Sequencing batch reactors for the treatment of egg processing wastewater

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Olsson, M.P., Lo, K.V. and Charter, E.A. 1997. **Sequencing batch reactors for the treatment of egg processing wastewater**. Can. Agric. Eng. **39**:195-202. Due to plant expansion, a British Columbia egg processor was looking for a means of increasing the capacity of an aerated lagoon system for treating egg processing wastewater. To avoid a major capital investment, upgrading to a sequencing batch reactor (SBR) appeared to be an attractive option. For this reason, two parallel lab-scale SBR systems were operated over an eight month period for the treatment of egg processing wastewater. The results showed very good removal rates of 99% for BOD, 88% for COD, and 65% for TSS. Aeration requirements were found to be 1.5 L/min and 0.5 L/min for two 4 litre reactors in series. The coefficients a and b, for the determination of oxygen requirements, were established at 0.68 g O_2/g BOD and 0.32 d^{-1}, respectively. Dissolved oxygen levels between 1 and 3 mg/L were maintained at a design mean cell residence time of 20 days. Coliforms were reduced from 3500 MPN/100 mL in the influent to 80 MPN/100 mL in the effluent. Confirmed coliforms were identified as *Bacillus sp.* and *Micrococcus sp. Salmonella* and fecal coliforms were not detected in either the influent or effluent wastewater.

Suite à un agrandissement, un producteur de produits d'oeufs transformés de la Colombie Britannique cherchait un moyen d'augmenter sa capacité de traitement d'eaux usées. On a choisi d'améliorer le système en transformant en réacteur séquentiel (RS) pour éviter une capitalisation importante en investissements capitaux. Pour conséquente, la performance de traitement de deux systèmes de RS en parallèle, à l'échelle de laboratoire, a été suivie pendant huit mois. On a obtenu une réduction de 99% de la DBO, 88% de la DCO, et 65% des SS. Les deux réacteurs de 4 litres, en série, ont requis un taux d'aération de 1,5 et 0,5 litres par minute. Les coefficients a' et b' de la demande d'aération ont été établis à 0,68 g O_2/g DBO et 0,32 par jour. L'oxygène en solution a été maintenu entre 1 et 3 mg/L pour une durée de résidence des cellules de 20 jours. Le niveau de coliforms est passé de 3500 MPN/100 mL avant traitement à 80 MPN/100 mL pour l'effluent. Des bacillus sp. et des micrococcus sp. ont été identifiés parmi les coliforms. Il n'y a pas eu de salmonella ni de coliforms fécaux détectés dans le système.

INTRODUCTION

Aerated lagoons are widely used for the treatment of food processing wastewater for two main reasons: low capital expenditures and low operating costs (Nemerow and Dasgupta 1991). Unfortunately, the construction of new or additional lagoons is not always possible due to the lack and/or high cost of land. If land is not available for additional lagoons, processing facilities which experience an increase in loading rates may have to upgrade to a more efficient system with a lower hydraulic retention time (HRT). Traditional aerated lagoons are operated without solids recycling and adequate clarification. Their use is limited to a simple reduction in the biochemical oxygen demand (BOD). To achieve a reduction in suspended solids, many aerobic lagoons now resort to solids recycling and employ a settling unit such as a clarifier (Metcalf and Eddy, Inc. 1991) which, in effect, increases the mean cell residence time (MCRT) within the system. For this reason, an aerated lagoon is designed following many of the principles for activated sludge systems. However, the addition of a clarification unit and sludge recycling can be expensive and may not be viable for many smaller food processing facilities. An inexpensive option is to operate an aerated lagoon as an aerobic sequencing batch reactor (SBR), whereby the need for a separate clarifier and solids recycle is eliminated.

The SBR process is a batch system which operates on a fill and draw mode of operation utilizing one or more reactors. The typical SBR system operates in five discrete stages: fill, react, settle, draw, and idle (Irvine et al. 1983). To control the concentration of biomass within the reactor, sludge wasting is usually accomplished during the idle stage.

The primary objective of this study was to assess the feasibility of operating aerated lagoons as aerobic sequencing batch reactors (SBR) for the treatment of egg processing wastewater using lab-scale reactors. A secondary objective was to determine the optimum operating conditions for the SBR treatment system.

MATERIALS AND METHODS

Basis of design

At an egg processing plant in British Columbia, the wastewater is presently being treated in two aerated lagoons arranged in series. The volumes of the first and second lagoons are 246 and 364 m^3, respectively, with depths of 1.8 to 2 m. The HRTs are 4.5 and 6.7 days, respectively, with an average influent flow rate of 55 m^3/d. As the flow through the system is continuous, the flow rate varies according to the water usage within the plant. The wastewater is aerated in three small equalization tanks prior to entering the first lagoon. Aeration in the first and second lagoons are supplied by a 3.7 kW and a 7.5 kW surface aerator, respectively. While these two aerators were assumed adequate for aeration, the dissolved oxygen (DO) levels in both lagoons were consistently below 0.5 mg/L in the first lagoon and 1.0 mg/L in the second lagoon. After treatment, the effluent is used to irrigate adja-

cent fields.

As the company plans on expanding to include an egg grading facility, the treatment efficiency of the two lagoons must be improved in order to handle an increase in loading rates. The projected increase in the influent flow rate to a total of 73 m^3/d would decrease the HRT to 3.4 days in the first lagoon and 5 days in the second. The increase in the flow rate would also result in higher loading rates on the adjacent fields. Therefore, two parallel lab-scale SBR systems were constructed and operated to determine if the efficiency of the aerated lagoons could be improved by upgrading to an SBR system using an anticipated HRT of 8 days.

Lab-scale SBR experiments

Lab-scale wastewater treatment runs were conducted in two parallel systems, each consisting of two identical reactors connected in series. The reactor vessels were made of acrylic plastic and each has a working volume of 4 L. Raw wastewater was collected from the egg processing plant on several occasions during the study. To ensure consistency in the quality of the raw wastewater gathered on different days, collection was done only on days when plant production was at approximately the same level. The entire SBR system was setup and operated in the laboratory where the ambient temperature was steady at 20 ∫ 1°C. Prior to feeding into the SBR system, the wastewater was stored in a cold room at 4°C in 80 L plastic pails. During treatment runs, the pail supplying wastewater to the SBR system was likewise immersed in a cooling water bath maintained at 4°C (Fig. 1) to prevent biodegradation in the pail. The addition of wastewater and withdrawal of effluent were done by means of peristaltic pumps (Masterflex®, Barrington, IL) with programmable controllers (Cole-Parmer, Chicago, IL). The system was automated with the use of solenoid valves and timers to deliver and extract a predetermined volume at regular intervals. Air was supplied through a diffuser placed on the bottom of each reactor and regulated with a flowmeter (Matheson, Edmonton, AB). Dissolved oxygen was monitored using a DO meter (YSI) connected to an ECD automatic digital data recorder. The pH was monitored using a pH meter (Corning, Corning, NY).

To maintain an aerobic environment and to establish the minimum aeration requirement, air supply to the diffusers was gradually increased from 0.2 to 1.5 L/min until DO levels in both reactors in each system were maintained over 1 mg/L.

To duplicate the expected conditions in the lagoons, the total HRT for the systems was set at 8 days which translated to an HRT of 4 days for each reactor. The MCRT was varied from 5 to 10 to 20 days per reactor. The specific 24 hour sequence of operations to achieve a 4 d FRT and a 20 d MCRT in each reactor is presented in Table I. With two reactors in series, the tabulated operation resulted in a total HRT of 8 d and a total MCRT of 40 d for each system. To achieve a 10 d MCRT for each reactor, 400 mL of the mixed-liquor were withdrawn while aeration was on and 600 mL of the supernatant were withdrawn after settling. To further reduce the MCRT to 5 d for each reactor, 800 mL were withdrawn while aeration was on and 200 mL were withdrawn after settling.

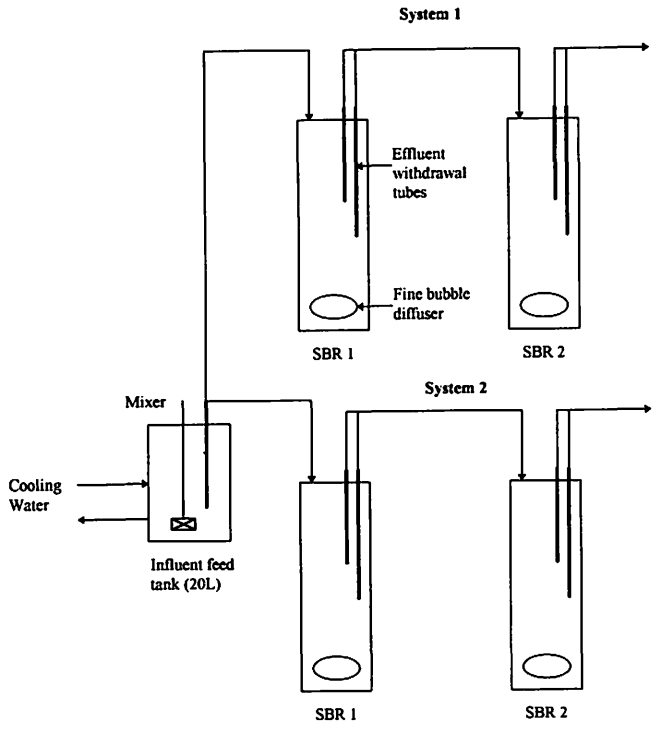

Fig. 1. Process flow for the lab-scale 4L sequencing batch reactor system.

Table I: Sequence of operations for a 4 day HRT and a 20 day MCRT in each reactor

Duration	Reactor 1		Reactor 2		Air
(min)	Operation	Volume (mL)	Operation	Volume (mL)	
10	Fill	1000			On
1355	React				On
5			Draw**	200	On
25			Settle		Off
5			Draw	800	Off
5	Draw*	200	Fill	200	On
30	Settle				Off
5	Draw	800	Fill	800	Off

* Volume drawn from Reactor 1 is transferred to Reactor 2.

** Volume drawn from Reactor 2 is discharged out of the system.

To determine the effects of cleaning chemicals on the DO levels in the first lagoon, a number of batch runs were monitored for DO levels after chemical additions. Table II lists the sanitary chemicals and concentrations used on a daily basis at the plant and which were therefore used in the experimental runs. The aeration rate was set at 1.0 L/min. Inasmuch as the chemicals added at the plant go through a number of reactions (e.g. oxidation) before reaching the lagoons, the

Table II: Sanitary chemicals used in the egg processing plant

1. Sodium hypochlorite (10-20%) at 0.15 mL/L
2. Bolt-569 caustic alkaline cleaner at 0.1 mL/L
   active ingredients:
   sodium hydroxide (10%)
   sodium dodecylbenzene sulfonate (3%)
3. D-Foam 477 silicone defoamer at 0.06 mL/L
4. Interest chlorinated cleaner at 0.01 mL/L
   active ingredients:
   potassium hydroxide (20-25%)
   alkaline phosphate (10-15%)
   sodium silicate (5-10%)
   available chlorine (3%)
5. Ova-Clean 589 alkali cleaner at 0.18 g/L
   active ingredient:
   sodium dichloroisocyanurate (2%)
6. Procid-573 acid cleaner at 0.04 mL/L
   active ingredients:
   phosphoric acid (35%)
   nitric acid (15%)
7. Solo-578 or Ovaclean alkali cleaners at 0.18 g/L
   active ingredients:
   soduim dodecylbenzene sulfonate (5%)
   sodium dichloroisocyanurate (2%)
8. Sting caustic-alkali cleaner at 0.2 g/L
   active ingredient:
   sodium hydroxide (80%)

concentrations used in the lab-scale reactors represented the extreme case (i.e. maximum concentrations). To measure the individual effect of each cleaning chemical on the DO level, separate batch runs were conducted using different combinations of distilled water, a simulated wastewater devoid of chemicals, and each one of the eight identified cleaning chemicals. The simulated wastewater was made using either whole eggs, yolks, or whites and diluted with distilled water. As the influent wastewater has a total solids level of 0.5%, the simulated wastewater was diluted to this concentration. Each run of the reactor was monitored for dissolved oxygen and biomass activity. Biomass activity was determined by determining colony forming units (CFU) on plate count agar.

Chemical analysis

Total solids (TS), total suspended solids (TSS), biochemical oxygen demand (BOD), and chemical oxygen demand (COD) were determined in accordance with the Standard Methods (APHA 1995). All BOD values presented were the results of 5-day BOD tests at 20°C. The COD tests were conducted using the closed reflux, colorimetric method (APHA 1995). Total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3-N), and ortho-phosphate levels were determined using an Auto-Analyzer (Technicon®) according to the Kjeldahl method, the phenate method, and the ascorbic acid method, respectively (APHA 1995).

Microbial identification

Viable aerobic plate counts were obtained using procedures described in Standard Methods (APHA 1995). Additional

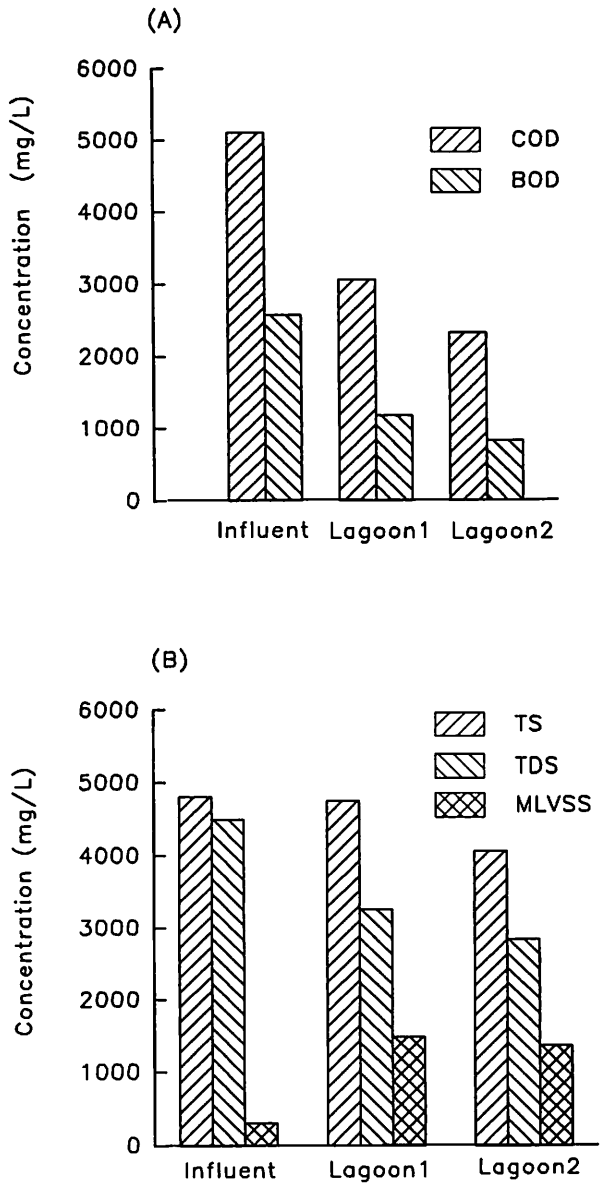

Fig. 2. Reductions in (A) BOD, COD, and (B) solids in egg processing wastewater treated by an aerated lagoon system.

aerobic plate counts were completed on R2A medium described by Reasoner and Geldreich (1985). Plates using the R2A medium were incubated at 28°C for 5 to 7 days. All plates and media were autoclaved at 121°C for 15 minutes.

Most probable number (MPN) tests were carried out to the completed stage using the multiple tube fermentation technique and fecal coliforms were identified using Standard Methods (APHA 1995). Fecal coliforms were isolated using EC medium and were incubated at 44.5°C for 24 h. All coliforms selected through the completed stage of the MPN tests were further identified to the genus level according to Bergeys Manual of Determinative Bacteriology (Buchanan and Gibbons 1975) and the Manual of Clinical Microbiology (Lennette et al. 1985).

Salmonella sp. were isolated using the methods described by Parry et al. (1982). *Salmonella* were concentrated in pep-

tone water, enriched in tetrathionate broth, and selected on *Salmonella-Shigella* agar and TSI agar. All positive TSI agar slopes were subjected to serological testing identifying the *O*, *Vi*, and *H* antigens.

RESULTS AND DISCUSSION

Waste characterization

Wastewater obtained from the egg processing facility was analyzed for pH, BOD, COD, solids, settleability, nitrogen, and phosphorus. The pH varied from 8.93 in the influent to 7.34 in the first aerated lagoon. Figure 2A illustrates the COD and BOD of the wastewater as it proceeded through the aerated lagoon system. The influent had a COD and BOD of 5105 mg/L and 2572 mg/L, respectively. After an approximate HRT of 4.5 d in lagoon 1, the COD was reduced by 40% while the BOD was reduced by 54%. An additional 6.7 d HRT in lagoon 2 resulted in a total reduction of COD and BOD of 55% and 68%, respectively. As aerobic lagoons are usually designed for BOD removals of 80-95%, the present removal rate of only 68% through the two lagoons was not deemed adequate. In this case, food to microorganism ratios (F/M = kg BOD applied/kg mixed liquor volatile suspended solids (MLVSS) x d) for COD and BOD were 0.53 and 0.27 d^{-1} for lagoon 1 and 0.55 and 0.21 d^{-1} for lagoon 2, respectively. Usual F/M ratios for BOD range from 0.2 to 0.6 d^{-1}(Metcalf and Eddy, Inc. 1991) for completely mixed activated sludge systems. Figure 2B shows the reductions in total and suspended solids. The TS decreased by only 15% and the MLVSS actually increased from 312 mg/L to 1372 mg/L in the first lagoon and to 1222 mg/L in the second lagoon. The increase in MLVSS was most likely the result of the increase in microbial biomass. Typical activated sludge systems contain biomass in the region of 1500 to 5000 mg/L. Settling tests were conducted on the influent and the effluents of the aerated lagoons and the interface settling curves are presented in Fig. 3. The calculated settling velocity of solids for the effluent was 1.04 m/h (Metcalf and Eddy, Inc. 1991).

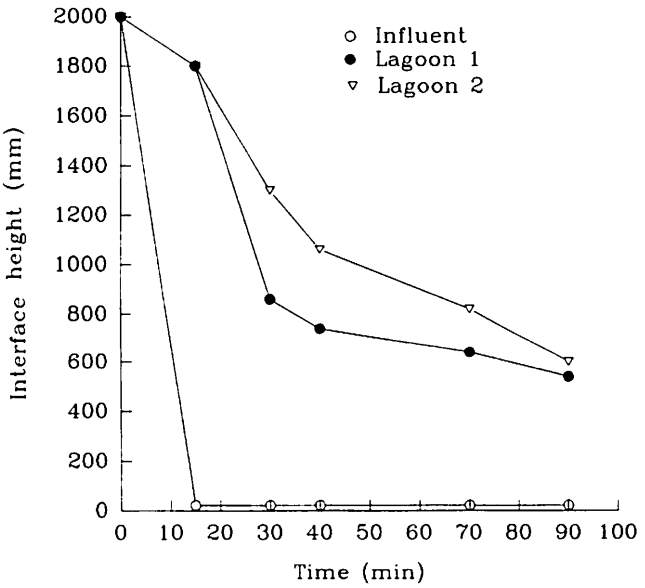

Fig. 3. Interface settling curves for egg processing wastewater in the aerobic lagoons.

Branion (1992) reported that solids with good settling characteristics had settling velocities ranging from 1.52 to 7.62 m/h. TKN decreased from 170 mg/L to 100 mg/L while ammonia nitrogen increased from 6 mg/L to 119 mg/L (Fig. 4). The increase in ammonia nitrogen was most likely the result of the mineralization of organic nitrogen to ammonia nitrogen. Figure 4 also shows that the concentration of orthophosphate was reduced by 54% from 41 mg/L to 19 mg/L. While total nitrogen levels above 85 mg/L, ammonia levels above 50 mg/L, and organic phosphorus concentrations above 5 mg/L are considered "strong" for wastewater (Metcalf and Eddy, Inc. 1991), but these levels are not too high if the wastewater is to be further treated through land treatment.

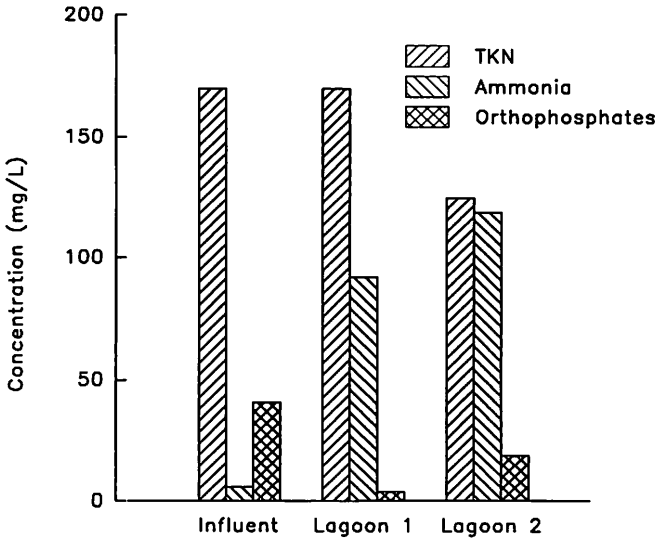

Fig. 4. TKN, ammonia, and orthophosphate values for egg processing wastewater treated by aerated lagoons.

Oxygen requirements

In an attempt to achieve satisfactory DO levels in both lagoons, various aeration rates were studied with the lab-scale reactors. At an aeration rate of 0.2 L/min for both reactors (Fig. 5A), the DO levels remained at 0 mg/L over the 24 h test. When the aeration rate was increased to 0.6 L/min, the DO level did not improve in the first reactor but increased to 4 to 6 mg/L in the second reactor (Fig. 5B). When the aeration rate was raised to 1.0 L/min in the first reactor and decreased to 0.5 L/min in the second reactor, the DO level in the first reactor increased to 2 mg/L and fluctuated between 1 and 4 mg/L in the second reactor (Fig. 6A). Since the DO level was still low in first reactor for the first 12 h of the run, the aeration rate was further increased. An increase to 1.5 L/min brought the DO level in the first reactor to 1 and 4 mg/L (Fig. 6B). The efficiency of the treatment runs was also evaluated through BOD and COD. At an aeration rate of 1.5 L/min for reactor 1 and 0.5 L/min for reactor 2, final reductions of 99% BOD and 88% COD were reached (Table III). Solids reduction was less efficient with a 10% and a 65% reduction in TS and TSS, respectively, when the aeration rate in reactor 1 was

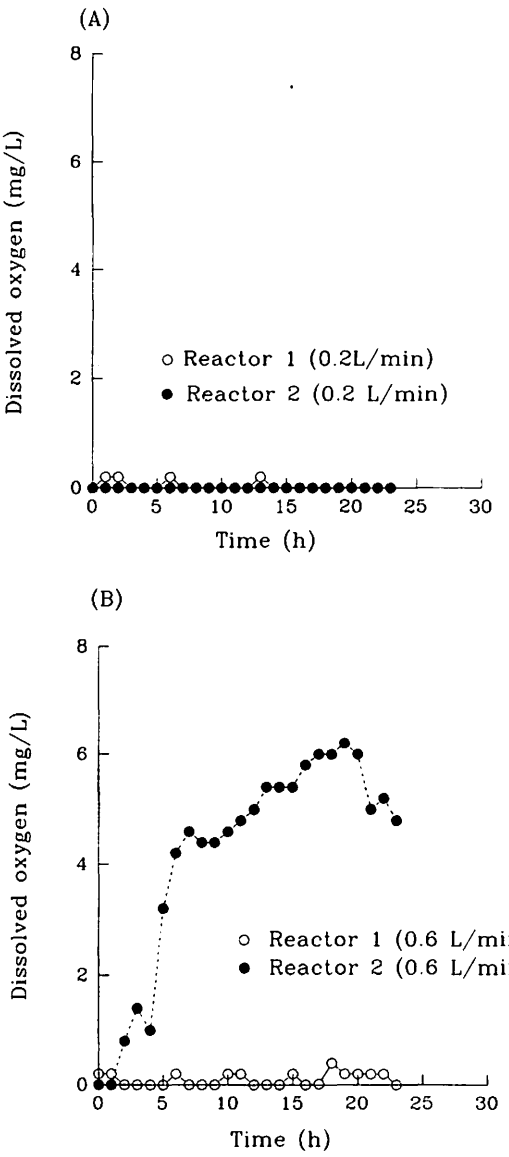

Fig. 5. Dissolved oxygen levels of egg processing wastewater at aeration rates (A) 0.2 L/min and (B) 0.6 L/min for both reactors 1 and 2.

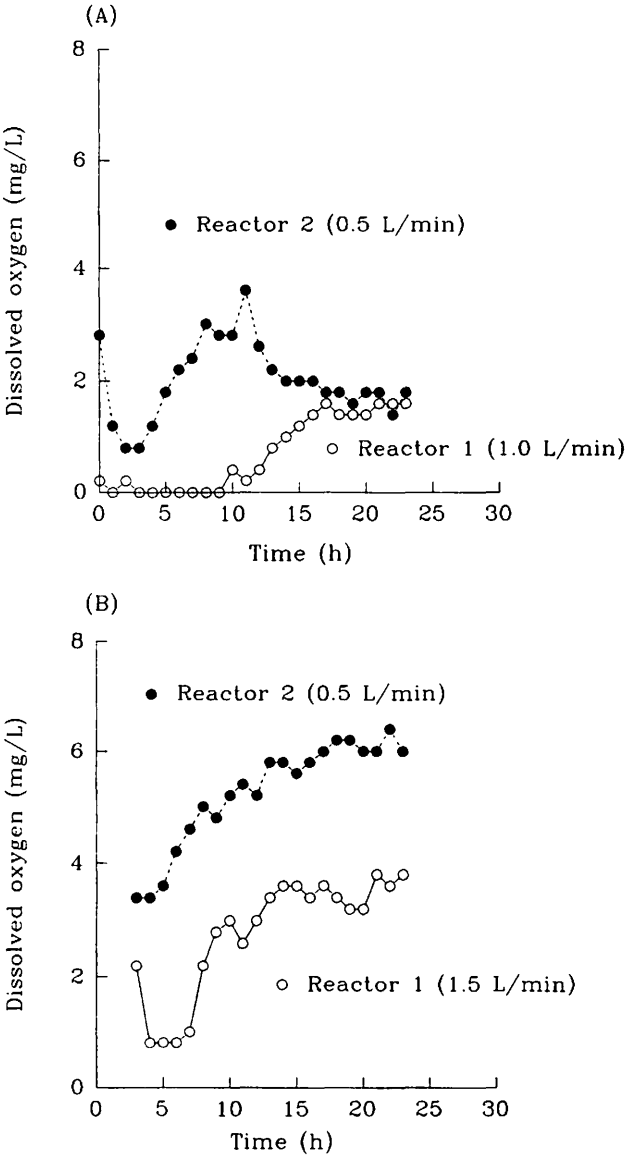

Fig. 6. Dissolved oxygen levels of egg processing wastewater at aeration rates of (A) 1.0 and 0.5 L/min and (B) 1.5 and 0.5 L/min for both reactors 1 and 2, respectively.

1.0 L/min. Due to the nature of the egg processing wastewater (Fig. 2B) where 95% of its TS was dissolved (TDS), a 65% reduction in TSS resulted in only 10% reduction in TS.

While the oxygen requirements can be determined through aeration studies, the requirements can also be expressed by (Balasha and Sperber 1974):

$$OUR = a' S_r Q + b' X V \quad (1)$$

where:

- OUR = oxygen uptake rate in system (g O_2 /d),
- a' = oxygen consumed per unit substrate removed (g O2 /g substrate),
- b' = endogenous rate coefficient (d^{-1}),
- S_r = influent BOD - effluent BOD (mg/L),
- X = MLVSS (mg/L),
- V = volume of aerated basin (m^3), and
- Q = volumetric flow rate (m^3/d).

Using the results of the runs employing aeration rates of 1.5 L/min (Table IV), the plot of OUR/XV versus S_r/X HRT, gave values of a' = 0.68 g O_2/g BOD removed and b' = 0.32 d^{-1} (Fig. 7). This information can be used as a guide for the full-scale operation. However, close monitoring of the actual DO levels in the full-scale reactors would be needed to ensure adequate oxygen transfer.

Mean cell residence time

To increase the efficiency of the biological treatment, biomass solids recycling was incorporated into the lab scale system. With aeration rates maintained at 1.5 and 0.5L/min for reactors 1 and 2, respectively. MCRT increased from 5 to 10 and to 20 days resulted in higher DO levels. A MCRT of 20 days resulted in DO levels within the recommended range of 1 to 3 mg/L (Metcalf & Eddy, Inc. 1991). The settling

Table III: BOD and COD reductions for various aeration rates

Aeration rate (mg/L)	Reactor number	Percent reductions BOD	COD
0.45	Lagoon 1*	55	40
0.23	Lagoon 2*	68	55
0.2	1	57	40
0.2	2	75	59
1.0	1	96	73
0.5	2	98	86
1.5	1	95	77
0.5	2	99	88

* Lagoons 1 and 2 refer to the system located at the egg processing facility.

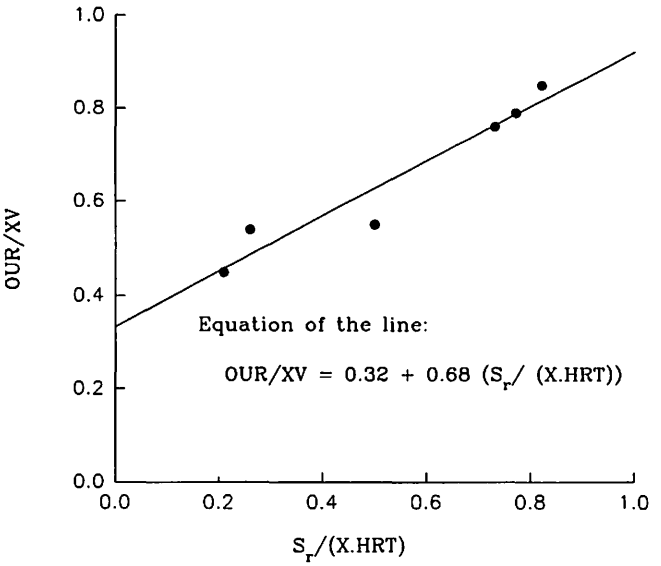

Fig. 7. Determination of the aeration coefficients a′ and b′.

velocity of the sludge improved from 0.5 m/h (5 d MCRT) to 2.0 m/h (10 d MCRT). By increasing the MCRT from 10 days to 20 days, there was little change in the settling velocity, suggesting that a MCRT of 15 days, would be sufficient for the reactors. Other operating parameters should be investigated to further improve the settling characteristics. To control the MCRT in a full-scale SBR, it would be advisable to withdraw sludge during the "idling" stage (after the "settling" stage) so that the amount of material withdrawn would be much less than if it were withdrawn during the "aeration" stage. A small liquid-solid separator may be needed to dewater the sludge withdrawn.

Cleaning chemicals and DO depletion

To determine the effects of cleaning chemicals on the DO levels in the first lagoon, a number of batch reactor runs were conducted to monitor the DO levels. Using the egg processing wastewater as the influent, the reactor was aerated at an airflow rate of 1.0 L/min over a 24 hour period (Figure 8A). The DO dropped from a high of 8.2 mg/L to 0 mg/L within the first 7 hours and stayed at 0 mg/L for the remainder of the testing period. Figure 8B exhibits the DO levels when simulated egg wastewater is combined with the cleaning chemicals. Without the presence of chemicals, the DO fell from approximately 8 mg/L to 6 mg/L over a 24 hour period. This consumption of oxygen is normal for wastewater actively undergoing microbial degradation. After 24 hours, the sanitary chemicals were added to the active digest. Within 14 hours, the DO dropped from approximately 6 mg/L to 0 mg/L and stayed at this level for the remainder of the monitored time. An aerobic plate count made on the wastewater revealed approximately 10 x 10^6 cells/ml, indicating that the sudden drop in DO could not be due to the microbes utilizing the substrate. Batch runs were also initiated using the cleaning chemicals in combination with distilled water. Figure 9A shows that the DO remained fairly constant over a 27 hour period. As the egg fraction must be present for a sudden drop in DO, wastewater mixtures were prepared which contained either egg whites or yolks plus chemicals (Figure 9B). It was found that the egg whites and yolks must both be present for a sudden drop in DO to occur. Further study is needed to offer an explanation of this phenomenon.

When reactors were run using each individual chemical, sodium hypochlorite, Ovaclean, Procid acid, D-Foam, and Bolt, there were sudden DO drops with most reductions occurring within 15 hours. The chemicals "Sting"and "Interest" resulted in no decreases in DO. To assure that proper DO levels could be maintained in the aerated lagoons, a recommendation was made to the egg processor to intercept the wastewater flow containing the chemicals and treat this portion of the wastewater separately in one of their three equalization tanks.

Table IV: Results of SBR runs using 1.5/min aeration

Parameter	Runs 1	2	3	4	5	6
X (mg/L MLVSS)	922	850	1315	965	1620	1340
S_r (mg/L BOD)	2862	2790	2195	2375	2692	2797
OUR/XV (d^{-1})	0.79	0.85	0.55	0.76	0.45	0.54
HRT (d)	4	4	4	4	8	8
S_r/X•HRT	0.77	0.82	0.50	0.73	0.21	0.26

Pathogens

As egg processing wastewater has the potential for supporting the growth of pathogenic microorganisms, the wastewater was analyzed for the presence of coliforms, fecal coliforms, and Salmonella. Multiple tube fermentation for the determination of coliforms resulted in an aver-

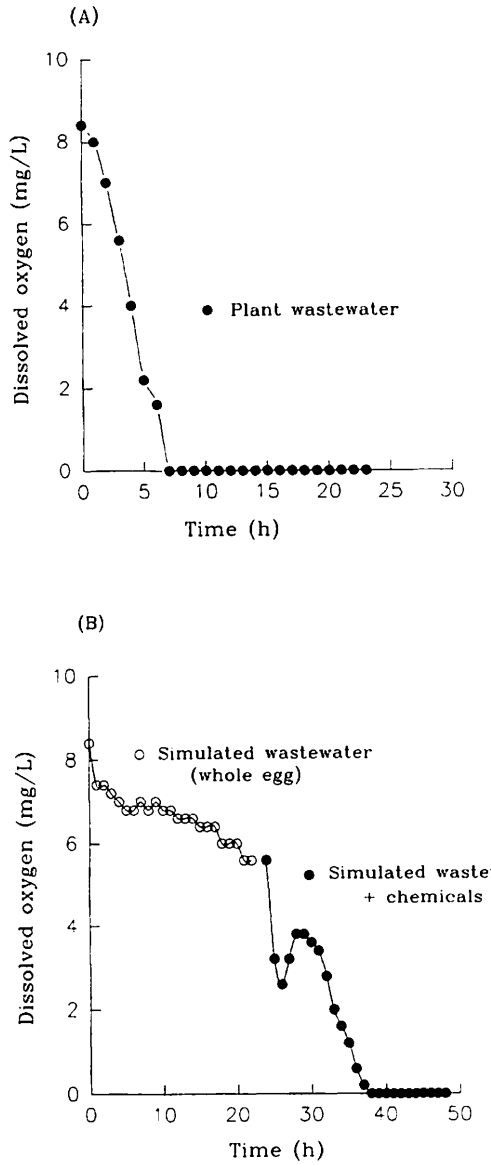

Fig. 8. Dissolved oxygen levels of (A) egg processing wastewater and (B) simulated egg processing wastewater and sanitary chemicals over time.

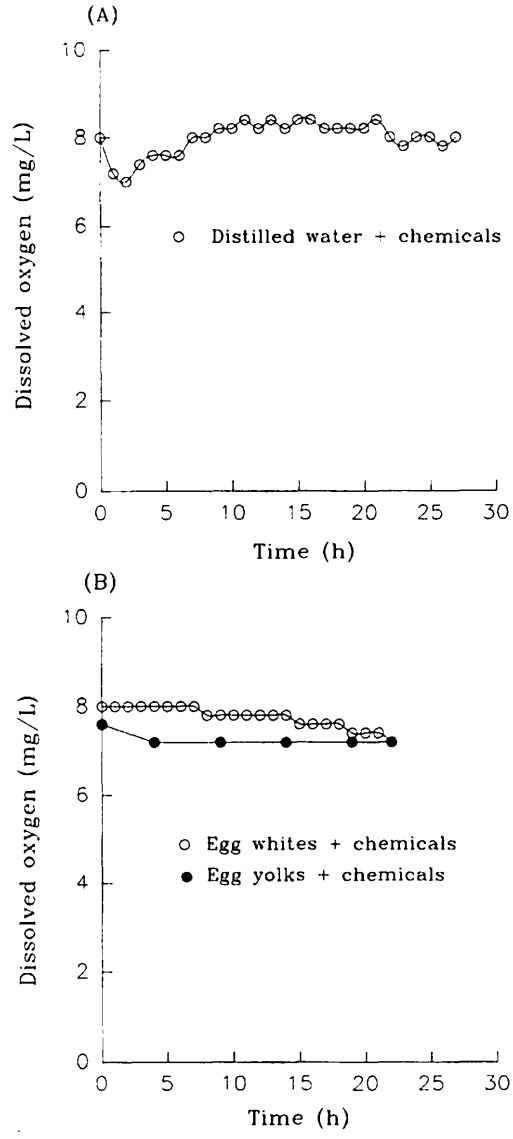

Fig. 9. Effects of sanitary chemicals on the dissolved oxygen levels of (A) distilled water and (B) different egg fractions.

age of 3500 MPN/100 mL for the influent and an average of 80 MPN/100 mL for the effluent from the SBRs. Fecal coliforms and *Salmonella* were not detected in any of the samples. Confirmed coliforms, later isolated on nutrient agar slants, were identified on the basis of colony morphology, microscopic morphology, biochemical tests, and growth on selected media. Two distinct bacteria were isolated in the influent and effluent. The first isolate resulted in typical orange colonies of approximately 3 mm in length. The second isolate resulted in typical colonies of white color with diameters ranging from 1 to 2 mm. Additional testing using differential procedures identified the isolates as *Bacillus sp.* and *Micrococcus sp.* (Table V) which are common microorganisms found on egg shells (Frazier and Westhoff 1988). Some species of both genera have been known to cause minor skin infections (Lennette et al. 1985), though both have been traditionally minimized in clinical microbiology. Furthermore, as most egg processing facilities use their wastewater for irrigation, the likelihood of disease transmission by these coliforms is minimal. Testing for coliforms and the fecal coliforms would positively ascertain the bacterial safety of the effluent.

CONCLUSIONS

Treatment of egg processing wastewater in a lab-scale aerated SBR system, consisting of two reactors in series, resulted in very good removal rates of 99% in BOD, 88% in COD, and 65% in TSS. The quality of the effluent was deemed suitable for irrigation purposes.

Aeration rates of 1.5 and 0.5 L/min for the first and second lab-scale reactors, respectively, maintained DO levels between 1 and 4 mg/L in the first reactor and between 3 and 6 mg/L in the second reactor. The coefficients a and b were determined to be 0.68 g O_2/g BOD and 0.32 d^{-1}, respectively.

Table V: Determination of bacterial isolates

Recognition factor	Isolate 1	Isolate 2
Gram reaction	+	+
Size (μm)	3.0	1.0 - 2.0
Shape	bacilli	cocci
Orientation	singular, chains	pairs, tetrads, clusters
Spore stain	+	-
Catalase reaction	+	+
Motility	-	-
Growth on plate count agar	orange-pink	white-yellow
Growth on MacConkey agar	-	-
Growth at 45°C	orange-pink	-

Under these same aeration rates and at a reactor MCRT of 20 days, the lab-scale SBR system was able to maintained DO levels between 1 and 3 mg/L and a sludge with good settling characteristics.

Many of the sanitary chemicals used in the egg processing facility reduced the DO in the lagoons thereby causing anaerobic conditions. By reducing or eliminating these chemicals in the influent stream, higher DO levels may be maintained throughout the treatment process.

Coliform count was reduced from an average of 3500 MPN/100 mL in the influent to 80 MPN/100 mL in the effluent. Further differential testing of confirmed coliforms indicated the presence of *Bacillus sp.* and *Micrococcus sp.* *Salmonella* and fecal coliforms were not detected in either the influent or effluent.

ACKNOWLEDGEMENT

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