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Cost of Treating Wastewater from Poultry Processing Plants, The

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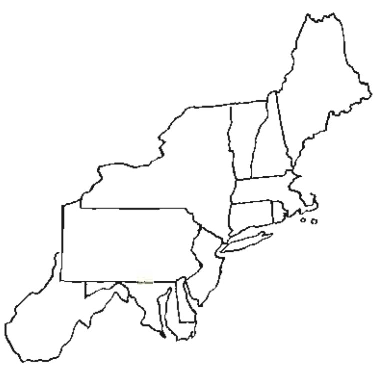

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THE COST OF TREATING WASTEWATER FROM POULTRY PROCESSING PLANTS

W. Davis Folsom and Robert L. Leonard*

ABSTRACT

The poultry processing industry faces increased concern from local and national interests to insure a clean environment. To comply with new federal regulations regarding the discharge of wastewater from poultry processing operations, some processors will have to make further investment in waste treatment facilities or join public treatment systems.

Respondents with privately owned treatment facilities reported the use of various lagoon systems, irrigation, extended aeration, and primary treatment. Extended aeration was the most expensive private treatment system averaging $14,750 capital cost per 1000 gallons of hourly capacity. Naturally aerated lagoons were the least expensive of those systems where capital cost could be estimated. Investment in naturally aerated lagoons averaged $1,680 per 1000 gallons of hourly capacity.

Operating costs for private treatment systems ranged from $0.048 per 1000 gallons for naturally aerated lagoons to $0.16 per 1000 gallons for irrigation disposal systems. Processors using municipal treatment on the average were charged $0.18 per 1000 gallons for public treatment of wastewater. Depending on the capital investment required for private treatment systems and the opportunity cost of capital, public treatment may be less expensive than private treatment of processing wastewater.

INTRODUCTION

The poultry industry is under increasing pressure to improve wastewater treatment. Federal pollution control standards will require progressively higher treatment levels with specific deadlines in 1977 and 1983. Considerable investment will be necessary to meet these requirements. The purpose of this report is to present a comparison of the cost, effectiveness, and limitations of different methods for treating and disposing of poultry processing wastewater.

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Many different methods are used to treat wastewater from poultry processing plants. The method used depends largely on the climate, location, availability of public treatment, and proximity to urban areas. Treatment systems include: irrigation, lagoon systems, extended aeration and municipal wastewater treatment both with and without preliminary treatment by the poultry processor. Irrigation and lagoon systems are practical in warmer parts of the country where freezing problems are infrequent. Irrigation requires a larger land area than the other disposal methods. Extended aeration is often used where space is limited. The feasibility of municipal treatment depends on the availibility of conveyance and treatment capacity and on municipal regulations and pricing policies.

There has been considerable research analyzing particular methods of treating poultry processing wastes and individual plant problems. Giffels Associates developed an extended aeration system for use at the Gold Kist plant in Live Oak, Florida. The Giffels study[1] compared different wastewater treatment methods before selection of extended aeration. The extended aeration system is capable of producing wastewater with less than 10 milligrams per liter (mg/l) of biochemical oxygen demand (BOD) and suspended solids. North Carolina State University and the University of North Carolina[2] conducted a workshop concerning poultry processing plant water utilization and waste control using as the example another Gold Kist plant located in Durham, North Carolina. At the workshop, Roy Carawan reported that installation of new equipment resulted in a reduction in water use by 30% and a 65% reduction in the amount of BOD.

In 1967, the U. S. Department of Interior[3] published an extensive study of the wastes from meat processing. This study included in-plant waste control, wastewater treatment, and associated costs. They estimated that in 1966 poultry processors paid $4.6 million dollars for municipal treatment of wastewater. Vertrees[4] surveyed poultry processors throughout the country in 1971. His analysis included water use and wastewater treatment. Vertrees estimated that an investment of $21 to $60 million would be required to upgrade private wastewater treatments to the "best available control technology". In Georgia, Kerns and Holemo[5] estimated that application of "best available technology" would require a threefold increase in current investment.

In the present study, a list of poultry processors and the type of treatment or disposal method used was obtained from the U.S.D.A.[6] A mail questionnaire appropriate to the type of treatment method was sent to 113 processors who used private treatment and 245 processors who used final municipal wastewater treatment. Information was received from three processors using primary treatment, nine processors using irrigation, nineteen processors using lagoon systems, and two processors using extended aeration. Of the 245 processors discharging to municipal systems, 46 supplied usable information.

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[1]Giffels Associates, Inc., Treatment for Discharge to a Stream. Industry Seminar for Pollution Control. Atlanta, Georgia, September 18 & 19, 1972. E.P.A. Technology Transfer Program.

[2]North Carolina State University, Department of Food Science, 1971. Proceedings of Workshop on Poultry Processing Plant Water Utilization and Waste Control. p. 41.

[3]United States Department of the Interior, The Cost of Clean Water. Volume III. Industrial Waste Profile No. 8, Washington, D.C., September 1967.

[4]James G. Vertrees, The Poultry Processing Industry: A Study of the Impact of Water Pollution Control Costs. U.S.D.A. Economic Research Service, Marketing Report #965, Washington, D.C., June 1972, p. ii.

[5]Waldon R. Kerns and Frederick J. Holemo, Cost of Wastewater Pollution Abatement in Poultry Processing and Rendering Plants in Georgia, ERC-0673, Dept. of Agricultural Economics, University of Georgia, Athens, Ga. June 1973. p. v.

[6]James G. Vertrees, op. cit., p. ii.

WASTEWATER VOLUME AND CONTENT

Information from processors concerning production and the volume and content of wastewater is summarized in Table 1. Average production for the processors responding was 5,989 broilers per hour with an average wastewater of 7.03 gallons per bird. While these averages appear representative of the industry, the range and standard deviation in production and wastewater usage show extreme variation within the industry.

TABLE 1
Broiler Processing Wastewater Volume and Content

	Production	Wastewater	Wastewater	BOD	SS
	(birds/hour)	(gal./hour)	(gal./bird)	(mg/l)	(mg/l)
Mean	5,989	41,827	7.03	547	390
Range	150-15,000	1,000-124,800	2.9-14.7	125-1,592	125-804
Standard Deviation	3,784	27,952	2.91	299	198
N	44	44	46	30	26

Along with the wide range in wastewater volume there exist a large variation in pollutant content as measured by biochemical oxygen demand (BOD) and suspended solids (SS) concentrations. BOD is a measure of organic wasteload which indicates the amount of oxygen utilized in the process of decomposition of the waste. Suspended solids are those solids which can be removed through filtration. BOD averaged 547 milligrams per liter (mg/l) and ranged from 125 to 1592 mg/l. Similarly, SS averaged 390 mg/l and ranged from 125 to 804 mg/l.

The extent of pollution problems and the cost of meeting new EPA standards vary greatly among processors. The variation in wastewater volume and pollutant content limits the validity of average figures for use by an individual processor.

PRIVATE TREATMENT

Many methods exist for treating wastewater. Of the 26 respondents using private treatment systems, thirteen used lagoon systems. Three processors used only primary treatment, eight used irrigation, and two processors had extended aeration systems (Table 2).

The rate of production of the 26 plants ranged from 150 to 14,400 birds per hour. Processors using primary treatment or irrigation tended to have smaller processing operations. Primary treatment and irrigation systems require less capital investment than other treatment methods, making them more suitable for small processing operations.

No significant correlation was found between wastewater per bird and the processing rate for either turkey or poultry processors. Variations in technology used for in-plant waste control probably obscure any actual relationship between water use per bird and processing rate.

TABLE 2
Wastewater Characteristics of Processors with Private Treatment Systems

Treatment Method		Processing Rate	Wastewater Flow	Wastewater per Bird	Untreated BOD	Untreated SS
		birds/hour	gal./hr. of operation	gal./bird	mg/1	
Primary		3000	25800	8.5		
"	(T)	2000	12000	6.0		
"		150	1000	6.6		
Irrigation	(T)	1000	30000	30.0		
"		12000	124800	10.4	400	
"		1500	10800	7.2	500	300
"	(T)	960	21000	21.8		
"	(T)	1200	12000	10.0		
"	(T)	4000	18400	4.6		
"		6000	21000	3.5		
"	(T)	1000	22000	22.0		
Lagoons		14400	78000	5.4	487	378
"		6000	20000	3.3		
"		12000	70000	5.8		
"		6000	24000	4.0		
"		180	2500	13.8		
"		6000	38000	6.3	615	
"		5400	36000	6.6	340	250
"		13400	90000	6.7	600	675
"		4800	22500	4.7		
"		6400	33000	5.1	600	600
"		1800	9000	5.0	720	660
"		6000	42000	7.0	432	721
"		12000	72000	6.0		
Extended Aeration		6000	21000	3.5	450	350
"		N.A.	63000	5.0	125	

(T)--Turkey Processor
N.A.--Not Available

The wastewater volume per bird was also compared with the waste content of the water. Processors were asked the biochemical oxygen demand (BOD) and suspended solids (SS) content of their wastewater before and after treatment. Neither BOD nor SS content before treatment were statistically related to wastewater per bird. It would be expected that processors with a greater volume of wastewater per bird would have lower BOD and SS content. This again assumes that in-plant waste control and by-product recovery is similar for all plants, which does not appear to be a valid assumption.

Primary Treatment and Pretreatment

Primary treatment and pretreatment of poultry processing wastewater includes screening and settling of solid wastes and dewatering of solids. Wastewater is sometimes chlorinated before release. Primary treatment is often used before discharge into sewer systems for municipal treatment.

Three poultry processors reported using primary treatment of processing wastewater. Screens are used to filter solid wastes from the wastewater. Solid wastes are then removed and sent to rendering plants. After screening, one processor discharged into a sewer, another into a septic system, and the third released into holding ponds.

Insufficient information was received to estimate the capital and operating costs of primary treatment. Capital cost items include screening and chlorinating equipment, and a settling or holding tank in some cases. Maintenance of screens and chlorination of wastewater are major operating cost items. Solids retrieved in screening are a posible source of revenue if sold to rendering plants.

Irrigation

Irrigation involves screening poultry processing wastewater to remove solid materials, pumping the wastewater to fields and then spraying or spreading on the fields. Irrigation appears to be the least costly and possibly the most simple method of dealing with poultry processing wastewater. The use of irrigation is limited to areas with suitable soils and available land away from populated areas.

Irrigation is often used by turkey processors who operate only seasonally. Of the eight plants using irrigation, five were turkey processors. Surprisingly, some processors in colder areas of the country were using irrigation.

Irrigation systems are used by processors of various sizes. The processing rates ranged from 960 turkeys to 42,000 broilers per hour. Wastewater volume varied between 10,800 and 168,000 gallons per hour (Table 3).

Most processors screen wastewater before irrigation. Costs of screening were small as compared to revenues received for the solid wastes. Screening costs ranged from 0 to $500 per week, while revenues from reclaimed materials ranged from $100 to $4,500 per week (Table 3). An implicit benefit from using irrigation could be the added growth of crops on the irrigated land. Processors grew either grass or hay in the irrigated areas, but did not report any direct revenue from the crop.

Investment costs for irrigation include pumps, piping, and land. Pump costs ranged from about $200 to $8,000 for power requirements of four to 340 horsepower. Plastic, aluminum, concrete and steel pipes were used. Some pipes were moveable, others fixed. The land used for irrigation is an important investment item. Because of the great variation in land values, it is not feasible to estimate total investment in irrigation. The area irrigated ranged from 12 to 250 acres.

The average daily volume per acre ranged from 2,009 to 14,666 gallons. This is equivalent to .062 to .459 inches per day. The processors with the highest irrigation rates were turkey processors, who were generating large quantities of wastewater but for only short periods of the year. Turkey processors averaged 8,223 gallons per acre per day, while poultry processors averaged 4,698 gallons per acre per day.

Operating costs for irrigation systems consist primarily of labor and power costs. Reported labor hours, pumping hours, and pump horsepower were combined with specified wage and power rates to estimate operating costs. Operating labor ranged from 1/2 to 30 man-hours per day, depending upon the size of the system. The operating labor per 1000 gallons of wastewater ranged from 0 to .071 man-hours. A major factor in determining operating labor was whether the pipe was fixed or moved. Using a wage rate of $3.00/hour, operating labor costs were $.003 to $.213 per 1000 gallons. Power

TABLE 3
Irrigation

Plant #	Birds per Hour	Wastewater	Operation and Maintenance				Kilowatthours per 1000 gallons	Pipe		Acres Irri-gated
			Labor		Pump					
		gal./hr. of operation	hrs./day	hrs./1000 gallons	Total	hrs./day		Feet	Type	
I-1	1000(T)	30000	3	.008	10	10	.83	4000	Alum.	70
I-2	12000	125000	16	.016	150	18	16.20			95
I-3	1500	10800	.5	.006	7.5	12	1.08	2500	Alum.	43
I-4	960(T)	21000	9	.053	20	4	.47	800	Concrete	--
I-5	1200(T)	12000	1	.008	20	8	1.66	5000	Alum.	20
I-6	42000[1]	168000	30	.030	340	24	6.07	65000	Concrete	175
I-7	4000(T)	18750	0	0	30	8	1.57			15
I-8	6000	21000	12	.071	1000	12	7.14	4000	Steel	30
I-9	1000(T)	22000	1	.006	4	24	.54			12

Plant #	Solids Screening Costs	Daily Gallons per Acre	Power Costs ($) per 1000 gallons	Maintenance Costs per 1000 gallons	Maintenance Costs per Week	By-Product Revenues
	$/wk.		$	$	$/wk.	$/wk.
I-1	N.A.	3438	0.025	.049	58.92	
I-2	500	3503	0.354	.402	2010.0	4500
I-3	N.A.	2009	0.024	.042	18.40	
I-4	0	--	0.020	.179	152.35	600
I-5	0	4800	0.054	.078	37.50	100
I-6	N.A.	7680	0.150	.240	1618.17	
I-7		10000	0.037	.037	28.35	
I-8	450	5600	0.205	.417	354.15	215
I-9		14666	0.013	.031	22.95	

(T) = Turkey
[1]Estimated

requirements for operating pumps (assuming 2 kw-hr/hp-hr) varied from .47 to 16.20 kwhrs. per 1000 gallons. Assuming an energy charge of 2.1¢ per kilowatthour and a monthly demand charge of $1.85 per kilowatt of maximum use[7], power costs were $.013 to $.205 per 1000 gallons. Combined power and labor costs for an irrigation system ranged from $.031 to $.417 per 1000 gallons of wastewater (Table 3).

A Department of Agriculture study[8] found that "annual (irrigation) costs for all except the very smallest plants should not exceed $10 to $20 per thousand pounds of weekly (plant) capacity." This can be converted to $.115 to $.230 per 1000 gallons of wastewater.

Smaller plants and seasonal turkey processors had lower operating and maintenance costs per 1000 gallons than larger poultry processors. It appears to take more pumping and more labor per 1000 gallons to operate a larger irrigation system.

Lagoon Systems

Lagoons are the most common method of treating poultry wastewater at private waste treatment installations. Lagoon systems were divided into three categories: anaerobic lagoons, aerated lagoons, and naturally aerobic lagoons. Responses were received from ten processors using mechanically aerated lagoons, five using naturally aerated lagoons, and four using a combination of anaerobic lagoons and other lagoons.

Lagoon systems utilize biological methods to remove pollutants from the processing wastewater since micro-organisms use the wastes as food. In anaerobic degradation organic wastes are oxidized; carbon dioxide water and small amounts of numerous minerals are produced as end products. In anaerobic degradation, where oxygen is not present, the end products are organic acids, aldehydes, ketones, and alcohol[9].

Mechanically Aerated Lagoons

The use of mechanical aerators or diffused air systems increases the oxygen available in the wastewater. The oxygen is then used by micro-organisms to decompose the waste material in the water. The amount of mechanical aeration needed in the lagoon system depends largely on the amount and content of the wastewater, the depth of the lagoon and detention time in the lagoon.

Poultry processors using mechanically aerated lagoons processed between 1,200 and 14,000 birds per hour, resulting in 9,000 to 90,000 gallons of wastewater per hour. Wastewater content averaged 504 mg/l BOD and 604 mg/l suspended solids.

Mechanically aerated lagoons ranged from two to 21 feet in depth. With the use of mechanical aeration, lagoons can be fairly deep and still facilitate biological decomposition. Most aerators were powered by electricity and were used continuously. As would be expected, processors with larger wastewater flows had larger aerators in their lagoon systems.

Considerable variation existed in the capital cost of mechanically aerated lagoon systems. Capital costs excluding land ranged from $12,000 to $200,000. This range is

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[7] Rate Schedule, Connecticut Light and Power Co.

[8] Frank M. Ross, Irrigation as a Low Cost Method of Sewage Disposal for the Poultry Processor, U.S.D.A., Agri. Marketing Services, Marketing Research Report No. 306, Washington, D.C., March 1959, p. 4.

[9] Giffels Associates, Inc.

TABLE 4
Lagoon Systems

Plant Number & Type	Birds per Hour	Wastewater gal./hr.	Lagoons: Area sq.ft.	Lagoons: Depth ft.	Capital Cost($)	Aeration hp.	% BOD Reduction	Capital Cost/ 1000 gal. hr. flow	Operating & Maintenance Cost per 1000 gal.
L-1	1500(D)	12,000	110,000	4	40,000	None	--	$3,333	.114
Aerobic			110,000	4		None			
			110,000	5		None			
L-2	--	3,600	15,000	4	5,000	None	--	1,388	.125
Aerobic			120,000	1		None			
L-3	12000		240,000	3	--	None	--		.002
Aerobic		93,000	240,000	5		None			
L-4	180	2,500	6,600	4	0	None	--	0	0
Aerobic									
L-5	1000(T)	30,000	400,000	3	10,000	None	--	333	0
Aerobic									
L-6	14400	78,000	320,000	21	150,000	80	88	1,923	.066
Mechanically			160,000	21		30			
Aerated			160,000	21		30			
			80,000	10		None			
L-7	6000(D)	20,000	2,568	8.5	200,000	45		10,000	.174
Mechanically			5,185	8.5		(total)			
Aerated									
L-8	5400	36,000	30,000		40,000	28		1,111	.044
Mechanically			160,000			(total)			
Aerated			80,000						
			40,000						
L-9	13400	90,000	103,000	20	250,000	50	91	2,777	.181
Mechanically			57,000	20		50			
Aerated			57,000	20		50			
			39,000	10		50			
L-10	1200(D)		40,000	14	200,000	50	87		
Mechanically			2,500	14		20			
Aerated									

TABLE 4 -- Lagoon System (Continued)

Plant Number & Type	Birds per Hour	Wastewater gal./hr.	Lagoons Area sq.ft.	Lagoons Depth ft.	Capital Cost($)	Aeration hp.	% BOD Reduction	Capital Cost/ 1000 gal. hr. gal.	Operating & Maintenance Cost per 1000 gal.
L-11	1400(D)	30,000	40,000	7	180,000	50	83	6,000	.123
Mechanically									
Aerated									
L-12	6400	33,000	52,000	4	50,000	5	95	1,515	.026
Mechanically			30,000	2		5			
Aerated			27,000	2		10			
			32,000	2		None			
L-13	1800	9,000	26,000	3	12,000	5	96	1,333	.435
Mechanically			7,500	4		7.5			
Aerated			39,000	3		None			
			17,000	3		None			
L-14	(T)	48,000	25,000	6		7.5	--	--	.023
Mechanically			15,000	2.5		7.5			
Aerated									
L-15	6000	42,000	70,000	6	84,000	15	95	2,000	.057
Mechanically			56,000	6		15			
Aerated									
L-16	6000	38,000	3,600	3		15	91		.036
Combination			22,500	6		None			
			27,000	66					
			50,000	3					
L-17	4800	22,500	430,000	4	40,000	None	--	1,777	.016
Combination			40,000	13		None			
			30,000	13		None			
L-18	6000	43,700	29,900	14	150,000	None		3,430	.039
Combination			6,400	8		25			
L-19	12000	72,000	120,000	--	500,000	60	96	7,000	.145
Combination			40,000	--		60			
			60,000			None			

D = duck processing
T = turkey processing
*Labor cost estimated at $3.00/hr.

similar to estimates of $16,800 and $100,333 for small and medium size mechanically aerated lagoon systems from another study[10]. The capital cost per 1000 gallons of hourly capacity ranged from $1,111 to $10,000 for mechanically aerated lagoon systems (Table 4).

Giffels Associates[11] estimated a capital cost of $740,000 for a mechanically aerated lagoon system capable of handling one million gallons of wastewater per day with a BOD of 450 milligrams per liter. With an hourly flow of 125,000 gallons, the capital cost per 1000 gallons hourly flow would be $5,120, which is approximately the middle of the range of estimates from the poultry processor survey.

Operating and maintenance costs for mechanically aerated lagoons ranged from $.023 to $.435 per 1000 gallons of wastewater. Surprisingly, operating and maintenance costs per 1000 gallons were not statistically correlated to either wastewater volume or capital cost. With only limited information concerning each particular lagoon system it was not possible to explain the variation in maintenance costs.

Reported BOD reductions ranged from 83 to 96% with an average reduction of 91%. Another study found aerated lagoons to reduce BOD content of the wastewater by 90% ±[12].

Naturally Aerated Lagoons

Naturally aerated lagoon treatment systems were used by five poultry processors in the study. Naturally aerated lagoons decompose wastes in the same manner as mechanically aerated lagoons except that oxygen is introduced into the system only through the surface area of the lagoon. For decomposition to work effectively, naturally aerated lagoons cannot be as deep as lagoons where oxygen is mechanically added. The five lagoon systems with natural aeration ranged from one to four feed in depth. These relatively shallow lagoons must either accept less wastewater or cover a larger land area than other lagoon systems.

Both small and large processors use naturally aerated lagoon treatment systems. Wastewater flows ranged from 3,600 to 70,000 gallons per hour. Both capital and maintenance costs were lower for naturally aerated lagoons than for mechanically aerated lagoons. Capital costs ranged from 0 (converted an old pit) to $40,000. Maintenance costs averaged $16 per week for the five processors using naturally aerated lagoon systems.

Anaerobic Lagoons

Anaerobic decomposition occurs in the absence of oxygen. Anaerobic lagoons are generally deeper than naturally aerobic lagoons and do not use mechanical aeration. Wastes are decomposed aerobically near the surface and anaerobically in deeper parts of the lagoon. Four poultry processors in the survey used anaerobic lagoons in combination with other types of lagoons. None of the respondents used anaerobic lagoons as their only treatment method. The anaerobic lagoons were used in combination with both naturally and mechanically aerated lagoons. The anaerobic lagoons ranged in depth from six to fourteen feet.

Maintenance costs of combination systems were greater than those of naturally aerated lagoons, but less than those of mechanically aerated lagoons. Maintenance costs averaged $.0728 per 1000 gallons for the four combination lagoon systems.

[10] U.S.D.I., The Cost of Clean Water, p. 63.
[11] Giffels Associates, Inc., p. 21.
[12] Ibid., p. 14.

Extended Aeration

Extended aeration involves introducing large amounts of oxygen into wastewater within a relatively short period to aerobically decompose waste material. Extended aeration is often used for small municipal sewage treatment systems. The operating costs are usually higher but capital costs are generally lower than those of the activated sludge systems. "While this process (extended aeration) is often frowned upon in large municipal work because of its high costs, it must be remembered that in an industrial waste treatment facility, the operating expenses are written off for tax purposes where capitalization costs cannot be."[13]

Only two plants in the survey used an extended aeration treatment system. Considerable information has already been published concerning the implementation of an extended aeration treatment system for one processor, the Gold Kist Poultry Plant in Live Oak, Florida. "The extended aeration process as it evolved, offered these advantages: the initial capitalization cost, although high, was not appreciably higher than other processes considered when sized to meet the strict effluent criteria. Again, though the operating costs were higher, due to the increased amount of compressed air required for the process, higher skilled operating techniques are not always required to keep the system operating near peak efficiency."[14]

The wastewater treatment components at the Gold Kist Plant consisted of the following devices:

1. A by-product collector tank.
2. Two concrete extended aeration tanks.
3. An aerobic digester.
4. A final settling tank.
5. A final aerobic stabilization pond.
6. A chlorinator.
7. Three turbo compressors.

In the present study, one processor's extended aeration system consisted of traps and screens, two aeration tanks using mechanical aerators, a final settler, and an aerobic final stabilization pond.

Capital costs for the extended aeration systems were greater than the costs of lagoon systems. The two extended aeration systems averaged $300,000 capital investment. Capital costs per 1000 gallons of hourly flow were $11,900 and $16,600. The 98% BOD reduction reported by the Gold Kist Plant was better than the reduction reported with any other system. The other extended aeration system reported a 94% BOD reduction.

A more detailed report of physical and cost aspects of the extended aeration system at Gold Kist can be found in "Upgrading Poultry Processing Facilities to Reduce Pollution," prepared by Giffels Associates, Detroit, Michigan, for the Environmental Protection Agency[15].

DISCHARGE TO A PUBLIC SEWER SYSTEM

Forty-three usable responses were obtained from poultry processors discharging wastewater to publicly owned treatment systems. As might be expected the survey indicated a wide range of charges and of cost-sharing arrangements. Charges ranged from no charge to

[13] Ibid., p. 34.
[14] Ibid., p. 34.
[15] Giffels Associates, Inc.

an equivalent of $0.079 per 100 pounds, live weight (LW), of birds processed. The methods of charging included: flat annual and monthly fees; charges based on volume (with both flat rates and declining block rates); and surcharges based on content in excess of specified concentrations.

Poultry processors commonly recover four by-products: blood, feathers, grease, and offal. Each of the 43 respondents reported collection of feathers and offal. Thirty-nine processors were recovering blood, and 28 processors were recovering grease. Twenty-four processors reported some type of treatment in addition to by-product recovery.

A Summary of Reported Costs

Eight of the 43 processors reported payment of a share of capital cost in addition to charges based on current use of the municipal system. Cost data have been adjusted to include separate charges for capital costs. Sewer rates and surcharges were not adjusted to include separate charges for capital costs. No attempt was made to determine the frequency and extent to which capital costs are included in reported sewer rates and surcharges. A summary of the cost data is provided in Table 5.

TABLE 5
Municipal Disposal of Poultry Processing Wastewater

	Birds per Hour	Volume (gal./hr.)	SS Content (mg/l)	BOD Content (mg/l)	Costs	
					$/1000 gal.	$/100 lb.
Average	5,477	41,385	321.3	538.6	.258	.032
Range	200-15,000	1200-92,640	130-600	190-1289	0-.900	0-.097
Standard Deviation	3,235	23,881	159.7	295.6	.220	.025
N	26	26	12	13	22	22

The high degree of variation in the data limits the usefulness of averaged information. The fact that one respondent was receiving wastewater treatment service without charge seems less significant when accompanied by the fact that his production was only 1500 broilers per hour for six hours per day. Moreover, several processors reported costs which are essentially insignificant in relation to the size of the operation.

Charges and Surcharges

Since pricing systems include declining block rates, surcharges, and fixed capital charges, an averaging of rates would not be meaningful. A perspective on rates can be gained from a general summary of major characteristics and a few specific examples.

Eleven respondents faced surcharges which varied widely in both the rate and the base level exempted from the surcharges. Six processors reported a declining block rate system. Surcharges for content and declining rates for volume were combined in four cases. The four sets of rates in Table 6 were selected to illustrate the more complex rate structures.

TABLE 6
Selected Municipal Sewer Rate Structures

	I	II	III	IV
Basic Sewer Charge	$.767/1000 gal.	1st 20,000 ft^3 $.42/100 ft^3 Next 100,000 ft^3 $.28/100 ft^3 Over 120,000 ft^3 $.185/100 ft^3	$.35/1000 gal.	1st 100,000 gal. $.45/1000 gal. Next 400,000 gal. $.435/1000 gal. Next 500,000 gal. $.20/1000 gal. Over 1,000,000 gal. $.15/1000 gal.
Surcharges	$.08/lb. BOD > 250 mg/l $.10/lb. SS > 500 mg/l	Extra Strength Charge $.177615/100 ft^3	$.0495/lb. BOD > 289 mg/l $.06/lb. SS >	No surcharges

Assuming that processors attempt to minimize the sum of all waste disposal costs, the following two hypotheses were formulated. First, processors facing surcharges are more likely to have pretreatment (defined as treatment by the processor in addition to by-product recovery) than processors not facing surcharges. Second, processors facing surcharges will discharge less waste relative to production than processors not facing surcharges.

Of the eleven processors facing surcharges for excess BOD and/or suspended solids, nine had some form of pretreatment. Of the 32 processors not facing surcharges only thirteen had pretreatment. This relative difference is sufficient at a 97.5 percent confidence level to reject a null hypothesis that there is no relationship between the existence of surcharges and pretreatment (see Table 7).

TABLE 7
Coexistence Between Pretreatment
Facilities and Surcharges for Waste Content

Surcharges	Pretreatment Facilities		Total
	Yes	No	
Yes	9	2	11
No	13	19	32
Total	22	21	43

Chi-square values:

Observed $X^2 = 5.640$
Distribution value at 97.5% confidence level - 5.024

All of the charges based on wastewater content were in the form of surcharges. The concentrations which were exempt from the surcharge varied considerably among processors. Thus, there was no basis for attempting to quantitatively relate the surcharge rate to the combined effectiveness of by-product recovery and pretreatment. However, data were available to calculate the pounds of BOD discharged per 100 pounds of birds processed for ten processors facing surcharges and for eighteen processors not facing surcharges. Contrary to expectations, the processors facing surcharges discharged an average of .693 pounds of BOD per 100 pounds of birds processed as compared to an average of .609 pounds for the processors not facing surcharges. The difference between the two averages is not statistically significant at a 95 percent confidence level. Data on the discharge of suspended solids was judged insufficient for a comparison of discharges with and without surcharges.

There is no obvious explanation for the high incidence of coexistence between surcharges and pretreatment and the lack of an association between surcharges and a low amount of BOD per 1000 pounds of birds processed. Three factors should be considered. First, the sample sizes were small. Second, there may be considerable variation in the local prices for by-products. Third, many of the processors are located in small towns where the existence of heavy waste loads from the poultry processor may have prompted the municipality to levy surcharges. Some processors may have responded by adding pretreatment rather than improving by-product recovery which might have required changes within the plant. On the other hand, processors with efficient by-product recovery had little need for pretreatment and did not prompt municipalities to levy surcharges. There was one especially clear example of this latter situation. A large processor, who was paying only one cent per 1000 gallons of wastewater and no surcharge, was discharging less than the average volume of wastewater per bird and reported a BOD concentration of only 265 mg/l as compared to an average BOD of 538.6 mg/l for all processors using public treatment. This processor was discharging to a small municipal system with treatment consisting of an oxidation pond. While the current cost to the processor was low, an increase in either volume or content might overload the municipal system and result in a substantial increase in costs to both the municipality and the poultry processor.

One respondent reported a surcharge which encourages dilution as well as actual reductions in the amount of waste discharged. In this case a volume charge of $.15 per 1000 gallons was combined with a surcharge of $.10 per pound of BOD in excess of 400 mg/l. With these rates the cost of discharging 1000 gallons of wastewater with a BOD of 800 mg/l would be $.48 as compared to $.30 for discharging 2000 gallons with a BOD of 400 mg/l. With these rates dilution would be less expensive than the surcharge if water cost less than $.18 per 1000 gallons. This situation could be avoided by either increasing the ratio of the volume charge to the surcharge or by lowering the concentration exempt from the surcharge.

Federal Cost Recovery Requirements

A new Federal policy regarding the recovery of wastewater treatment costs from industrial discharges was established by Public Act 92-500.[16] Beginning March 2, 1973, the requirements for approval of Federal grants to municipalities for the construction of wastewater treatment facilities included assurance by the municipality that: (1) each recipient of waste treatment services will pay its proportionate share of operating and maintenance costs, and (2) industrial users will pay that portion of construction costs allocable to the treatment of industrial wastes to the extent attributable to the Federal share of construction costs. The same Act increased the Federal share to 75 percent of construction costs. The Act requires that volume, strength, and delivery flow rate characteristics be considered in determining the adequacy of charges. As required by the Act, the Environmental Protection Agency has issued guidelines for allocating cost among recipients of waste treatment services[17].

Component Pricing

A previous research project at the University of Connecticut was focused on the pricing of industrial wastewater treatment services. The objective was to develop a pricing system which would be consistent with Federal cost recovery requirements and would encourage an efficient combination of waste control at the source and final treatment by the municipality. The research resulted in the development of a component pricing technique for allocating costs in proportion to the marginal costs for volume and for selected measures of content[18].

The component pricing method involves a separate, but similar, allocation of capital costs and operating and maintenance costs. Component prices which will recover actual costs

[16] U.S. Public Law 92-500, "Federal Water Pollution Control Act Amendments of 1972," 92nd Congress, S.2770, October 18, 1972. "Title II - Grants for Construction of Treatment Works," (See Section 204 (b)).

[17] U.S. Environmental Protection Agency, "Proposed Rules--User Charges and Industrial Cost Recovery," Federal Register, Vol. 38, No. 98, (Tuesday, May 22, 1973), pp 13524-13526.

[18] Robert L. Leonard, "Pricing of Industrial Wastewater Treatment Services," Report No. 20, Institute of Water Resources, University of Connecticut.

are calculated through proportional adjustment of marginal capital costs and marginal operating and maintenance costs for volume and for each priced contaminant. Long run, marginal operating and maintenance costs can be estimated with hypothetical changes in plant size. Short run, marginal operating and maintenance costs can be estimated with hypothetical changes in loading rates for a plant of fixed size. Cost data and computer simulation models developed for preliminary design of water pollution control facilities can be used in estimating marginal costs for volume and for selected measures of content.

COMPARISON OF TREATMENT AND DISPOSAL METHODS

With only limited information concerning the different wastewater treatment methods it is difficult to make comparisons of the relative cost and effectiveness of the treatment systems. The type of treatment system utilized to treat poultry processing wastewater is related to the amount of wastewater generated. Most of the larger processors have lagoon systems or extended aeration. However, one of the largest processors uses irrigation, which was commonly used by small processors.

The capital costs of treatment systems varied with the complexity of the system. The capital cost of naturally aerated lagoons averaged $18,300 as compared to $95,000 for anaerobic/aerobic lagoons and $129,500 for mechanically aerated lagoons. Extended aeration systems averaged $300,000 capital cost (Table 8). Similarly, capital cost per 1000 gallons of hourly flow was lowest for naturally aerated lagoons and highest for extended aeration systems.

Operating costs varied among the different wastewater treatment methods. Processors using municipal treatment had the highest costs per 1000 gallons, but many of these processors incurred no capital costs. Depending on the capital cost of an alternative treatment method and the opportunity cost of capital, total costs of using public treatment may be less than the cost of private treatment. Processors using irrigation averaged $0.16 operating costs per 1000 gallons of wastewater. Irrigation operating costs consisted mostly of labor needed to operate and move irrigation pipes. The higher operating costs of mechanically aerated lagoons as compared to the other lagoon system can be attributed to the power needed to operate the mechanical aerators.

The extended aeration systems were found to be more effective in reducing BOD content of processing wastewater than any of the lagoon systems. The two extended aeration systems averaged 96% BOD reduction and a final effluent average of 14 milligrams per liter. Average BOD reductions ranged from 90% to 93% for the various types of lagoon systems, and average BOD in the final effluent ranged from 33 to 60 milligrams per liter (Table 8).

Irrigation may be the least costly method of wastewater treatment in areas where there is sufficient land and freezing is not a problem. Based on published research results, well managed irrigation systems meet the 1983 effluent requirements and do not contaminate the groundwater[19]. Primary treatment appears to be adequate only where wastewater is subsequently sent to a municipal treatment system.

Except for irrigation there exists a direct relationship between the cost and effectiveness of poultry processing wastewater treatment systems. The most expensive system, extended aeration, proved the most effective in reducing BOD content of the wastewater. Naturally aerated lagoons were found to be the least effective in BOD reduction. With land cost excluded naturally aerated lagoons were much less expensive than mechanically aerated or combination lagoon systems. However, naturally aerated lagoons require more

[19] Richard E. Thomas, Survey of Facilities Using Land Application of Wastewater, EPA # 430/9-73 D06. July 1973. p. 371.

TABLE 8
Comparison of Treatment Methods

Type of Treatment	Wastewater Volume (N)	Wastewater Volume gal./hr.	Average Capital Cost (N)	Average Capital Cost $	Average Capital Cost (N)	Average Capital Cost $/1000 gals. hr. flow	Operating Costs (N)	Operating Costs $/wk.	Operating Costs (N)	Operating Costs $/ 1000 gals.	Average BOD (N)	Average BOD % Reduction	Average BOD (N)	Average BOD effluent mg/l
Primary Treatment	(3)	1716		N.A.		N.A.		N.A.	N.A.			N.A.		N.A.
Irrigation	(9)	3457		N.A.		N.A.	(9)	476	(9)	0.16		N.A.		N.A.
Naturally Aerated Lagoons	(5)	23620	(3)	18300	(3)	1680	(3)	26	(5)	0.48	(1)	90	(2)	33
Mechanically Aerated Lagoons	(9)	38500	(9)	129500	(8)	3332	(9)	88	(9)	0.126	(7)	91	(7)	42
Anaerobic Aerobic Lagoons	(4)	39500	(2)	95000	(2)	4128	(3)	33	(4)	.073	(2)	93	(2)	60
Extended Aeration	(2)	45000	(2)	300000	(2)	14750		N.A.		N.A.	(2)	96	(2)	14
Municipal Disposal	(26)	41385		---		---		---	(10)	0.18		---		---

N.A. -- Not Available.
(N) -- Number in average.

land than the other types of lagoon systems. Comparatively little space is required for an extended aeration system.

The Environmental Protection Agency has developed effluent standards for the poultry processing industry. Maximum concentration levels are 29 mg/l BOD and 57 mg/l suspended solids[20]. In 1977 EPA will require 20 mg/l BOD and 35 mg/l SS with application of the "best practicable control technology currently available". Extended aeration systems and some lagoon systems were achieving these standards at the time of the study. In the future, more processors will have to apply the "best practicable control technology" to meet new standards for wastewater content. Comparison of the cost and effectiveness of different treatment methods will assist in achieving this goal.

[20] U.S. Environmental Protection Agency, Effluent Limitation Guidance for the Refuse Act Permit Program. Meat Products Industry. (SIC 2011, 2013, 2015), July 1972. p. 7.

APPENDIX

CONFIDENTIAL

THE UNIVERSITY OF CONNECTICUT
Department of Agricultural Economics
Storrs, Connecticut 06268

PLANT NAME ____________________ U.S.D.A. # __________

Some questions may not be applicable to your plant. We would appreciate whatever information you have available.

Plant Production Data

1. What is the hourly processing rate — # broilers/hour __________

2. How many hours/day, on the average, is the plant operated — hours/day __________

3. How many days/week is the plant usually operated — days/week __________

Wastewater Volume

1. On the average, how many gallons of wastewater are produced either per minute, or per hour — per minute __________ per hour __________

Water Content - discharged into sewer system

1. BOD loading ________ lbs./day or ____________ per ________

2. Suspended solids ________ lbs./day or ____________ per ________

3. Other measured characteristics, please specify, ____________ per ________

By-Product Recovery

1. Which of the following by-products are recovered: (please circle)

Blood   Offal   Feathers   Grease

Pre-Treatment

1. Is there wastewater treatment in addition to by-product recovery before discharge to the municipal system? Yes _____ No _____

   If yes, what treatment is done? ____

   ____

   What costs are associated with pre-treatment? ______________________________

   ____

Municipal Charges

1. What are the municipal charges and surcharges for wastewater collection and treatment?

   ______¢/1000 gallons

   ______¢/lb. of BOD in excess of ______ mg/l

   ______¢/lb. of suspended solids in excess of ______ mg/l

   Other charges or surcharges? ____

   ____

2. Are there any discounts for large volume? Yes _____ No _____

   If yes, please explain: ____

   ____

3. Are you paying a share of capital cost in addition to the above service charges?

   If yes, please explain: ____

   ____

4. On the average what is your monthly or quarterly bill for wastewater treatment?

   ____________$/month ____________$/quarter

5. What type of treatment is used in the municipal system? _____________________

   ____

   ____

CONFIDENTIAL

THE UNIVERSITY OF CONNECTICUT
Department of Agricultural Economics
Storrs, Connecticut 06268

PLANT NAME ______________________________ U.S.D.A. # ______________

Some questions may not be applicable to your plant. We would appreciate whatever information you have available.

Plant Production Data:

1. What is the hourly processing rate: # broilers/hour ____________

2. How many hours/day, on the average is the plant operated: hours/day ____________

3. How many days/week is the plant usually operated: days/week ____________

Wastewater Volume:

1. On the average, how many gallons of wastewater are produced either per minute, or per hour per minute ____________

   per hour ____________

2. Was the waste treatment system designed for the present flow of wastewater? Yes _____ No _____

   If no, what is the design capacity? ____________________ per ____________

Wastewater Content: -- prior to treatment --

1. BOD loading ______ lbs./day or _____ per _____.

2. Suspended solids ______ lbs./day or _____ per _____.

3. Total solids ______ lbs./day or _____ per _____.

PRIMARY TREATMENT

What is the capacity of the tank?

Depth ______ Feet   Surface Area _______ Square Feet or ______ Gallons

What is the normal detention time? ______ hours or ______ minutes.

What was the construction cost of primary treatment facility? $ ____________

Type of construction? concrete Yes _____ No _____. Other ________________

A. Maintenance of Settling Tank

1. How much maintenance is required for the settling tank?

   ______ per ______.

2. Briefly describe the necessary maintenance:

3. Are there any chemicals used? Yes ______ No ______

   If so, quantity __________ price __________.

4. What maintenance expenses are normally incurred?

5. How are solids removed?

B. Solids Disposal

1. How are solids dewatered?

2. What solids disposal method is used?

3. What is the cost of solids removal and disposal?

C. Treated Effluent Characteristics

BOD	________	per	________
Suspended Solids	________	per	________

IRRIGATION

1. What is done with solids screened from the wastewater:

   weekly costs $______________ revenues $____________ from this practice.

2. What is the housepower of the irrigating pump? ________

   How many hours per day is the pump operated? ________

3. How much pipe is used? ________

   Type of pipe? ________

   Is the pipe moved or fixed? ________

4. How many acres are irrigated? ________

   What is the cover crop? ____________

   What is the average yearly revenue from sale of the crop? $_______________

5. How much labor is used to operate the irrigating system?

   ________ hours per ________

6. Have you had any problems with this system?

ANAEROBIC, AEROBIC LAGOONS

1. Lagoon: Type and size: (if more than one, please list)

		Surface area	Depth	Detention time
a. aerobic	#1	______	______	______
	#2	______	______	______
b. anaerobic	#1	______	______	______
	#2	______	______	______

2. How much did the lagoon system cost to construct? (excluding land) $__________

3. Do you use mechanical aeration? Yes _____ No _____

   If yes, What is the horsepower of the motor? ______________________________

   Powered by electricity, gas, other? ______________________________

   How many hours/day is it used? ______________________________

4. Is sludge removed from the lagoon? Yes _____ No _____

   If yes, How often? ______________________________

   How is sludge removed? ______________________________

   How long does this take? ______________________________

   How is sludge disposed of? ______________________________

5. How much maintenance other than sludge removal is required for the lagoon system?

   ______________ hours per ______________

   Briefly describe necessary maintenance:

6. Treated effluent characteristics:

   BOD ______________ per ______________

   Suspended solids ______________ per ______________

EXTENDED AERATION

What is the capacity of the tank? ________ gallons

or dimensions: ________ ________ ________

In what year was the tank constructed? ________

What is the normal detention time? ________ hours or ________ days

A. Aeration tank:

Aeration is by (circle): mechanical, compressed air

If mechanical, what is the horsepower? ____________________

Powered by (circle): electricity,, gas

If compressed air:

What is the horsepower of the blower? ____________________

What is the output of the blower? ____________________

How much maintenance is required for the areation tank?

________ hours per ________

What maintenance expenses are normally incurred?

Briefly describe necessary maintenance:

B. Final settler:

Is there a separate final settling tank or lagoon? ____________

(If no, skip to part C)

Size of final settler or lagoon:

Depth ________ feet; surface area ________ sq. ft.

How often is sludge removed? ____________________

How is the sludge removed? ____________________

How long does this take? ____________________

C. Solids removal from the aeration tank:

How often are solids removed? ______________________________

How are solids removed? ______________________________

How long does this take? ______________________________

D. Solids disposal:

What solids disposal method is used? ______________________________

E. Treated effluent characteristic:

BOD __________ per __________

Suspended solids __________ per __________

What was the cost of constructing the treatment facility? $____________