Environment Protection Engineering

Vol. 5 1979 No. 3

W. K. WHITEHEAD*

STUDIES ON ACTIVATED SLUDGE TREATMENT OF POULTRY PROCESSING WASTEWATER

Laboratory- and pilot-scale studies with activated sludge treatment of poultry processing wastewater showed that over 90% of the pollutants can be removed with the conventional process. Over 50% of the BOD_5 and suspended solids and 75% of the oil and grease can be removed at hydraulic detention times as short as 2 hours.

1. INTRODUCTION

Poultry processing wastewater, which may average 4.5 dm^3/bird in a typical plant [2] is difficult to treat and dispose off. The BOD_5 discharges have been reported to be as high as 9.9 kg/Mg live weight killed (LWK) [6].

The proposed performance standards for discharge into streams in the United States [3] would eventually limit discharges to 0.30 kg BOD_5/Mg of LWK, 0.34 kg total suspended solids (TSS) /Mg of LWK, 0.20 kg oil and grease/Mg of LWK and 4.0 mg NH_3/dm^3 of effluent. These levels are not impossible to attain, but are not met consistently by many poultry processing waste treatment systems.

Maximum permissible waste concentrations of 300 mg BOD_5/dm^3, 300 mg SS/dm^3 and oil and grease 200 mg/dm^3 are common when effluents are discharged to city sewerage in many municipalities. When the wastewater concentrations exceed those levels, processors are required to pay a surcharge on the excess. The surcharge is important because city waste treatment systems probably will be pressured to improve their effluent and will pass this cost on to the processor by increasing the surcharge rate.

Since its conception, the activated sludge process has been widely used for treatment of both municipal and industrial wastewaters. Various modifications of the process have been developed, but all have basic common principles. The conventional activated sludge process can remove 95% of the BOD_5 and suspended solids [4]; and although the process produces solids that must be disposed of, it is very stable and reliable. The greatest advan-

* Research Agricultural Engineer, Environmental Engineering Laboratory USDA, SEA-AR P.O. Box 5677 Athens, Georgia 30604, USA.

tage of the process as compared to lagoon or land application systems is the small land area required. About 65% of the federally inspected poultry processing plants in the United States discharge waste into a municipal treatment system [7]. The remaining 35% that do not have access to municipal sewers must have an efficient, private waste-treatment system to meet the discharge standards.

Tests were conducted for over 2 years with laboratory and pilot-scale systems to determine the applicability of activated sludge for treating poultry processing wastewater.

2. LABORATORY STUDIES

2.1. CONVENTIONAL TREATMENT

A laboratory-scale activated sludge unit consisting of a reactor and a solids-liquid separator (fig. 1) was constructed of clear plastic. Volume of the reactor (20.3 cm I.D. by 35.6 cm deep) was 7 dm^3. Compressed air was supplied to the reactor through a 7-mm-I.D. plastic tube with holes on 13-mm centers. Air flow was controlled by a pressure regulator to provide enough oxygen to the reactor to maintain a minimum dissolved oxygen concentration of 1 to 2 mg/dm^3. A mechanical stirrer provided agitation. The solids-liquid separator had a 30.5 cm by 30.5 cm top opening, a 32 mm by 32 mm bottom and its liquid volume was 17 dm^3. The bottom was fitted with a plastic tubing that served as the solids recycle line, and the clarified effluent flowed from the separator into a collection tank. The system was located in a room kept at 21°C (294 K).

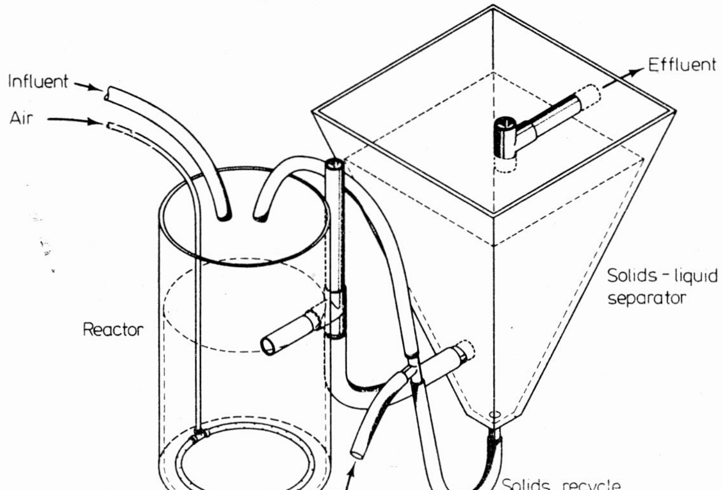

Fig. 1. Laboratory-scale conventional activated sludge unit

Rys. 1. Konwencjonalne urządzenie do oczyszczania osadem czynnym w skali laboratoryjnej

Raw wastewater, obtained twice a week from a local commercial processing plant was sampled (table 1), analyzed [1] and stored at 2–3°C until ready for use. The wastewater was pumped continuously into the reactor with a variable-speed, peristaltic pump at 28 dm³/day from glass bottles maintained at 2–3°C by a refrigerated-water bath.

Table 1

Sampling schedule for laboratory-scale study of conventional activated sludge
Schemat poboru prób z laboratoryjnych konwencjonalnych komór osadu czynnego

Parameter	Schedule		
	Influent	Effluent	Reactor Mixed Liquor
COD[1]	2/week	M, W, F	
Suspended Solids[2] — SS	2/week	M, W, F	M, W, F
Oil and grease	2/week	W	
Total (Kjeldahl) Nitrogen — TKN	2/week	W	
Ammonia Nitrogen — NH_3	2/week	W	
Phosphorous — P	2/week	W	
pH	2/week		M, T, W, Th, F
Dissolved Oxygen — DO	2/week		M, T, W, Th, F
Temperature	2/week		M, T, W, Th, F

1) Effluent COD was determined on filtrated samples.
2) Both total and volatile determinations were made.
Note: M, T, W, Th, F, stand for days of the week.

On initial start-up, 20 dm³ of activated sludge from a municipal activated sludge plant was used to seed the reactor. The laboratory system was operated at low hydraulic flow rate (6–10 dm³/d) for several days during which the sludge and the poultry processing wastewater were acclimated. The feed rate, Q, was then increased to 28 dm³/d. This rate gave a hydraulic detention time, θ_H, in the reactor of 6 h and was maintained throughout the remainder of the study. The recycle rate, Q_R, was not controlled but normally was not controlled but normally was greater than 3 Q.

The sludge age (θ_S), or the mean solids residence time was the variable and was controlled by daily wasting solids from the mixed liquor in the reactor. Sludge age, which is best determined by correcting for the mass of organisms that are unintentionally wasted each day with the effluent, is given by

$$\theta_S = \frac{VX}{Q_W X + (Q - Q_W) X_E} \tag{1}$$

where:

V — volume of the reactor;

X — organism concentration in the reactor expressed as mixed liquor volatile suspended solids (MLVSS), mg/dm³;

Q_W — amount of sludge wasted daily from the reactor;
Q — hydraulic flow rate,
X_E — effluent volatile suspended solids (VSS), mg/dm^3 [4].

Sludge age was controlled by wasting solids from the reactor at the rates 1.0 V, 0.5 V, 0.29 V, 0.14 V, 0.10 V and 0.07 V per day. Actual sludge age was calculated by use of eq. (1).

Performance of the system was determined by analysis of the mixed liquor and the effluent (table 1) [1]. Because effluent COD was determined on filtered samples, reported COD values are based on the soluble material in the wastewater. Settling characteristics of the sludge in the solids-liquid separator were noted after the system had reached steady state.

Only data for the system at steady-state were analyzed. The system was operated for a time period at least three times the set sludge age before any steady-state data were taken, and was considered to be at steady-state when the concentration of the MLVSS (mixed liquor volatile suspended solids) and the calculated sludge age were relatively constant from day to day. Uniformity in the settling rate of the sludge in the solids-liquid separator was also a good indicator of steady-state operation. After reaching steady-state, the system was operated 3–4 weeks at each sludge age.

Data for the system at each sludge age, θ_S, are given in table 2. Soluble COD of the effluent was not dependent on θ_S, and the reductions in COD averaged 93% for all values of θ_S (fig. 2). However, suspended in the effluent increased with θ_S. When the observed sludge settling characteristics were optimum, θ_S of 2 to 3.5 days, the suspended solids concentration was only about 50% greater than the concentration at θ_S of 1 day and about

Table 2

Summary[1] of data for the laboratory-scale conventional activated sludge system at steady state
Kompilacje wyników pracy konwencjonalnej laboratoryjnej komory osadu czynnego w warunkach ustalonych

Daily solids wasting rate	θ_S d	MLVSS mg/dm^3	COD Inf.[2] mg/dm^3	COD Eff.[3] mg/dm^3	SS Inf. mg/dm^3	SS Eff. mg/dm^3	Oil and grease Inf. mg/dm^3	Oil and grease Eff. mg/dm^3	TKN Inf. mg/dm^3	TKN Eff. mg/dm^3
1 V[4]	0.98	1208	1126	68	355	8	174	5	75	7
0.5 V	1.93	2248	1097	119	320	17	178	5	73	10
0.29 V	3.26	2306	905	39	297	15	246	5	82	7
0.14 V	5.91	3120	1216	76	292	26	80	23	89	3
0.10 V	8.11	4687	1582	116	438	30	154	6	94	2
0.07 V	8.25	2271	983	65	248	31	109	13	86	30

1 Effluent COD and SS and MLVSS values are averages of 9–12 samples. All influent values are averages of 6–8 samples. Effluent oil grease and TKN values are averages of 3–4 samples.
2 Influent concentration.
3 Effluent concentration.
4 V is the volume of the reactor.

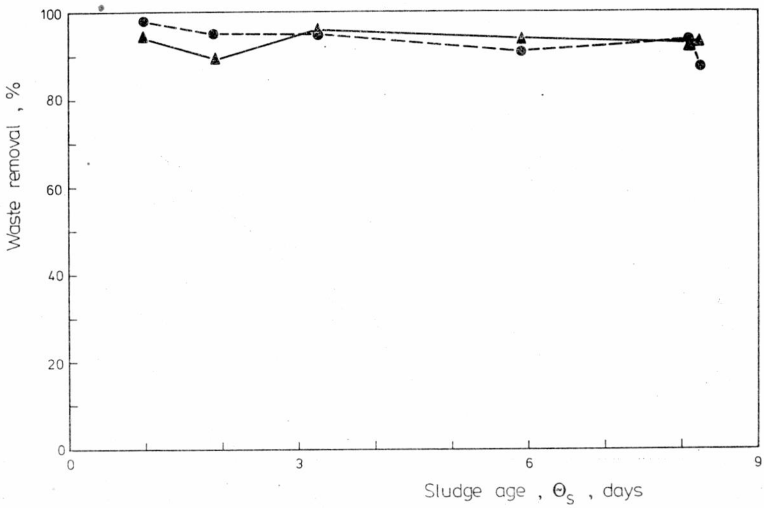

Fig. 2. Percent removal of COD and suspended solids (TSS) as a function of sludge age (θ_S) for the conventional treatment laboratory-scale study

Rys. 2. Procentowe usuwanie ChZt i zawiesin w zależności od wieku osadu (θ_S) dla badania konwencjonalnego oczyszczania w skali laboratoryjnej

95% of the suspended solids were removed. Thus, soluble COD and suspended solids data for the effluent showed little difference in the performance of the system with change in θ_S.

The efficiency of oil and grease removal was more variable than the reductions in COD or suspended solids, but the activated sludge system effectively degraded the oil and grease in the wastewater. The data indicated that for four of the six sludge ages, than 96% of the oil and grease were removed.

The concentration of the biomass in the reactor ranged from 1208 to 4687 mg MLVSS/ /dm^3 and generally increased with sludge age. The pH of the mixed liquor varied from 6.0 to 6.3. The average concentrations of dissolved oxygen in the reactor and mixed liquor temperatures varied but were not dependent on θ_S.

The activated sludge process removed from 65 to 98% of the total nitrogen (TKN) in the wastewater. In general, the TKN concentration in the effluent decreased as biomass concentration in the reactor and sludge age increased. The phosphorous concentration ranged from 0.9 to 4.6 mg P/dm^3 and 4687 mg MLVSS/dm^3, respectively, and increased with sludge age. On the basis of overall performance and θ_S for optimum sludge settling characteristics, 2–3.5 days, the activated sludge system could be expected to reduce total nitrogen concentration about 90% and phosphorous concentration about 50 to 60%.

The kinetic coefficients of the activated sludge system were determined, and trial-and-error solutions for the Monod equation [4] showed that the specific growth rate of the biomass, $\hat{\mu}$, was between 1.5 and 2.0 d^{-1} and K_S, the COD saturation coefficient, between 20 and 24 mg O_2/dm^3. However, the specific substrate removal rate, U, was essentially independent of substrate COD concentration and is best expressed as a constant

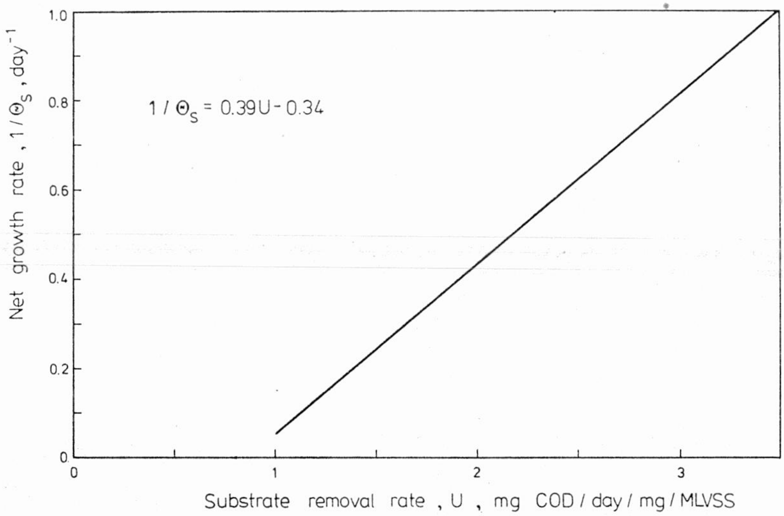

Fig. 3. Relationship between sludge age (θ_S) and substrate (COD) removal rate (U) for the conventional treatment laboratory-scale study

Rys. 3. Związek pomiędzy wiekiem osadu (θ_S) i położeniem (ChZT), szybkością usuwania (U) dla badania oczyszczania konwencjonalnego w skali laboratoryjnej

value of 1.5 mg COD/d/mg MLVSS for all θ_S. This indicates that the activated sludge system could daily reduce soluble COD by 1.5 g/g of MLVSS in the reactor. At θ_S of 3.26 days, the system could daily reduce COD by about 3.5 g/dm^3 of reactor volume.

A regression analysis on the growth rate, $1/\theta_S$, plotted against the specific substrate removal rate, U, (fig. 3) showed that the yield was 0.39 mg VSS/mg COD removed and the specific organism decay rate, k_d, was 0.34 d^{-1}. Based on this analysis, the specific organism decay rate was about one-fifth of the specific growth rate.

2.2. INTERMITTENT HIGH HYDRAULIC FLOW RATE

A second laboratory-scale study was conducted to determine the effects of intermittent high hydraulic flow rates on the performance of an activated sludge system. The laboratory--scale equipment (fig. 4) consisted of three reactors, a solids-liquid separator and a recycle pump. The reactors were clear platic, 5-dm^3 containers (203 mm I.D. by 203 mm deep). Compressed air was supplied to each reactor through a porous stone and a mechanical stirrer was used for agitation. A solids-liquid separator as used in the previous study was modified to hold 4.5 dm^3. Recycled sludge was pumped to the first reactor at a controlled rate, usually equal to the hydraulic flow rate, by a peristaltic pump.

Tests were conducted at hydraulic detention times, θ_H, of 9, 6, 3, 1, and 0.5 h. The θ_H was controlled by varying the reactor volume and hydraulic flowrate. Total reactor volume was held at 15 dm^3 at flow rates of 5, 2.5 and 1.67 dm^3/h for the 3, 6 and 9 h de-

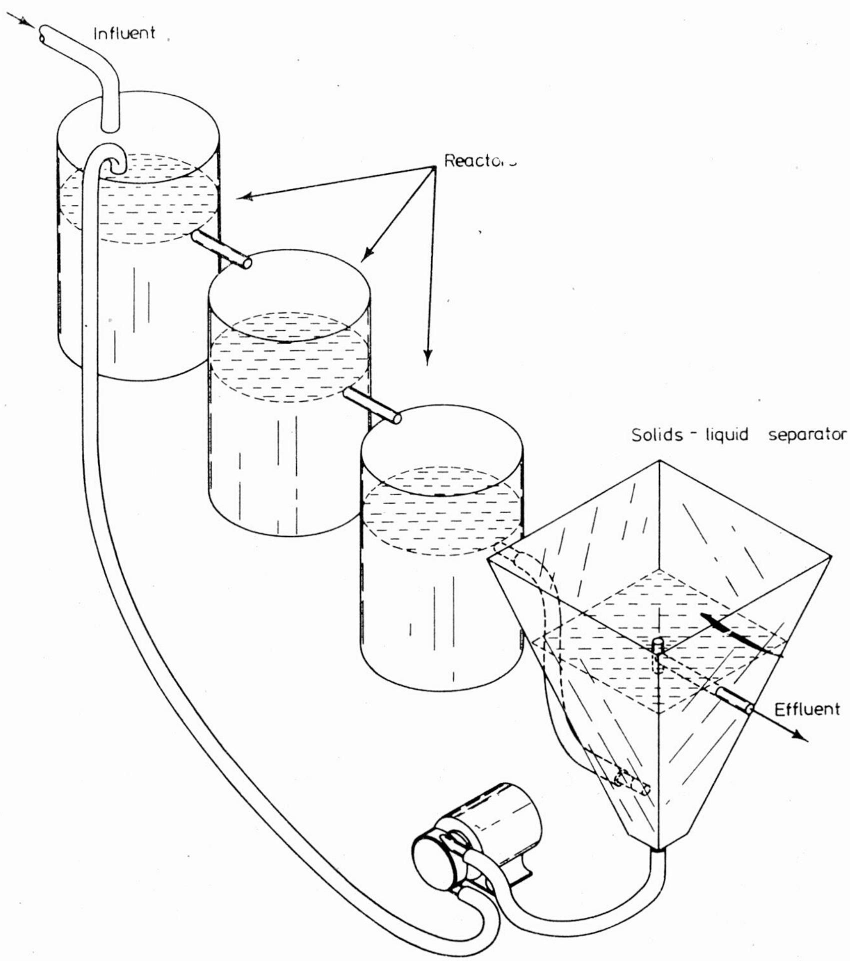

Fig. 4. Laboratory-scale intermittent high hydraulic flow rate activated sludge unit

Rys. 4. Urządzenie dla oczyszczania osadem czynnym przy przemysłowym wysokim tempie przepływu hydraulicznego w skali laboratoryjnej

tention times, respectively. Flowrates were 10 and 5 dm^3/h, respectively, for θ_H of 0.5 and 1 h with a reactor volume of 5 dm^3. The volume of the solids-liquid separator remained constant for all tests.

Raw wastewater, collected as needed from a local poultry processing plant, was sampled and analyzed for COD, total suspended solids and oil and grease [1]. Wastewater not used the day of collection was stored at 2–3°C until used; chilled wastewater was held at room temperature for several hours before it was fed to the reactors. The wastewater was pumped into the reactors for 8–9 h/d from Monday through Friday. No wastewater was fed to the reactors on weekends to simulate normal processing plant operation.

On initial start-up, all three reactors were filled with activated sludge from the other operating laboratory-scale activated sludge unit. About 20 dm^3 of raw wastewater was added daily for about 5 days to acclimate the system.

The unit was operated for 3 weeks at each flow rate. Daily measurements were made of pH, dissolved oxygen and temperature of the mixed liquor in the reactors. Total and volatile suspended solids of the mixed liquor were determined three times a week. COD and TSS and VSS of the effluent were determined three times a week and oil and grease were measured once a week. COD was determined once a week on a filtered effluent sample.

Biomass concentration for the intermittent flow laboratory-scale activated sludge experiments ranged from 1689 mg MLVSS/dm^3 at θ_H of 9 h to 3931 mg MLVSS/dm^3 at θ_H of 1 h (table 3). The system effectively degraded the COD in the wastewater and 47% was removed at θ_H of 0.5 h and over 60% at θ_H of 1 h (fig. 5). The amount of COD in the effluent typically decreased as the θ_H increased.

Removal of suspended solids varied and was only about 20% at θ_H of 1 h and about 40% at 0.5 h. However, removal was 57% at θ_H of 3 h and increased to 90% at θ_H of 9 h.

The system degraded both COD and suspended solids equally at high θ_H, but removed much less of the suspended solids at the low θ_H, i.e. 3.1 and 0.5 h. In the effluent soluble COD was considerably less than total COD. Oil and grease concentration in the effluent was reduced by more than 90% at θ_H of 9, 6, and 3 h and by 74% and 69% at θ_H of 1 and 0.5 h; apparently the system effectively removed oil and grease at the high flowrates.

The COD remaining in the effluent increased linearly with the food-to-microorganism ratio (F/M) expressed as kg COD/d/kg MLVSS based on an 8-hour day. The F/M ratio increased from 0.61 for θ_H of 6 and 9 h to 5.42 kg COD/d/kg MLVSS for θ_H of 0.5 h.

Table 3

Summary[1] of data for the laboratory-scale activated sludge system with intermittent, high hydraulic flow rate

Kompilacja wyników w laboratoryjnej komorze osadu czynnego pracującej w warunkach nieciągłego wysokiego obciążenia hydraulicznego

Hydraulic detention time, θ_H h	Reactor conditions		COD		Suspended Solids		Oil and grease	
	D.O.[2] mg/dm^3	(MLVSS) concentration mg/dm^3	Inf.[3] mg/dm^3	Eff.[4] mg/dm^3	Inf. mg/dm^3	Eff. mg/dm^3	Inf. mg/dm^3	Eff. mg/dm^3
0.5	1.6	3449	1169	625	316	186	119	37
1	2.1	3931	1277	484	424	341	165	43
3	7.0	1809	1343	346	388	165	392	17
6	8.5	2535	1156	196	373	100	104	4
9	7.5	1689	1152	103	623	65	125	10

1 Data for 2 weeks at each hydraulic detention time. Influent values are averages of 10 samples for θ_H of 0.5 h 5 samples at θ_H 's of 1,3 and 6 h and 3 samples at 9 h. All D.O. values are averages of 10 measurements. MLVSS and effluent COD and SS values are averages of 6 samples. Effluent oil and grease is an average of 2 samples.

2 Disssolved oxygen.

3 Influent concentration.

4 Effluent concentration.

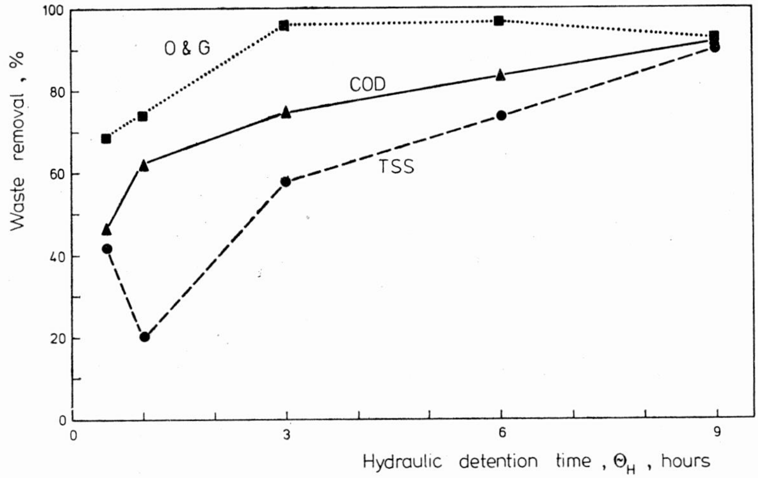

Fig. 5. Percent removal of COD, total suspended solids (TSS) and oil and grease (O&G) as a function of hydraulic detention time for the laboratory-scale study with intermittent, high hydraulic flow rate

Rys. 5. Procentowe usuwanie ChZT, ogólnych zawiesin (TSS) oraz oleju i tłuszczu (0 and G) w zależności od czasu przetrzymywania dla badań w skali laboratoryjnej przy nieciągłym wysokim tempie przepływu hydraulicznego

The yield of the biomass (mg MLVSS/mg COD removed) decreased with θ_H. The system produced about 0.15 kg of VSS/kg COD removed from the influent wastewater. The plot of the net growth rate versus COD removal rate (fig. 6) shows that the overall growth-yield coefficient was 0.26 mg MLVSS/mg COD removed and the microorganism

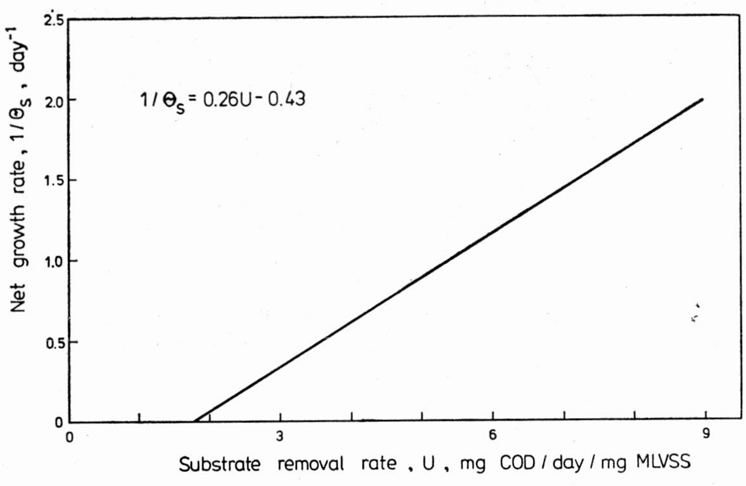

Fig. 6. Relationship between sludge age (θ_S) and substrate (COD) removal rate (U) for the laboratory-scale study with intermitted, high hydraulic flow rate

Rys. 6. Zależność między wiekiem osadu (θ_S) a prędkością usuwania ChZT (U) w badaniu laboratoryjnym z nieciągłym wysokim obciążeniem hydraulicznym decay coefficient was 0.43 mg MLVSS/d/mg MLVSS. Those coefficients indicate that the system produced 0.26 mg of volatile suspended solids in the reactor for each mg of COD removed from the wastewater and that 0.43 mg of volatile suspended solids decayed and was lost daily for each mg of volatile suspended solids in the reactor.

3. PILOT-SCALE STUDY

A pilot-scale activated sludge unit was designed and built (fig. 7) with the reactors and settling tank constructed in one unit in the form of a rectangular tank 4.9 m long by 1.5 m high by 1.5 m wide. Each of the three reactor tanks has an approximate liquid volume of 1.89 m^3; total reactor volume is 5.67 m^3. The solids-liquid separator was constructed with sloping sides and held about 2.46 m^3 with a surface area of 2.8 m^2.

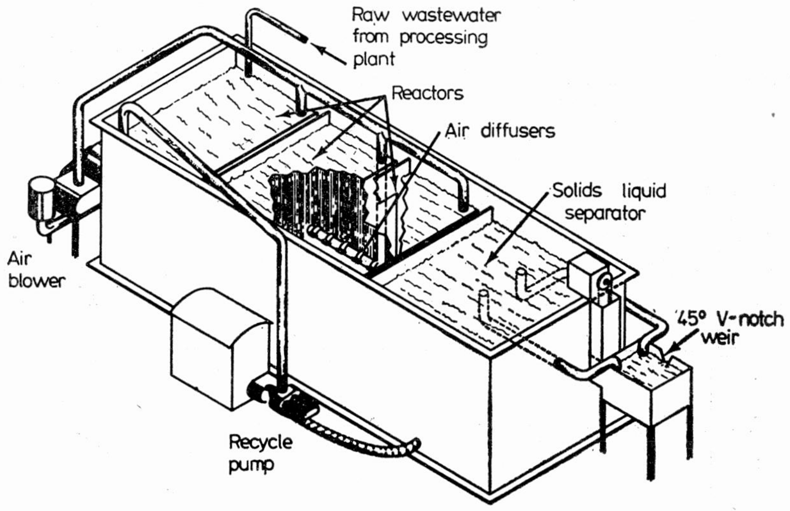

Fig. 7. Pilot-scale activated sludge unit
Rys. 7. Pilotowe urządzenie z osadem czynnym

Raw wastewater was pumped into reactor *1* and flowed over the dividing walls to reactors *2* and *3*. Baffles were mounted on the inlet side of the last two reactors and on the solids-liquid separator to force the incoming water to flow downward and to prevent short-circuiting of the flow. The solids-liquid separator was equipped with a 102-mm diameter outlet, at the bottom of the tank, that served as the solids-recycle line. The clarified effluent flowed out the top of the separator through two 102-mm diameter pipes to a weir box where the flowrate was measured with a weir and a level recorder.

Raw wastewater was pumped to the reactors from the final discharge flume in the processing plant with a 1.12 kW centrifugal pump. Recycled solids were pumped from the bottom of the solids-liquid separator to reactor *1* with a 1.5 kW positive- displacement--process pump. Air was supplied to the reactors through air diffusers by a 7.35 kW rotary positive blower.

The unit was installed at a poultry processing plant and on start-up, about 130 dm^3 of activated sludge from a municipal activated sludge plant was mixed with about 420 dm^3 of raw waste in reactor *1*. Reactors *2* and *3* were filled to the same level with water and the air blower was started. Wastewater was added daily for the next 4 weeks until the reactors were full. Wastewater was fed to the system for 8 h/d, Monday through Friday for the duration of the study except for days when the processing plant did not operate.

The unit was operated at hydraulic flowrates of 3.0, 1.5, 0.5 and 0.25 dm^3/s to give hydraulic detention times (θ_H) of 0.5, 1, 3, and 6 h, respectively. Following the completion of these tests, two of the reactor tanks were drained and the unit was operated with only one reactor tank. This gave a total reactor volume of 1.89 m^3 with the solids-liquid separator at the same volume as in the previous tests, 2.46 m^3. This was done to improve the clarification of suspended solids in the effluent and to increase the reactor biomass concentration by increasing the solids settling time in the solids-liquid separator. The system was operated at flowrates of 0.5 and 0.25 dm^3/s to give θ_H of 1 and 2 h.

The performance of the system was evaluated by sampling and analyzing [1] the influent, effluent and the mixed liquor (table 4). Influent and effluent samples were collected with small pumps actuated by a clock controller and the samples composited and sto-

Table 4

Sampling schedule for pilot-scale activated sludge system
Schemat poboru prób w pilotowej komorze osadu czynnego

Parameter	Schedule
Influent and effluent	
BOD_5[1]	W, TH, F
COD	M, T, W, TH, F
Oil and grease	M, T, W, TH, F
$N-NH_3$	M, W, F
TKN	M, W, F
Suspended Solids[2]	M, T, W, TH, F
Reactor mixed liquor	
pH	M, T, W, TH, F
Dissolved Oxygen	M, T, W, TH, F
Temperature	M, T, W, TH, F
Suspended Solids[2]	M, T, W, TH, F
Total Solids[2]	M, T, W, TH, F
Recycle line	
Suspended Solids[2]	M, T, W, TH, F

[1] Both total and soluble determinations for effluent.
[2] Both total and volatile determinations.

Table 5

Summary of data[1] for the pilot-scale activated sludge system

Kompilacja wyników z pilotowej komory osadu czynnego

Hydraulic detention time, θ_H (h)	Duration of tests (weeks)	Reactor conditions			BOD$_5$			Suspended Solids		Oil and grease	
		D.O.[2] (mg/dm^3)	Temp. (°C)	Biomass (MLVSS) conc. (mg/dm^3)	Inf.[3] (mg/dm^3)	Eff.[4] (mg/dm^3)	Soluble Eff.[5] (mg/dm^3)	Inf. (mg/dm^3)	Eff. (mg/dm^3)	Inf. (mg/dm^3)	Eff. (mg/dm^3)
6[6]	8	7	26	848	1213	713	88	947	709	463	94
				(37)	(16)	(16)	(7)	(36)	(36)	(36)	(36)
3[6]	14	7	23	807	1430	872	190	871	730	388	194
				(68)	(31)	(31)	(15)	(60)	(60)	(60)	(60)
1[6]	7	6	26	793	1634	1067	214	1006	708	483	260
				(33)	(21)	(21)	(11)	(33)	(33)	(33)	(33)
1[7]	9	8	14	1074	1225	758	229	878	585	388	193
				(30)	(19)	(19)	(19)	(30)	(30)	(30)	(30)
2[7]	7	6	7	786	1046	490	74	822	429	406	90
				(28)	(12)	(12)	(11)	(28)	(28)	(28)	(28)

1 Numbers in parenthesis are the number of samples in each average.
2 Dissolved oxygen.
3 Influent concentration.
4 Effluent concentration.
5 Concentration of soluble BOD$_5$ in effluent.
6 Three reactor tanks.
7 One reactor tank.

red in insulated containers until they were taken to the laboratory for analysis. Grab samples of the reactor mixed liquor and recycle line solids were taken 4–6 h after the feed pump had been started. Dissolved oxygen (DO), pH and temperature of the mixed liquor were measured in the morning.

The MLVSS (table 5) were low for all hydraulic detention times (θ_H). The low biomass concentration is partly attributed to the design of the solids-liquid separator. The pilot-scale separator was only 1.3 m deep; the recommended minimum depth is 3 m [5] but we could not build a pilot unit that deep.

The system failed when operated at a θ_H of 0.5 h and those data were not included in any of the analyses. There were no noticeable differences in the performance of the system at the different temperatures of the mixed liquor in the reactor. The system did not decrease the concentration of the ammonia-nitrogen and total nitrogen in the wastewater.

About 40% of the total BOD_5 was removed at θ_H's of 6 and 3 h (fig. 8) and about 33% was removed at θ_H's of 1 h with all 3 reactor tanks. There was very little difference in total BOD_5 removal at θ_H of 1 h for the arrangements with 3 reactor tanks or 1 reactor tank. At a θ_H of 2 h with one reactor tank, over 50% of the total BOD_5 was removed. COD removals showed the same overall trend as BOD_5.

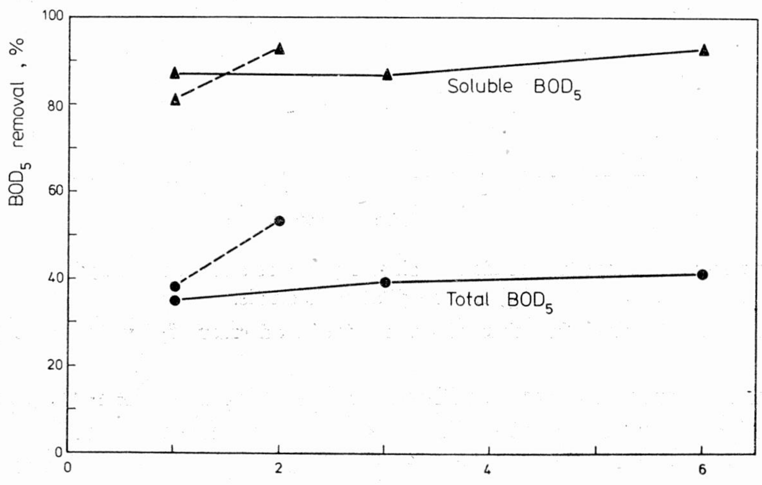

Fig. 8. Percent removal of total soluble BOD_5 as a function of hydraulic detention time (θ_H) for the pilot-scale studies)

Rys. 8. Procent obniżki BZT_5 — całkowitego i rozpuszczonego w zależności od czasu (θ_H) w badaniach pilotowych

The soluble BOD_5 remaining in the effluent is a measure of the BOD_5 that was not removed by the waste treatment system. This portion of the waste remaining in the effluent is an indication of removal efficiencies that would be expected from an activated sludge system where all of the suspended solids were removed from the waste system. The soluble BOD_5 fraction remaining in the effluent was about 15% of the total influent BOD_5 at detention times of 1 and 3 h and about 8 % at 6 h. The tests conducted with 1 reactor tank did not show an appreciable difference from the 3-tank arrangement at a θ_H of 1 h; the soluble fraction remaining at θ_H of 2 h with 1 tank was about the same as the soluble BOD_5 remaining at θ_H of 6 h with 3 tanks. Overall, about an 85 % BOD_5 removal could be expected with good SS removal from the clarified effluent for an activated sludge system operated at $\theta_H = 1\text{–}2$ h.

About 50 % of the oil and grease was removed at θ_H's of 1 and 3 h with 3 tanks and at 1 h with 1 tank (fig. 9). Increasing the detention to 6 h resulted in an 80 % reduction in oil and grease. About 75 % was removed at a θ_H of 2 h with 1 reactor tank and the improved solids-liquid separation.

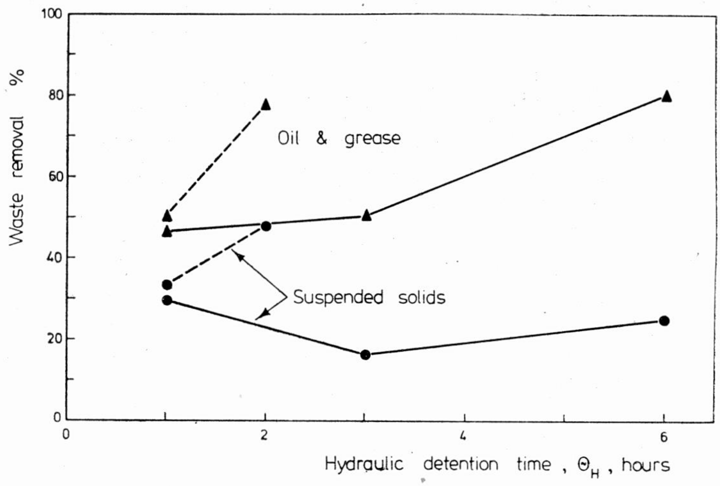

Fig. 9. Percent removal of suspended solids and oil and grease as a function of hydraulic detention time (θ_H) for the pilot scale studies

Rys. 9. Procent obniżki zawiesin i tłuszczów w zależności od czasu (θ_H) w badaniach pilotowych

Because the system was operated without solids wasting from the reactor or the solids recycle line, high effluent suspended solids concentrations were expected. When the system was operated with 3 reactor tanks about 30 % of the suspended solids were biologically degraded at a θ_H of 1 h (fig. 9). Tests with 1 reactor tank and the same size solids-liquid separator showed about the same 30 % efficiency at θ_H of 1 h, but nearly 50 % of the suspended solids were removed at a θ_H of 2 h. Increasing the hydraulic detention time to 3 and 6 h did not improve the suspended solids reduction.

4. DISCUSSION

The laboratory studies showed that the conventional activated sludge process effectively treated high-strength wastewater from a poultry processing plant. At a hydraulic detention time of 6 h, the system removed 93 % of the soluble COD, 94 % SS and more than 97% of the oil and grease when operated at a sludge age of 2–3.5 d. The process also reduced the TKN and P concentrations. Sludge age affected the operation of the system, and sludge settling characteristics were best at $\theta_s = 2\text{–}3.5$ d.

Results from the operation of the pilot-scale system showed that activated sludge could remove one-third of the BOD_5 at 1 h hydraulic detention. Suspended solids removal was 30% and oil and grease degradation was 50% at 1 h. Increasing the detention time to 2 h and improving solids-liquid separation increased waste removals to: BOD_5, 55%, suspended solids, 50%; and oil and grease 75%. A potential 90% reduction of BOD_5 is possible with good suspended solids removal in the clarified effluent.

REFERENCES

[1] American Public Health Association, Standard Methods for the Examination of Water and Wastewater, American Public Health Assoc., New York 1971.

[2] Carawan R. E., Crosswhite W. M., Macon J. A., and Hawkins B. K., *Water and Waste Management in Poultry Processing*, EPA-660/2-74-031 (1974).

[3] Federal Register, Environmental Protection Agency, Poultry Processing Products, Proposed Performance and Pretreatment Standards, Vol. 40 (1975), No. 80, Part III, April 24.

[4] Metcalf and Eddy, Inc., *Wastewater Engineering: Collection, Treatment, Disposal*, McGraw Hill Book Co., New York 1972.

[5] McKinney R. E. and O'Brien W. J., *Activated sludge — basic design concepts*, Jour. Water Poll. Cont. Fed., Vol. 40 (1968), pp. 1831–1843.

[6] Reid R. J., Pilney J. P., Parnow R. J. and Erickson E. E., *Development document for effluent limitations guidelines and standards of performance for the poultry processing industry*, North Star Research Institute, EPA Contract Number 68-01-0593 (1974).

[7] Vertrees J. G., *The poultry processing industry: a study of the impact of water pollution control costs*, Marketing Research Report No. 965, U. S. Dept. Agr. (1972).

BADANIA NAD OCZYSZCZANIEM ŚCIEKÓW Z PRZETWÓRSTWA DROBIU OSADEM CZYNNYM

Przedstawiono wyniki badań nad częściowym biologicznym oczyszczaniem ścieków z zakładów drobiarskich w komorach osadu czynnego. Badania prowadzono w laboratoryjnych komorach o ciągłym przepływie 7d/tydz. (I); w komorach laboratoryjnych obciążonych nieciągle, wysokimi ładunkami hydraulicznymi (II); oraz w urządzeniach pilotowych pracujących pod nieciągłym obciążeniem hydraulicznym (III).

Wykazano, że dla retencji 6h można uzyskać w warunkach I i iII 93% obniżkę ChZT rozpuszczonego oraz 94% obniżkę zawiesin i 97% tłuszczy, przy wieku osadu 2–3,5 d, który równocześnie był optymalny dla sedymentacji zawiesin osadu czynnego. Wyniki pracy oczyszczalni pilotowej (III) dowiodły możliwości obniżki 33% BZT_5, 30% zawiesin i 50% tłuszczy przy retencji hydraulicznej 1 h. Dwugodzinna retencja spowodowała wzrost obniżki BZT_5 do 55%, zawiesin do 50% i tłuszczy do 75%. Stwierdzono także możliwość uzyskania 90% obniżki BZT_5 przy odpowiednio dobranych parametrach procesu.

Interpretując wyniki wzorem Monoda uzyskano w badaniu I właściwą prędkość wzrostu $\hat{u} = 1{,}5$–$-2{,}0\ d^{-1}$ przy $K_S = 20\text{–}24\ mgO_2/dm^3$ — ChZT. Właściwa prędkość usuwania substratu wyniosła $U = 1{,}5$ mg ChZT/d/mg zaw. osadu cz. i była stała dla wszystkich wartości θ_S (wiek osadu) — niezależna od stężenia ChZT. Przyrost osadu wynosił 0,39 mg zawiesin org./mg ChZT usuniętego, zaś prędkość rozkładu $k_d =$

$= 0.34$ d^{-1} (równanie $1/\theta_S = 0.39$ U–0.34.) W badaniu II uzyskano zależność $1/\theta_S = 0.26$ U–0.43. Obciążenia osadu ładunkiem ChZT wahało się, w zależności od czasu retencji, w granicach 0.6–5.4 g O_2/g.s.m. na dobę.

ZUR REINIGUNG VON ABWÄSSERN AUS DER GEFLÜGELVERARBEITUNG MITTELS BELEBTSCHLAMM

Dargestellt werden Versuche zur biologischen Teilreinigung der Abwässer aus Geflügelverarbeitung im Belebtschlammverfahren. Die Versuche wurden parallel wie folgt gefahren:
(I) Labormaßstab, kontinuierliche Beschickung 7 Tage/Woche,
(II) Labormaßstab, diskontinuierliche Beschickung mit hydraulischen Belastungsstößen,
(III) Pilotanlage, diskontinuierliche Beschickung.

Bei Versuchsbedingungen wie (I) und (II) und bei einer Aufenthaltszeit von 6 Stunden, konnte ein Abbau von 93 % des CSB, 94 % der Schwebestoffe und 97 % der Lipide erreicht werden. Ein Schlammalter von 2–3,5 d war zugleich optimal für die Absetzeigenschaften des Belebtschlamms. In der Pilotanlage (III) bei einer Verweilzeit von einer Stunde, wurden folgende Abbauraten erreicht: 33 % BSB_5, 30 % Schwebestoffe und 50 % Lipide. Die Verlängerung der Verweilzeit bis zu zwei Stunden, wirkte sich in der Erhöhung der Abbauraten wie folgt aus: 55 % BSB_5, 50 % Schwebestoffe und 75 % Fettstoffe. Bei der Wahl anderer Parameter, ist ein Abbau von 90 % des BSB_5 möglich.

Werden die Ergebnisse nach der Formel von Monod ausgewertet, dann ist in (I) die Wachstumsrate $\hat{u} = 1{,}5$–$2{,}0$ d^{-1} bei $K_S = 20$–24 mg O_2/dm^3 (als CSB). Die spezifische Abbaurate des Substrats war $U = 1{,}5$ mg CSB /d und von der Konzentration unabhängig. Der Schlammzuwachs war 0,39 mg organische Substanz/mg des abgebauten CSB und die Abbaugeschwindigkeit $k_d = 0{,}34$ d^{-1} (Gleichung $1/\theta_S = 0{,}39$ U–0,34). In (II) war $1/\theta_S = 0{,}26$ U–0,43. Die Schlammbelastung mit dem CSB betrug – je nach Verweilzeit – 0,6–5,4 g O_2/g TS.d.

ИССЛЕДОВАНИЯ ПО ОЧИСТКЕ СТОЧНЫХ ВОД С ПЕРЕРАБОТКИ ДОМАШНЕЙ ПТИЦЫ АКТИВНЫМ ИЛОМ

Представлены результаты исследований по частичной биологической очистке сточных вод, стекающих с завода переработки домашней птицы в камерах активного ила. Испытания проводились непрерывно в лабораторных камерах с непрерывным течением 7 сут./нед (I), в лабораторных камерах, прерывно нагруженных большими гидравлическими грузами (II); а также в полузаводских установках, работающих под прерывной гидравлической нагрузкой (III).

Доказано, что для шестичасовой ретенции можно достигнуть в условиях I и II 93% понижения ХПК растворенном, а также 94% понижения суспензий и 97% жиров, при возрасте ила 2–3,5 суток, который одновременно был оптимальным для седиментации суспензий активного ила. Результаты работы полузаводского очистного сооружения (III) показали возможности понижения 33% $БПТ_5$, 30% суспензий и 50% жиров при одночасовой гидравлической ретенции. Двучасовая ретенция вызвала увеличение понижения $БПК_5$ до 55%, суспензий до 50% и жиров до 75%. Отмечена также возможность достижения 90% понижения $БПК_5$ при соответственно подобранных параметрах процесса.

Интерпретируя результаты формулой Монода, в испытании I была достигнута соответствующая скорость возрастания $\hat{\mu} = 1{,}5$–$2{,}0$ g^{-1} при $K_S = 20$–24 мг O_2/дм^3 – ХПК. Соответствующая скорость удаления субстрата составляла $U = 1{,}5$ мг ХПК/d/мг содержания активного ила и была постоянной для всех значений θ_S (возраст ила) – независимо от концентрации ХПК. Прирост ила составлял 0,39 мг органических суспензий/мг ХПК, удалённом, скорость же распределения $k_d = 0.34$ g^{-1} (уравнение $1/\theta_S = 0.39$ U–0.34). В испытании IIб ыла достигнута зависимость $1/\theta_S =$ $= 0.26$–0.46. Нагрузка ила грузом ХПК колебалось в зависимости от времени ретенции в пределах 0.6–5.4 г O_2/g.s.m. – сутки.