DRAFT TUBE CHANNEL APPROACH TO POULTRY PROCESSING WASTEWATER TREATMENT

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A large poultry processing company, located in central Pennsylvania, had to undergo an extensive upgrading of its waste treatment facilities due to an increase in plant production capability and a tightening of the plant discharge criteria as imposed by the Pennsylvania Department of Environmental Resources. This paper details the selection of the LIGHTNIN™ draft tube channel as the most cost-effective design, the process design criteria, the start up, and the operating history of this industrial waste treatment plant.

BACKGROUND

The basic concept of the oxidation ditch was developed by Pasveer in Holland in the early 1950s. The original concept was built around simplicity, both from a design standpoint and also from an operational standpoint. Since the initial development, there have been many modifications made to allow more flexibility in design to both improve process performance and also reduce construction and operating cost.

The initial design had a number of drawbacks which became increasingly critical on scale up to larger sizes:

1. The use of brush aerators for oxygen transfer and flow development limited the depth of the oxidation ditch to approximately 5 ft to ensure adequate mixing for dissolved oxygen distribution and blending in of the influent waste.
2. The brush aerator design consisted of horizontal rotor shafts with bearings that were exposed to the splash and spray generated by the aerators. This type of design has generated a high percentage of downtime associated with the operation of the equipment.
3. The depth limitation of 5 ft increases amount of land area required and consequently the capital cost of the entire system.
4. The use of brush aerators increased the amount of waste cooling due to low ambient temperatures. This created additional mechanical problems for the brush aerators and the cooling effect decreased the removal efficiency of the biological system. This limited the use of oxidation ditches in cold weather climates.

With the development of the nitrification/denitrification process during the early 1960s, additional advantages were found for the oxidation ditch with respect to power consumption and process design. Through the use of a low F/M ratio, and the attendant high sludge age, nitrification normally occurs to a significant extent in oxidation ditch systems. By taking advantage of the denitrification reaction occuring in the anoxic zone, a sizable amount of BOD is removed which decreases the total oxygen requirement.

In the late 1960s, the LIGHTNIN organization began development of a mechanical submerged turbine aerator called the draft tube aerator. It was designed to generate a large volume of controlled flow, using the liquid flow to drive compressed air to the bottom of complete mixed activated sludge systems for improved oxygen transfer efficiency. This new system was built around an airfoil type impeller, pumping axial within a draft tube modified to permit high hydraulic efficiencies. Low pressure compressed air was introduced beneath the impeller through a sparger and was sheared into fine bubbles and driven downward by the high fluid velocity passing across the sparger. This air/waste mixture was driven to the bottom of the basin and then radially dispersed throughout the basin. This concept has been in use in various municipal and industrial waste treatment plants since 1972 in basins up to 37 ft deep.

A major advancement occurred in 1975, when John Reid, a private consultant located in Virginia, pioneered the use of a barrier inserted across the oxidation ditch so that controlled flow could be maintained by the use of a positive pumping device through a tube extending underneath the barrier. The marriage of the draft tube aerator with the barrier in an oxidation ditch first occurred at Woodberry Forest School in Virginia.

The basic oxidation ditch concept, modified to take advantage of the unique characteristics of the draft tube aerator, created new dimensions in terms of its operational control and applicability to larger systems:

1. The use of the draft tube aerator and its positive controlled flow provides complete blending of raw waste rapidly and reliably without relying on induced flow, and providing buffering for shock loads.
2. The use of the draft tube aerator eliminates the waste cooling, icing, splashing, and mechanical problems associated with surface aerators.
3. The ability to control the anoxic zone, by varying the channel velocity independent of oxygen transfer, allows nitrification/denitrification to occur in the same ditch, thus reducing power consumption. The use of the anoxic zone also helps to limit filamentous growth, thus improving sludge settling characteristics.
4. A positive and uniform channel velocity profile is developed by the introduction of the draft tube flow at the bottom of the channel, thus eliminating any channel depth limitations.

The use of the integral clarifier is another major design modification which has decreased the overall cost and improved the operation of the basic oxidation ditch. The initial concept of simplicity of design and operation is continued with the controlled flow clarifier design which has recycle rates in excess of twice the system throughput. The direct flow generated by the draft tube aerator is used to develop the hydraulic flow for sludge recirculation. The integral clarifier is capable of handling slows levels well in excess of 5000 mg/l, with the recycle rate automatically controlled by the draft tube aerator flow rate.

PROCESS DESIGN

The poultry processor's existing waste treatment system consisted of dissolved air flotation followed by a series of facultative mixed lagoons and a final polishing lagoon. The effluent was then chlorinated and discharged into a small stream. At the time the processor was considering a substantial increase in the plant production capability, the Pennsylvania DER was also imposing much more stringent discharge limitations on the processors effluent. The processor hired a local consulting engineer to aid in the design and construction of improved waste treatment facilities. A number of design alternatives were considered including fixed film contactors, conventional activated sludge, an expanded and improved lagoon system, and the oxidation ditch. To decrease the overall treatment plant size, the processor substantially increased the removal efficiency of its existing dissolved air flotation system. Table I shows the expected dissolved air flotation effluent and also the effluent discharge limitations.

During the initial design spade work, the poultry processor and their consulting engineer were impressed with the possibilities presented by the LIGHTNIN draft tube channel. However, both parties wanted to make sure that they had the most cost-effective system that would satisfy their present and future needs, while at all times meeting their discharge permit limitations. In addition, horsepower consumption and operational flexibility were prime considerations in their search for the most cost-effective design. The stringent ammonia nitrogen effluent limitation effectively ruled out any modification to their existing lagoon treatment system.

The poultry processing plant operated on either a 1- or 2-shift/day schedule on a normal Monday–Friday work week, depending on customer demand. In addition, there was end

Table I. Design Waste Parameters

	Influent[a]	Effluent[b]
Flow (mgd)	0.62	0.62
BOD_5	300	12 (7-day ave) 24 (peak)
Suspended Solids (mg/l)	300	25[c]
NH_3-N (mg/l)	15	1.5 (6/1 to 10/31) 4.5 (11/1 to 5/31)
Phosphorus (mg/l)	15	2.0 (7-day ave) 4.0 (peak)
Oil & Grease (mg/l)	100	15 (7-day ave) 30 (peak)

[a] Effluent from modified dissolved air flotation unit.
[b] Effluent from polishing lagoon.
[c] Except during spring turnover.

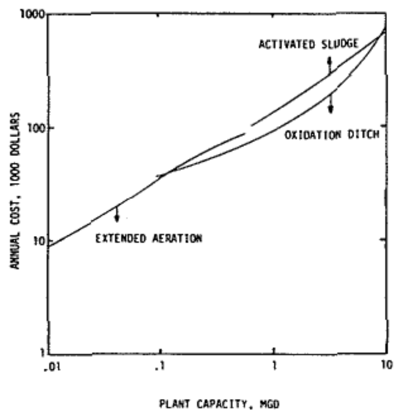

Figure 1. Total annual cost vs plant capacity.

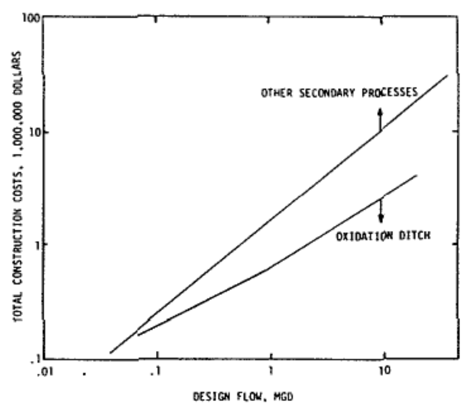

Figure 2. Construction cost vs design flow.

of work shift and weekend clean up flows to consider. The future treatment plant had to be designed to accept widely fluctuating daily loads in addition to being able to operate with essentially no flow over a 2-day or longer period. These design considerations effectively ruled out the use of fixed film contactors due to the cost consideration of building in sufficient equalization capacity.

The selection process was therefore narrowed down to the LIGHTNIN draft tube channel and other modifications of the activated sludge process. Figures 1, 2, and 3 show the total annual cost, construction cost, and incremental total annual cost for nitrification for oxidation ditches and other modifications of the activated sludge process. While the operating costs are fairly close, there is a large difference in construction costs and the incremental annual operating cost for nitrogen removal. The decision to go with the LIGHTNIN draft tube channel was based on the expected savings in constructions costs and annual operating costs, along with LIGHTNIN's previously successful treatment of poultry processing wastewaters. In addition, integral clarifier design eliminates the need for any sludge recycle pumps and their attendant power consumption and maintenance requirements, and further reduces construction cost due to its integral wall construction.

The biological process design was performed by Mixing Equipment Co., Inc. based on its past successful experience with poultry processing waste. The plant was designed with a F/M = 0.08, MLVSS = 4000 mg/l, and a volume of 600,000 gal.

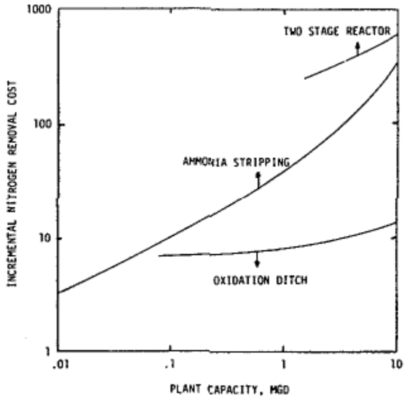

Figure 3. Incremental nitrogen removal cost vs plant capacity.

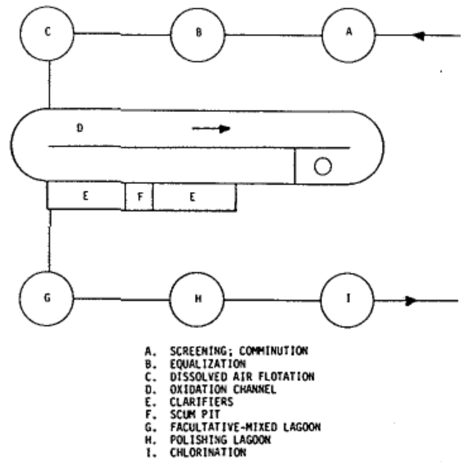

Figure 4. Schematic of treatment system.

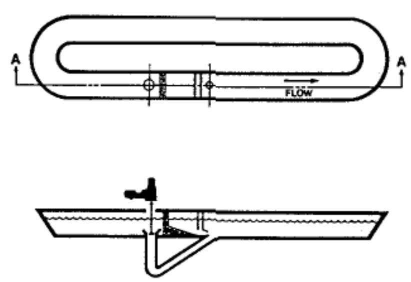

Figure 5. Cross-sectional view of the draft tube aerator U-tube and barrier wall.

CONSTRUCTION

Figure 4 is a line drawing showing the flow scheme, feedpoint location, and clarifier arrangement of the final installation. The channel was designed with a centerline length of 487 ft, a cross-sectional area of 165 ft^2, and a depth of 11 ft. The centerline depth of the U-tube was 20 ft. Figure 5 is a cross-sectional view of the draft tube aerator U-tube and barrier wall. Two integral clarifiers were supplied, each with a settling area of 18 x 60 ft. Located between the clarifiers was a sludge holding tank with a capacity of 5900 gal.

The focal point of the draft tube channel is the LIGHTNIN draft tube aerator. Figure 6 is a cross-sectional view of a draft tube aerator. A highly efficient airfoil type impeller pumps axially downward in the close clearance draft tube. Low pressure compressed air is sparged underneath the impeller and sheared to small bubbles for optimum oxygen transfer efficiency by the velocity of the liquid stream. This air/liquid mixture is then driven down to the bottom of the U-tube and ejected on the opposite side of the barrier wall. The oxygen transfer efficiency of the system is greatly increased by the hydrostatic head over the bottom of the U-tube section. This allows high oxygen transfer efficiencies while only requiring excavation to deeper depths in a small area of the channel. As the air/liquid mixture exits from the U-tube, the air stream gradually disengages from the liquid mixture. When the aerator is operating on high speed, the bulk channel velocity is 1.2 ft/sec. The vertical velocity profile measured about 50 ft downstream from the aerator discharge is essentially uniform. This uniformity in velocity distribution is maintained around the remainder of the channel.

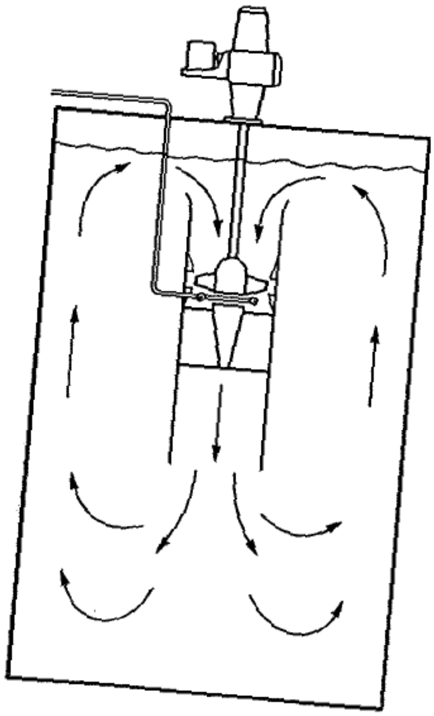

Figure 6. Cross-sectional view of a draft tube aerator.

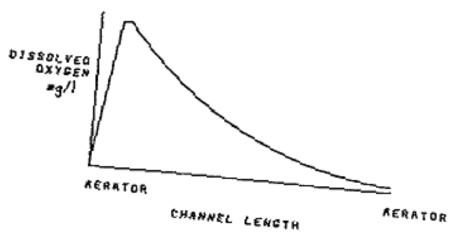

Figure 7. Dissolved oxygen profile.

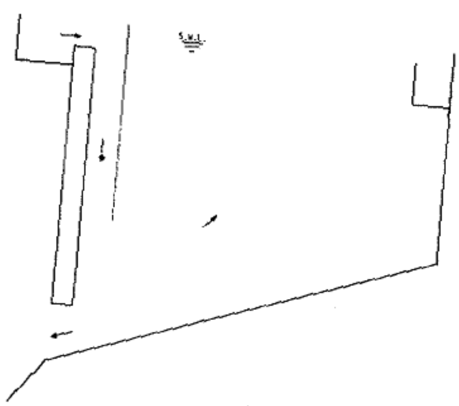

Figure 8. Cross-sectional view of the clarifier.

Figure 7 shows the dissolved oxygen profile as the waste makes its way around the channel. The initial high dissolved oxygen levels ensure that adequate nitrification will take place. As the dissolved oxygen level decreases on its path around the channel, carbonaceous BOD removal occurs. As the dissolved oxygen level decreases to below approximately 0.5 mg/1, the waste enters the anoxic zone where denitrification and additional carbonaceous BOD removal are effected. The anoxic zone also helps to control filamentous organism growth by placing the sensitive filamentous organisms into a zero DO environment. The dissolved oxygen level is then increased again as it passes through the aerator.

A portion of the channel flow is sent to a flow directing duct work arrangement that feeds the clarifier and also returns the settled solids to the oxidation channel. This is clearly shown in the clarifier cross-sectional drawing in Figure 8. The downward flow in the chimney area is approximately 10 times the flow rate through the clarifier. This ensures that adequate flow is available to recycle the settled solids. To aid in this return, there is a sludge collector mechanism that moves the solids gently down the sloped clarifier bottom. There is also a surface scum skimmer that removes any floating solids or grease that may have gotten into the clarifier. The flow of the highly oxygenated waste from the aerator exit ensures that the clarifier is maintained in an aerobic condition. This prevents any problems from sludge rising due to a septic condition or due to denitrification in the sludge. Sludge wasting is effected by allowing the sludge pit to fill with mixed liquor from the oxidation channel. This is then allowed to settle and the supernatant is pumped back into the aeration channel. This procedure is repeated until the desired amount of solids has then been removed. For this installation, excess solids are sent to a facultative mixed lagoon for further decomposition and then finally to land disposal.

The oxidation channel itself has sloped sidewalls and a flat bottom. The channel is constructed out of 3 in. thick gunited concrete over wire mesh. This eliminates the need for expensive and time consuming forming. The draft tube aerator fits into a 8-ft-diameter circular steel U-tube. The U-tube is constructed of mitered sections of circular steel pipe cut and welded to fit. The entire U-tube structure is then coated and pressure tested to check for leaks. Located in the U-tube is a diffuser assembly connected to a high pressure blower. This is a standby system that is used to supply additional oxygen transfer to meet peaks and in the event of a loss of the draft tube aerator, the air lift flow to the U-tube will provide some circulation around the channel. Since there is only one aerator installed, there is a spare reducer and motor stored at the jobsite to minimize any downtime associated with an aerator failure. The aerator is powered by a two-speed, 50-HP motor. In addition to the high pressure blower used for the standby diffuser system, there is two-speed 15-HP low pressure blower used for the two-speed draft tube aerator. As part of the integral wall construction with the oxidation channel are two clarifiers. They are constructed of formed reinforced steel concrete walls. Any scum removed from either clarifier flows to the centrally located sludge holding pit.

In order to meet the stringent timetable set to meet the DER requirements for their discharge permit, time was of the essence. To save as much time as possible, the oxidation channel was built on the "fast-track" approach. Through the use of a design engineer and a construction company that were familiar with this type of draft tube channel, construction was started before final construction drawings were prepared. This required extremely close cooperation between the equipment supplier, design engineer, construction company, and owner. The entire plant was constructed and ready for operation six months from the time the notice to proceed was received.

START UP

Mixing Equipment Co., Inc. as part of a contract project had responsibility for the mechanical, hydraulic, and process start up of the system. Prior to the oxidation channel being filled with water, a service mechanic inspected the mechanical equipment to make sure that all equipment was properly and securely installed, correctly wired, lubricated according to specifications, and that all tolerances were maintained within the specifications. The mechanical equipment was then operated in the "dry" condition to ascertain that proper running clearances and rotation of the equipment was maintained. During this time, the plant operators were also instructed in the lubrication, operation, and function of the particular pieces of equipment.

Subsequent to the initial mechanical check out, the system was filled with lagoon effluent to check for leaks and the physical functioning of the mechanical system. At this time the operation of the draft tube aerator and blower was observed to make sure that everything was functioning properly and nonoverloading. In addition, the draft tube aerator flow was measured to make sure that it was within the design range. The operation of the clarifier scum skimmer and collector mechanism was also adjusted at this time, as was the setting of the flow control gates and ducts to assure that proper hydraulic velocities were present for operation of the clarifier.

AWARE, Inc. of Nashville, TN, was chosen to perform the process start up. Once the hydraulic and mechanical check out were completed, arrangements were made to obtain waste activated sludge from a nearby poultry processing plant. This work was started under the direction of AWARE. However, the nature of the waste activated sludge was primarily oil and grease, and it was decided to find a new source of excess sludge. Domestic excess sludge was obtained through a local municipal waste treatment facility, and was added to the basin with a portion of the plant waste. This procedure was continued until the system had a sufficient volatile solids level to handle the entire poultry processing waste load and generate additional volatile solids. The system was gradually brought up to full load over a period of about three weeks.

As part of its contract, AWARE supplied a qualified operator for one month of onsite operation. In addition to conducting and overseeing the analysis of samples, AWARE also *conducted operational and maintenance training for the plant operators, including the basics* of waste treatment plant design. Detailed operation and maintenance training was jointly conducted by the equipment vendor and AWARE with regard to all the mechanical equipment on-site. In addition, AWARE developed analytical techniques and sample schedules for the plant operators in addition to a comprehensive operations manual. AWARE will have one year of operation supervision before the plant operators will be completely on their own.

OPERATING DATA

The first six months of operation have shown that the plant has consistently met its stringent effluent requirements. The mixed liquor suspended solids level has shown a steady rise and reached approximately 5500 mg/l at the end of March, 1980. With the onset of warmer weather, this level is gradually being reduced. While design flows have not been up to the 0.62-mgd level, the influent BOD strength has been above the 300 mg/l level. This was done for two reasons, to make sure that the system would perform when the BOD load is up to design, and also to allow the processing plant to cut back on chemical dosage in the dissolved air flotation system. The plant is currently fine tuning the DAF system to minimize operating costs.

The operating data are shown in Tables II through VII for the first six months of operation. These have been maintained without any chemical dosage to either the oxidation channel or in the clarifier, although chemicals have been used in the dissolved air flotation system. It is noted that there was no loss of nitrification even though the basin temperature dropped to as low as 7 C.

The amount of operator attention has been minimal for this system. Most of the operators time is spent in taking and analyzing samples that must be submitted to the state DER to show that the plant is in compliance with its discharge permit. Other tests are performed to make sure that the operational parameters are kept within specified guidelines. The operator also checks the system to make sure that the mechanical equipment is operating properly and has adequate lubrication. Major maintenance of the equipment is normally performed at six-month intervals. This will consist of regreasing certain bearings and changing the lubricating oil in the gear reduction units.

Table II. Channel Operating Data (October 1979)

Date	Flow	Temp.	MLVSS	TSS Inf	TSS Eff	BOD Inf	BOD Eff	NH_3 Inf	NH_3 Eff
3	144,000	18.8	134	146	29	265	11	19	30
8	343,000	16.6	366	116	13	320	4	15	35
10	341,000	16.6	612	108	14	370	4	14	37
15	358,000	16.8	710	97	62	240	5	12	3
22	334,000	20.3	805	124	21	250	6	14	2
24	328,000	18.4	885	116	13	320	3	18	0.6
29	309,000	16.0	850	128	21	350	5	12	0.3

Table III. Channel Operating Data (November 1979)

Date	Flow	Temp.	MLVSS	TSS Inf	TSS Eff	BOD Inf	BOD Eff	NH_3 Inf	NH_3 Eff
5	321,000	14.9	716	140	36	370	5	14	0.6
7	306,000	15.0		204	58	510	4	17	1.2
12	332,000	15.3	856	172	26	360	17	16	0.7
14	315,000	15.3		150	27	360	27	24	2.9
20	307,000	15.4	1,100	158	42	340	21	15	1.2
28			1,132	254	29			13	1.0

Table IV. Channel Operating Data (December 1979)

Date	Flow	Temp.	MLVSS	TSS Inf	TSS Eff	BOD Inf	BOD Eff	NH_3 Inf	NH_3 Eff
5	337,000	12.5	1,020	174	34	490	24	16	1.2
10	357,000	11.0	885	109	16	310	16		
12	315,000	14.2	980	166	29	470	31	25	8.2
18	324,000	10.3	1,140	169	24	388	22	10	1.0
19	325,000	11.0	1,190	160	36	340	31	12	0.9
27	337,000	12.9	2,010	144	50	370	50	9	1.0

Table V. Channel Operating Data (January 1980)

Date	Flow	Temp.	MLVSS	TSS Inf	TSS Eff	BOD Inf	BOD Eff	NH_3 Inf	NH_3 Eff
3	282,000	10.5	2,080	158	32	360	32	13	0.7
8	266,000	10.8	2,280	122	24	320	25	9	1.2
15	279,000	11.4	2,480	244	19	590	22	14	1.8
23	289,000	12.5	2,730	186	21	500	25	8	3.1
29	259,000	10.5	2,690	188	17	385	18	7	0.6

Table VI. Channel Operating Data (February 1980)

Date	Flow	Temp.	MLVSS	TSS		BOD		NH_3	
				Inf	Eff	Inf	Eff	Inf	Eff
5	235,000	7.9	3,720	172	18	375	23	8	0.8
12	246,000	10.5	3,800	164	21	370	20	8	0.3
20	176,000	10.2	4,010	237	20	500	22	11	0.6
26	213,000	13.0	4,195	246	21	575	22	11	1.2

Table VII. Channel Operating Data (March 1980)

Date	Flow	Temp.	MLVSS	TSS		BOD		NH_3	
				Inf	Eff	Inf	Eff	Inf	Eff
4	196,000	8.8	4,450	148	18	350	15	11	0.7
11	196,000	14.0	4,420	230	16	500	13	13	0.4
18	238,000	13.4	4,240	488	18	950	14	24	0.7
25	21,800	13.5	4,195	269	29	610	26	15	6.6

Table VIII. Operating Horsepower

Unit	Normal	Peak
Aerator	18	50
Blower	10	15
Clarifier Drive	0.5	0.5

CONCLUSIONS

The plant effluent data presented here show that this plant has consistently met its discharge permit limitations. In addition to this important criterion, the plant was also constructed and placed in operation on time in accordance with a strict timetable.

Of very great concern to the owner is the power usage drawn by this system. Table VIII shows the normal operating horsepower associated with the major mechanical pieces of equipment in the channel. As can be seen, the operating horsepower is very low considering the flow rates and biological floatings encountered in this plant. Most importantly, the owner is pleased with the operation, performance, and cost-effectiveness of this very important component of his total production facilities.