in the herring catch, the 1971 volume being 45,000 tons. The herring are brined prior to process for removal of the roe. The roe are salted, packaged and refrigerated prior to shipment. Following roe removal the remaining herring flesh is sent for reduction to fish meal or to pet food production.

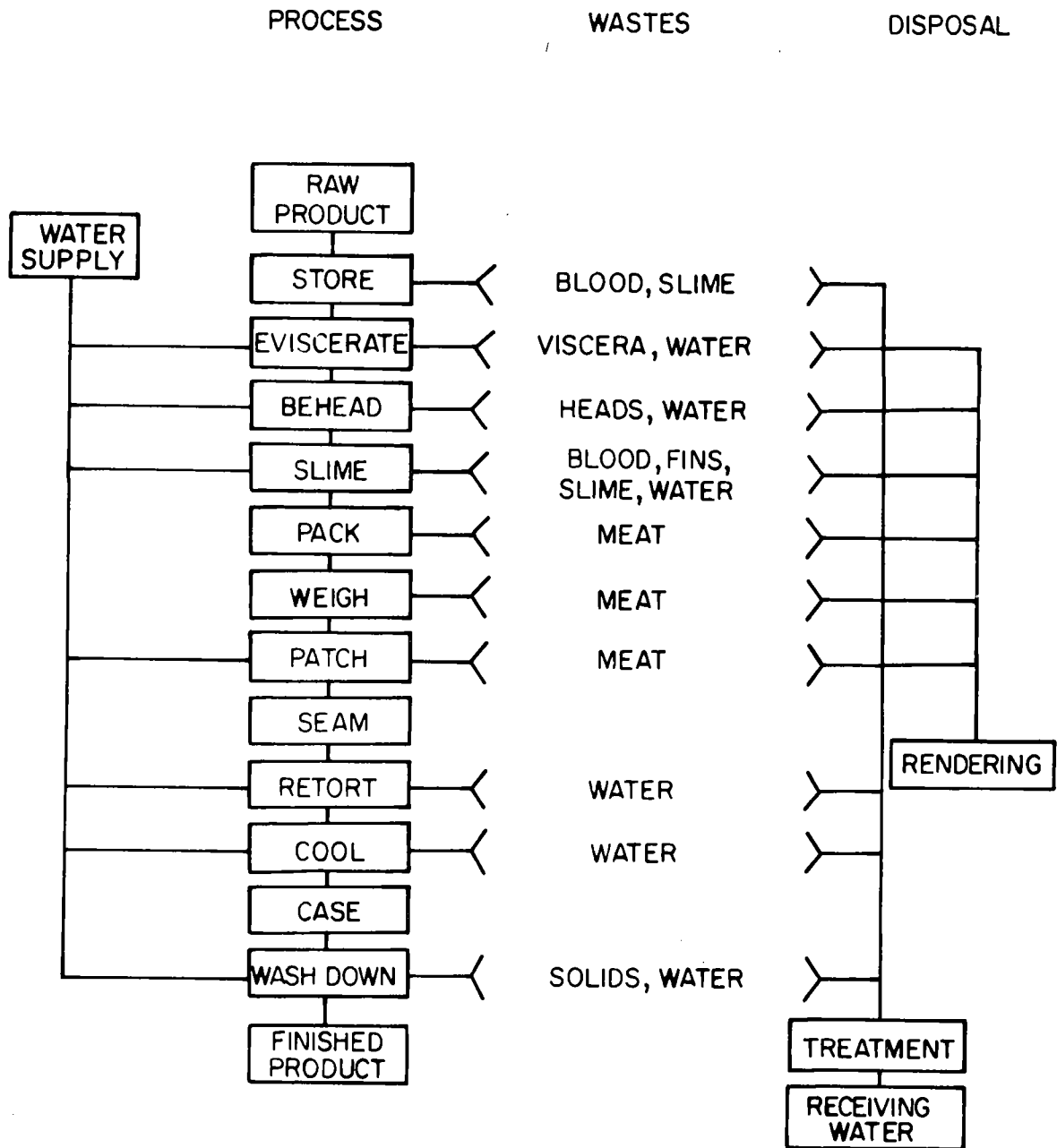


FIGURE 4. SALMON CANNING

2.3 Molluscs and Crustaceans

The major species in B.C. is oyster, followed by crab, shrimp and prawn.

2.3.1 Oyster

Oysters are marketed shucked or unopened. If marketed unopened, only washing, packing and chilling of the shellfish are required. Prior to shipment, the oysters may be stored in chlorinated water to minimize bacterial growth.

Most oysters are sold as shucked meats. The meats, when removed from the shells, are aerated in water to remove the sand and silt. After washing, the meats are graded and then packed into cartons, tins or glass containers.

2.3.2 Crab

Crabs are harvested from shallow water in baited traps. Rapid and careful handling is necessary to keep the crabs alive; dead crabs must be discarded because of rapid decomposition.

At most plants, whole crabs are steam cooked in retorts for 20 to 30 minutes. Cooked crabs are marketed in the shell, butchered or whole, or the meats, picked from the shell, are marketed fresh, frozen or canned.

The crabs are water cooled after cooking to facilitate handling. The backs are removed if the crabs were not butchered before cooking, and the remaining viscera are washed free. The cooking, cooling and washing waters contain considerable solids and organic pollutants. The meat is picked from the shells by hand with a small knife. Mechanical methods have only recently been developed to extract the meat from the shells.

Crab meat quickly degrades in quality and must be chilled, frozen or canned. Chilled meat can be stored for only a few days; even frozen meat loses some of its texture and flavor over a period of 6 months. Canning of crab meat results in additional wastewater flows: retort and can cooling waters.

2.3.3 Shrimp

Shrimp are caught commercially to a distance of approximately 50 miles offshore. The shrimp are separated from the trash fish aboard the catching vessel and stored usually in ice.

The shrimp are unloaded usually in wooden boxes from the vessel and placed in chill rooms until processing begins. The shrimp are cooked from 1 to 3 minutes in boiling water. They are then passed to the peeling tables. By hand a picker can peel from 100-400 pounds of shrimp per day.

After peeling, the meats are inspected and washed. They are then blanched in a salt solution for about 10 minutes and dried by various methods to remove surface water. Again the shrimp are inspected and then packed. Shrimp are marketed fresh, frozen, breaded, canned, cured and as specialty products.

3. WASTE CHARACTERISTICS

3.1 Groundfish

The groundfish operations involve the processing of halibut, cod, sole and rockfish. Two different types of processing are used:

- a) dry line operation which uses a system of conveyors to move the raw product and mechanically operated filleting tables. In the majority of cases offal is removed from the filleting tables by fluming.

- b) wet line operation characterized by the use of water to flume raw product and offal.

In general, dry line operations are used in the larger operations whereas the smaller plants rely on wet transportation of raw product and offal. In all cases fish are washed in tanks or spray conveyors immediately prior to processing.

3.1.1 Dry Line Process

During the summer of 1971 an effluent study of five fish plants was undertaken in B.C. by Environment Canada. Of the five plants surveyed three were groundfish filleting operations, the remaining two being salmon canning operations. The results of that study will be compared with the following:

- a) Dr. K. Brodersen study of groundfish operations in the Maritime Region (1971)
- b) Results from an Environment Canada Study of groundfish operations in the Atlantic Provinces (1972).
- c) Results from work by F. Claggett of Fisheries Research Board, Vancouver (1972).
- d) Report by Stanley Associates Engineering Ltd., entitled, "Fish Processing Plants: Liquid Waste and Receiving Water Study". This study was carried out for the Fisheries Association of British Columbia and completed in January 1972.

Tables 4 to 8 give the BOD_5 suspended solids and ether soluble oil loadings in the effluent from the processing of halibut, grey cod, ling cod, sole and rockfish. The results, taken from the 1971 Environment Canada Study, are given in both concentrations, means and ranges, and in pounds of parameter per 1000 pounds of raw product, again in both means and ranges.

Table 4: Effluent from Dry Line Processing of Halibut

Species: Halibut

Plant Size	BOD ₅				S.S.				Ether Soluble Oil			
	Conc. (mg/l)		Lbs./1000 lbs. raw fish		Conc. (mg/l)		Lbs./1000 lbs. raw fish		Conc. (mg/l)		Lbs./1000 lbs. raw fish	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Environment Canada (1971)												
10,000 lbs. raw fish per day	282	145-420	2.6	1.3-4.0	170	95-245	1.6	0.8-2.4	--	--	--	--
15,000 lbs. raw fish per day	204	--	4.0	--	352	--	7.2	--	--	--	--	--
Stanley Associates (1972)												
washwater												
40,000 lbs. raw fish per day	64	--	0.3	--	66	--	0.3	--	--	--	--	--
120,000 lbs. raw fish per day	150	--	0.7	--	110	--	0.5	--	--	--	--	--
fillet process water												
15,000 lbs. raw fish per day	140	--	3.2	--	110	--	2.5	--	--	--	--	--

Table 5: Effluent from Dry Line Processing of Grey Cod - Environment Canada (1971)

Species: Grey Cod

Plant Size	BOD ₅				S.S.				Ether Soluble Oil			
	Conc. (mg/l)		Lbs./1000 lbs. raw fish		Conc. (mg/l)		Lbs./1000 lbs. raw fish		Conc. (mg/l)		Lbs./1000 lbs. raw fish	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
6,000 lbs. raw fish per day	607	120-1775	8.1	0.7-39.1	259	196-694	2.5	0.6-6.0	61.6	9.0- 227.7	1.7	0.04-5.0
10,000 lbs. raw fish per day	435	53-1547	2.2	0.3-7.5	293	75-1006	1.5	0.4-4.8	16.7	0.4- 55.2	0.2	0.01-0.64
15,000 lbs. raw fish per day	74	27-117	0.9	0.4-1.5	44.1	20.5- 90.0	0.5	0.3-0.6	--	--	--	--

Table 6: Effluent from Dry Line Processing of Ling Cod - Environment Canada (1971)

Species: Ling Cod

Plant Size	BOD ₅				S.S.				Ether Soluble Oil			
	Conc. (mg/l)		Lbs./1000 lbs. raw fish		Conc. (mg/l)		Lbs./1000 lbs. raw fish		Conc. (mg/l)		Lbs./1000 lbs. raw fish	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
6,000 lbs. raw fish per day	500.1	471-1050	6.3	2.2-12.7	248.3	173.6- 517	3.5	1.6-5.1	45.7	--	0.3	--
10,000 lbs. raw fish per day	468	30-1102	4.1	0.22-7.4	237	28-564	2.2	0.21-5.5	320	--	0.37	--
15,000 lbs. raw fish per day	300	54-546	6.0	1.1-11.0	95.5	41.6- 121.1	1.8	0.8-2.3	--	--	--	--

Table 7: Effluent from Dry Line Processing of Sole - Environment Canada (1971)

Species: Sole

Plant Size	BOD ₅				S.S.				Ether Soluble Oil			
	Conc. (mg/l)		Lbs./1000 lbs. raw fish		Conc. (mg/l)		Lbs./1000 lbs. raw fish		Conc. (mg/l)		Lbs./1000 lbs. raw fish	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Environment Canada (1971)												
6,000 lbs. of raw fish per day	213.8	96-540	1.4	0.3-4.8	124.8	92.1- 269.8	0.8	0.2-1.9	109.4	37.6- 290.6	1.3	0.2-2.3
10,000 lbs. of raw fish per day	515	200-990	2.7	1.5-7.6	332	118- 908	1.4	0.69-3.2	215	3.0- 526.4	1.6	0.01-4.1
15,000 lbs. of raw fish per day	81.8	45-130	0.7	0.4-1.1	70.5	32.6- 173.8	0.6	0.04-1.5	10.9	0.3- 43.6	0.1	0.02-0.4
Stanley Associates (1972)												
Fillet process water 7,000 lbs. of raw fish per day	177	160- 195	8.3	7.4-9.0	60.0	34-85	2.7	1.6-3.9	--	--	--	--

Table 8: Effluent from Dry Line Processing of Rockfish

Species: Rockfish (Ocean Perch)

Plant Size	BOD ₅				S.S.				Ether Soluble Oil			
	Conc. (mg/l)		Lbs./1000 lbs. raw fish		Conc. (mg/l)		Lbs./1000 lbs. raw fish		Conc. (mg/l)		Lbs./1000 lbs. raw fish	
Environment Canada (1971)	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
15,000 lbs. of raw fish per day	77	40-114	0.7	0.4-1.1	48.9	14.4- 101.3	1.3	0.1-3.5	23.9	12.9- 35.0	0.2	0.12-0.35
Canadian Plant and Process Eng. (1970) Unknown	366	130-780	--	--	298	62-1120	--	--	--	--	--	--
Shaffner (1971) Unknown	465	390-540	--	--	862	330-1395	--	--	--	--	--	--

In the fish processing industry the variability of the effluent in terms of concentrations of BOD₅, suspended solids and oil is considerable due to differences in water usage, amount of fish processed as well as the processing techniques. Attempts to minimize this variability for each species of fish processed have been undertaken by converting concentrations of a parameter to pounds of a parameter per 1000 pounds of raw products.

The results from the Stanley Associates Report were originally given in terms of pounds of parameter per 1000 pounds of product, they were changed from pounds of product to pounds of raw fish by allowing 2/3 loss of fish due to processing.

In examining the data for BOD₅ loadings for individual species, it was noted that a wide range of BOD₅ loadings existed for particular species from plant to plant and even within a plant. Sole, grey cod, and ling cod processing were common to all plants studied and a comparison of the BOD₅ loadings by species for the plants studied (Environment Canada 1971 Study) appears in Table 9 below.

Table 9. Summary of BOD₅ Loadings from Groundfish Processing Plants

<u>Plant Size</u>	<u>Sole</u>	<u>Grey Cod</u>	<u>Ling Cod</u>
<u>Lbs of Raw Product per day</u>	<u>lbs BOD₅ /1000 lbs raw fish</u>		
6,000	1.4	8.1	6.3
10,000	2.7	2.2	4.1
15,000	0.7	0.9	6.0
Average	1.6	3.7	5.5

Table 10 gives the total effluent values for groundfish processing plants of varying production sizes. The Environment Canada (1971) Study indicated that the range of BOD₅ loadings from a groundfish processing plant varied from 1.3 pounds of BOD₅ per 1000 pounds of raw product to 5.7 pounds of BOD₅ per 1000 pounds of raw product. These results compare to 5.0 pounds of BOD₅ per 1000 pounds of raw product from Brodersen's 1971 Maritime Study, and 7.9 pounds of BOD₅ per 1000 pounds of raw product from the Environment Canada (1972) Study.

Examination of Table 10 indicates a variability in suspended solids loadings of from 0.98 to 2.4 pounds per 1000 pounds of raw product and of 0.13 to 1.0 pounds per 1000 pounds of raw product for oil (Environment Canada 1971 Study). As for BOD₅ loadings, a wide variation in suspended solids and oil loadings existed for particular species from plant to plant and even within a plant (see Tables 4 to 8).

3.1.2 Wet Line Process

The Environment Canada 1971 Study of fish plants in B.C. did not include the analysis of effluent from wet line processing of groundfish. Brodersen (1971) analysed effluents from both the wet and dry line processes and since his dry line results coincide with the results of the B.C. (1971) Study, it is reasonable to assume his wet line results should provide an indication of the effluent characteristics from wet line processing in B.C. Brodersen's (1971) results are shown in Table 11.

Comparison between the effluent from dry line and wet line processing of groundfish (Tables 10 and 11) indicates that wet line processing produces an effluent in excess of three times the dry line BOD₅ loading.

Table 10 : Total Effluent from Dry Line Groundfish Processing

Plant Size	BOD ₅				S.S.				Ether Soluble Oil			
	Conc. (mg/l)		lbs./1000 lbs. raw fish		Conc. (mg/l)		lbs./1000 lbs. raw fish		Conc. (mg/l)		lbs./1000 lbs. raw fish	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Environment Canada (1971)												
6,000 lbs. of raw fish per day	451.5	96-1775	5.7	0.3-39.1	226.5	92.1-1006.4	2.4	0.2-6.2	56.8	2.4-260.6	1.0	0.03-5.0
10,000 lbs. of raw fish per day	411.0	30-1547	2.7	0.22-7.6	254	6.8-1006	1.6	0.1-5.5	93.3	0.4-526.4	0.75	0.01-4.1
15,000 lbs. of raw fish per day	101.9	27-546	1.3	0.4-11.0	64.5	14.4-173.8	0.98	0.04-3.5	14.6	0.33-43.6	0.13	0.02-0.4
Brodersen (1971)												
Unknown	455	100-1140	5.0	--	135	30-232	1.0	--	100	0-500	1.0	--
Soderquist (1970)												
Unknown	--	192-1726	--	--	300	--	--	--	--	--	--	--
Environment Canada (1972)												
300,000 lbs. of raw fish per day												
flume process water	131	62-415	--	--	390	84-960	--	--	--	--	--	--
			7.9				22.5					
wash water	279	178-389	--	--	290	140-576	--	--	--	--	--	--

Table 11: Total Effluent from Wet Line Groundfish Processing

Plant Size	BOD ₅				S.S.				Ether Soluble Oil			
	Conc. (mg/l)		Lbs./1000 lbs. raw fish		Conc. (mg/l)		Lbs./1000 lbs. raw fish		Conc. (mg/l)		Lbs./1000 lbs. raw fish	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Brodersen (1971)												
Unknown	1136	602- 1205	15	--	489	148-965	7	--	900	200- 1500	13	--

These increased loadings are due to:

- a) increased BOD_5 , suspended solids and oil concentrations in the wet line processing effluents.
- b) water consumption figures (Table 12) indicate that wet line processing requires between 2 to 3 times the water required for dry line processing.

Such a situation supports the theory that the longer water is in contact with fish solids (as in wet line processing) the higher the BOD_5 , suspended solids and oil concentrations in the effluent. A study of fresh water fish processing plants carried out in 1971 by Environment Canada supported this theory.

3.2 Pelagic and Estuarial

3.2.1 Salmon

Spring, coho and some chum and pink salmon are usually glazed and sold whole, while the majority of the remaining salmon catch is canned. The wastes from the canning operation include butchering water, viscera, wash water, retort water and cooling water.

Table 13 below shows the values of total effluent from salmon canning and glazing operations as given in studies by Environment Canada (1972), Stanley Associates and Soderquist (1970). Stanley Associates results were converted from pounds of parameter per 1000 pounds of product to 1000 pounds of raw fish by allowing for 30 percent loss during processing. A comparison of the results indicates that BOD_5 loadings of between 18 to 30 pounds per 1000 pounds of raw fish can be expected from salmon canning using iron chink techniques. The suspended solids in the effluent will vary from about 12 to 23 pounds per 1000 pounds of raw fish.

Table 12: Water Consumption in Groundfish Processing

<u>Author</u>	<u>Plant Size</u>	<u>Process</u>	<u>Water Consumption (fresh and salt) Gals./1000 lbs. fish filleted</u>
Environment Canada (1971)	6,000 lbs. raw fish/day	Groundfish - dry line	2040
	10,000 lbs. raw fish/day	Groundfish - dry line	1630
	15,000 lbs. raw fish/day	Groundfish - dry line	3780
Brodersen (1971)	Unknown	Groundfish - dry line	1500
		Groundfish - wet line	4600
Environment Canada (1972)	300,000 lbs. raw fish/day	Groundfish - dry line	16,700
	270,000 lbs. raw fish/day	Groundfish - wet line	32,900
	180,000 lbs. raw fish/day	Groundfish - wet line	18,500
	40,000 lbs. raw fish/day	Groundfish - wet line	10,000
Stanley Associates	Varied	Groundfish - (not specified)	2000

Table 13: Summary of Total Effluent Results from Salmon Processing

Author	Processing and Plant Capacity	BOD ₅	Suspended Solids	Ether Soluble Oil
		(Lbs. of parameter/1000 lbs. of raw fish)		
Environment Canada (1971)	Spring Salmon (Glazing)	1.83	1.2	0.2
	Hand Processing (Canning)	29.1	16.8	3.8
	30,000 lbs. raw fish per day			
	Iron Chink	27.3	22.6	7.4
	70,000 lbs. raw fish per day			
Soderquist (1970)	Canning	3.2-89	--	--
Stanley Associates (1972)	Iron Chink			
	90,000 lbs. raw fish per day	26.5	18.0	--
	150,000 lbs. raw fish per day	18.5	12.6	--
	300,000 lbs. raw fish per day	19.8	13.0	--
	350,000 lbs. raw fish per day	26.0	12.0	--

A comparison of water use figures from the Environment Canada (1971) Study and Stanley Associates report indicates that salmon canning requires between 0.9 to 8 gallons per pound of salmon canned. The processing of spring salmon (glazing and storage) requires approximately 1.5 gallons per pound of product.

Frequently, water used in the unloading of salmon at the plant dock is discharged direct to the harbour. Following unloading, the ships holds are washed, this wash water also enters the harbour directly. Table 14 gives the results obtained from the Environment Canada (1971) study and the report by Stanley Associates (1972). These results are for the hydraulic pumping method of unloading salmon. Examination of Table 14 indicates that the wastes from unloading operations should be considered as part of the plants effluent and should therefore, be treated in the plants effluent treatment system.

3.2.2 Herring

The rapid increase in the volume of herring being landed in B.C. indicates that in the future food herring processing, as distinct from reduction (see later section), could constitute a significant pollution potential from the fish processing industry.

The major waste sources include pumpout water, brine and water used during the splitting of the herring to recover the roe. The total plant effluent is made up the brine and wash water, the pumpwater usually being discharged direct to the harbour.

Table 15 gives the effluent characteristics for food herring production as reported by Bordersen (1971), and results obtained by Claggett (1972) at a food herring operation in B.C. The results indicate the high strength wastes generated by food herring production.

Table 14: Effluent Characteristics from Hydraulic Pumping of Salmon Unloading

<u>Author</u>	<u>Salmon Species</u>	<u>BOD₅</u> <u>(Lbs. of parameter/1000 Lbs. of raw product)</u>	<u>Suspended Solids</u> <u>(Lbs. of parameter/1000 Lbs. of raw product)</u>
Environment Canada (1971)	Pink	2.8 (5,100)	0.81 (1475)
	Sockeye	1.54 (1,420)	0.49 (457)
	Coho	1.13 (2470)	0.26 (567)
Stanley Associates (1972)		2.4 (2010)	1.2 (1127)

(Concentrations in mg/l given in parentheses)

Table 15: Effluent Characteristics from Food Herring Processing

Author	BOD ₅				S.S.				Ether Soluble Oil			
	Conc. (mg/l)		Lbs./1000 lbs. raw fish		Conc. (mg/l)		Lbs./1000 lbs. raw fish		Conc. (mg/l)		Lbs./1000 lbs. raw fish	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Brodersen (1971)												
Plant Effluent	3859	3200- 5800	22	--	3011	1150- 5310	21	--	1200	200- 3000	10	--
Water Usage: 600 gallons per 1000 pounds raw fish												
Pumpout water (Herring pumps)	33,500	--	--	--	7955	--	--	--	500	--	--	--
Claggett (1972)												
	Cod (mg/l)		Total Solids (mg/l)		Settleable Solids (mg/l)		Soluble Solids (mg/l)					
Total Plant Effluent	6258		6986		1476		5530					

The high BOD₅ and suspended solids in the pumpout water indicates clearly the necessity of treating these wastes in the plants treatment system rather than allowing direct discharge to the harbour. At the present time food herring is being unloaded using either once through herring pumps (previously used for unloading herring for reduction) or the hydraulic pumping techniques previously used for salmon unloading, the latter system recycles the water, discharging the waste only intermittently, e.g. after completion of boat unloading.

Many of the studies reported previously indicate that the results obtained from BOD₅, suspended solids and oil analyses varied widely. This is due to:

- 1) Inherent sampling and analysis problems.
- 2) Variable characteristics of the fish such as age, sex and season of the year.
- 3) Variations in the catch handling and storage techniques employed by the fisherman as well as the time required to transport the fish to the plant.
- 4) Variations in off-loading, storage and processing techniques employed by the plants.

Reliable results of fish plant effluents can only be obtained from a thorough sampling program. In most cases such a sampling program can only be carried out on the total effluent, since the sampling of individual process waste streams would necessitate the committing of considerable resources to a project.

4. SOLIDS WASTES HANDLING

4.1 Fish Meal Production

In the processing of most species of fish for food purposes from 30 to 80 percent of the raw material is waste. Efforts are made by most plants to recover all edible portions, and the recent introduction of deboning machines promises greater utilization in the future. Still, much of the fish poses a disposal problem and one practice has been to produce a protein concentrate for poultry feed. Oil may also be recovered from oily species.

The waste material, termed offal is normally conveyed wet or dry to the fish meal plant and stored in pits until enough is accumulated to warrant operation. Added to this is any solids recovered by screening of off-loading and processing water. During this storage some liquid is drained or pressed from the offal. This stream is not large in volume but is very strong in terms of organic content, often having a BOD₅ greater than 50,000 mg/l. Some plants attempt to recover this, but most discharge the stream with the plant effluent.

The general flow for fish meal production is shown in Figure 5. The offal is hashed by machine if large pieces are present, and then cooked in direct or indirect continuous steam cookers for up to 10 minutes. Non-oily offal may be added directly to driers, while oily species are pressed to expel most of the water and oil prior to entering the drier.

In the latter case the press liquor undergoes a fine solids separation using vibrating screens or decanting centrifuge followed by oil separation in nozzle centrifuges. The oil is further clarified in polishing centrifuges before sale as either an edible oil or animal oil. The aqueous phase may still contain up to five or six percent organic solids and is termed stickwater. At one time this was discarded, but now many plants employ multiple effect evaporators to concentrate these solids. The resultant product is termed condensed fish solubles and contains from 30 to 50 percent solids. It is marketed as a poultry or animal feed, a specialty fertilizer, or sprayed back into the driers. The condenser water used in the evaporators does pick up volatile solids and gases, the extent depending on the degree of freshness of the offal and the manner of operation of the evaporators.

The fish meal driers are usually rotary kilns, with heat being supplied by direct flame heating of the air, or by indirect heating using steam. The solids are dried to between 5 to 10 percent moisture content, ground to pass 10 mesh screens and sold in either 100 lb. bags or in bulk. The steam and odors generated during the drying of the meal can be very obnoxious and most plants employ some sort of direct water scrubbing of these vapours prior to release. Large volumes of water are employed for this, and the scrubber effluents will contain a significant quantity of organic material.

There is a moratorium at the present time in British Columbia on the direct use of herring for fish meal and oil production although in the 1950's and 60's over 200,000 tons of herring were processed annually for that purpose. The processing method is similar to that of offal reduction from oily species.



Table 16. Typical Characteristics of Streams Generated During Fish Meal Production

Waste Stream	BOD ₅ (mg/l)	Total Volatile Solids (mg/l)	Settleable Solids (mg/l)	Ether Soluble Oil (mg/l)	pH
Non-Oily Bloodwater	100,000	80,000	--	--	6.6
Oily Bloodwater	85,000	70,000	--	15,000	6.8
Deodorizer water	10	5,000	100	--	8.5
Condenser water	10	3,000	80	--	8.0
Stickwater	125,000	65,000	nil	5,000	6.5

4.2 Animal Feed

Much of the waste from groundfish processing finds its way into mink feed. Most of this material is ground and pumped into 50 lb. bags and frozen, although some is marketed unfrozen to the mink farmers.

Waste from salmon is generally too oily for mink, but salmon heads are sold to various firms for production of pet food and compounded feeds for fish farms.

4.3 Ocean Disposal

Small amounts of offal still finds its way back into the oceans, primarily at the smaller and more isolated plants. The use of the ocean for solids disposal can be a practical and perhaps beneficial alternative, providing biological data is available on the fertilization rate best suited for each specific locations. The major problem other than that of weather is the difficulty of controlling such a disposal system. The State of Alaska and the regional offices of the U.S. Environmental Protection Agency are currently considering controlled ocean fertilization as a possible solution to the difficult problem facing them with regard to the handling of solids waste in their fishing industry.

5. PRESENT WASTE TREATMENT PRACTICES

5.1 Processing Water

The water used in processing all species of fish becomes laden with flesh particles, scales, blood, slime, soluble protein and fish oil. The extent of this contamination has been detailed elsewhere, but is a function of the species processed, condition of the fish, type of processing and the amount of water used.

Most plants employ screens of from 4 to 10 mesh for solids recovery prior to the release of this water. The most common screen types used are the travelling mesh belt and the rotary trommel. Finer meshes have been tried in these screens unsuccessfully due to the presence of raw protein and fish oil. Vibrating screens have also been unsuccessful.

In older plants and in plants located in remote areas screens are only employed on waste streams used for fluming of offal.

5.2 Pump-out or Brail Water

Water is used by various devices to flume fish such as salmon and herring from the holds of the vessels to the processing plants. These systems range from the caisson-flume, syphon and air-lift pumps used for salmon to the large off-set impeller pumps used for herring. The water required by the first two types is normally reused several times prior to discharge, whereas the water used in the herring pumps must be discharged after a single pass due to emulsification.

Several plants do not screen the pump water prior to release, but by agreement the plants screen the herring pumpwater with 4 to 10 mesh screens and credit the vessels with the value of the recovered solids.

5.3 Stickwater

As outlined under the section concerning solid wastes, the stickwater obtained during the production of fish meal is normally condensed in multiple effect evaporators for sale or for spraying back into the meal driers. However, some small plants still discharge stickwater directly into the receiving water.

In the processing of herring for filleting, canning or roe recovery the fish is heavily salted to obtain the desired texture or to assist in handling. When the offal from this process is used for reduction to fish meal, the resultant stickwater is too salty to be evaporated to a usable product and is generally discharged to the receiving water.

6. CURRENT WASTE TREATMENT TECHNOLOGY

6.1 Screening

In the course of pilot plant studies in treatment of processing wastes, the Vancouver Laboratory of the Fisheries Research Board of Canada established that tangential screens with as fine as 40 meshes to the inch could successfully screen salmon canning wastewater and herring brail water. A diagram of such a screen is shown in figure 6. A design flow-rate of 50 IGPM per foot of cross-section could be maintained with periodic spraying of the screen surface.

In a subsequent demonstration unit designed by the Fisheries Research Board staff, two 6-foot 45° tangential screens were used in parallel to handle a flow of 650 IGPM of salmon canning wastewater. The screen sizes were equivalent to 18 and 25 mesh and subsequent visual examination revealed that the 25 mesh screen was subject to less plugging of the holes. With the addition of high pressure sprays working on a time clock of 10 seconds on every three minutes, the screens have operated satisfactorily on water from salmon canning, groundfish filleting, salmon unloading, herring unloading and herring roe recovery. These screens are preceded in line by a 4 mesh rotary screen, and typical recovery rates are given in Table 17.

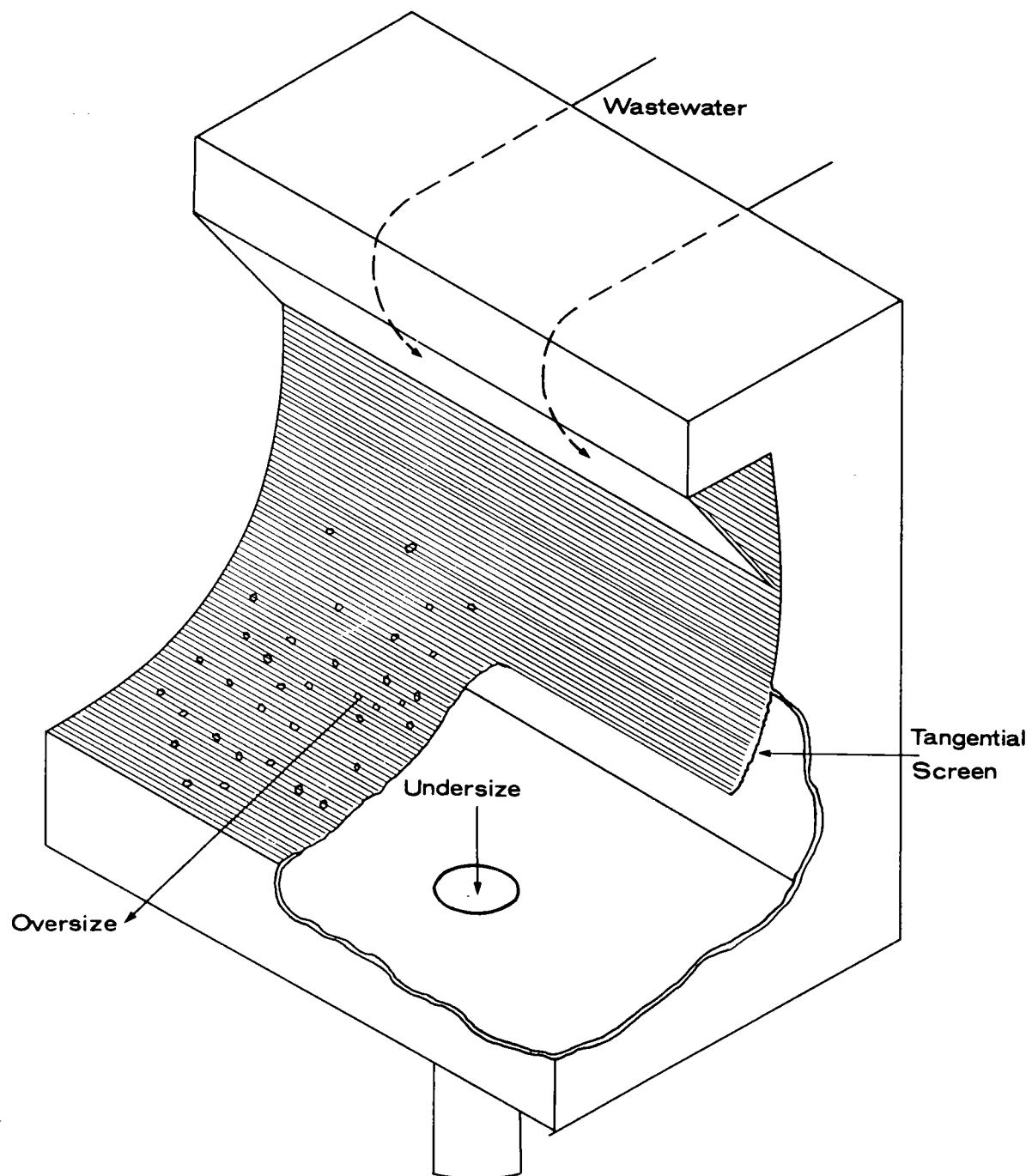


Figure 6 . DSM Tangential Screen

Table 17: Solids Removal by Tangential Screens

<u>Wastewater Source</u>	<u>Flow Rate (Gals/ft. of cross section)</u>	<u>Insoluble Solids Removal %</u>	<u>Dry Solids Recovery (lb/hr)</u>
Salmon Canning	56	43	280
Groundfish	66	10	24
Herring pump water plus process water	28	50	1500

Tangential screens have also been tested on a pilot plant scale in the United States on shrimp processing water and menhaden brail water. The latter is a fish similar to herring and used solely for fish meal and oil production.

6.2. Protein and Oil Recovery

Based on the pilot plant studies of the Fisheries Research Board of Canada, a demonstration protein and oil recovery system has been installed at a Steveston fish processing plant as a joint venture of the Fisheries Association of British Columbia, B.C. Packers Ltd., and the Industrial Development Branch of the Fisheries Service, Department of the Environment. The unit was designed by Fisheries Research Board staff, and the operation of the unit has been monitored for two years. A flow diagram of the unit is shown in figure 7.

The unit consists basically of two 6-foot tangential screens of 18 and 25 mesh, operating in parallel, followed by a dissolved air flotation cell. In this unit the screened water is pressurized to 45 psig, air is injected at 2 percent by volume, and retention time under pressure is supplied to allow the air to enter solution. As the pressure is released by passage through a throttling valve the water enters a baffled tank. Air comes back out of solution under the reduced pressure as pin-point bubbles which attach themselves to any

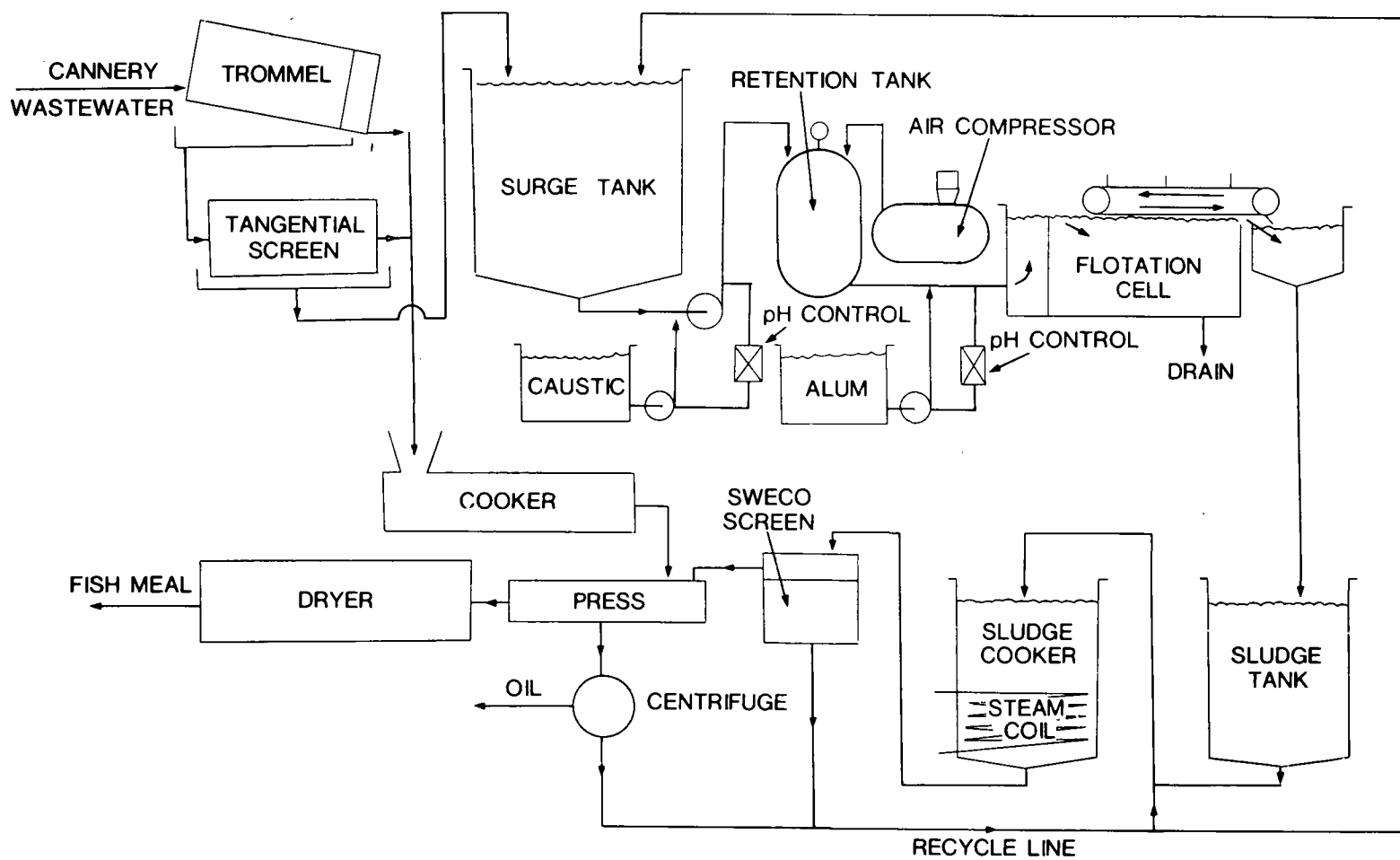


Figure 7 PROPOSED PLANT LAYOUT

solid or oil particles present. These rise rapidly to the surface and are skimmed off for recovery of protein and oil. The clarified liquid is withdrawn by stand-pipe from the bottom of the tank.

The use of chemical additives has been found necessary for proper clarification, for emulsion breaking, colloid destabilization, protein precipitation and flocculation. Two particular chemical combinations have been found effective for treating wastewater generated in fish processing. In the caustic-alum combination the incoming water is dosed with sodium hydroxide to raise the pH to about 9.2. Enough aluminum sulphate is then added to lower the pH to about 5.4. In the alum-polymer combination enough aluminum sulphate is added to lower the pH to about 5.4 and an anionic poly-electrolyte is added to assist in proper flocculation. The systems are equally effective, but the latter has been favored slightly due to lower chemical costs, ease in solids recovery and lesser sensitivity to operating parameters. The clarification achieved is shown in Table 18.

Table 18: Degree of Removal of Various Characteristics by Air Flotation

<u>Water Source</u>	<u>Insoluble Solids</u>	<u>Soluble Solids</u>	<u>Protein</u>	<u>BOD₅</u>	<u>Oil</u>
Salmon	92%	28%	61%	84%	90%
Herring	74%	44%	--	72%	85%
Groundfish	86%	14%	--	77%	--
Stickwater	95%	60%	--	--	95%

The solids are skimmed from the flotation cell in a stream representing about 3 percent of the total flow treated. The solids content averages about 5 percent. Recovery is affected by raising the temperature of the stream to roughly 200°F. to denature the protein followed by removal of the solids and oil by centrifuging. The solids are added to the driers for recovery as fish meal. Analyses of the recovered solids is given in Table 19.

Table 19: Analysis of Solids Recovered by Air Flotation

Protein	65.0%
Oil	9.4%
Ash	12.6%
Moisture	10.1%

The effluent from a flotation cell will have a biochemical oxygen demand (BOD_5) of from 100 to 500 mg/l. as opposed to screened wastewater of from 200 to 3500. The BOD_5 remaining is essentially soluble, is readily dispersed in the receiving water, and is easily assimilated by bacteria. In addition, this effluent is fully saturated with oxygen due to the use of dissolved air flotation.

Experiments in the demonstration unit indicated that better than 85 percent of the solids in stickwater can be recovered during air flotation by mixing 9 parts of clarified effluent with 1 part of stickwater prior to treatment (i.e. operating at 90 percent recycle). The resultant BOD_5 is still very high, averaging over 5000, but this does offer a partial solution to the problem of handling salty stickwater. Yet to be established is the value of the recovered solids as an animal feed ingredient, and these experiments are planned for the near future.

Other chemical combinations are possible with the air flotation process. One currently under test in the Scandanivian countries involves the precipitation of protein by pH adjustment using sulphuric acid followed by reaction of the protein with a derivative of lignosulphonic acid, a pulp mill waste product.

The economics of dissolved air flotation treatment have not been fully established, but based on interim results obtained on salmon canning wastewater, the value of the recovered solids sold as fish meal should offset the direct operating costs but not the capital investment.

6.3 Biological Treatment

Several problems exist in attempting to design biological treatment systems for fish processing plants. Superimposed on the seasonal nature of the industry are discontinuous operating periods within the seasons. For example, many salmon canneries operate only one or two days a week in all except the busiest part of the fishing period. Such operations make almost any biological treatment system except lagoons impossible to use. This type of discontinuous flow would tend to upset the operation of all but the largest of joint municipal-industrial treatment plants.

Anaerobic treatment, common in other industries having highly concentrated organic wastes, would be difficult since odor problems are not easily controlled in wastes containing as much sulphur as that from fish processing.

Numerous studies performed by the Fisheries Research Board of Canada, the Canada Centre for Inland Waters, private consulting firms and universities have shown that there is a rapid degradation of organics from fish processing wastewater in all types of biological treatment units. The rate constant for the BOD_5 reaction varies from 0.3 to 0.55 for various species of fish, compared to rates of between 0.1 to 0.2 for municipal sewage.

The Fisheries Research Board of Canada's Vancouver Laboratory have been experimenting with the use of a rotating biological contactor (RBC) pilot plant as a high rate biological treatment system for reducing the BOD_5 load after air flotation. This system involves passing wastewater through a compartmented trough in which styrofoam discs are slowly rotating. A biological growth develops on the disc and is alternately exposed to the wastewater and air. Some of the biomass is constantly sloughed off the discs and is carried through the unit to a clarifier. Not only is the system stable to hydraulic surges, but continues to operate under the low flow or recycle conditions. Preliminary results indicate that, under normal conditions, a BOD_5 removal of

4.5 lbs. per 1000 sq. ft. of disc surface per day is easily attainable on salmon canning plant effluent previously treated by air flotation, resulting in an effluent of about 50 mg/l of BOD₅.

In addition to previously mentioned advantages, the capital costs of this type of system is competitive with other high rate systems, whereas the operating costs are considerably lower.

7. COST OF TREATMENT SYSTEMS

The capital costs associated with the installation of fine screening and air flotation can be estimated fairly readily from the data obtained in the installation of the demonstration unit at Steveston. These are in the order of \$2,500 and \$10,000 per 100 gallons per minute respectively. Estimation of the cost of biological treatment by aerobic lagoons is more difficult because the largest portion of the total cost is in land acquisition. Roughly one acre of land per 100 gallons per minute is required if the water is from a groundfish plant or has been previously treated by screening and air flotation to about five acres per 100 gallons per minute for untreated wastes. Thus near metropolitan areas the cost could range from \$40,000 to \$200,000 per 100 gallons per minute to achieve proper secondary treatment, based on a price of \$30,000 per acre.

Table 20: Cost Estimate to Achieve Various BOD₅ Levels
(per 100 GPM of flow)

	<u>BOD₅ Level (mg/l.)</u>		
<u>Waste</u>	<u>3000</u>	<u>500</u>	<u>100</u>
Salmon	\$2500	\$12,500	\$52,500
Herring	\$2500	\$12,500	\$52,500
Groundfish	--	--	\$12,500

8. WATER USAGE

The design of fish processing plants to minimize water usage should be encouraged. The dry transportation of raw fish from

storage to processing is used in many of the large fish processing plants. The dry conveyance of offal from the fish processing area should also be considered.

Reductions in the use of water will bring about reductions in the cost of pollution control facilities. Any reductions in water usage are, of course, consequent to the maintenance of the sanitary quality of the product.

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SECTION II

TOXICITY

1. Characteristics and Toxicity of Wastewaters
 - 1.1 Tanneries
 - 1.2 Non-Metallic Mineral Products Industries
 - 1.3 Laundromats
 - 1.4 Metal Processing Industry
 - 1.5 Carpet Manufacturing
 - 1.6 Potato Processing
 - 1.7 References Cited
2. Application of Toxicity Tests
3. Toxicity Methodology
 - 3.1 Regulatory Bioassay
 - 3.2 Routine Bioassay
 - 3.3 Discussions

SECTION II

TOXICITY

1. Characteristics and Toxicity of Wastewaters

In this section data are presented to identify the chemical constituents of wastewaters from some of the industries which are the subject of this Inquiry. Where possible their ranges of concentration as discharged and also data on concentrations known to be acutely toxic to fish is given. These toxicity values should be considered exemplary rather than absolute. Toxicity values are subject to wide variation due to physical and chemical variation of the test water such as temperature, dissolved oxygen content, hardness and alkalinity as well as the age, condition and species of the test organisms. (These and other factors relating to measurement of toxicity will be discussed in greater detail in 2. and 3. of this Section.)

1.1 Tanneries

The main toxic constituents of leather tannery wastes include salts used in the curing operation, lime and sodium sulphide used in dehairing processes, ammonium salts, organic and inorganic solvents used to degrease hides, chromium used in chrome tanning and small amounts of dyes and bleaching chemicals used in various finishing processes. The main wastewater constituents and corresponding toxicity values are presented in Table 1.

1.2 Non-Metallic Mineral Products Industries

Non-metallic mineral products industries includes establishments engaged in the manufacture of such products as: plate glass and glass products, cement, clay products, concrete and gypsum products, cut stone, abrasive and asbestos products, and other materials made from stone, clay and sand. Constituents of their wastewaters and their toxicity to fish and other aquatic organisms are given in Table 2.

TABLE 1 - TANNERY WASTEWATERS

<u>WASTEWATER CONSTITUENT AND TYPICAL CONC. mg/l</u>	<u>AQUATIC SPECIES TESTED</u>	<u>TOXIC mg/l CONCENTRATION</u>	<u>REMARKS</u>	<u>REFERENCE</u>
Sodium Bisulphite	<u>Daphnia magna</u>	102	100 hr. toxicity threshold, 23°C distilled water	48
Sodium Carbonate	<u>Daphnia magna</u>	524	100 hr. toxicity threshold,	48
Sodium Chromate	<u>Daphnia magna</u>	0.42	100 hr. toxicity threshold,	48
Sodium Silicate	<u>Daphnia magna</u>	247	100 hr. toxicity threshold,	48
Sodium Sulphate	<u>Daphnia magna</u> Fingerling Trout	4547 5000	100 hr. toxicity threshold, lethal in 1-6 days	48 56
Sodium Hydroxide	Brook Trout	15	lethal in 24 hrs.	32
Aluminum Nitrate	Stickleback	0.07	lethal conc. limit very soft water	12
	Stickleback	0.55	toxicity threshold, tap water	24

TABLE 1 - TANNERY WASTEWATERS

<u>WASTEWATER CONSTITUENT and TYPICAL CONC mg/l</u>	<u>AQUATIC SPECIES TESTED</u>	<u>TOXIC mg/l CONCENTRATION</u>	<u>REMARKS</u>	<u>REFERENCE</u>
Sodium Chloride 600 - 3000	Bluegill	12946	96 hr. TLm, aerated water	52
	Daphnia magna	4600	threshold concentration, 20-25°C lake water, Na Cl decreases somewhat the toxicity of some metallic compounds toward fish.	46
Sodium Sulfide (Na ₂ S) 100 ² - 300	Salmonoid Fish	1.0	threshold conc., pH 5.2	
Calcium Hydroxide (Ca (OH) ₂) 1000 - 1500	Trout	92	toxic after 26 minutes	46
	Mosquito-fish	160	96 hr. TLm, turbid water	20
Sulphuric Acid (H ₂ SO ₄) 200	Trout	6.25	toxic in 24 hours toxicity towards aquatic life is a function of pH strong mineral acids are lethal to adult fish in natural waters when pH is reduced to below 5.0	32
Formic Acid	Daphnia magna	120	median threshold conc. 48 hrs. 23°C	54
Sodium formate 40	Daphnia Magna	4700	threshold conc. after 48 hrs. 25°C	54
Ammonium chloride (N H ₄ Cl) 10	Daphnia magna	535	lethal in 6 hrs. 25°C	3

TABLE 1 - TANNERY WASTEWATERS (Cont'd)

<u>WASTEWATER CONSTITUENT AND TYPICAL CONC. mg/l</u>	<u>AQUATIC SPECIES TESTED</u>	<u>TOXIC mg/l CONCENTRATION</u>	<u>REMARKS</u>	<u>REFERENCE</u>
Ammonium Sulphate ($\text{N H}_4)_2 \text{SO}_4$ 70	Goldfish	264	lethal in 6 days, hard water	3
Titanium Dioxide			insoluble	
Titanium Sulphate	Fathead Minnow	8.2	96 hr. TLm, soft water	35
	Fathead Minnow	120	96 hr. TLm, hard water	35

TABLE 2 - NON-METALLIC MINERAL PRODUCTS INDUSTRY

<u>WASTEWATER CONSTITUENT AND TYPICAL CONC. mg/l</u>	<u>AQUATIC SPECIES TESTED</u>	<u>TOXIC mg/l CONCENTRATION</u>	<u>REMARKS</u>	<u>REFERENCE</u>
Titanium Salts (Ti)	Scenedesmus	2.0	median threshold effect, 24°C, 4 days. tit. chloride in river water	46
Titanium Sulphate	Fathead Minnow	8.2	96 hr. TLm, soft water	54
Stannous Chloride (SnCl ₂)	Daphnia magna	25	toxicity threshold, 25°C, lake water	24
Acids	Goldfish		toxic at pH value of 4.0 or less in soft water	3
Alkalinity			non-toxic to adult fish when conc. is not sufficient to raise the pH above 9.0	46
Vanadium (V)	Fathead Minnow	4.8 as V 30 as V	96 hr. TLm soft water 96 hr. TLm hard water	35 35
Ferric Oxide	Trout and Salmon	2	kills through blocking gills (exposure period unstated)	46
	Salmonoid Embryos	5.0	freshwater, at 18°C, 24 hr. TLm	14
Selenium	Daphnia magna	2.5	48 hr. median threshold effect 23°C.	46

1.3 Laundromats

Laundry wastes originate from the use of soap, detergents, and commercial cleaners in removing grease, dirt and starch from soiled clothing. The main toxic constituents include boron salts, surface active agents such as alkyl benzene sulphonates (ABS), linear alkyl sulphonates (LAS), carbonates, silicates, sulphates and alkalis. These chemicals, their typical wastewater concentrations and toxic concentrations are shown in Table 3. (Information concerning dry cleaning wastes was not available. Most of the solvents employed are recycled by distilling.)

1.4 Metal Processing Industry

Because wastewaters from the primary metal, metal fabricating and metal plating industries contain many of the same constituents and because the strengths and volumes of these wastes vary widely even within single plant operations, the toxicities of the various wastewater constituents have been presented as a single group. These are shown in Table 4.

References giving the toxicity values cited are listed in Section II - 1.6.

1.5 Carpet Manufacturing

In the manufacture of wool and synthetic fiber carpets the usual toxicants are hypochlorite bleach, dyes, and acidity.

In Table 5, the results of five bioassays conducted on wastewater from a carpet manufacturing plant in one of the Maritime Provinces are presented.

1.6 Potato Processing

The results of four tests of the toxicity of wastewater from an establishment (in the Maritimes) producing frozen potato products are presented in Table 6. In this case, treatment consists of settleable solids removal by clarifiers, followed by secondary treatment in the form of high-rate trickling filters.

TABLE 3 - LAUNDROMAT WASTEWATERS

<u>WASTEWATER CONSTITUENT AND TYPICAL CONC. mg/l</u>	<u>AQUATIC SPECIES TESTED</u>	<u>TOXIC mg/l CONCENTRATION</u>	<u>REMARKS</u>	<u>REFERENCE</u>
Alkyl Benzene Sulfonate (ABS) 1-40	Rainbow Trout	3.48	freshwater, LD	36
Linear Alkylate Sulfonate (LAS) 1-40	Bluegills	1.0	freshwater, threshold value	37
	Food Organisms	7-27	freshwater, 96 hr. TLm	45
Detergents 50-100	Silver Salmon	5.6 - 20.0	freshwater, threshold value	25
Boric Acid	Mosquito-fish	5600	96 hr. TLm, 20-23°C, turbid water	46
	Minnows	19,000	20°C, hard water, lethal in 6 hrs.	46
Sodium Borate	Mosquito-fish	3600	96 hr. TLm, 22-26°C, turbid water	20
Sodium Carbonate 60-250	Silver Salmon	70	lethal in 120 hrs. tap water	41
Sodium Silicate	Daphnia magna	247	distilled water, 23°C 100 hr. threshold	48
	Mosquito-fish	2320	turbid water, 21-22°C, 96 hr. TLm	20
Sodium Phosphates	Rainbow Trout	1120	lethal in 24 hours, mixture of phosphates	46
	Daphnia magna	52	trisodium phosphate, threshold conc. 25°C	

TABLE 3 - LAUNDROMAT WASTEWATERS

<u>WASTEWATER CONSTITUENT AND TYPICAL CONC. mg/l</u>	<u>AQUATIC SPECIES TESTED</u>	<u>TOXIC mg/l CONCENTRATION</u>	<u>REMARKS</u>	<u>REFERENCE</u>
Sodium Sulphate	Fingerling Trout	5000	lethal in 1 to 6 days	46
Sodium Nitrate	Mosquito-fish	7.5	96 hr. TLm, 21-24°C, turbid water	20
Sodium Thiosulphate	Daphnia magna	520	threshold conc., lake water	50
Ammonia (NH ₃)	Rainbow Trout	0.7	toxic in 390 minutes	46

TABLE 4 - METAL PROCESSING INDUSTRY

<u>WASTEWATER CONSTITUENT</u>	<u>AQUATIC SPECIES TESTED</u>	<u>TOXIC mg/l CONCENTRATION</u>	<u>REMARKS</u>	<u>REFERENCE</u>
Iron (Fe)	Fish	0.3	freshwater, threshold value	46
Ferrie Sulphate (Fe ₂ (SO ₄) ₃)	Fish	0.1 as Fe	freshwater, lethal conc.	5
	Carp, suckers	0.72	freshwater	3
	<u>Cambusia affinis</u>	133	freshwater, 96 hr. TLm, 19 to 23°C	20
Ferrous Sulphate (Fe SO ₄)	Shiners, carp	6.4	freshwater, lethal in 24 hrs.	32
	Suckers	2.9	freshwater, lethal in 4-24 hrs	3
Fluoride (NaF)	Aquatic Life	1.5	freshwater, threshold value	46
	Rainbow Trout	2.3 to 7.3	softwater, 18°C, TLm	5
	Rainbow Trout	2.6 to 6.0	softwater, 13°C, TLm	5
	Rainbow Trout	0.03	freshwater, threshold value	6
	Chinook Salmon Fry	0.03 Cd with 0.15 Zn	lethal "Cd/Zn Solution" cadmium combines synergisti- cally with other toxic substances, eg. Zn, CN, other metals etc.....	7
Cadmium Nitrate (Cd (NO ₃) ₂ 4H ₂ O)	Guppy	0.056 LD ₅₀ as Cd	freshwater	8

TABLE 4 - METAL PROCESSING INDUSTRY

(Cont'd)

<u>WASTEWATER CONSTITUENT</u>	<u>AQUATIC SPECIES TESTED</u>	<u>TOXIC mg/1 CONCENTRATION</u>	<u>REMARKS</u>	<u>REFERENCE</u>
Sodium Arsenite (Na AsO ₂)	Pink Salmon	5.0	freshwater, 10 day exposure, lethal	12
	Chum Salmon Fry	8.4	freshwater, 48 hr. TLm	13
Phenol	Fish	0.2	freshwater, threshold value	46
	Salmonid Embryos	5.0	freshwater at 18°C, 24 hr. TLm	14
	Sticklebacks	15.5	synthetic water at 15°C, 48 hr. TLm	15
Chlorides	Trout	400		
	Fish	1500	threshold value	46
Lead (Ph)	Sticklebacks	0.34	freshwater, 96 hr. TLm	16
Zinc (Zn)	Coho Salmon			
	Juvenile Rainbow Trout	0.01-0.4	Note: Toxicity highly dependent on hardness of water	5
Zinc Chloride (ZnCl ₂)	Carp	1.0	tap water, lethal in 24 hrs.	5
	Bluegill Sunfish	8.02 as Zn	freshwater, 96 hr. TLm Note: Toxicity highly dependent on hardness and dissolved oxygen tension	17
Zinc Sulfate (Zn SO ₄ · 7 H ₂ O)	Juvenile Trout	3-6	lethal in 48 hrs.	19

TABLE 4 - METAL PROCESSING INDUSTRY

(Cont'd)

<u>WASTEWATER CONSTITUENT</u>	<u>AQUATIC SPECIES TESTED</u>	<u>TOXIC mg/l CONCENTRATION</u>	<u>REMARKS</u>	<u>REFERENCE</u>
Aluminum Chloride (Al Cl ₃)	eels	2.7 as Al	freshwater, lethal in 3.6 hrs.	5
	mosquito-fish (<u>Gambusia affinis</u>)	133	freshwater, 96 hr. TLm	20
Aluminum Hydroxide (Al (OH) ₃)	Rainbow Trout	0.5 as Al	freshwater, threshold value	31
Phosphorus (P (Colloidal))	Bluegill Sunfish	0.105	freshwater at 26°C, pH 7, 48 hr. TLm	22
Copper (Cu)	Brook Trout	0.0095 to 0.0174	freshwater, threshold value for long term exposure	46
	Brook Trout	0.10	freshwater, 96 hr. TLm	30
	Oysters	1.9	sea water, 96 hr. TLm	23
Copper Chloride (Cu Cl ₂ · 2 H ₂ O)	<u>Daphnia magna</u>	0.027 as Cu	freshwater, threshold value	24
	Bluegill Sunfish	1.25 as Cu	freshwater, 96 gr. TLm	25
Tin (Sn)	<u>Daphnia</u>	25 (SnCl ₂)	freshwater, threshold value	24
Copper Nitrate (Cu (NO ₃) ₂ · 3 H ₂ O)	Pink Salmon	0.10 as Cu	freshwater, lethal (long term)	27
Nickel (Ni)	Stickleback	0.8	freshwater	9

TABLE 4 - METAL PROCESSING INDUSTRY (Cont'd)

<u>WASTEWATER CONSTITUENT</u>	<u>AQUATIC SPECIES TESTED</u>	<u>TOXIC mg/1 CONCENTRATION</u>	<u>REMARKS</u>	<u>REFERENCE</u>
Nickel Chloride (Ni Cl ₂ · 6 H ₂ O)	Fundulus	8.1	freshwater (soft), lethal	5
	Fundulus	259	freshwater (hard), survival	5
	Fathead Minnow	4.0	freshwater (soft), 96 hr. TLm	5
	Fathead Minnow	24	freshwater (hard), 96 hr. TLm	35
Nickel Nitrate (Ni (NO ₃) ₂)	Sticklebacks	1.0 as Ni	freshwater at 15-18°C, lethal	2
Cyanide (CN)				
	Bluegill Sunfish	0.12-0.18	freshwater, hard and soft, 96 hr. TLm	27
Magnesium Chloride (MgCl ₂)	Minnows	476	lethal in 4-6 days, distilled water	3
Magnesium Sulphate (Mg So ₄)	Mosquito-fish	15,500	96 hr. TLm, turbid water	20
Manganese Chloride	<u>Daphia magna</u>	50	threshold conc. lake water	24
Molybdenum (Mo)	Fathead Minnows	70 as MoO ₃	soft water 96 hr. TLm	35
		370 as MoO ₃	hard water 96 hr. TLm	35
pH	Trout	4.4 to 8.7	toxic limits for trout	46

TABLE 4 - METAL PROCESSING INDUSTRY (Cont'd)

<u>WASTEWATER CONSTITUENT</u>	<u>AQUATIC SPECIES TESTED</u>	<u>TOXIC mg/l CONCENTRATION</u>	<u>REMARKS</u>	<u>REFERENCE</u>
Potassium Cyanide (KCN)	Brook Trout Rainbow Trout	0.09 0.175	48 hr. TLm lethal after 76 hrs. more toxic at low tensions of dissolved oxygen	46 & 20
Selenium (Se)	<u>Daphnia magna</u>	2.5	48 hr., median threshold effect, 23 ^o C	46
Silver (Se)	Salmon Fry	0.04	lethal to some of test fish after 48 hrs. tap water	5

Table 5: CARPET MANUFACTURING

WASTEWATER <u>CONSTITUENTS</u>	<u>CONCENTRATIONS</u>			<u>PERCENT SURVIVAL</u> <u>OR MEDIAN SURVIVAL TIME</u>
Bleach, dyes, acidic conditions				
1. Inlet	65% effluent by volume			100% survival in 96 hrs.
Outlet	"	"	"	" " "
2. Inlet	"	"	"	LT 50 28 hrs.
Outlet	"	"	"	LT 50 65 hrs.
3. Inlet	"	"	"	60% survival in 96 hrs.
Outlet	"	"	"	LT 50 8.7 hrs.
4. Inlet	"	"	"	LT 50 10 hrs.
Outlet	"	"	"	LT 50 57.8 hrs.
5. Inlet	"	"	"	LT 50 41 hrs.
Outlet	"	"	"	LT 50 56 hrs.

* All effluents analyzed were grab samples.

This industry manufactures both wool and synthetic carpeting. Wastes produced are discharged to an equalization pond with 24 hour retention from which the effluent is discharged to a municipal sanitary sewer system.

Table 6: POTATO PROCESSING

<u>WASTEWATER</u> <u>CONSTITUENTS</u>	<u>CONCENTRATIONS</u>	<u>PERCENT SURVIVAL OR MEDIAN</u> <u>SURVIVAL TIME</u>
Dissolved starch, high BOD	1. 65% by volume	100% survival - 96 hrs.
	2. 65% by volume	LT 50 - 6.6 hrs.
	3. 65% by volume	LT 50 - 6.6 hrs.
	4. 65% by volume	LT 50 - 11.1 hrs.

All tests on effluent treated by clarifier and high-rate trickling filter.

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2. Application of Toxicity Tests

In reviewing any toxicity data, for example those data given in Section 2 of this brief, it is evident that there is a very wide variation in concentrations of a toxicant reported to be lethal (or harmful by other criteria) to fish. Consider for example, the forty-fold range of concentration shown in Table 4 of toxicity of zinc to rainbow trout. It should also be noted that very low concentrations of some ions provide harmful responses (see data in Table 4 for threshold values of copper to brook trout for example). The extremely low concentrations needed to produce harmful effects force any regulatory agency to recognize that it must reduce to an absolute minimum and in some cases eliminate discharges of such ions into waters in which it is deemed important to preserve a healthy aquatic environment.

At this point it must be stated that there are explanations for some of the variations. High temperatures have been reported to make a pollutant more toxic due to increased rates of uptake coupled with an associated decrease in oxygen saturation levels (note the inference that high BOD_5 could produce the same effect). Hydrogen ion concentration is a critical water quality parameter in its own right, but it also has a direct bearing on metal toxicity because it influences the ionization and solubility of metals present in water. The effect of increasing water hardness in causing a reduction in acute metal toxicity is well known and the presence of some organic compounds reduces toxicity by chelating metals. Jones (54) for example, believes that it is possible that the toxic action of heavy metals depends on the type and amount of gill secretions. In fish with little gill secretion exposure to heavy metals results in decay of gill tissue, whereas in fish with potential heavy gill secretions, the secretion may be precipitated by metallic ions resulting in asphyxiation.

Considerable variation in response to toxic substances is exhibited between different species; the salmonids typically found in B.C. being considerably less resistant than the bluegill sunfish in the central United States for which a considerable body of acute toxicity data has been generated. Sprague (59) notes that acclimation to toxicants is common and "no less important than acclimation to temperature and dissolved oxygen", but he also warns that acclimation may affect chronic or sublethal toxicity. In other words, there may be a biological price, for example stunted growth

or reduced reproductive success. Genetic selection may allow certain races of fish to survive in naturally-occurring concentrations which could not normally be tolerated by the species as a whole. For example, Hynes (60) states that local fish populations in the Sacramento River seem to "do well" in reaches polluted by copper. Hatchery reared fish of the same species die when introduced into the same reach of river. Combinations of some metallic ions are antagonistic, e.g. in the presence of calcium, copper is less toxic than it would normally be alone. In other cases the effect is synergistic, i.e., the toxicity of a mixture of ions is greater than the sum of the individual toxicities. In view of the foregoing it is apparent that:

- 1) An acute toxicity measurement represents a first order of magnitude assessment of the potential severity of a discharged effluent on fish, and by broad inference, upon the receiving environment.
- 2) The methodology of acute toxicity testing needs standardizing to be useful as a regulatory tool. For example, a standard species of fish should be used. Conditions of tests such as temperature, pH, reporting of percentage survival and duration of exposure should also be standardized.
- 3) Until a great deal more is known about the reason for toxicity, tests should be "empirically" rather than "theoretically" oriented, which is to say that they should be conducted on "whole" effluents containing all chemical constituents rather than attempting to second guess the toxicity of an effluent from knowledge of the toxicity of its individual constituents.
- 4) Having conducted a standardized toxicity test, presumably for the purpose of assessing treatment effectiveness, it should not be assumed that the biota of receiving waters are fully protected; that tests in situ using the receiving water for dilution purposes, indigenous species (and races) of fish, and other selected organisms, should be carried out, encompassing if possible critical stages of development such as reproduction and incubation.

The Department of the Environment has formed a working group of scientists with representatives from the Fisheries Research Board, the Fisheries Service and the Environmental Protection Service to study and

recommend a suitable methodology for acute toxicity testing. After discussions with leading toxicologists in Canada and the United States, the following summarizes the rationale and methodology which the working group has suggested for the application of toxicity criteria.

3. Toxicity Methodology

The effluent toxicity test to be recommended is similar to standard bioassay procedures which have been outlined in Standard Methods (APHA, 1972). As the duration of such a test is only four days, any lethal responses observed within that time frame are referred to as acute toxicity. It is important to distinguish between the acute toxicity of an effluent sample and the sub-lethal and/or chronic toxic effects that might also be present. For example, toxic constituents such as organo phosphates would not necessarily exhibit an acute toxic (lethal) response within the 96 hour period, however, the well being of the test organism would be adversely affected. The effluent toxicity test described below considers only a standard 96 hour acute toxicity assessment.

To be accurate toxicity tests must meet exacting biological and statistical criteria and as such are time-consuming and may require large quantities of effluent. However, to obtain an estimate of the acute toxicity a less rigorous methodology may be adopted. It therefore seems appropriate to have two bioassay procedures as follows:

3.1 Regulatory bioassay

This is a bioassay procedure which would be nationally standardized as to the species of fish used (rainbow trout), the temperature of test as (15 degrees C), the minimum weight: volume relationship (1 g/l liter/day), and other experimental parameters dependent on the type of effluent being tested (viz. aeration, filtration, neutralization, etc.). The recommended bioassay procedure would consist of five (5) continuous flow tanks containing the effluent solution and five (5) continuous flow "control" tanks. A maximum of ten (10) fish would be placed in each tank and the toxicity criterion would be that there was no significant mortality ($P \leq 0.05$) between

the effluent-containing and control tanks after 96 hours. An effluent to be in compliance with the toxicity requirements of effluent regulations would have to pass this test.

The regulatory bioassay should be conducted on a regular basis for each industrial plant (a quarterly assessment is recommended, an annual test would be the minimum) in order that the plant would be rated according to the toxicity of its effluent and in order that its status as to compliance with the regulations might be evaluated. The regulatory bioassay may also be used to produce scientific evidence as required for enforcement purposes.

A static bioassay may be used as a regulatory bioassay to demonstrate a violation of the effluent toxicity requirement should there be a significant difference between the five replicated effluent-containing and control tanks at the end of the first 24 hour period. Although this practice would reduce some of the complexities of the bioassay testing procedure as outlined above for those industries which have highly toxic discharges, the 96 hour continuous flow regulatory test would be required to ensure strict compliance with the toxicity requirement of the regulations.

3.2 Routine Bioassay

This bioassay testing procedure would be intended for routine monitoring programs, industrial self-appraisal studies, treatment facilities trouble-shooting, and generally in cases where a less detailed and exacting evaluation of effluent toxicity is required. Whenever possible, rainbow trout or a similarly sensitive fish species should still be used. The test temperature should be controlled and maintained within an acceptable range for the test species.

Routine bioassays will generally be static with or without the complete replacement of the effluent test solution every 24 hours. The weight to volume ratio should not exceed 1 gm/liter with artificial aeration. There should be a control test carried out with each series of effluent-containing bioassay tanks. In other details of the bioassay test procedure, the routine bioassay test should follow, as closely as conveniently possible, that procedure which is outlined for the regulatory bioassay.

3.3 Discussion

It is impossible to outline a single toxicity criterion or standard to apply to the wide range of industrial effluents that must be evaluated by the regulatory agencies. Hence, each group of industries must have its own specific toxicity standard.

Nevertheless, there are certain concepts that are evolving, which are basic to all toxicity evaluations of industrial effluents. Firstly, that a "regulatory bioassay" should be used to demonstrate violation or compliance with the regulations and that a "routine bioassay" should be used for monitoring purposes. Secondly, that a standard fish should be used (rainbow trout) and tested under standardized bioassay conditions, so that eventually, all effluent toxicity evaluations will be based on the same basic toxicity testing procedure. A spin-off from this standardization of methodology approach would allow the development of a toxic unit index relating fish toxicity to the volume of effluent discharged or the industrial production rate. Using a toxic unit based on bioassay data and effluent volumes it would be possible to assess and rate the relative environmental impact of every industrial effluent.

Thirdly, the minimum acceptable weight to volume relationship for the bioassay tanks should be 1 gram fish weight/liter of test solution/day. These conditions can be met by continuous flow, static tests with daily replacement of the test solution, or by large volume static tests.

Bioassay test procedures for industries should follow the general toxicity testing procedures outlined above. In some cases it may be necessary to make adjustments to test samples prior to following the procedures. In the case of food processing wastes for example, because of the high organic content of the wastes, the effluents should be coarsely prefiltered and the oxygen content of the solution should be maintained at an air saturation level in the order of 70%. The pH level should also be adjusted if it lies outside of the 5.0-8.5 range. Bioassays should be conducted at 100% effluent concentrations, and the fish mortality response during the 96 hour period expressed as the median lethal response of 50% of the tested fish (LT 50). Percentage survival values should be reported in instances where partial fish mortalities are observed during the maximum test period of 96 hours.

SECTION III

AIR POLLUTION

1. Atmospheric Environment Considerations.
2. Technical Considerations for Air Pollution Abatement.
3. Technical Aspects of Air Pollution Control Regulations.
4. The Air Pollution Problem in Miscellaneous Industries.
 - 4.1 Metallurgical Operations.

APPENDICES

- A. National Air Quality Objectives
- B. Metallurgical Operations and Airborne Emissions.
- C. Emission Characteristics for Various Metallurgical Operations.
- D. Description of Air Pollution Control Equipment and Collection Efficiencies.
- E. Atmospheric Emissions from the Agriculture and Food Industries.
- F. Atmospheric Emissions from the Mineral Products Industry.
- G. Bibliography of Air Pollution Control References.

SECTION III

AIR POLLUTION

1. Atmospheric Environment Considerations

1.1 The Atmospheric Environment Service (A.E.S.) has gathered a large body of weather information which illustrates some of the problems that occur in British Columbia, but much more information is needed to evaluate climatology at a particular location. Dispersal of contaminants into the atmosphere is normally brought about by atmospheric turbulence caused by uneven wind flow and differential surface heating. The two most important meteorological parameters that cause fumigation are:

- a) the presence of an inversion - an effective lid or cap at some layer in the atmosphere which prohibits the upward movement of air currents and so holds all pollutants beneath it; and
- b) light winds.

1.2 The Province of British Columbia has many unique features that contribute to the problem of air pollution. The extremely rugged terrain leaves deep narrow valleys which resist scouring out by atmospheric disturbances (cyclones). Many of these same valleys are partially covered by bodies of cold water that contribute to the frequency of low level or ground based inversions. The parallel mountain ranges at right angles to the prevailing westerly winds force the main air currents aloft and leave areas of light winds and little precipitation in their lee. In winter, particularly, cold masses of air from the north spread southward over the Province and become ensconced in the valleys and on the leeward slopes, and are little affected by the storms that pass overhead.

1.3 Studies on Canadian meteorological conditions have demonstrated that persistent light winds occur most frequently in the Province of British Columbia, most frequently in the valleys of the interior, and most frequently in the winter season (1).

(1) Persistence of light winds in Canada; R.W. Shaw, M.S. Hirt and M.A. Tilley, 1971.

1.4 The frequency of inversions is another, and very important parameter, in the meteorology of air pollution. For ground based inversions an A.E.S. study (2) estimated that night time inversions occur on the British Columbia coast about 40 to 50% of the time, and in the interior, 50% of the time in winter and 80% in summer. Persistent inversions lasting throughout the daylight hours are relatively frequent only in the autumn when they approximate 10% of the time at both coastal and inland points.

1.5 Since light winds and frequent inversions contribute to an air pollution potential in many areas of British Columbia, it is of the utmost importance that all necessary precautions be taken in planning, engineering and siting new industry. In critical areas where meteorological information is inadequate, it is desirable to undertake a specific climatological monitoring program with as long a lead time as possible. This should be followed by a careful analysis of data in the light of planned levels, and types of emissions. Only in this way can one determine, in critical areas, the effects of siting, exposure, slope, elevation and valley orientation on the future emissions, and thus ensure that all possible precautions have been taken.

2. Technical Considerations for Air Pollution Abatement

2.1 There are two main approaches available for implementing an air pollution control program:

- a) comprehensive resource management, and
- b) the application of "best practicable technology" to prevent and control the discharge of pollutants.

The key principle of the first approach is to optimize benefits through rational resource management. It attempts to maximize the beneficial use of air in an "airshed". The finite limits of the air resource to receive and "assimilate" wastes is determined. In theory, it is the ideal waste management approach, and hopefully will be a valid source of environmental management over the long term.

(2) A Preliminary Climatology of Ground Based Inversions in Canada:

R.E. Munn, V. Tomlain and R.S. Titus, Atmosphere, Volume 3, 1970.

The difficulty in applying this comprehensive approach immediately is the indeterminate state of knowledge relating to the capacity of the environment to "assimilate" wastes. This is particularly the case with mining wastes which contain essentially non-biodegradable refractory substances and these are not appropriate components in a classical evaluation of "assimilative capacity". Further, there is a growing body of evidence shown that ecological changes brought about by the discharge of many substances into the biosphere may be profound over the long term. Until a better capability is developed to understand and predict the potential interactions and relationships between the animate and inanimate components of our environment, it is only prudent to be cautious. It will be necessary to proceed slowly and carefully in the use of the comprehensive approach to managing ecosystems.

2.2 The approach being taken by many regulatory agencies today is the application of "best practicable technology" meaning that the best proven technology is used to contain and treat wastes at source. This will be the approach taken in the development of national regulations.

Regulations will be based on best practicable technology and represent minimum baseline standards. They will equalize the opportunity for an acceptable environment throughout Canada. The equity aspect, however, cannot be applicable in an area where, by virtue of the fragility of the environment more stringent local requirements are considered to be necessary. In such areas, specific effluent or emission controls would be instituted in addition to those required under national baseline regulations.

3. Technical Aspects of Air Pollution Control Regulations

3.1 Air pollution control regulations developed for industry should emphasize containment at source, and should incorporate both production process data and the capability of pollution control equipment. Information on the regulated emission rates based on the theoretical quantity of gaseous or particulate emissions calculated from the total production rate of a particular operation and the efficiency of appropriate collection devices, may be lacking. However, considerable general information is available to permit initial calculations for determining the potential effects of locating industries in critical areas. Under special conditions monitoring and collecting meteorological data may be the only recourse. The meteorological

conditions existing in British Columbia have been considered previously in this Section.

4. The Air Pollution Problem In Miscellaneous Industries

4.1 Metallurgical Operations

Some preliminary information is provided on emission rates and characteristics from various metallurgical operations, and the efficiency of appropriate pollution control equipment. The information is appended in Appendices "B" and "D".

An important practical consideration is assessing the suitability of the regulated emission should be the ground level concentrations or concentrations on receptors. These are calculated for single point or multiple point sources using Brigg's and Holland (5) plume rise and Pasquill - Gifford (6) dispersion equations.

The values thus obtained should not exceed the maximum acceptable levels for the proposed National Air Quality Objectives.

Corresponding information on some of the other industries being considered at this Inquiry are given in the subsequent Appendices "E" and "F".

Bibliography of air pollution control references is given in Appendix "G".

APPENDIX A

NATIONAL AIR QUALITY OBJECTIVES

NATIONAL AIR QUALITY OBJECTIVES

BACKGROUND INFORMATION

The desirability of having uniform Air Quality Objectives throughout Canada has been recognized for sometime. It is hoped that by providing graded scales and detailed explanations, responsible authorities (Municipal, Provincial and Federal) will apply them with understanding, judgement and discretion. It should be noted, however, that our constantly increasing understanding of the cause and effect relationships between pollutants and the environment will require that these Objectives be periodically reviewed and updated as circumstances demand.

National Air Quality Objectives are required:

- to provide a uniform yardstick for assessing the quality of the air in all parts of Canada,
- to provide the framework for enforcement programs by control agencies,
- to provide a basis for an anti-degradation policy for the unpolluted parts of the country,
- to provide a basis for determining priorities for tackling pollution problems,
- to provide an indication for the need and extent of surveillance programs.

Six Major Air Pollutants

The following pollutants constitute approximately 98% of air pollution today on a mass weight basis:

Sulfur Dioxide

Sulfur dioxide comes primarily from the combustion of sulfur-containing fossil fuels. Its presence has been associated with the increased incidence of respiratory diseases and property damage.

Particulate Matter

Particulate matter, either solid or liquid, may originate as a result of industrial processes and other human activities as well as from nature. By itself or in association with other pollutants, particulate matter, in high enough concentrations, may injure the lungs or cause adverse effects elsewhere in the body. They also reduce visibility and contribute to property damage and soiling.

Carbon Monoxide

Carbon Monoxide is the by-product of the incomplete burning of carbon-containing fuels and some industrial processes. It decreases the oxygen-carrying capacity of the blood and at levels often found in city air, may impair mental processes.

Photochemical Oxidants

Photochemical Oxidants are produced in the atmosphere when reactive organic substances, chiefly hydrocarbons, and nitrogen oxides are exposed to sunlight. Photochemical Oxidants irritate mucous membranes, reduce resistance to respiratory infection, damage plants and contribute to the deterioration of materials.

Hydrocarbons

Hydrocarbons in the air come mainly from the processing, marketing and use of petroleum products. Some of the hydrocarbons combine with nitrogen oxides in the air to form photochemical oxidants. The hydrocarbon objectives are, therefore, for use as a guide in achieving the oxidant objectives.

Nitrogen Oxides

Nitrogen oxides usually originate in high temperature combustion-processes. Nitrogen dioxide is essential in the natural production of photochemical oxidant. The presence of nitrogen dioxide in the air has been associated with a variety of respiratory diseases.

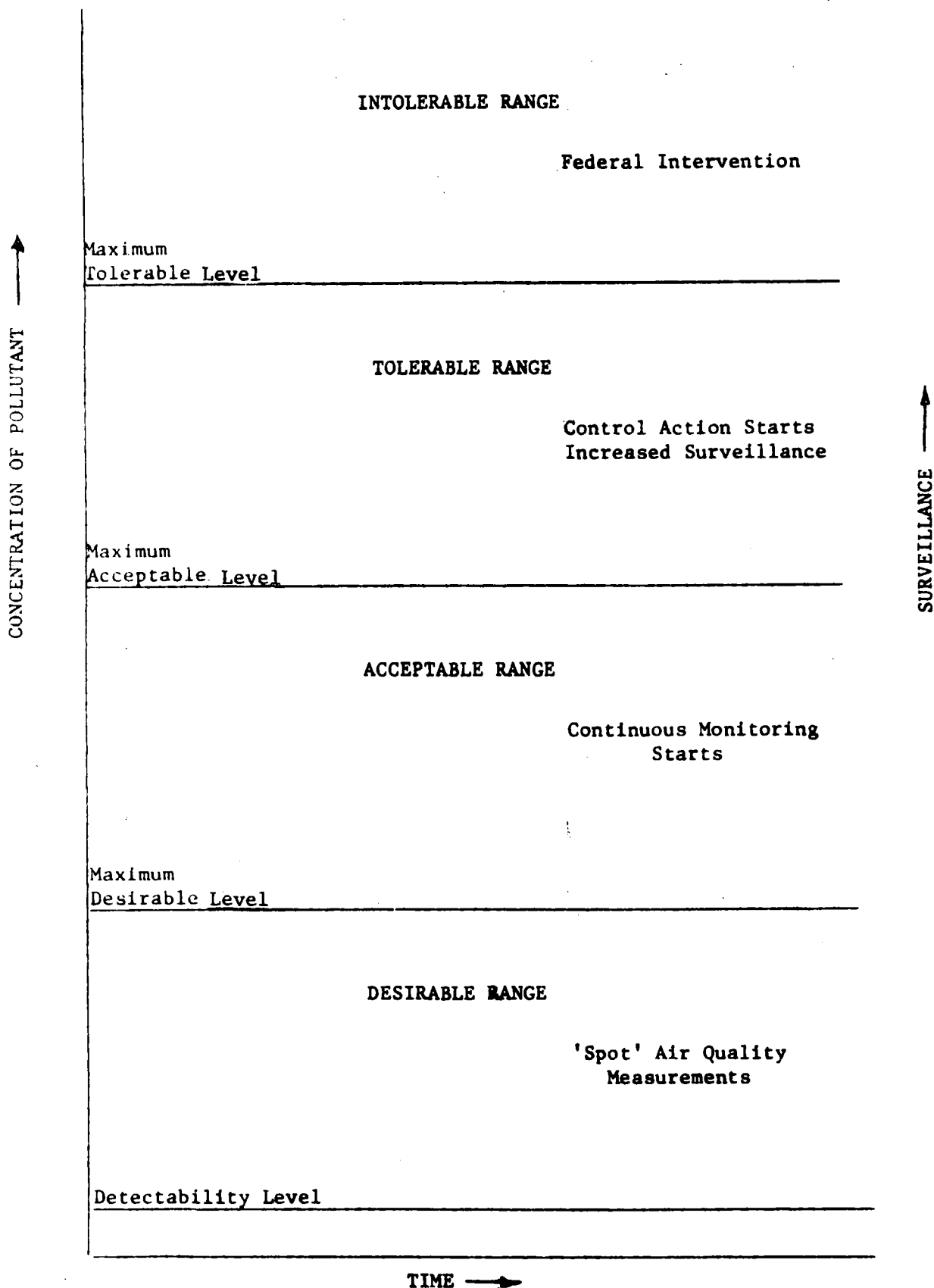
NATIONAL AIR QUALITY OBJECTIVES
in mass units ($\mu\text{g}/\text{m}^3$)
with volume units (ppm) in brackets

	<u>Max. Desirable</u>	<u>Max. Acceptable</u>	<u>U.S. Secondary</u>	<u>Ont. Objectives</u>
<u>Sulfur Dioxide</u>				
1 hr	450 (0.17)	900 (0.34)	1300 (0.50)**	650 (0.25)
24 hr	150 (0.06)	300 (0.11)	260 (0.10)	260 (0.10)
1 yr	30 (0.01)	60 (0.02)	60 (0.02)	60 (0.02)
<u>Particulates</u>				
24 hr		120	150	90
1 yr***	60	70	60	60
<u>Carbon Monoxide*</u>				
1 hr	15 (13)	35 (30)	40 (35)	46 (40)
8 hr	6 (5)	15 (13)	10 (9)	18 (15)
<u>Oxidants</u>				
1 hr	100 (0.05)	160 (0.08)	160 (0.08)	200 (0.10)
24 hr	30 (0.015)	50 (0.025)		60 (0.03)
1 yr	20 (0.01)	30 (0.015)		
<u>Hydrocarbons</u>				
3 hr		160 (0.24)	160 (0.24)	

* mg/m^3

** 3 hr max.

*** geometric mean



APPENDIX B

METALLURGICAL OPERATIONS AND AIRBORNE EMISSIONS

- (i) Emission Rates - uncontrolled and controlled
- (ii) Emission Characteristics
- (iii) Best Practicable Technology for the
Metallurgical Industry

TABLE B-1
METALLURGICAL PLANTS IN BRITISH COLUMBIA (2)

	No. of <u>Plants</u>	Production <u>tons</u>	<u>Products</u>
Primary Iron and Steel	9	437,000	Pig iron, steel ingots, castings, bars and rods.
Roasting and Sintering	5	760,000	Molybdenum, iron, zinc and lead oxides.
Smelters	4	554,000	Aluminum, lead zinc.
Foundries	38	104,000	Ferrous and non- ferrous castings.
Coking Ovens	<u>1</u>	<u>N/A</u>	Coke
Totals	57	1,855,000	

Extensive studies have been carried out to determine emission factors for various metallurgical industries. The results of this work have been reported in the literature (3) and (4).

(i) Emission Rates - Uncontrolled and Controlled

The particulate and gaseous emission factors for various operations are listed in Appendix "C". The reduction in emissions expected when various air pollution control devices are employed is also indicated.

The emission factor is a statistical average of the rate at which a pollutant is released to the atmosphere as a result of some activity, such as combustion or industrial production, divided by the level of that activity. The emission factors presented in Appendix "C" were estimated by numerous techniques including:

(4).

- (a) a detailed source testing involving many measurements related to a variety of process variables.
- (b) single measurements not clearly defined as to their relationship to process operating conditions.
- (c) process material balances and engineering appraisals of a given process.

It should be noted that the reported data covers metallurgical operations over the whole of the North American continent, including the smelter complexes at Trail and Kitimat.

The limitations and applicability of emission factors must be understood. To give some data of how good the factors presented for a specific process are, each process has been ranked as either "A", "B", "C", "D" or "E". For a process with an "A" ranking the emission factor should be considered excellent, i.e., based on field measurements of a large number of sources. A

process ranked "B" should be considered above average, i.e. based on a limited amount of field measurements. A ranking of "C" is considered average, "D", below average and "E" poor. These rankings are presented in the tables in Appendix "C".

(ii) Air Pollution Control Equipment

Equipment available for the control of particulate matter consists of cyclones, wet scrubbers, electrostatic precipitators, and fabric filters. Figure 1 in Appendix "D", shows the size range of metallurgical fumes in microns and the type of equipment utilized to contain the various emissions. A brief description of air pollution control equipment is also given in Appendix "D".

(iii) Relative Efficiency

An indication of the relative efficiency of various collection devices is shown in Figure 1, as a function of particle size Appendix "D". These curves were obtained using one standard test dust which compares to a typical fly ash (3). Average collection efficiencies for various particle sizes and various particulate control equipment are tabulated in Table D-1, Appendix "D" (4).

(iv) Control Practices

Steel Industry

The operation and types of furnaces associated with the steel industry in North America vary widely. Therefore, the criteria for the type of control equipment are determined by the specific operation. A tabulation of the types of equipment is given in Table D-2 Appendix "D" (3). It shows the type of air pollution control equipment used with the various aspects of steel making.

Aluminum Industry

Efficiency data for currently used and prototype control devices are summarized in Table D-3, for primary aluminum potline air pollution controls. Particulate control efficiencies vary from 40 to 60% except where an electrostatic precipitator is used in conjunction with other devices.

APPENDIX C

EMISSION CHARACTERISTICS FOR VARIOUS
METALLURGICAL OPERATIONS

TABLE C-1 UNCONTROLLED EMISSION FACTORS FOR IRON AND STEEL MILLS
(RANK A)
(pounds per ton of product)

Type Operation	Particulates	Carbon Monoxide
Iron Production		
Blast Furnace		
Ore Charge	110	1,400-2,100 ^a
Agglomerates Charge	40	
Sintering		
Windbox	20	--
Discharge	22	44 ^b
Steel Production		
Open Hearth Furnace		
Oxygen Lance	22	--
No Oxygen Lance	12	--
Basic Oxygen Furnace	46	120-150 ^c
Electric Arc Furnace		
Oxygen Lance	11	18
No Oxygen Lance	7	18
Scarfig	20	--

a - Represents the amount of CO generated; normally all of the CO generated is used for fuel. Abnormal conditions may cause the emission of CO.

b - Pounds per ton of finished sinter.

c - Represents generated CO, after ignition of the gas above the furnace, the CO amounts to 0-3 lbs/ton of steel produced.

TABLE C-2
(RANK A)

UNCONTROLLED EMISSION FACTORS FOR BRASS AND BRONZE
MELTING FURNACES
(pounds per ton of charge)

Type Furnace	Particulates
Blast	18 ^a
Crucible	16
Cupola	73
Electric Induction	2
Reverberatory	70
Rotary	60

a - Represents emissions following precleaner.

TABLE C-3
(RANK B)

EMISSION FACTORS FOR GRAY IRON FOUNDRIES
(pounds per ton of metal charged)^a

Type Furnace	Particulates	Carbon Monoxide
Cupola		
Uncontrolled	17	145 ^b
Wet Cap	8	--
Impingement Scrubber	5	--
High-Energy Scrubber	3	--
Electrostatic Precipitator	2.7	--
Baghouse	2.2	--
Reverberatory	2	--
Electric Induction	2	--

a - Approximately 85% of the total charge is metal. For every 1 pound of coke in the charge, 7 pounds of gray iron are produced.

b - A well designed afterburner can reduce emissions to 9 pounds per ton of metal charged.

TABLE C-4
(RANK A)

EMISSION FACTORS FOR STEEL FOUNDRIES (SECONDARY OPERATION)

(pounds per ton processed)

Type Process	Particulates ^a	Nitrogen Oxides
Melting		
Electric Arc	13 (4-40)	0.2
Open Hearth	11 (2-20)	0.01
Open Hearth Oxygen Lanced	10 (8-11)	--
Electric Induction ^b	0.1	--

a - If the scrap metal is quite dirty or oily or increased oxygen lancing is employed the emission factor should be chosen from the high side of the factor range.

b - Usually not controlled.

APPENDIX D

DESCRIPTION OF AIR POLLUTION CONTROL EQUIPMENT
AND COLLECTION EFFICIENCIES

DESCRIPTION OF AIR POLLUTION

CONTROL EQUIPMENT

CYCLONES

Cyclonic collectors are round conically shaped vessels in which the gas stream enters tangentially and follows a spiral path to the outlet. The spiral motion produces the centrifugal forces that cause the particulate matter to move toward the periphery of the vessel and collect on the walls and fall to the bottom of the vessel.

WET SCRUBBERS

Wet collectors use water "sprays" to collect and remove particulate matter. There are many variations of wet collectors but they may generally be classified as low or high energy scrubbers. Low energy scrubbers of 1-6 in. of pressure drop may consist of simple spray towers, packed towers or impingement plate towers. Water requirements may run 3-6 gal/1,000 cu.ft. of gas and collection efficiencies can exceed 95%. The lower energy scrubber finds frequent application in incinerators, fertilizer manufacturing, lime kilns, and iron foundries.

The high energy scrubber, or Venturi, imparts high velocity to the gas stream by means of converging-diverging duct section, and contacts the stream with injected water. The high velocities provide increased collection efficiency, up to 99.5%, but the pressure drop may range from 10-60 in. of water. This requires a draft fan with high power input. The Venturi scrubber is often used in conjunction with steel furnaces and foundry cupolas.

ELECTROSTATIC PRECIPITATORS

The operating principle of electrostatic precipitation requires three basic steps:

- (1) Electrical charging of the suspended particulate matter.
- (2) Collection of the charged particulate matters on a grounded surface.
- (3) Removal of the particulate matter from the collecting surfaces by mechanical scrubbing or flushing with liquids.

The electrical charging is accomplished by passing the suspended particles through a high-voltage, direct-current corona. Peak voltage requirements usually range from 30 to 100 kilowatts. Gas velocities range from 3 to 15 ft/sec. This low linear velocity promotes deposition and minimizes re-entrainment. However, this also means that the precipitators will be large in size, or cross-sectional area, to achieve the low gas velocities. Uniform flow distribution is also an important factor that must be considered in design of ductwork.

The proper operation of an electrostatic precipitator is dependent on the electrical resistivity of the particles. Pre-conditioning with water sprays may be required to impart beneficial resistivity character to the particles. Proper control of operating voltages must also be provided if efficient particulate removal is to be maintained. The precipitator generally has high initial cost but it is capable of high collection efficiency, exceeding 99%, at a pressure drop less than 0.5 in. of water.

Electrostatic precipitators have been used extensively for many years to reduce particulate emissions from coal-fired power plants. These units handle very large gas volumes with low pressure drops. They have also been applied in steel mills to clean the gases from blast furnaces and basic oxygen furnaces.

FABRIC FILTERS

Fabric filter systems, i.e., baghouses, usually consist of tubular bags made of woven synthetic fabric or fiberglass, in which the dirty gases pass through the fabric while the particles are collected on the up-stream side by the filtering action of the fabric. The dust retained on the bags is periodically shaken off and falls into a collecting hopper for removal.

Fabric filters usually provide very high collection efficiencies, exceeding 99.5%, at pressure drops usually ranging from 4-6 in. of water. The amount of filter area required is often based on an air-to-cloth ratio of 1.5-3.0 cu.ft/min. of gas/sq.ft. of cloth. The maximum operating temperature for a baghouse is 550° F using fiberglass bags. However, there may also be a minimum temperature limitation so as to maintain the gas temperature 50° F to 75° F above the dew point. Inlet dust loadings range from 0.1 to 10.0 grains/cu.ft. of gas. Higher concentrations are removed by a precleaning device, such as a low efficiency cyclone.

Some of the industries that employ large baghouse operations are electric arc furnaces, foundry cupolas and non ferrous smelting operations.

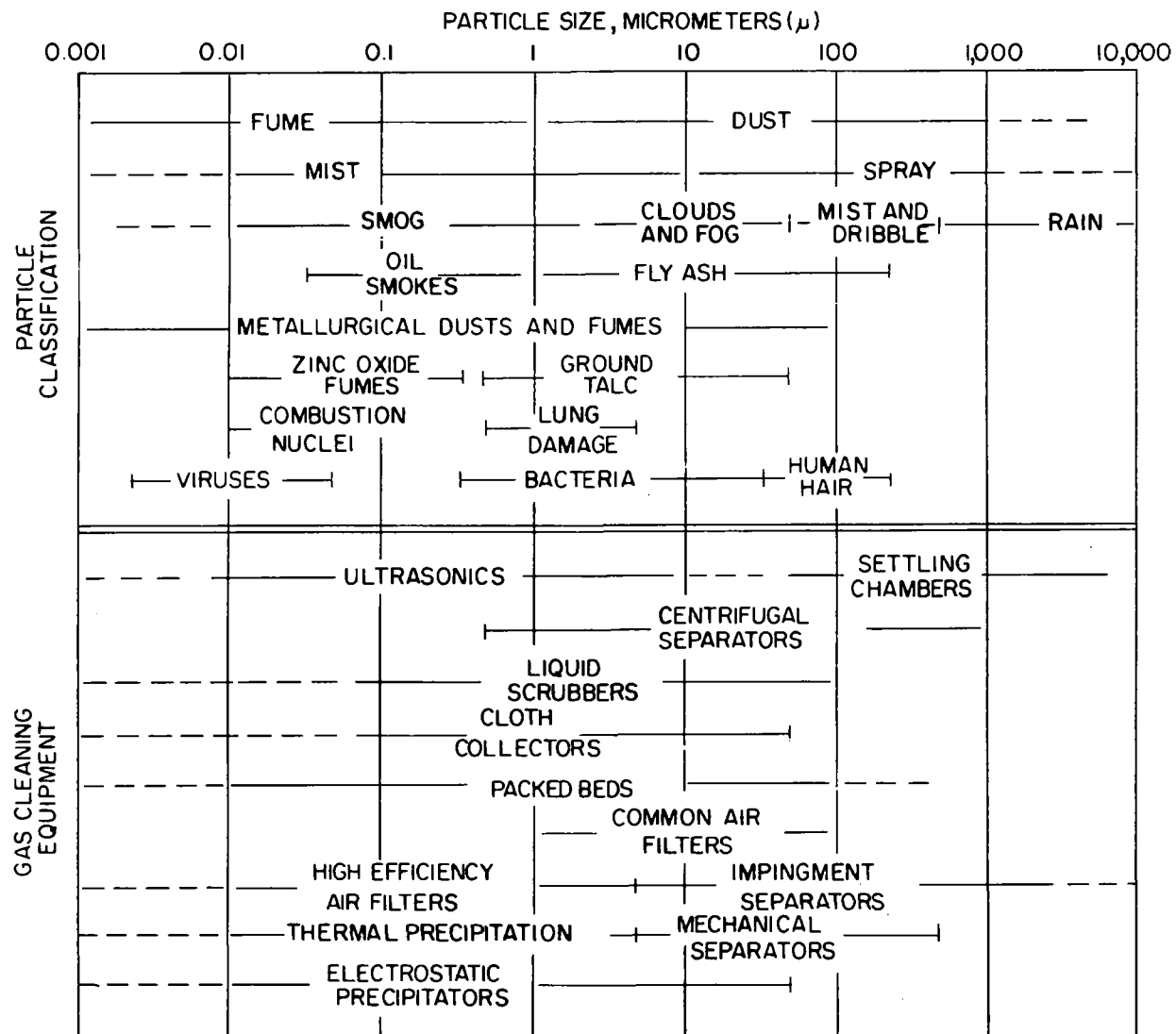


FIGURE D-1. PARTICLE CLASSIFICATIONS AND COLLECTION EQUIPMENT

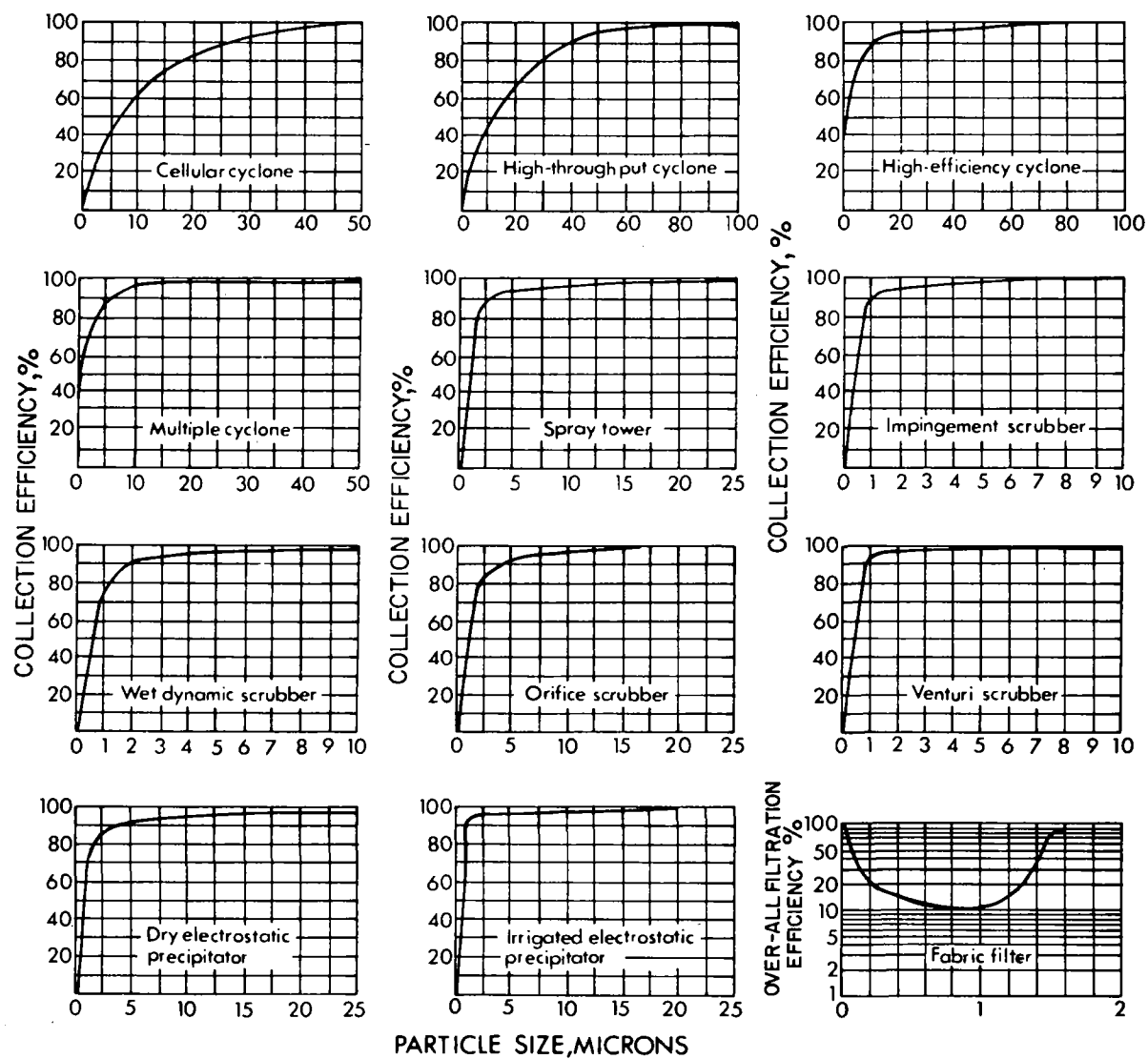


FIGURE D-2 EFFICIENCY CURVES FOR VARIOUS TYPES OF DUST COLLECTING EQUIPMENT²

TABLE D-1 AVERAGE COLLECTION EFFICIENCIES FOR VARIOUS PARTICLE SIZES
AND VARIOUS PARTICULATE CONTROL EQUIPMENT^a

Type Collector	Overall	Efficiency, %				
		0-5	5-10	10-20	20-44	>44
Baffled Settling Chamber	58.6	7.5	22	43	80	90
Simple Cyclone	65.3	12	33	57	82	91
Long-cone Cyclone	84.2	40	79	92	95	97
Multiple Cyclone (12 in. diameter)	74.2	25	54	74	95	98
Multiple Cyclone (6 in. diameter)	93.8	63	95	98	99.5	100
Irrigated Long-cone Cyclone	91.0	63	93	96	98.5	100
Electrostatic Precipitator	97.0	72	94.5	97	99.5	100
Irrigated Electrostatic Precipitator	99.0	97	99	99.5	100	100
Spray Tower	94.5	90	96	98	100	100
Self-induced Spray Scrubber	93.6	85	96	98	100	100
Disintegrator Scrubber	98.5	93	98	99	100	100
Venturi Scrubber	99.5	99	99.5	100	100	100
Wet Impingement Scrubber	97.9	96	98.5	99	100	100
Baghouse	99.7	99.5	100	100	100	100

a - Data based on standard silica dust with the following particle distribution:

Particle Size Range Microns	Percent by Weight
0-5	20
5-10	10
10-20	15
20-44	20
>44	35

Table D-2: REPRESENTATIVE EMISSION-CONTROL APPLICATIONS IN THE INTEGRATED IRON AND STEEL INDUSTRY

<u>Iron-or Steel-Making Segment</u>	<u>Total No.</u>	<u>Type of Emission-Control Equipment</u>			
		<u>Mechanical</u>	<u>Scrubbers</u>	<u>Precipitators</u>	<u>Fabrics</u>
Sinter plant	31	17	2	9	3
Blast furnace ^a	172	13 ^b	51	108	0
Open-hearth furnace	99	0	6	93	0
Basic oxygen furnace	38	0	15	23	0
Electric furnace	35	0	5	1	29
Scarfig	13	4	4	3	2

a Final control equipment.

b Dust collectors followed by other equipment are not considered.

Table D-3: CURRENT AND NEWEST AIR POLLUTION CONTROLS FOR PRIMARY ALUMINUM POTLINE AIR POLLUTION CONTROLS

<u>Type of Cell</u>	<u>Existing Collectors</u>	<u>Est. Removal efficiencies, %</u>		<u>Latest Collectors</u>	<u>Est. Removal efficiencies, %</u>	
		<u>Fluorides^a</u>	<u>Particulates</u>		<u>Fluorides^a</u>	<u>Particulates</u>
H.S. ^b	Soderberg Spray scrubbers	80-90	40-50	1. Floating bed scrubber ^c	90	80-90
				2. Wetted plate electrostatic (with conditioning of flue gases)	90	99
Prebake	Multiclones	0	< 60	1. Fluidized alumina contacts cell exhausts, followed by collection in alumina coated baghouse	99	96-98
	Dry electrostatic precipitators		90			
V.S. ^f	Spray scrubbers	80-90	40-50 ^d < 10 ^e	2. Counterflow packed scrubber	90	95
	Soderberg multiclones	0	< 60	Sieve plate scrubber	95	70
	Spray scrubbers	80-90	40-50			

a Gaseous and particulate fluorides.

b H.S. = horizontal stud.

c One section of bed employed.

d When used after multiclones.

e When used after e.s.p.

f V.S. = vertical stud.

APPENDIX E

ATMOSPHERIC EMISSIONS FROM THE AGRICULTURE
AND FOOD INDUSTRIES

Feed and Grain Mills and Elevators

Fermentation

Fish Processing

Meat Smokehouses

Starch Manufacturing

FEED AND GRAIN MILLS AND ELEVATORS

General

Grain elevators are primarily transfer and storage units and are classified as either the smaller, more numerous country elevators or the larger terminal elevators. At grain elevator locations the following operations occur: receiving, transfer and storage, cleaning, drying, and milling or grinding. Many of the large terminal elevators also process grain at the same location. The grain processing may include wet and dry milling (cereals), flour milling, oil-seed crushing, and distilling. Feed manufacturing involves the receiving, conditioning (drying, sizing, cleaning), blending, and pelleting of the grains, and their subsequent bagging or bulk loading.

Emissions

Emissions from feed and grain operations may be separated into those occurring at elevators and those occurring at grain processing operations or feed manufacturing operations. Emission factors for these operations are presented in Table E-1.

Because dust collection systems are generally applied to most phases of these operations to reduce product and component losses, the selection of the final emission factor should take into consideration the overall efficiency of these control systems.

Emissions from grain elevator operations are dependent on the type of grain, the moisture content of the grain (usually 10 to 30 percent), the amount of foreign material in the grain (usually 5 percent or less), the degree of enclosure at loading and unloading areas, the type of cleaning and conveying, and the amount and type of control used.

Factors affecting emissions from grain processing operations include the type of processing (wet or dry), the amount of grain processed, the amount of cleaning, the degree of drying or heating, the amount of grinding, the temperature of the process, and the degree of control applied to the particulates generated.

Factors affecting emissions from feed manufacturing operations include the type and amount of grain handled, the degree of drying, the amount of liquid blended into the feed, the type of handling (conveyor or pneumatic), and the degree of control.

Table E-1: PARTICULATE EMISSION FACTORS FOR GRAIN HANDLING

AND PROCESSING

EMISSION FACTOR RATING: B

<u>Type of source</u>	<u>Emissions</u>	
	<u>lb/ton</u>	<u>kg/MT</u>
Terminal elevators		
Shipping or receiving	1	0.5
Transferring, conveying, etc.	2	1
Screening and cleaning	5	2.5
Drying	6	3
Country elevators		
Shipping or receiving	5	2.5
Transferring, conveying, etc.	3	1.5
Screening and cleaning	8	4
Drying	7	3.5
Grain Processing		
Corn Meal	5	2.5
Soybean processing	7	3.5
Barley or wheat cleaner	0.2 ^a	0.1 ^a
Milo cleaner	0.4 ^a	0.2 ^a
Barley flour milling	3 ^a	1.5 ^a
Feed Manufacturing		
Barley	3 ^a	1.5 ^a

a - At cyclone exit (only non-ether-soluble particulates).

FERMENTATION

General Process Description

For the purpose of this report only the fermentation industries associated with food will be considered. This includes the production of beer, whiskey, and wine.

The manufacturing process for each of these is similar. The four main brewing production stages and their respective sub-stages are: (1) brewhouse operations, which include (a) malting of the barley, (b) addition of adjuncts (corn, grits, and rice) to barley mash, (c) conversion of starch in barley and adjuncts to maltose sugar by enzymatic processes, (d) separation of wort from grain by straining, and (e) hopping and boiling of the wort; (2) fermentation, which includes (a) cooling of the wort, (b) additional yeast cultures, (c) fermentation for 7 to 10 days, (d) removal of settled yeast, and (e) filtration and carbonation; (3) aging, which lasts from 1 to 2 months under refrigeration; and (4) packaging, which includes (a) bottling-pasteurization, and (b) racking draft beer.

The major differences between beer production and whiskey production are the purification and distillation necessary to obtain distilled liquors and the longer period of aging. The primary difference between wine making and beer making is that grapes are used as the initial raw material in wine rather than grains.

Emissions

Emissions from fermentation processes are nearly all gases and primarily consist of carbon dioxide, hydrogen, oxygen, and water vapor, none of which present an air pollution problem. However, emissions of particulates can occur in the handling of the grain for the manufacture of beer and whiskey. Gaseous hydrocarbons are also emitted from the drying of spent grains and yeast in beer and from the whiskey-aging warehouses. No significant emissions have been reported for the production of wine. Emission factors for the various operations associated with beer, wine and whiskey production are shown in Table E-2.

Table E-2 EMISSION FACTORS FOR FERMENTATION PROCESSES

EMISSION FACTOR RATING: E

Type of Product	lb/ton	kg/MT	lb/ton	kg/MT
Beer				
Grain handling ^a	3	1.5	--	--
Drying spent grains, etc. ^a	5	2.5	NA ^b	NA
Whiskey				
Grain handling ^a	3	1.5	--	--
Drying spent grains, etc. ^a	5	2.5	NA	NA
Aging	--	--	10 ^c	0.024 ^d
Wine	Neg ^e	Neg	Neg ^e	Neg

a - Based on section on grain processing.

b - NA^b : no emission factor available, but emissions do occur.

c - Pounds per year per barrel of whiskey stored.

d - Kilograms per year per liter of whiskey stored.

e - No significant emissions.

FISH PROCESSING

Process Description

The canning, dehydration, and smoking of fish, and the manufacture of fish meal and fish oil are the important segments of fish processing. There are two types of fish canning operations: the "wet-fish" method, in which the trimmed fish are cooked directly in the can, and the "pre-cooked" process, in which the whole fish is cooked and then hand-sorted before canning.

A large fraction of the fish received in a cannery is processed into by-products, the most important of which is fish meal. In the manufacture of fish meal, fish scrap from the canning lines is charged to continuous live-steam cookers. After the material leaves the cooker, it is pressed to remove oil and water. The pressed cake is then broken up, usually in a hammer mill, and dried in a direct-fired rotary drier or in a steam-tube rotary drier.

Emissions and Controls

The biggest problem from fish processing is odorous emissions. The principal odorous gases generated during the cooking portion of fish-meal manufacturing are hydrogen sulfide and trimethylamine. Some of the methods used to control odors include activated-carbon adsorbers, scrubbing with some oxidizing solution, and incineration. The only significant sources of dust emissions in fish processing are the driers and grinders used to handle dried fish meal.

MEAT SMOKEHOUSES

Process Description

Smoking is a diffusion process in which food products are exposed to an atmosphere of hardwood smoke, causing various organic compounds to be absorbed by the food. Smoke is produced commercially in the United States by three major methods: (1) by burning dampened sawdust (20 to 40 percent moisture), (2) by burning dry sawdust (5 to 9 percent moisture) continuously, and (3) by friction. Burning dampened sawdust and kiln-dried sawdust are the most widely used methods. Most large, modern, production meat smokehouses are the recirculating type, in which smoke is circulated at reasonably high temperatures throughout the smokehouse.

Emissions and Controls

Emissions from smokehouses are generated from the burning hardwood rather than from the cooked product itself. Emissions from meat smoking are dependent on several factors, including the type of wood, the type of smoke generator, the moisture content of the wood, the air supply, and the amount of smoke recirculated. Both low-voltage electrostatic precipitators and direct-fired afterburners may be used to reduce particulate and organic emissions.

STARCH MANUFACTURING

General Process Description

The basic raw material in the manufacture of starch is dent corn, which contains starch. The starch in the corn is separated from the other components by "wet milling".

The shelled grain is prepared for milling in cleaners that remove both the light chaff and any heavier foreign material. The cleaned corn is then softened by soaking (steeping) it in warm water acidified with sulphur dioxide. The softened corn goes through attrition mills that tear the kernels apart, freeing the germ and loosening the hull. The remaining mixture of starch, gluten, and hulls is finely ground, and the coarser fiber particles are removed by screening. The mixture of starch and gluten is then separated by centrifuges, after which the starch is filtered and washed. At this point it is dried and packaged for market.

Emissions

The manufacture of starch from corn can result in significant dust emissions. The various cleaning, grinding, and screening operations are the major sources of dust emissions. Table E-3 presents emission factors for starch manufacturing.

Table E-3: EMISSION FACTORS FOR STARCH MANUFACTURING^a

EMISSION FACTOR RATING: D

	Particulates	
Uncontrolled	8	4
Controlled ^a	0.02	0.01

a - Based on centrifugal gas scrubber

APPENDIX F

ATMOSPHERIC EMISSIONS FROM THE

MINERAL PRODUCTS INDUSTRY

- Asphalt Batching
- Asphalt Roofing
- Bricks and Related Clay Products
- Castable Refractories
- Portland Cement Manufacturing
- Ceramic Clay Manufacturing
- Clay and Fly Ash Sintering
- Concrete Batching
- Glass Manufacturing
- Gypsum Manufacturing
- Lime Manufacturing
- Mineral Wool Manufacturing
- Phosphate Rock Processing
- Stone Quarrying and Processing

This section involves the processing and production of various minerals. Mineral processing is characterized by particulate emissions in the form of dust. Frequently, as in the case of crushing and screening, this dust is identical to the material being handled. Emissions also occur through handling and storage of the finished product because this material is often dry and fine. Particulate emissions from some of the processes such as quarrying, yard storage, and road dust are difficult to control. Most of the emissions from the manufacturing processes discussed in this section, however, can be reduced by conventional particulate control equipment such as cyclones, scrubbers, and fabric filters. Because of the wide variety in processing equipment and final product, emissions cover a wide range; however, average emission factors have been presented for general use.

ASPHALT BATCHING

Process Description

Hot-mix asphalt paving consists of a combination of aggregates uniformly mixed and coated with asphalt cement. The coarse aggregates usually consist of crushed stone, crushed slag, crushed gravel, or combinations of these materials. The fine aggregates usually consist of natural sand and may contain added materials such as crushed stone, slag, or gravel.

An asphalt batch plant involves the use of a rotary dryer, screening and classifying equipment, an aggregate weighing system, a mixer, storage bins, and conveying equipment. Sand and aggregate are charged from bins into a rotary dryer. The dried aggregate is conveyed to the screening equipment, where it is classified and dumped into storage bins. Asphalt and weighed quantities of sized aggregates are then dropped into the mixer, where the batch is mixed and then dumped into trucks for transportation to the paving site.

Emissions and Controls

The largest source of dust emissions is the rotary dryer. Combustion gases and fine dust from the rotary dryer are exhausted through a precleaner, which usually consists of a single cyclone, although twin or multiple cyclones are also used. The exit gas stream of the precleaner usually passes through air pollution control equipment. Other sources of dust emissions include the hot aggregate bucket elevator, vibrating screens, hot aggregate bins, aggregate weigh hopper, and the mixer. Emission factors for asphalt batching plants are presented in Table F-1.

Table F-1

PARTICULATE EMISSION FACTORS FOR

ASPHALT BATCHING PLANTS^a

EMISSION FACTOR RATING: B

Source and type of control	Emissions	
	lb/ton	kg/MT
Rotary dryer		
Uncontrolled ^b	35	17.5
Precleaner	5	2.5
High-efficiency cyclone	0.8	0.4
Multiple centrifugal scrubber	0.2	0.1
Baffle spray tower	0.2	0.1
Orifice-type scrubber	0.08	0.04
Baghouse	0.005	0.0025
Other sources, uncontrolled	10	5
(vibrating screens, hot aggregate bins, aggregate weigh hopper, and mixer)		

^a - Emission factors expressed as units per unit weight of asphalt produced.

^b - Almost all plants have at least a precleaner following the rotary dryer.

ASPHALT ROOFING

Process Description

The manufacture of asphalt roofing felts and shingles involves saturating fiber media with asphalt by means of dipping and/or spraying. Although it is not always done at the same site, preparation of the asphalt saturant is an integral part of the operation. This preparation, called "blowing", consists of oxidizing the asphalt by bubbling air through the liquid asphalt for 8 to 16 hours. The saturant is then transported to the saturation tank or spray area. The saturation of the felts is accomplished by dipping, high-pressure sprays, or both. The final felts are made in various weights: 30 and 55 pounds per 100 square feet (0.72, 1.5, and 2.7 kg/m²). Regardless of the weight of the final product, the makeup is approximately 40 percent dry felt and 60 percent asphalt saturant.

Emissions and Controls

The major sources of particulate emissions from asphalt roofing plants are the asphalt blowing operations and the felt saturation. Another minor source of particulates is the covering of the roofing material with roofing granules. Gaseous emissions from the saturation process have not been measured but are thought to be slight because of the initial driving off of contaminants during the blowing process.

A common method of control at asphalt saturating plants is the complete enclosure of the spray area and saturator with good ventilation through one or more collection devices, which include combinations of wet scrubbers and two-stage low-voltage electrical precipitators, or cyclones and fabric filters. Emission factors for asphalt roofing are presented in Table F-2.

Table F-2

EMISSION FACTORS FOR ASPHALT ROOFING MANUFACTURING

WITHOUT CONTROLS^a

EMISSION FACTOR RATING: D

Operation	Particulates		Carbon monoxide		Hydrocarbons (CH ₄)	
	lb/ton	kg/MT	lb/ton	kg/MT	lb/ton	kg/MT
Asphalt blowing	2.5	1.25	0.9	0.45	1.5	0.75
Felt saturation						
Dipping only	1	0.5	-	-	-	-
Spraying only	3	1.5	-	-	-	-
Dipping and spraying	2	1	-	-	-	-

^a - Approximately 0.65 unit of asphalt input is required to produce 1 unit of saturated felt. Emission factors expressed as units per unit weight of saturated felt produced.

^b - Low-voltage precipitators can reduce emissions by about 60 percent; when they are used in combination with a scrubber, overall efficiency is about 85 percent.

BRICKS AND RELATED CLAY PRODUCTS

Process Description

The manufacture of brick and related products such as clay pipe, pottery, and some types of refractory brick involves the grinding, screening, and blending of the raw materials and the forming, drying or curing, firing, and cutting or shaping of the final product.

The drying and firing of pressed bricks, both common and refractory, are accomplished in many types of ovens, the most popular being the long tunnel oven. Common brick or building brick is prepared by molding a wet mix of 20 to 25 percent water and 75 to 80 percent clay, then baking it in chamber kilns. Common brick is also prepared by extrusion of a stiff mix (10 to 12 percent water), followed by the pressing and baking of sections cut from the extrusion.

Emissions and Controls

Particulate emissions similar to those obtained in clay processing are emitted from the materials handling process in refractory and brick manufacturing. Combustion products are emitted from the fuel consumed in the curing, drying, and firing portion of this process, and fluorides, largely in a gaseous form, are emitted from brick manufacturing operations. Sulphur dioxide may also be emitted from the bricks when firing temperature are 2500°F (1370°C) or more, or when the fuel contains sulfur.

A variety of control systems may be used to reduce both particulate and gaseous emissions. Almost any type of particulate control system will reduce emissions from the materials handling process. Fluoride emissions can be reduced to very low levels by using a water scrubber. Emissions factors for brick manufacturing are presented in Table F-3.

Table F-3

EMISSION FACTORS FOR BRICK MANUFACTURING

WITHOUT CONTROLS^a

EMISSION FACTOR RATING: D

Type of process	Particulate		Nitrogen oxides (NO ₂)		Fluorides ^b	
	lb/ton	kg/MT	lb/ton	kg/MT	lb/ton	kg/MT
Raw material handling ^c						
Drying	70	35	-	-	-	-
Grinding	76	38	-	-	-	-
Storage	34	17	-	-	-	-
Curing and firing						
Gas-fired	Neg	Neg	0.6	0.3	0.8	0.4
Oil-fired	Neg	Neg	1.3	0.65	0.8	0.4
Coal-fired	5A to 10A ^d	2.5A to 5A ^d	1.5	0.75	0.8	0.4

^a - One brick weighs about 6.5 pounds (2.96 kg). Emission factors expressed as units per unit weight of bricks produced.

^b - Expressed as HF and based on a raw material content of 0.05 percent by weight fluoride.

^c - Based on data from section on ceramic clays.

^d - A is the percentage of ash in the coal, and emissions are given on the basis of pounds per ton (kg/MT) of fuel used. This is an estimate based on coal-fired furnaces.

CASTABLE REFRACTORIES

Process Description

Castable or fused-cast refractories are manufactured by carefully blending such components as alumina, zirconia, silica, chrome, and magnesia; melting the mixture in an electric-arc furnace at temperatures of 3200° to 4500°F (1760° to 2480°C); pouring it into molds; and slowly cooling it to the solid state. Fused refractories are less porous and more dense than kiln-fired refractories.

Emissions and Controls

Particulate emissions occur during the drying, crushing, handling and blending phases of this process, during the actual melting process, and in the molding phase. Fluorides, largely in the gaseous form, may also be emitted during the melting operations.

The general types of particulate controls may be used on the materials handling aspects of refractory manufacturing. Emissions from the electric-arc furnace, however, are largely condensed fumes and consist of very fine particles. Fluoride emissions can be effectively controlled with a scrubber. Emission factors for castable refractories manufacturing are presented in Table F-4.

Table F-4

PARTICULATE EMISSION FACTORS FOR CASTABLE

REFRACTORIES MANUFACTURING^a

EMISSION FACTOR RATING: C

Type of process	Type of control	Uncontrolled		Controlled	
		lb/ton	kg/MT	lb/ton	kg/MT
Raw material dryer	Baghouse	30	15	0.3	0.15
Raw material crushing	Scrubber			7	3.5
and processing	Cyclone	120	60	45	22.5
Electric-arc melting	Baghouse	50	25	0.8	0.4
	Scrubber			10	5
Curing oven	-	0.2	0.1	-	-
Molding and Shakeout	Baghouse	25	12.5	0.3	0.15

^a - Fluoride emissions from the melt average about 1.3 pounds of HF per ton of melt (0.65 kg HF/MT melt). Emission factors expressed as units per unit weight of feed material.

PORTLAND CEMENT MANUFACTURING

Process Description

The raw materials required to make cement may be divided into the following components: lime (calcareous), silica, (siliceous), alumina (argillaceous), and iron (ferriferous). The four major steps in the production of portland cement are: (1) quarrying and crushing, (2) grinding and blending, (3) clinker production, and (4) finish grinding and packaging.

In the first step the cement rock limestone, clay, and shale are worked in open quarries. The rock from the quarries is sent through a primary and a secondary crusher. The various crushed raw materials are properly mixed and are then sent through the grinding operations. After the raw materials are crushed and ground, they are introduced into a rotary kiln that is fired with pulverized coal, oil, or gas. In the kiln the materials are dried, decarbonated, and calcined to produce a cement clinker. The clinker is cooled, mixed, ground with gypsum, and bagged for shipment as cement.

Emissions and Controls

Particulate matter is the primary emission in the manufacture of portland cement and, it is emitted from crushing operations, storage silos, rotary dryers, and rotary kilns. Dust production in the crusher area depends on the type and moisture content of the raw material and on the characteristics and type of crusher. In the process of conveying the crushed material to storage silos, sheds, or open piles, dust is generated at various conveyor transfer points. A hood is normally placed over each of these points to control particulate emissions.

Another major source of particulate matter is the rotary dryer. Hot gases passing through the rotary dryer will entrain dust from the limestone, shale, or other materials being dried. Control

systems in common use include multi-cyclones, electrostatic precipitators, and fabric filters.

The largest source of emissions within cement plants is the kiln operation, which has three units: the feed system, a fuel-firing system, and a clinker-cooling and handling system. The complication of kiln burning and the large volume of materials handled have led to many control systems for dust collection. Because of the diversity of these control systems, they will not be discussed in this publication. Table F-5 summarizes particulate emissions from cement manufacturing. The effect of control devices on emissions is shown in Footnote b.

Table F-5

PARTICULATE EMISSION FACTORS

FOR CEMENT MANUFACTURING^a

EMISSION FACTOR RATING: B

Type of process	Uncontrolled emissions ^b	
	lb/bbl	kg/MT
Dry process		
Kilns	46 (35 to 75)	123
Dryers, grinder, etc.	18 (10 to 30)	48
Wet process		
Kilns	38 (15 to 55)	100
Dryers, grinders, etc.	6 (2 to 10)	16

^a - One barrel of cement weighs 376 pounds (171 kg).

^b - Typical collection efficiencies are:
multicyclones, 80 percent;
old electrostatic precipitators, 90 percent;
multicyclones plus old electrostatic precipitators, 95 percent;
multicyclones plus new electrostatic precipitators, 99 percent;
and fabric filter units, 99.5 percent.

CERAMIC CLAY MANUFACTURING

Process Description

The manufacture of ceramic clay involves the conditioning of the basic ores by several methods. These include the separation and concentration of the minerals by screening, floating, wet and dry grinding, and blending of the desired ore varieties. The basic raw materials in ceramic clay manufacture are kaolinite ($\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$) and montmorillonite ($(\text{Mg},\text{Ca}) 0.\text{Al}_2\text{O}_3 \cdot 5\text{SiO}_2 \cdot n\text{H}_2\text{O}$) clays. These clays are refined by separation and bleaching, blended, kiln-dried, and formed into such items as whiteware, heavy clay products (brick, etc.), various stoneware, and other products such as diatomaceous earth used as a filter aid.

Emissions and Controls

Emissions consist primarily of particulates, but some fluorides and acid gases are also emitted in the drying process. The high temperature of the firing kilns are also conducive to the fixation of atmospheric nitrogen and the subsequent release of NO , but no published information has been found for gaseous emissions. Particulates are also emitted from the grinding process and from storage of the ground product.

Factors affecting emissions include the amount of material processed, the type of grinding (wet or dry), the temperature of the drying kilns, the gas velocities and flow direction in the kilns, and the amount of fluorine in the ores.

Common control techniques include settling chambers, cyclones, wet scrubbers, electrostatic precipitators, and bag filters. The most effective control is provided by cyclones for the coarser material, followed by wet scrubbers, bag filters, or electrostatic precipitators for dry dust. Emission factors for ceramic clay manufacturing are presented in Table F-6.

Table F-6

PARTICULATE EMISSION FACTORS FOR

CERAMIC CLAY MANUFACTURING^a

EMISSION FACTOR RATING: A

Type of process	Uncontrolled		Cyclone ^b		Multiple-unit cyclone and scrubber ^c	
	lb/ton	kg/MT	lb/ton	kg/MT	lb/ton	kg/MT
Drying	70	35	18	9	7	3.5
Grinding	76	38	19	9.5	-	-
Storage	34	17	8	4	-	-

^a - Emission factors expressed as units per unit weight of input to process.

^b - Approximate collection efficiency: 75 percent.

^c - Approximate collection efficiency: 90 percent.

CLAY AND FLY ASH SINTERING

Process Description

Although the processes for sintering fly ash and clay are similar, there are some distinctions that justify a separate discussion of each process. Fly-ash sintering plants are generally located near the source, with the fly ash delivered to a storage silo at the plant. The dry fly ash is moistened with a water solution of lignin and agglomerated into pellets or balls. This material goes to a travelling-grate sintering machine where direct contact with hot combustion gases sinters the individual particles of the pellet and completely burns off the residual carbon in the fly ash. The product is then crushed, screened, graded, and stored in yard piles.

Clay sintering involves the driving off of entrained volatile matter. It is desirable that the clay contain a sufficient amount of volatile matter so that the resultant aggregate will not be too heavy. It is thus sometimes necessary to mix the clay with finely pulverized coke (up to 10 percent coke by weight). In the sintering process the clay is first mixed with pulverized coke, if necessary, and pelletized. The clay is next sintered in a rotating kiln or on a travelling grate. The sintered pellets are then crushed, screened and stored, in a procedure similar to that for fly-ash pellets.

Emissions and Controls

In fly-ash sintering, improper handling of the fly ash creates a dust problem. Adequate design features, including fly-ash wetting systems and particulate collection systems on all

transfer points and on crushing and screening operations, would greatly reduce emissions. Normally, fabric filters are used to control emissions from the storage silo, and emissions are low. The absence of this dust collection system, however, would create a major emission problem. Moisture is added at the point of discharge from the silo to the agglomerator, and very few emissions occur there. Normally, there are few emissions from the sintering machine, but if the grate is not properly maintained, a dust problem is created. The consequent crushing, screening, handling, and storage of the sintered product also create dust problems.

In clay sintering, the addition of pulverized coke presents an emission problem because the sintering of coke-impregnated dry pellets produces more particulate emissions than the sintering of natural clay. The crushing, screening, handling, and storage of the sintered clay pellets creates dust problems similar to those encountered in fly-ash sintering. Emission factors for both clay and fly-ash sintering are shown in Table F-7.

Table F-7

PARTICULATE EMISSION FACTORS FOR

SINTERING OPERATIONS^a

EMISSION FACTOR RATING: C

Type of material	Sintering operation ^b		Crushing, screening, and yard storage ^{b,c}	
	lb/ton	kg/MT	lb/ton	kg/MT
Fly ash	110	55	d	d
Clay mixed with coke ^e	40	20	15	7.5
Natural clay ^f	12	6	12	6

^a - Emission factors expressed as units per unit weight of finished product.

^b - Cyclones would reduce this emission by about 80 percent. Scrubbers would reduce this emission by about 90 percent.

^c - Based on data in section on stone quarrying and processing.

^d - Included in sintering losses.

^e - 90 percent clay, 10 percent pulverized coke; travelling-grate, single-pass, up-draft sintering machine.

^f - Rotary dryer sinterer.

CONCRETE BATCHING

Process Description

Concrete batching involves the proportioning of sand, gravel, and cement by means of weight hoppers and conveyors into a mixing receiver such as a transit mix truck. The required amount of water is also discharged into the receiver along with the dry materials. In some cases, the concrete is prepared for on-site building construction work or for the manufacture of concrete products such as pipes and prefabricated construction parts.

Emissions and Controls

Particulate emissions consist primarily of cement dust, but some sand and aggregate gravel dust emissions do occur during batching operations. There is also a potential for dust emissions during the unloading and conveying of concrete and aggregates at these plants and during the loading of dry-batched concrete mix. Another source of dust emissions is the traffic of heavy equipment over unpaved or dusty surfaces in and around the concrete batching plant.

Control techniques include the enclosure of dumping and loading areas, the enclosure of conveyors and elevators, filters on storage bin vents, and the use of water sprays. Table F-8 presents emission factors for concrete batch plants.

Table F-8

PARTICULATE EMISSION FACTORS

FOR CONCRETE BATCHING^a

EMISSION FACTOR RATING: C

Concrete batching	Emissions	
	lb/yd ³ of concrete	kg/m ³ of concrete
Uncontrolled	0.2	0.12
Good control	0.02	0.012

^a - One cubic yard of concrete weighs 4,000 pounds (1m³ = 2,400 kg). The cement content varies with the type of concrete mixed, but 735 pounds of cement per yard (436 kg/m³) may be used as a typical value.

GLASS MANUFACTURING

Process Description

Nearly all glass produced commercially is one of five basic types: soda-lime, lead, fused silica, borosilicate, and 96 percent silica. Of these, the modern soda-lime glass constitutes 90 percent of the total glass produced and will thus be the only type discussed in this section. Soda-lime glass is produced on a massive scale in large, direct-fired, continuous-melting furnaces in which the blended raw materials are melted at 2700°F (1480°C) to form glass.

Emissions and Controls

Emissions from the glass-melting operation consists primarily of particulates and fluorides, if fluoride containing fluxes are used in the process. Because the dust emissions contain particles that are only a few microns in diameter, cyclones and centrifugal scrubbers are not as effective as bag-houses or filters in collecting particulate matter. Table F-9 summarizes the emission factors for glass melting.

Table F-9

EMISSION FACTORS FOR GLASS MELTING

EMISSION FACTOR RATING: D

Type of glass	<u>Particulates^a</u>		<u>Fluorides</u>	
	lb/ton	kg/MT	lb/ton	kg/MT
Soda-lime	2	1	4F ^b	2F ^b

^a - Emission factors expressed as units per unit weight of glass produced.

^b - F equals weight percent of fluoride in input to furnace; e.g., if fluoride content is 5 percent, the emission factor would be 4F or 20 (2F or 10).

GYPSUM MANUFACTURING

Process Description

Gypsum, or hydrated calcium sulfate, is a naturally occurring mineral that is an important building material. When heated gypsum loses its water of hydration, it becomes plaster of paris, or when blended with fillers it serves as wall plaster. In both cases the material hardens as water reacts with it to form the solid crystalline hydrate.

The usual method of calcination of gypsum consists of grinding the mineral and placing it in large, externally heated calciners. Complete calcination of 1 ton (0.907 MT) of plaster takes about 3 hours and requires about 1.0 million Btu (0.25 million kcal).

Emissions

The process of calcining gypsum appears to be devoid of any air pollutants because it involves simply the relatively low-temperature removal of the water of hydration. However, the gases created by the release of the water of crystallization carry gypsum rock dust and partially calcined gypsum dust into the atmosphere. In addition, dust emissions occur from the grinding of the gypsum before calcining and from the mixing of the calcined gypsum with filler. Table F-10 presents emission factors for gypsum processing.

Table F-10

PARTICULATE EMISSION FACTORS FOR

GYPSUM PROCESSING^a

EMISSION FACTOR RATING: C

Type of process	Uncontrolled emissions		With fabric filter		With cyclone and electrostatic precipitator	
	lb/ton	kg/MT	lb/ton	kg/MT	lb/ton	kg/MT
Raw-material dryer (if used)	40	20	0.2	0.1	0.4	0.2
Primary grinder	1	0.5	0.001	0.0005	-	-
Calciner	90	45	0.1	0.05	-	-
Conveying	0.7	0.35	0.001	0.0005	-	-

^a - Emission factors expressed as units per unit weight of process throughput.

LIME MANUFACTURING

General

Lime (CaO) is the high-temperature product of the calcination of lime stone (CaCO_3). Lime is manufactured in vertical or rotary kilns fired by coal, oil, or natural gas.

Emissions and Controls

Atmospheric emissions in the lime manufacturing industry include particulate emissions from the mining, handling, crushing, screening, and calcining of the limestone and combustion products from the kilns. The vertical kilns, because of a larger size of charge material, lower air velocities, and less agitation, have considerable fewer particulate emissions. Control of emissions from these vertical kilns is accomplished by sealing the exit of the kiln and exhausting the gases through control equipment.

Particulate emission problems are much greater on the rotary kilns because of the smaller size of the charge material, the higher rate of fuel consumption, and the greater air velocities through the rotary chamber. Methods of control on rotary-kiln plants include simple and multiple cyclones, wet scrubbers, baghouses, and electrostatic precipitators. Emission factors for lime manufacturing are summarized in Table F-11.

Table F-11

PARTICULATE EMISSION FACTORS FOR
LIME MANUFACTURING WITHOUT CONTROLS^a

EMISSION FACTOR RATING: B

Operation	Emissions ^b	
	lb/ton	kg/MT
Crushing		
Primary	31	15.5
Secondary	2	1
Calcining		
Vertical kiln	8	4
Rotary kiln	200	100

^a - Emission factors expressed as units per unit weight of lime processed.

^b - Cyclones could reduce these factors by about 70 percent. Venturi scrubbers could reduce these factors by about 95 to 99 percent. Fabric filters could reduce these factors by about 99 percent.

MINERAL WOOL MANUFACTURING

Process Description

The product mineral wool used to be divided into three categories: slag wool, rock wool, and glass wool. Today, however, straight slag wool and rock wool as such are no longer manufactured. A combination of slag and rock constitutes the charge material that now yields a product classified as a mineral wool, used mainly for thermal and accoustical insulation.

Mineral wool is made primarily in cupola furnaces charged with blast-furnace slag, silica rock, and coke. The charge is heated to a molten state at about 3000°F (1650°C) and then fed to a blow chamber, where steam atomizes the molten rock into globules that develop long fibrous tails as they are drawn to the other end of the chamber. The wool blanket formed is next conveyed to an oven to cure the binding agent and then to a cooler.

Emissions and Controls

The major source of emissions is the cupola or furnace stack. Its discharge consists primarily of condensed fumes that have volatilized from the molten charge and gases such as sulphur oxides and fluorides. Minor sources of particulate emissions include the blowchamber, curing oven, and cooler. Emission factors for various stages of mineral wool processing are shown in Table F-12. The effect of control devices on emissions is shown in footnotes to the table.

Table F-12

EMISSION FACTORS FOR MINERAL WOOL

PROCESSING WITHOUT CONTROLS^a

EMISSION FACTOR RATING: C

Type of process	<u>Particulates</u>		<u>Sulphur oxides</u>	
	lb/ton	kg/MT	lb/ton	kg/MT
Cupola	22	11	0.02	0.01
Reverberatory furnace	5	2.5	Neg	Neg
Blow chamber ^b	17	8.5	Neg	Neg
Curing oven ^c	4	2	Neg	Neg
Cooler	2	1	Neg	Neg

^a - Emission factors expressed as units per unit weight of charge.

^b - A centrifugal water scrubber can reduce particulate emissions by 60 percent.

^c - A direct-flame afterburner can reduce particulate emissions by 50 percent.

PHOSPHATE ROCK PROCESSING

Process Description

Phosphate rock preparation involves beneficiation to remove impurities, drying to remove moisture, and grinding to improve reactivity. Usually, direct-fired rotary-kilns are used to dry phosphate rock. The material from the dryers may be ground before storage in large storage silos. Air-swept ball mills are preferred for grinding phosphate rock.

Emissions and Controls

Although there are no significant emissions from phosphate rock beneficiation plants, emissions in the form of fine rock dust may be expected from drying and grinding operations. Phosphate rock dryers are usually equipped with dry cyclones followed by wet scrubbers. Particulate emissions are usually higher when drying pebble rock than when drying concentrate because of the small adherent particles of clay and slime on the rock. Phosphate rock grinders can be a considerable source of particulates. Because of the extremely fine particle size, baghouse collectors are normally used to reduce emissions. Emission factors for phosphate rock processing are presented in Table F-13.

Table F-13

PARTICULATE EMISSION FACTORS FOR
PHOSPHATE ROCK PROCESSING WITHOUT CONTROLS^a

EMISSION FACTOR RATING: C

Type of source	Emissions	
	lb/ton	kg/MT
Drying ^b	15	7.5
Grinding ^c	20	10
Transfer and storage ^c	2	1
Open storage piles	40	20

^a - Emission factors expressed as units per unit weight of phosphate rock.

^b - Dry cyclones followed by wet scrubbers can reduce emissions by 95 to 99 percent.

^c - Dry cyclones followed by fabric filters can reduce emissions by 99.5 to 99.9 percent.

ROCK QUARRYING AND PROCESSING

Process Description

Rock and gravel products are loosened by drilling and blasting them from their deposit beds, and they are removed with the use of heavy earth-moving equipment. This mining of rock is done primarily in open pits. The use of pneumatic drilling and cutting, as well as blasting and transferring, causes considerable dust formation. Further processing includes crushing, regrinding, and removal of fines. Dust emissions can occur from all of these operations, as well as from quarrying, transferring, loading, and storage operations. Drying operation, when used, can also be a source of dust emissions.

Emissions

As enumerated above, dust emissions occur from many operations in stone quarrying and processing. Although a big portion of these emissions is heavy particles that settle out within the plant, an attempt has been made to estimate the suspended particulates. These emission factors are shown in Table F-14. Factors affecting emissions include the amount of rock processed; the method of transfer of the rock; the moisture content of the raw material; the degree of enclosure of the transferring, processing, and storage areas; and the degree of which control equipment is used in the processes.

Table F-14

PARTICULATE EMISSION FACTORS FOR

ROCK-HANDLING PROCESSES

EMISSION FACTOR RATING: C

Type of process	<u>Uncontrolled total^a</u>		<u>Settled out in plant</u>	<u>Suspended emission</u>	
	lb/ton	kg/MT	%	lb/ton	kg/MT
Crushing operations ^b					
Primary crushing	0.5	0.25	80	0.1	0.05
Secondary crushing and screening	1.5	0.75	60	0.6	0.3
Tertiary crushing and secondary (if used)	6	3	40	3.6	1.8
Recrushing and screening	5	2.5	50	2.5	1.25
Fines mill	6	3	25	4.5	2.25
Miscellaneous operations ^c					
Screening, conveying and handling	2	1			
Storage pile losses ^d	10	5			

^a - Typical collection efficiencies: cyclone, 70 to 85 percent; fabric filter, 99 percent.

^b - All values are based on raw material entering primary crusher, except those for recrushing and screening, which are based on throughput for that operation.

^c - Based on units of stored product.

^d - The factor assigned here is the author's estimate for uncontrolled total emissions. Use of this factor should be tempered with knowledge about the size of materials stored, the local meteorological factors, the frequency with which the piles are disturbed, etc.

APPENDIX G

BIBLIOGRAPHY OF AIR POLLUTION CONTROL REFERENCES

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