Γ+KP-11

Control and Treatment of Egg Breaking and Processing Wastes Part 2

by W. J. Jewell, W. Siderewicz, R. C. Loehr, R. R. Zall, O. F. Johndrew Jr., and H. R. Davis, Cornell University and J. L. Witherow, EPA, Corvallis, Oregon

Part 1 appeared on page 23 of the March/April issue.

In a study of five egg breaking plants ranging in size from small to very large installations, in-plant waste conservation methods resulted in recovery of product with a value between $250 and $500 per day for a medium sized facility.

After completion of the effluent analysis, detailed in-plant sampling was conducted to determine the source of pollutants. This included collecting weighted composited samples of the egg washer overflow and sump contents, continual overflow from the egg breaker and flushing of vats, tanks, strainers, piping and pasteurizer. Other sources of water included rejected inedible eggs from the washer and breaker operations that were not deposited in the proper receptacles, egg product dripping from the breaking machine, malfunctioning egg loading device on the egg washing machine, leaking pumps and piping connections and vat spillovers. All of the latter losses are examples of unmeasurable losses that were referred to as floor losses. Examples of the comparison of the total of various sources are shown in **Figure 6.** Although the egg washers contributed only five to ten percent of the plant's total wastewater, the BOD loss represented from one quarter to half the total plant loss. Since the total volume of egg washing water in a medium sized facility (three breakers, for example) would be about 500 gpd, it seemed appropriate to consider removing this entire stream from the sewer. The water use **(Figure 6)** for the egg breaking machine is excessive due to malfunctioning of a float valve. See **Figure 7** for an estimate of the relative quantities of organic wastes in most egg breaking facilities and their sources. The differences between values in **Figure 6** and **Figure 7** can be attributed to a high water usage for plant A during the day the data were taken, and inclusion of the pasteurizer flushing in the floor losses in **Figure 6.**

Informing management of the weight of BOD_5 lost in their operations provides little understanding or motivation for decreasing the losses. BOD or COD losses should be related to the loss of egg product which can be easily translated to dollar losses. Although frequently difficult to achieve, a mass balance of all materials at a facility indicates the relationship of various losses to the quantity of final product. The mass balance for plant A shown in **Figure 8** is an average of three separate days of sampling in which the total weight of material passing out of the plant was five percent more than the measured total input weight. The losses of egg product to the sewer represent a daily loss of about $440 in revenue for plant A. This magnitude of loss represents a significant portion of the income of the plant.

Analysis of the waste source survey resulted in developing 13 steps that could be taken to control wastes by in-plant management **(Table 4).** Plants A, B and C attempted to implement those identified as 2, 3, 4, 6, 11 and 13. Each plant manager adopted the changes that he could implement quickly at a low cost. It was estimated that the cost of the plant modifications was less than $300. The egg washwater was segregated from the sewer and placed in a sanitary landfill along with the shells.

For plant A, the percent of material lost to the sewer was about 6.3 percent of processed egg before efforts were made to control waste losses. This was reduced to an average loss of 1.7 percent using in-plant management (see **Table 5**). The total amount of edible egg liquid did not change, but the animal food recovered increased by nearly five percent. The degree of waste control achieved in plant A represented an estimated 80 percent of the control that is practically feasible. A summary of all water and BOD_5 losses before and after modification is shown in **Figure 9.** The average quantity of the eggs lost in all facilities before modification was about 12.5 percent of the liquid eggs processed, while the average losses after use of in-plant management were 6.4 percent. In-plant control of wastes was capable of decreasing water usage by about 26 percent and BOD_5 reduction by more than 50 percent.

Treatability studies were conducted on wastewaters from egg breaking operations in New York State. In considering possible solutions to the effluent problem, the small size of each individual facility must be kept in mind. The largest facility has a production capacity less than 150,000 dozen per day (about 180,000 lb/day) and a total design waste flow of less than 200,000 gpd, equivalent to 2000 per capita per day. It can be difficult to provide an efficient and inexpensive waste treatment system for such small but highly contaminated waste flows. Development of efficient, inexpensive and simple waste treatment approaches that could provide varying levels of treatment was the focus of this por-

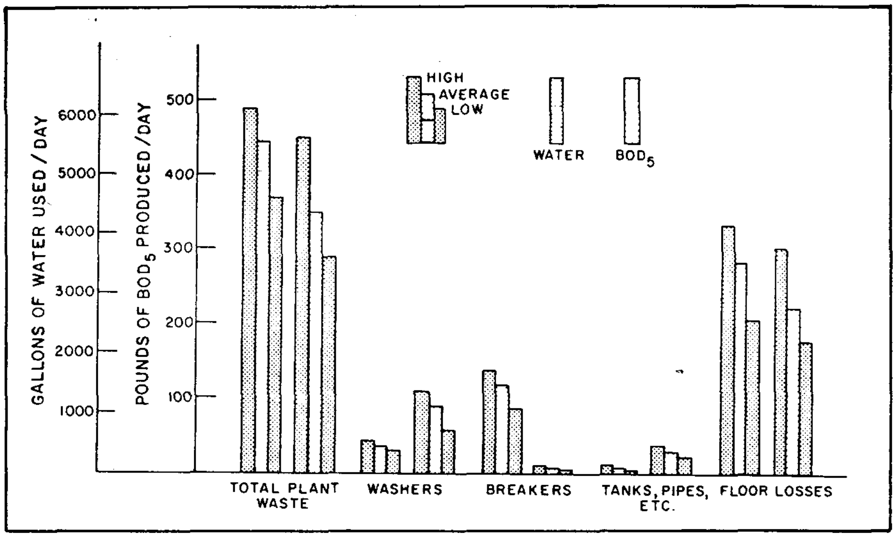

Figure 6. Unit operations contribution of waste of egg breaking wastes before in-plant modification for waste reduction in Plant A.

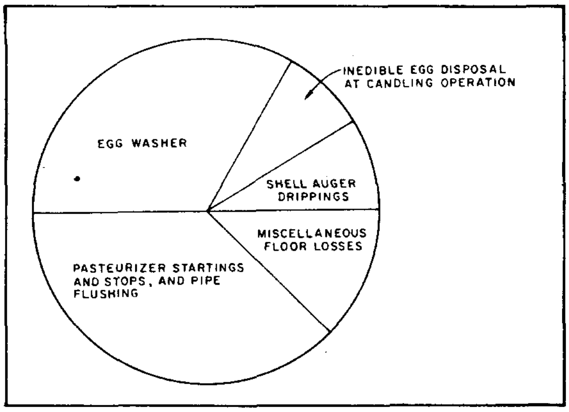

Figure 7. Approximate sources of organic waste loads generated in egg breaking facilities.

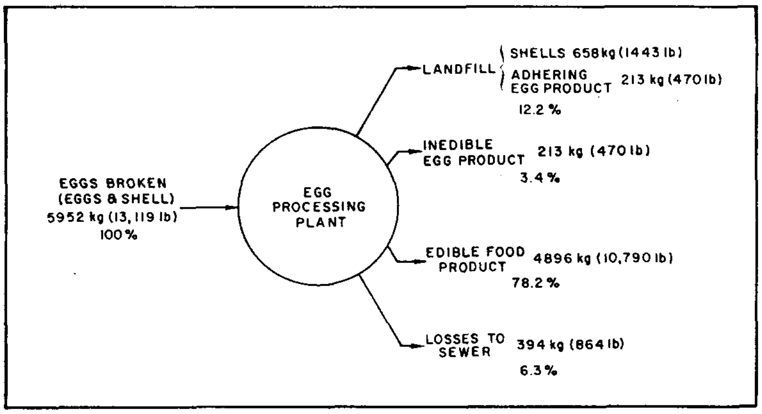

Figure 8. Mass balance of egg materials in processing Plant A before waste control modification.

tion of the study. Four types of treatment systems were examined—aerated lagoons, activated sludge, anaerobic lagoons and rotating biological contactors.

The aerated lagoons were simulated using a 20-liter reactor with a surface area of 2.5 ft^2. The system was inoculated with mixed liquor from a local activated sludge plant. The lagoons were fed on a fill-and-draw basis, usually once per day, with distilled water added to account for evaporation losses. Multiple compartment units were used and were of the same size as the aerated lagoons but with baffles added. The activated sludge system consisted of a 5.5 liter reactor followed by an 800 ml. clarifier. Settled sludge was returned to the activated sludge unit. Substrate was fed continuously to the activated sludge unit over a 16 hour period. Solids were wasted from the clarifier to maintain a specific solids retention time (SRT).

The rotating biological contactor (RBC) had four sections with a total of 36 polyethylene discs (effective surface area of 250 ft^2). The liquid volume was 136 liters.

The anaerobic-aerobic series lagoon treatment was tested using a volume of 30 liters in the first unit and a second unit with a hydraulic detention period of six days. Feed for all units was obtained from either plant A or B after in-plant modifications had been completed. All feed samples were obtained by compositing wastes over an entire working day.

The egg processing wastes which were fed to the various treatment processes and the resulting treated effluent were analyzed for a number of characteristics. Total solids, total alkalinity, ortho-phosphate and BOD_5 determinations were made in accordance with procedures outlined in *Standard Methods.*[6] Ammonia and Kjeldahl nitrogen were determined as described by Prakasam et al.[7] Both nitrogen analyses are identical to procedures presented in *Standard Methods* except for the use of micro-Kjeldahl digestion and distillation equipment. COD values were obtained by use of the Jeris COD test.[8]

Additional analyses performed included suspended solids, by use of a Millipore filter apparatus and No. 9-873B (2.4 cm dia.) Reeves Angel glass fiber filters. Dissolved oxygen determinations and oxygen uptake were determined by a Y.S.I. Model 54 D.O. meter. Effluent turbidity of certain treatment processes was determined using a Hach Model 2100 turbidimeter.

Examples of the performance of the aerated lagoons are shown in **Figure 10.** The BOD_5 loading rate on the 30 day HRT aerated lagoon was 120 lb. per acre per day or about eight lb. per 1000 ft^3 of reactor per day. Nitrification was more than 90 percent complete, with from 0 to 4.6 mg/l NH_3-N and 0.1 to 4.5 mg/l NO_2-N appearing in the effluent. Oxygen uptake rates decreased from 25.3 to 7.0 mg/l/hr as the hydraulic retention period increased from 10 to 30 days. The aerated lagoons were capable of reducing a total influent COD ranging from 4000 to 6000 mg/l to a soluble effluent of less than 700 mg/l at all three hydraulic retention periods. The effluent from all units was characterized by fine non-settling suspended solids (SS) varying from 560 to 1300 mg/l. The SS in the effluent impart-

Table 4. Recommendations for Minimizing Waste Generation in Egg Breaking Facilities
1. Minimize use of improper stacking of eggs in storage, or weak storage boxes.
2. Minimize number of times eggs handled and length of conveyor system.
3. Efficient collection of discarded eggs.
4. Frequent adjustment of brushes in washers to minimize breakage.
5. Frequent inspection of egg breaking carrying trays to insure efficient collection.
6. Collection of shell attached albumen from conveyance system.
7. Eliminate storage vat spillovers.
8. Reduce lengths of product lines.
9. Minimize usage of water in plant clean-up.
10. Efficient removal of egg solids from storage units prior to rinsing.
11. Recovery egg chalazaes and gelatinous egg solids from the egg strainer.
12. Recovery of initial flush of blend tanks and pasteurizer.
13. Segregate and recover or dispose on land the overflow and sump discharge from egg washing.

Table 5. Comparison of Mass Balances Obtained for Egg Breaking Operations in Plant A Before and After Modifications for Waste Control

	Fate of Input Fraction of Total Throughput, Percent			
	Shells and Adhering Albumen	Animal Food	Edible Food	Loss to Sewer
Before Modification	12.2	3.4	78.2	6.3
After Modification	12.2	7.9	77.3	1.7

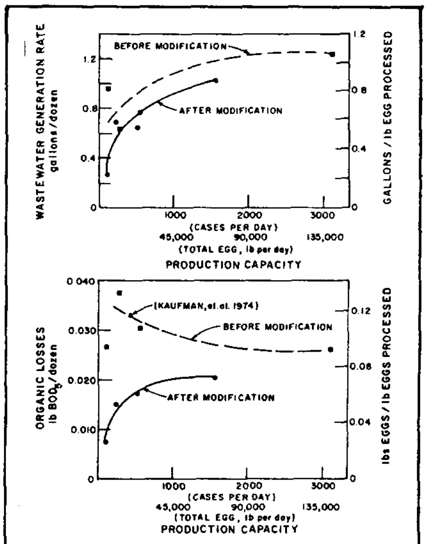

Figure 9. Summary of the average organic and water volume losses before and after plant modification for waste control.

ed a highly turbid yellow appearance to the effluent. Even though these results indicate that this process is capable of soluble COD removal efficiencies greater that 90 percent, the effluent quality will probably not satisfy most discharge requirements.

Graphical kinetic analyses were conducted to determine the substrate removal coefficient, K, base 10, COD basis at 20 degrees C. For substrate from plants A and B, the removal coefficient was 0.76 day^{-1} (least square regression coefficient r = 0.90) and 0.58 day^{-1} (r = 0.97), respectively.

It was anticipated that treatment of egg breaking wastewaters with the activated sludge process would be difficult because of the high strength of the wastes. In order to achieve an acceptable organic mass loading it was necessary to maintain the hydraulic detention period longer than four days. The data shown in **Figure 11** illustrate that the effluent quality was similar to the effluent from the aerated lagoons. The sludge in these units settled poorly, and high effluent turbidities (70 to 100 JTU) indicated that this process would be a poor choice for the treatment of egg breaking wastes.

The activated sludge process is capable of producing an effluent suitable for discharge to a joint treatment system without resulting in a surcharge for excessive oxygen demand or suspended solids. However, problems with settleability of the sludge should be anticipated.

A final aerobic treatment process investigated was the rotating biological contactor (RBC). All of the previous treatment schemes involved suspended growth systems, while the RBC is an adhered growth treatment unit. This system is similar to the previous processes in that excess solids are produced by the oxidation of the substrate and must be removed from the effluent.

Table 6 summarizes the results obtained with the RBC study. The pH of the effluent varied from 7.2 to 7.7. Regardless of the loading rates used (1.4 to 7.3 lb COD/1000 ft^2), there was always a dissolved oxygen level in all of the four RBC cells. The RBC units are capable of producing effluents suitable for further treatment and at low loadings can produce effluents with turbidities less than 27 JTU.

Anaerobic lagoons would not usually be acceptable because of the oxygen demand of their discharges, and in cold climates removal efficiencies would be depressed. Thus, all anaerobic lagoons were followed in series with aerobic lagoons operating with a six day detention period. Comparative studies were conducted at 20 and 10 degrees C.

The data shown in **Figure 12** is representative of the capability of the combined system. A total hydraulic retention period of 26 days reduced a total influent COD of 6000 to 8000 mg/l to between 5 and 15 mg/l soluble BOD_5. This system also resulted in an effluent that contained large flocs of rapidly settling suspended solids leaving a clear effluent. Data for all units are summarized in **Table 7.** All soluble COD removal efficiencies exceeded 98 percent.

Graphical analysis for the substrate removal coefficient, K, was conducted for the anaerobic lagoons. The 20 degrees C anaerobic lagoon K was 0.63 day^{-1}. This was very similar to the removal coefficients obtained for the aerobic lagoon treatment of wastes (0.76 and 0.58 day^{-1} for plants A and B, respectively). This procedure was not applicable to the lower temperature units because the effluent characteristics of the units studied were similar. The observed efficiencies at 10 and 20 day hydraulic retention periods at 10 degrees C were similar to those observed at 20 degrees C.

In no case did the total effluent turbidity exceed ten JTU for units operated at 20 and 10 degrees C. Since all solids settled rapidly the soluble BOD_5 values shown in **Figure 12** of about ten mg/l are indicative of the efficiency that this treatment combination is capable of achieving with an influent COD varying between 5,000 and 10,000 mg/l and a total system hydraulic detention period of 26 days.

Egg wastewaters are highly biodegradable and for this reason can be treated by various combinations of systems. Utilization of multi-cell units enables the use of smaller systems to achieve the same treatment efficiency. Data supporting this statement are illustrated in **Figure 13.** Total COD removal with a one-cell aerated lagoon at ten-day HRT achieved 60 percent removal efficiency, while a five-cell aerobic lagoon with the same overall HRT achieved a removal efficiency of 83.5 percent and a five-cell anaerobic unit with a ten day HRT obtained a removal efficiency of 91 percent. These data indicate that addition of individual compartments to lagoons treating egg breaking wastes will improve the efficiency for any given volume. To protect the system against shock loads, no more than three cells should be used for any lagoon.

Empirical approximations of the quantities of sludge accumulated in both the anaerobic and aerobic lagoons are summarized in **Tables 8** and **9.** In all anaerobic units operated at 20 degrees C, the accumulation of solids was low and represented about five percent of the solids added. The higher accumulations at ten degrees C reflect lower rates of stabilization. However, bioprecipitation of the solids in these units enables the treatment efficiency to be nearly equal to that at 20 degrees C.

Discussion

In cases where in-plant waste control was not utilized, 12.5 percent of its processed product was lost to the sewer. This level of product loss agrees with a recent survey of plant practices in the U.S. where average loss was reported to be 12.1 percent with the maximum range of 4 to 25 percent.[5] It was relatively simple and inexpensive to reduce the loss from 12 percent down to 6 percent, and in one case to 3 percent on a long term basis using in-plant management. On the basis of this analysis it was concluded that of the total losses of around 12 percent, about half are readily controlled by good in-plant management. Of the remaining wastes (6 percent), 3 percent can be removed by careful management and further implementation of some of the more costly suggestions shown in **Table 4.** This level of in-plant control would provide 75 percent BOD_5 reduction and would be considered difficult to achieve by many facilities. It is estimated that product losses in the industry could be controlled at about 2 percent with high quality management using all recommendations given in **Table 4.**

The maximum range of water and product loss for all plants was 0.43 to 1.41 gal. per dozen and 0.0048 to 0.0478 lb BOD_5 per dozen eggs processed (0.0062 to 0.058 lb BOD_5 per lb liquid egg produced), respectively. On the average, more than one egg per dozen processed goes to the sewer in 0.9 gal. of water. The water use compares well with the U.S. survey[5] where the range was 0.485 to 3.27 gal. per dozen eggs processed with an average of 1.49 gal. per dozen eggs. A survey of three Dutch plants reported water use to be 0.49 to 1.56 gal. per dozen eggs.[9] The Dutch study reported the amount of product loss varying from 0.5 to 4.2 percent.

In large plants (10 to 12 breakers) it may be uneconomical to collect and land dispose 9460 to 13,625 liters (250-3600 gal.) a day of the highly contaminated egg washing waters. An alternative solution might be to recover the protein either by drying, chemical precipitation, or heat treatment.

Since the major contributor to egg losses in the breaking industry is the egg washer, it seems logical that a larger plant with multiple breakers could set aside one of its breakers

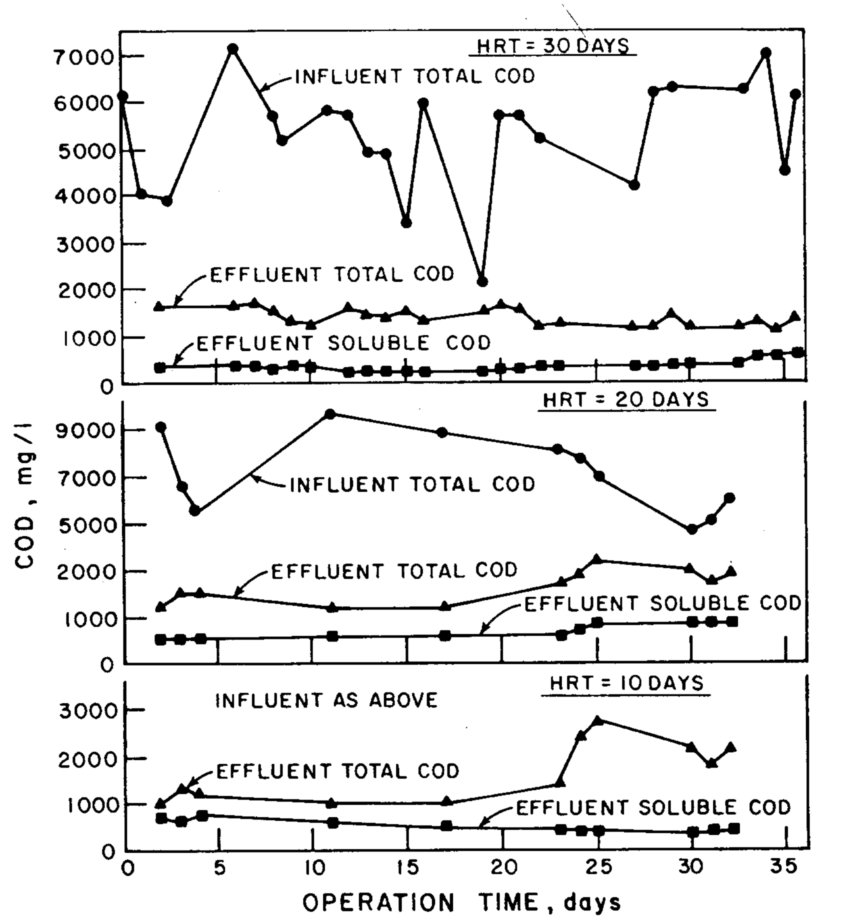

Figure 10. Aerobic lagoon treatment of total egg breaking wastewater from Plant B at 20 degrees C.

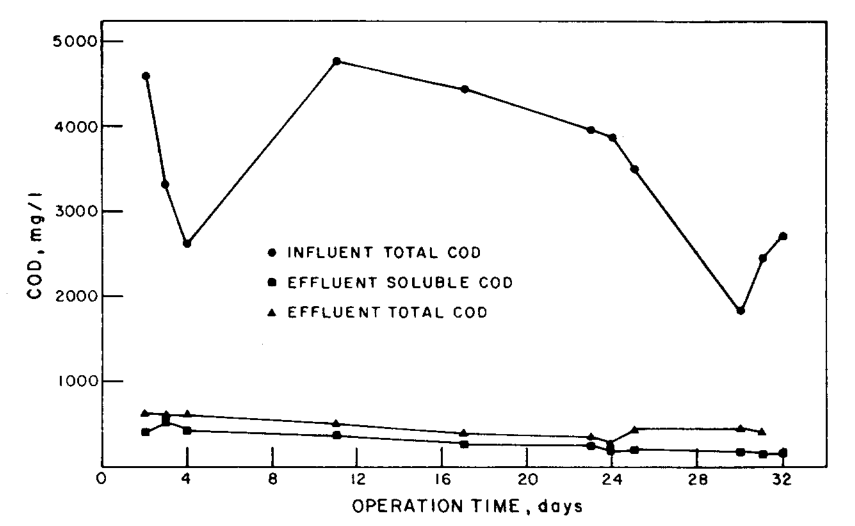

Figure 11. Activated sludge treatment of wastewaters from Plant B at 20 degrees C, four-day hydraulic retention period, ten-day sludge retention period.

to be preceded by a washer, to handle "dirties," and the remainder of the breakers could be operated without washers. Kraft, et al.[10] have shown that commercially processed whole eggs resulting from both washed and unwashed eggs contain similar bacterial population counts.

The advantage of breaking eggs without first washing them is that egg processors will reduce the amount of egg product lost to the sewer and at the same time recover an inedible by-product. Assuming that egg processors lose 0.04 lb COD/dozen eggs, 25 percent from washers, and 5.83 x 10^8 dozen eggs are broken annually, it is estimated that 12 million lbs of inedible liquid eggs could be recovered by eliminating washers. Further study of this possible change in processing is necessary.

Four of the five plants surveyed disposed of empty egg shells by trucking them to local sanitary land fills on a daily basis. One of the plants used an incineration system to reduce the moisture content of the shells from 30 to 2 percent. Air drying collects and retains the nutrients present in the adhering liquid portion of the shell,[11] and may be an asset when sold to poultry feed producers.[12] Assuming 20 million cases of egg at 47 lb/case are processed each year and 11 percent of an egg's weight is shell, the egg breaking industry has capabilities of providing nearly 53,000 tons of dried egg shell products annually.

Although egg breaking accounts for only 11 percent of the nation's eggs and grading operations, the remainder, the pollution potential of the processing industry, is greater than that of the grading process. BOD losses from the grading operation of plant C amount to 0.001 lb BOD/dozen eggs graded. Hamm et al.[13] indicated that egg grading losses average 0.0014 lb BOD/dozen in egg grading plants. Therefore, egg breakers handle a small portion of the country's eggs, but the losses per dozen are tenfold higher than losses of grading operations.

This treatability study encompassed a variety of aerobic and combination anaerobic bench scale treatability units. It is evident that the high degree of treatment of egg processing wastewaters for the purpose of direct discharge to surface waters can be achieved most easily by the combination anaerobic-aerobic lagoon treatment. Anaerobic-aerobic lagoons are advantageous from the standpoint of low maintenance requirements, energy requirements and capital costs. Treatability studies have shown that the two-lagoon system is capable of producing an effluent of low turbidity with good solids settling characteristics and extremely low oxygen demand substances. These results are illustrated in **Figure 14.** Thus, the treatment which was found to be most effective in controlling the egg breaking wastewater is shown in **Figure 15.**

There are a number of design considerations involved with full-scale operation of anaerobic-aerobic systems. Bench scale studies indicated that a scum layer will form on the anaerobic lagoon and retain odors associated with the system. It is not known how stable this scum layer will be under field conditions.

Another possible drawback of these systems is the possible impact of low temperatures on treatment plant efficiency. At temperatures lower than ten degrees C, the removal capacity of this combination may be diminished even though the organic removal efficiencies were nearly the same at ten degrees C as they were at 20 degrees C.

Often, municipal systems utilize aerobic treatment processes. If an industry such as an egg breaking plant discharges to a particular plant, there may be difficulty in meeting regulatory effluent guidelines. Experience from this study indicated that poor effluent quality can be expected when treating egg processing wastes aerobically. In the town where plant E is located, there does not seem to be a problem with the operation of the municipal trickling filter, but the egg processing wastes constitute less than ten percent of the municipality's organic loading.

Table 6 [illegible]

	RBC Loading Rates		
Volumetric (gal/1000 ft.^{2}-day)	40	80	160
Organic (16 COD/1000 ft.^{2}-day)	1.38	3.13	7.32
Parameter Influent [illegible]istics			
[illegible] total			262
Clarified Effluent Characteristics			
COD, total	320	350	760
COD, soluble	200	170	240
SS	45	104	304
TKN, total	29.7	54.5	63.8
NH_3-N	1.5	16.3	17.0
NO_2-N	1.9	4.1	42.5
NO_3-N	11.5	3.4	60
JTU	27	56	86
Removal Efficiency, %			
COD, total	92.3	92.5	86.1
COD, soluble	95.1	96.3	95.7
TKN, total	86.8	70.0	75.6

Table 7. Characteristics of the Anaerobic-aerobic Lagoon Series Treatment System

Parameter	System No.				
	1	2	3	4	5
Temp., °C	20	10	20	10	20
HRT					
Anaerobic Unit	20	20	10	10	5
Aerobic Unit	6	6	6	6	6
System Effluent Soluble COD, mg/l	90	66	72	86	72
Removal Efficiency, Total COD, %	98.7	98.4	98.5	98.1	96.7
Effluent Turbidity, JTU	4.8	9.1		21.4	

Conclusions

1. Eleven percent of eggs produced in the U.S. go to egg breaking plants resulting in 2.9 x 10^8 kg (6.40 x 10^8 lb) of liquid egg products which grossed $195 million in 1969.
2. Most egg breaking plants are located in small communities. The highly contaminated wastewaters generated in egg breaking industries can cause difficulties in municipal treatment facilities. In the five egg breaking plants sampled, the wastewater ranged between eight and 1500 percent of the wastes generated from all other sources in the communities in which they were located.

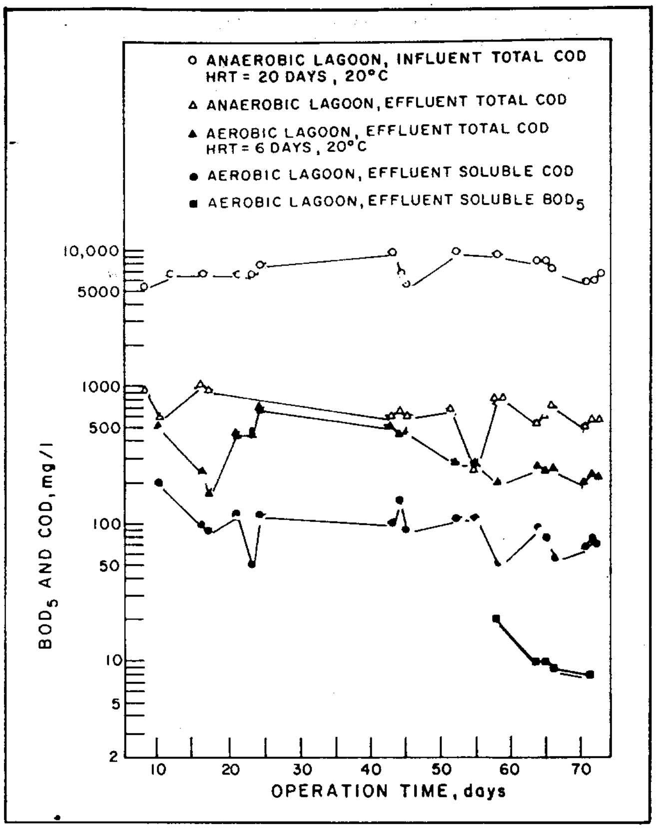

Figure 12. Series lagoon treatment with 20 day HRT at 20 degrees C in the first anaerobic lagoon and six-day HRT at 20 degrees C in the aerobic lagoon.

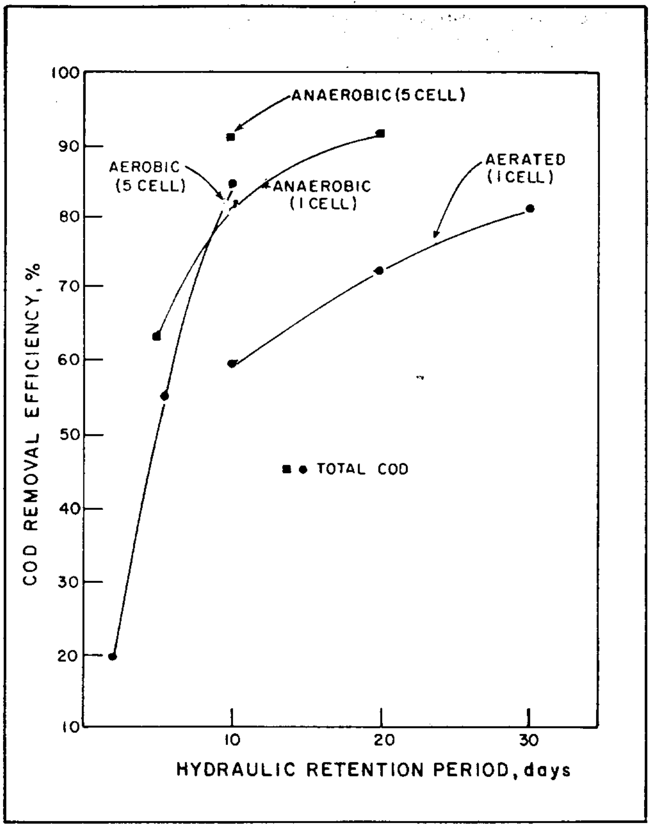

Figure 13. Comparison of multi-cell and single cell aerobic and anaerobic treatment processes at 20 degrees C.

3. Wastewater characterization indicated a highly contaminated discharge with COD's greater than 6000 mg/l, and BOD_5 equal to about 60 percent of the COD.
4. Up to 15 percent of the total egg liquid output was lost to the sewer in plants where good in-plant management was not practiced. Losses equivalent to three eggs for every dozen broken were reported as maximum losses that occur in plants where no waste conservation measures were practiced. The average pre-modification product loss in all five plants sampled was 12.5 percent (by weight) of the processed output.
5. the measured average amount of liquid egg recovered per dozen eggs broken was 0.55 kg (1.21 lb), and this represented recovery of 80 percent of the total egg weight.
6. The average egg liquid loss in a medium size facility (two or three breakers) represents a decrease in revenue between $500 and $700 per day.
7. The losses on a product basis averaged as follows: before in-plant waste conservation 0.034 kg BOD_5/kg egg liquid produced and wastewater volumes of 7.5 l/kg (0.90 gal/lb) egg liquid produced. In-plant modifications decreased average BOD_5 losses by 50 percent and wastewater volume by 24 percent.
8. In-plant waste control reduced the waste generated from an average of 12.5 percent product loss to 6.4 percent product loss. This is equivalent to additional egg product recovered worth between $250 and $500 per day in a medium sized breaking facility, not including the savings from reduction in cost of waste treatment.
9. Adoption of in-plant waste control measures that cost less than $300 per plant could result in reduction of waste load equivalent to about two-thirds of that which is technically achievable. Good plant management appears to be capable of reduction of product loss to about five percent of the liquid egg output. If more extensive and costly modifications are made to the plant to recover the first flushing from the pasteurizers, pipes, and tanks, the product loss to the sewer could probably be reduced to less than two percent of the output.
10. On a national basis in-plant waste control would result in annual product recovery of 3.2 x 10^7 kg (7 x 10^7 lbs) of liquid egg of a quality suitable for animal food which is now lost to the sewer.
11. Egg breaking wastes obtained from three facilities, A, B, and C, were highly biodegradable with no observed toxic effect to biological treatment processes.
12. High concentrations of organic material were not reduced to levels acceptable for direct discharge to surface waters in conventional processes, such as activated sludge and aerobic lagoons; even at low design loadings.
13. Aerobic lagoons, with hydraulic retention times (HRT) of 30 days reduced the total COD from 5800 to 1000 mg/l and resulted in a high effluent turbidity.
14. When anaerobic lagoons were followed by six-day HRT aerobic lagoons, the overall system efficiency COD removal was greater than 98 percent at 20 degrees C and 10 degrees C and at anaerobic lagoon HRT's of 5, 10, and 20 days. Effluent quality from the aerobic lagoon in a series system operating at 20 degrees C with a 20 day HRT anaerobic primary unit averaged as follows: 90 mg/l soluble COD, 13 mg/l soluble BOD_5, 92 mg/l NO_3-N, 21 mg/l NH_3-N and turbidity of five JTU.
15. Design capacity should be related to the maximum production capacity that can be achieved when eggs are plentiful during the months of May and June. In most facilities wastewater flows are very low at night and during weekends.

Acknowledgments

This study is the result of a multidisciplinary effort representing four major disciplines. The authors are appreciative of the advice, contributions and support of the following individuals: C. J. Barton, D. Brown, R. J. Cunningham, E. Davis, R. Draper, R. Dil, P. Gellert, G. Grey, R. J. Hynek, C. R. Kilmer, P. Kodukula, M. Kool, R. McCrea, J. H. Martin, R. McNamara, J. N. Nickum, R. Ridley, S. Sotiracopoulos, and W. T. Wallace.

Portions of this study were presented at the 1975 (May) Purdue University Industrial Waste Conference, the Sixth National Symposium on Food Processing Wastes Research at Madison, Wisconsin (April), and the American Society of Agricultural Engineering Chicago meeting, December, 1974.

Support for this study was provided by the College of Agriculture and Life Sciences of Cornell University and the U.S. Environmental Protection Agency, Grant S-802174.

Table 8. Measured Sludge Solids Accumulation Rate in Anaerobic Lagoons

Anaerobic Lagoon Operating Conditions		Solids Accumulation Rate
HRT (days)	Temp (°C)	% of total solids added per day
10	10	30
20	10	68
5	20	12
10	20	6.0
20	20	5.4

Table 9. Measured Sludge Volume Accumulation Rate in Effluents Lagoons from 6-day HRT Aerobic Lagoons Following Anaerobic

Pretreatment Anaerobic lagoons		Aerobic lagoon	Sludge volume accumulated
HRT (days)	Temp (°C)	Temp (°C)	(% total volume treated)
10	10	10	1.7
20	10	10	3.7
20	20	20	2.7
10 (5-cell)	20	20	1.2

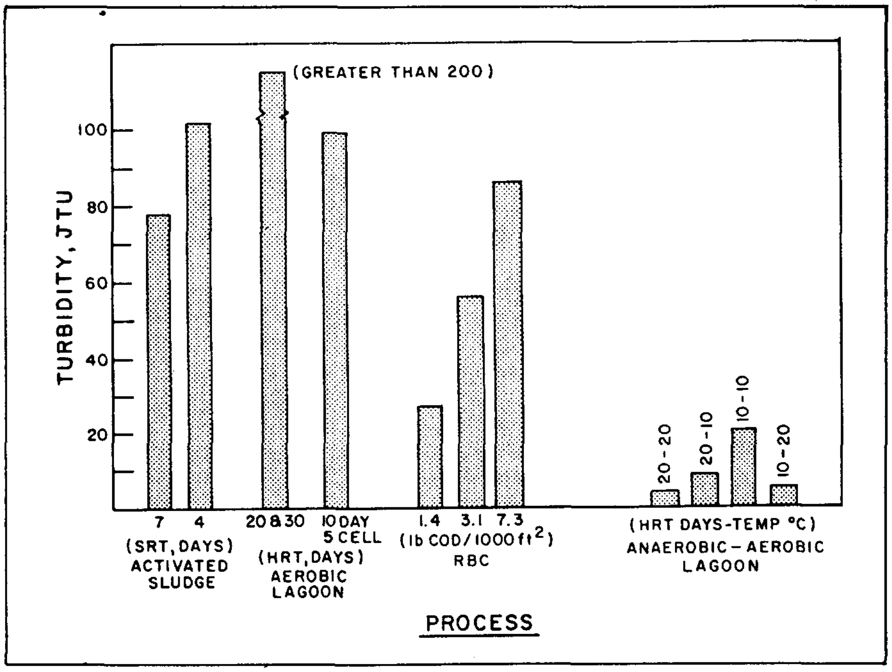

Figure 14. Summary of effluent turbidity from various aerobic and anaerobic-aerobic treatment systems.

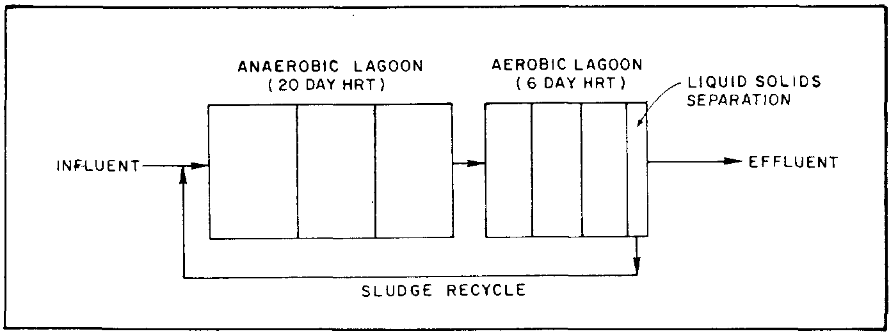

Figure 15. A recommended wastewater treatment system to achieve maximum organic pollution control of egg breaking wastewaters.

REFERENCES

1. Jewell, W. J., H. R. Davis, O. F. Johndrew, Jr., R. C. Loehr, W. Siderewicz, and R. R. Zall. "Egg Breaking and Processing Waste Control and Treatment." U.S. Environmental Protection Agency Report, To be published. 1975.
2. Kondele, J. W. and E. C. Heinsohn. "The Egg Products Industry of the U.S. Part 2, Economic and Technological Trends 1936-61." North Central Regional Research Publication No. 154. Bulletin 466. Agricultural Experiment Station. Kansas State University. Manhattan. January, 1964.
3. Jones, H. B. and H. R. Smalley. "Vertically Integrated Methods of Producing and Marketing Eggs: An Economic Evaluation." Bulletin N.S. 160. Georgia Agricultural Experiment Station. Athens. May, 1966.
4. Statistical Research Service. "Egg Products, February, 1968 - April, 1971." U.S. Department of Agriculture, Washington, DC.
5. Kaufman, V. F., D. H. Bergquist, K. Ijicki, and A. L. Porter. "Wastewater Control at Egg Products Plants." An Informal Report from the Poultry and Egg Institute of America and the U.S. Department of Agriculture, Washington, DC. 1974.
6. American Public Health Association. *Standard Methods for the Examination of Water and Wastewater*. New York. 1971.
7. Prakasam, T. B. S., E. G. Srinath, P. Y. Yang, and R. C. Loehr. "Evaluation of Methods of Analysis for the Determination of Physical, Chemical and Biochemical Parameters of Poultry Wastewater." Presented at American Society of Agricultural Engineers Committee SE-42, Chicago, Illinois. 1972.
8. Jeris, J. S. "A Rapid COD Test." *Water and Waste Engineering*, (1967) 89.
9. Dekleine, H. and G. P. Friskorn. "Research Into the Wastewater Disposal Situation in Egg-breaking Industries." State Agriculture Waste Disposal Service Report No. 4372. Inst. for Poultry Research. September, 1972. Holland.
10. Kraft, A. A., G. S. Torrey, J. C. Ayers, and R. H. Forsythe. "Factors Influencing Bacterial Contamination of Commercially Produced Liquid Egg." *Poultry Science*, 46 (September, 1967) 1204-1210.
11. Walton, H. V., O. J. Cotterill, and J. M. Vandepopuliere. "Cashing In on Breaking Plant Wastes." *Egg Industry*, (April, 1973) 25-26.
12. Walton H. V., O. J. Cotterill and J. M. Vandepopuliere. "Egg Shell Waste Composition." University of Missouri-Columbia. Presented at Winter Meeting American Society of Agricultural Engineers. Paper No. 72-886. Chicago, Illinois. December 11-15, 1972.
13. Hamm, D., G. K. Searcy, and A. J. Mercuri. "A Study of Waste Wash Water From Egg Washing Machines." *Poultry Science*, 53 (1974) 191-197. ■