II LITERATURE REVIEW

2.1 Slaughterhouse Wastewater

Wastewater from slaughterhouses varies considerably according to size, type of operation, degree of recovery and water supply utilized in the process. The size of slaughterhouse can be classified into three main slaughter and packing sizes : small, medium and large. The annual live weights killed for each size are set at 10, 45 and 90 million kiligrams which equals 30, 125 and 250 t/d, respectively.

Normally, the two main parts that generate wastewater are stockyard and slaughterhouse area. Stockyard wastewater basically consists of animal manure, urine, straw and unconsumed food, whereas, the slaughterhouse wastewater contains blood, flesh, rumen, grease and dirt.

2.1.1 Slaughterhouse Process

The process flow diagram of general slaughterhouses that is used throughout the country is shown in Figure 2.1

Before animals are sent to the killing area, it is essential to keep them in the holding pens for ante-mortem inspection for at least 24 hours. Prior to killing, animals are immobilized and stunned by mechanical or electrical means such as stunning. Then, suspended by their hind feet, they are left to bleed and blood is collected underneath. After that, cattle hide is removed by both mechanical and manual means, while hog is dehaired by scraping after scalding in a water tank at 140^{o}F. The viscera are then removed and devided into as edible and inedible portions. The paunches are also opened and contents removed. Trimming and carcass cutting are further processed.

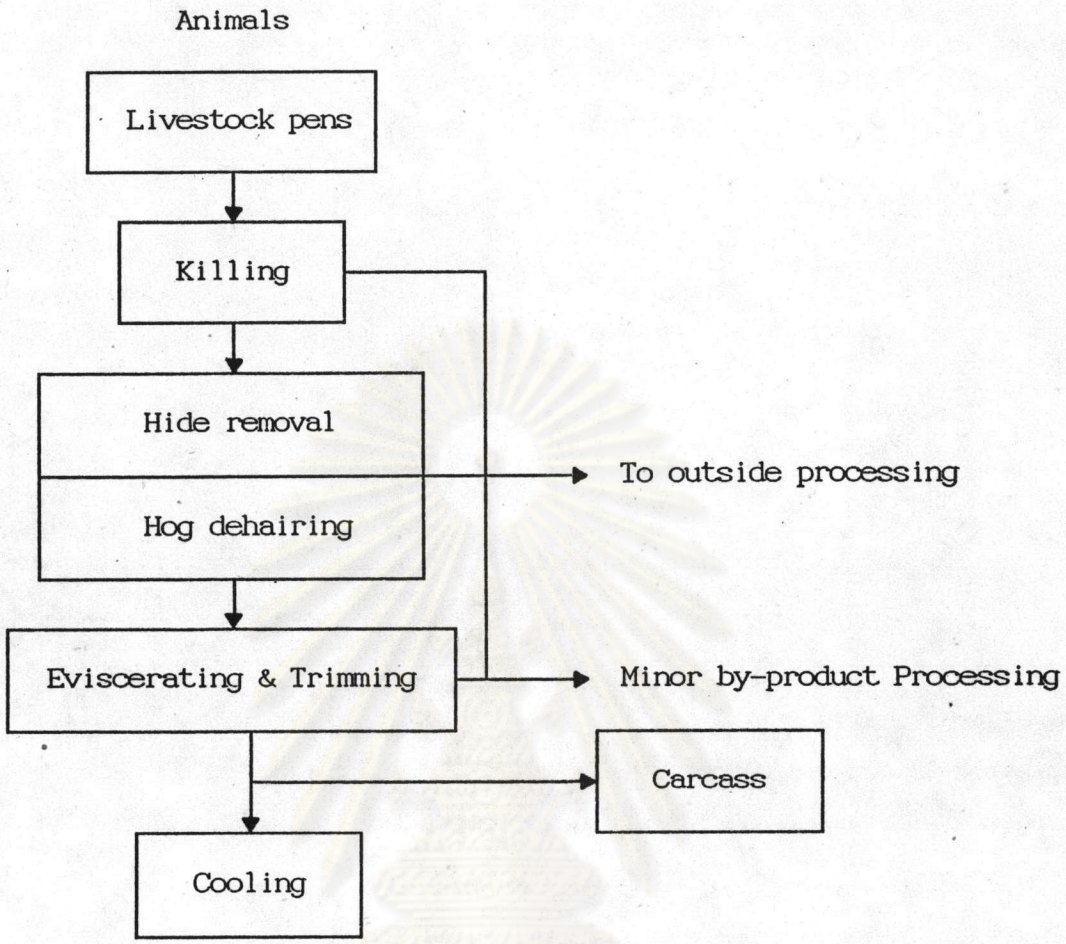

Figure 2.1 Process flow diagram of slaughterhouses

2.1.2 Sources of Wastes from Slaughterhouses

Sources and types of wastes are illustrated in Figure 2.2. In the killing area, blood, which is 1/12-1/15 of the animal's weight, is the main waste released. When killed,they release about 50% of the whole blood content. The blood is excessively high in organic contents, approximately 100,000 mg/l of BOD can be detected.Blood is however commercially valuable in the local market, so it should be recovered and utilized as fertilizer, animal feed and/or clinical raw material (Dussadee Uttapab, 1985). Less pollution therefore results from better blood collection.

Hide removing and hog dehairing processes generate dirt and hair in discharges. In the same way, the intestine removal also produces strong wastewater which contains manure and liquor. If it is possible to collect the manure by dry handling, the pollution will be further greatly decreased.

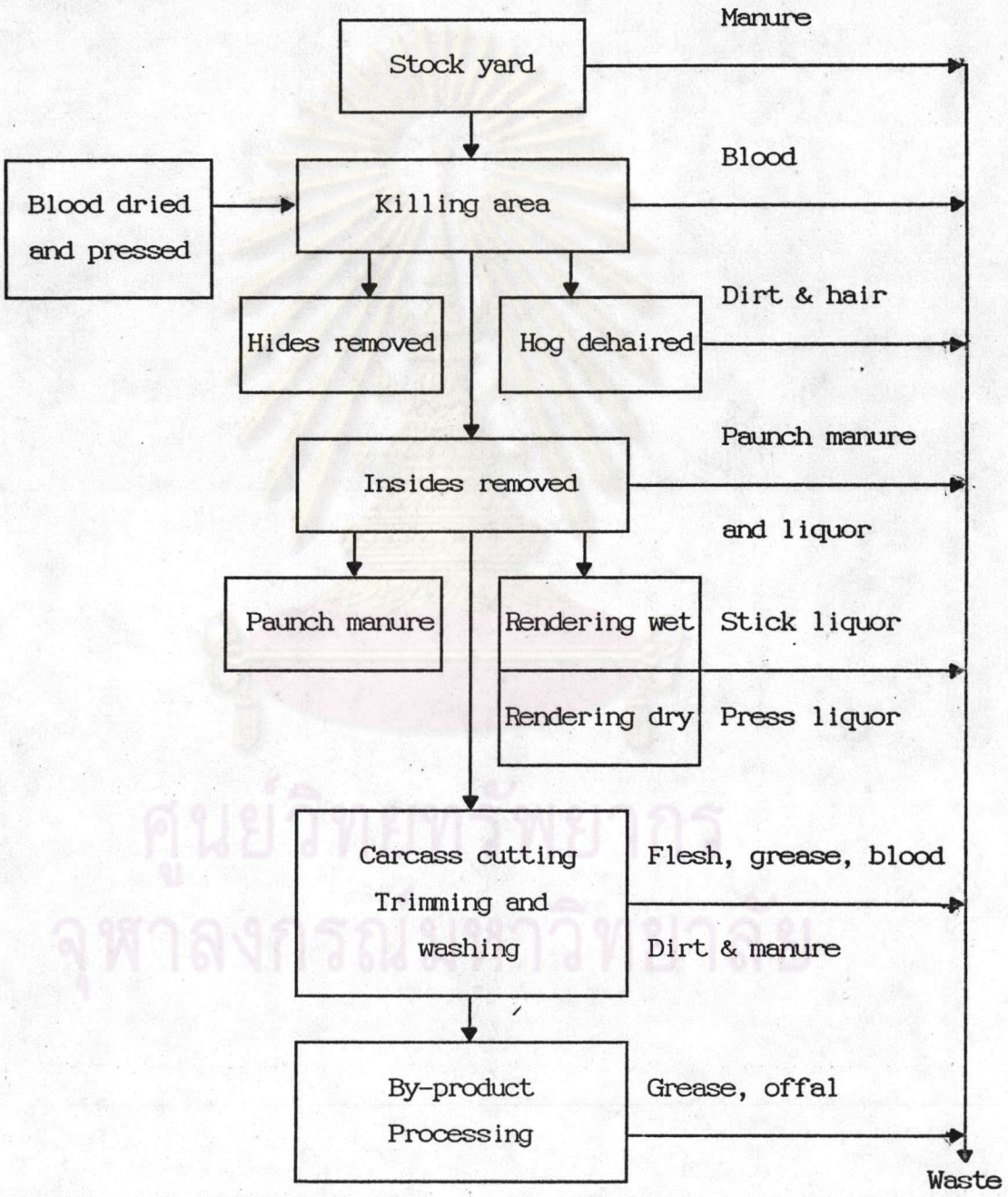

Figure 2.2 Sources of wastes from slaughterhouses

The carcass cutting and trimming processes generate flesh, grease, blood and dirt which are very high in organic contents.These processes induce high organic loading, but perhaps slightly less troublesome than that in the killing area.

The whole process, except bleeding, uses water for washing. After processing, floor and stockyard cleaning is essential.However, if a high volume of tap water is used more wastewater will be generated. The operation process can therefore govern the quantity of the wastewater.

2.1.3 Characteristics of the Wastewater

It is difficult to clearly state the composition of the wastewaters. Even samples collected from the same plant at different times are not identical. The affecting factors are the volume of tap water used, quantity killed and types of wastes released at that time. In this chapter, the data collected from different sources are presented for comparison.

Oanh (1991), studied assessment and control of wastewater in this slaughterhouse (thesis submitted in March, 1991), reported that the processes which produced a high concentration of COD, SS and fat were the killing, offal processing and floor washing. The rendering unit also discharged some fat residue and dried blood which induced high SS,fat and COD. Unlike wastewaters mentioned before, the wastewater from the meat processing unit and condensate water were quite lowly polluted, only high pH and temperature were a problem. (She also stated that wastewater sampling from the manhole inlet was much more polluted than wastewater from inside due to dilution from nearby diluted wastewater streams).Table 2.1 illustrates wastewater characteristics that have been analysed.

Table 2.1 Average characteristics of composite samples during working days

Sampling place		pH	Cond mg/l	SS mg/l	COD(T) mg/l	COD(F) mg/l	OP mg/l	TP mg/l	NH_3 mg/l	TKN mg/l	Fat mg/l	Set.S mg/l
1. Meat Processing Unit	**	7.5	1441	52	-	83	3.4	-	-	-	-	-
2. Meat Processing Unit	**	7.0	914	108	350	160	1.3	6	-	-	-	-
3. Hog offal Processing	**	7.8	1025	194	345	247	10.8	35	28	58	-	-
4. Hog offal Processing	*	7.8	1530	1248	2970	610	23.9	112	43	147	248	13.5
5. Cattle offal Processing	*	7.1	1077	1080	3252	700	12.7	54	19	92	294	16.0
6. Hog killing Floor	**	7.2	1040	310	796	597	5.4	29	21	64	36	-
7. Cattle Killing Floor	**	7.6	1097	330	896	550	7.6	30	29	74	75	4.4
8. Cattle Killing Floor	*	7.5	869	1164	2282	728	3.6	16	0	87	64	14.0
9. Hog dehairing	*	7.1	840	310	1494	652	4.3	17	11	128	99	15.0
10. Hog carcass	*	7.0	1097	1577	9994	1569	7.3	160	195	435	2200	28.6
11. Hog Rendering & Condensate	*	8.2	1259	61	524	282	0.2	3	31	35	29	-
12. Cattle Rendering & Condensate	*	8.0	1230	260	642	391	5.0	20	-	-	49	1.7

* manhole inlet sampling

** manhole inside sampling

Wipitch Chaisrisongkram (1976) gathered data from different processes in a slaughterhouse. Wastewater characteristics from the stockyard showed the average BOD_5 concentration to be about 100 mg/l or equivalent to the wastewater generated by 3,100 persons. For the killing area the average BOD_5 was about 2,000 mg/l and the total nitrogen was estimated to be 500 mg/l. Valuable data for design consideration were also proposed, as shown in Table 2.2

Table 2.2 Characteristics of wastewater from slaughterhouse and its by-product

Waste source	SS (mg/l)	Organic Nitrogen (mg/l)	BOD (mg/l)
Killing floor	220	134	825
Blood and tank water	3,690	5,400	32,000
Scalding tub	8,360	1,290	4,600
Meat cutting	610	33	520
Gut washer	15,120	643	13,200
Sausage department	560	136	800
Lard department	180	84	180
By-product	1,380	186	2,200

Source : Wipitch Chaisrisongkram (1976) Department of Livestock Development

Azad (1976) stated that the average blood generated from beef slaughtering was 29.5 kg/ton live-weight kill. This resulted in BOD_5 of 156,500 mg/l or 4.67 kg BOD/ton live weight kill. If the recovery process was properly managed, BOD load could be decreased by 72 percent. He also estimated paunch content to be 18-27 kg, with an average of 24 kg per animal. The rumen was another source of pollution which contained BOD_5 of 50,200 mg/l, equivalent to 2.49 kg BOD/ton live-weight kill. Table 2.3 and 2.4 indicated

characteristics of wastewater observed.

Table 2.3 Characteristics of cattle fresh whole blood

Parameter	Unit	Mean	Std. dev.	n
pH	–	7.3	0.1	37
Moisture	%	82.4	3.4	39
COD	g/l	218.3	35.7	70
BOD_5	g/l	156.5	58.0	35

Sorce : Industrial Wastewater Management Handbook (1976)

Table 2.4 Characteristics of cattle rumen

Parameter	Unit	Mean	Std. dev.	n
pH	–	6.5	0.5	57
Moisture	%	84.7	3.4	58
COD				114
Liquid portion	g/l	51	12,800	
percent liquid	%	88	3.3	
Solids portion	g/l	1,138	82,000	
percent solids	%	11	3.3	
Total COD	g/l	177	38,500	
COD from liquid	%	26		
COD from solids	%	73		
BOD_5				
Liquid portion	g/l	28	11,410	
Solids portion	g/l	151	40,800	
Total BOD_5	g/l	50	13,400	
BOD from liquid	%	59		
BOD from solids	%	40		

Source : Industrial Wastewater Management Handbook (1976)

2.1.4 Quantity of Wastewater

Slaughterhouse produces a high volume of wastewater. The wastewater produced from a slaughterhouse is quite large in volume. Considering its contents, the organic loading discharged is harmful to natural waterways. According to Wipitch Chaisisongkram (1976), the volume of wastewater generated and its impurities were as shown in Table 2.5.

Table 2.5 Volume of wastewater and impurities

Type of kill	Volume per Animal (m^3)	Suspended Solids (mg/l)	Organic Nitrogen (mg/l)	BOD (mg/l)	Population equivalents per animal
Mixed	1.36	929	324	2,240	40.2
Cattle	1.50	820	154	996	19.6
Hog	0.05	717	122	1,046	7.5

Source : Wipitch Chaisrisongkram (1976) Department of Livestock Development

Lund (1971) collected data on flow and characteristics of wastewaters from slaughterhouse, packing house and processing plants from U.S. Public Health Service. The data were as shown in Table 2.6.

Table 2.6 Approximate range of wastewater flow and characteristics

Operation	Waste flow, m^3/1,000 kg live weight slaughtered	Typical analysis, mg/l		
		BOD	Suspended Solids	Grease
Slaughterhouse	4.2 - 16.7	650-2,200	930-3,000	200-1,000
Packinghouse	6.2 - 29.2	400-3,000	230-2,000	200-1,000
Processing plant	8.3 - 33.3	200-800	200-800	100-300

Approximate waste load

Operation	kg per 1,000 kg live weight slaughtered		
	BOD	Suspended Solid	Grease
Slaughterhouse	9.2-10.8	12.5-15.4	4.2-3.3
Packinghouse	18.7-11.7	12.5-6.7	6.3-5.8
Processing plant	6.7	6.7	2.5-3.3

Source : Industrial Pollution Control Handbook (1971)

Gutteridge et al. (1978) presented the data of effluent from slaughterhouses in Australia as shown in Table 2.7 to the conferences at the Australian Meat Technology Group of the AIFST seminar, 1978.

Table 2.7 Effluent production per day

Effluent Parameter	Unit	Amount/t LWK/d	Abattoir Type	
			Large	Small
Volume	m^3	5	5,810	318
BOD	kg	11	12,782 (2,200 mg/l)	699
Oil & Grease	kg	1.8	2,092 (360 mg/l)	114
Suspended Solids	kg	3.6	4,183 (720 mg/l)	229
Nitrogen	kg	0.18	290	11
Phosphorus	kg	0.06	70	4

Source : The Australian Meat Technology Group of the AIFST Seminar (1978)

2.2 Treatment of Meat-Industry Wastewater

Lund (1971) said that the slaughterhouse wastes were amenable to treat, whether in municipal sewage treatment plants or by an own treatment plant. Prior to releasing the wastewaters into city sewers, pretreatment of screening, sedimentation and flotation were normally practiced. He also showed the data on treatment process employed by 108 meat industries, see Table 2.8 :

Table 2.8 Types of waste treatment of 108 meat packing and processing plants

Method	No. of Plants
Screening	59
Sedimentation	71
Filtration	2
Flotation (air)	11
Flotation (gravity)	87
Flocculation	2
Evaporation	2
Chemical coagulation	1
Trickling Filter	1
Activated Sludge	12
Anaerobic digestion	5
Septic tank	13
Irrigation	2
Stabilization pond	7

Source : Industrial Pollution Control Handbook (1971)

Lund (1971) also observed the efficiency of treatment by anaerobic contact process. It was reported that a BOD removal of 96% can be achieved at a loading of 0.95 $kg/m^3.d$ on treating a raw waste of 1,400 mg/l BOD at a treatment plant in Austin, Minnesota. Another meat packing plant in Albert Lea. Minnesota also treated its waste by the anaerobic contact process. Stabilization pond was subsequently used as a back-up treatment. Data of both anaerobic contact process alone and together with stabilization pond are presented in Table 2.9.

Table 2.9 Anaerobic contact process on treating meat packing wastes, Albert Lea, Minnesota

	Raw waste	Anaerobic Process effluent	Pond effluent	Loss in ponds
Flow (m^3)	5,337	5,337	2,922	2,415

	Raw waste		Anaerobic process effluent		Pond effluent corrected for seepage	
	mg/l	kg	mg/l	kg	mg/l	kg
BOD	1,381	7,373	129	690	26	138
Suspended solids	988	5,277	198	1,057	23	122

	% removal			
	Through anaerobic Unit	Through ponds	Through entire plant	Digester BOD loading $kg/m^3.d$
BOD	90.8	79.8	98.2	2.5
Suspended solids	80.2	88.4	97.6	1.8

Source : Industrial Pollution Control Handbook (1971)

Azad (1976) studied treating meat packing wastes with anaerobic lagoons. The BOD loading rate and removal efficiency were observed as shown in Table 2.9. The overall treatment efficiency was theoretically higher with an aerobic treatment as a secondary unit. Either aerated lagoon or tricking filter was recommended. Table

2.10 summarizes data on performance of anaerobic pond together with aerobic treatment.

Table 2.10 Efficiency of anaerobic lagoons on treating meat packing wastes

Type of waste	Loading rate, kg BOD/1,000 m^3	Efficiency, %
Beef	258	58
Beef	503	87
Beef and hogs	106	85*
Beef and hogs	240+	85
Hogs	208	65

* Recirculation Provided

\+ Average of all plants studied by Iowa state Health Department

Source : Industrial wastewater management handbook (1976)