Bull. Environ. Contam. Toxicol. (1994) 52:856-863

Environmental Contamination and Toxicology

Effect of Detention Time on Aerobic Waste Stabilization Pond Performance in Southeast Asia

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Received: 1 April 1993/Accepted: 30 October 1993

The rising level of pollution in rivers, lakes and other bodies of water has created problems of significant magnitude in Southeast Asia. Apart from the aesthetic desirability of clean rivers are the pressing dangers to health and detrimental effects on aquatic life. Pollution of these sources must be controlled so as not to interfere with the waters' legitimate uses.

Waste stabilization ponds are well-accepted as an effective and economical means of waste disposal (Hodgson 1964; Parker 1973; Fritz 1979). A "stabilization pond" is an artificially created body of water intended to retain sewage or organic wastes until biological processes have rendered the wastes stable. The stabilization process consists of bacteria and algae interaction. Bacteria oxidize the wastes and produce sludge, carbon dioxide and ammonia. The nutrients produced from bacterial oxidation, along with light energy, supply the requirements for algal photosynthesis. Algae produce oxygen needed to sustain the treatment process (Bartsh 1961). Optimum detention time refers to the average length of time required for waste to become stabilized within a pond (Silva and Papenfuss 1953).

Properly designed and operated, a stabilization pond can provide treatment comparable to a more costly waste treatment plant (Porges 1963; Meron et al. 1965) However, the design criteria for a particular climate may not be applicable to other climates. This study was conducted to establish suitable detention times for aerobic stabilization ponds in Southeast Asia.

MATERIALS AND METHODS

The effect of different detention times on stabilization pond performance was evaluated at the Environmental Engineering Laboratory, Asian Institute of Technology, Bangkok, Thailand. Parallel studies were conducted outdoors and in the laboratory. Three stabilization pond models (ponds 1, 2, and 3) were utilized (Figs. 1 and 2). Models were made from PVC sheets and all were of the same dimensions: 45 cm long, 30 cm wide, and 30 cm high. Ponds were operated at a liquid depth of 25 cm and provided with perspex baffles 15 cm from the effluent location to minimize algal loss.

A 200-L influent holding tank served as a waste storage unit. From the holding tanks, the waste went to a constant level tank, with a float as control, and on to the kinked tube doser controlled by a synchronous motor for intermittent dosing. Weinberger's (1969) synthetic sewage was used as the BOD source (Table 1). This consisted of 12 components proportioned to give a BOD_5 of 100 mg/L which simulates Southeast Asian sewages.

Table 1. Weinberger's synthetic sewage.

Components	mg/L
Nutrient broth	50.0
Soluble starch	50.0
Urea	15.0
Sodium bicarbonate	84.0
Castile soap	25.0
Di-sodium hydrogen phosphate	12.5
Diatomaceaous earth	12.5
Magnesium sulfate	2.5
Aluminum sulfate	2.5
Sodium chloride	15.0
Potassium chloride	3.5
Calcium chloride	3.5

A mean influent BOD of 100 mg/L was fed into the ponds at organic loading rates of 100, 200, and 300 lb/d/A to give detention times of 2.4, 1.2, and 0.8 d. Experiments were carried out for a 50-d period.

In the laboratory, light was provided by four 65-watt PHILIPS TL 65W/55 fluorescent lamps suspended 15 cm above the pond water surface. The models were illuminated for 12 hr out of each 24-hr period. Light intensities on the pond surface averaged 1,340 ft-cand indoors and 12,600 ft-cand outdoors. At the bottom,

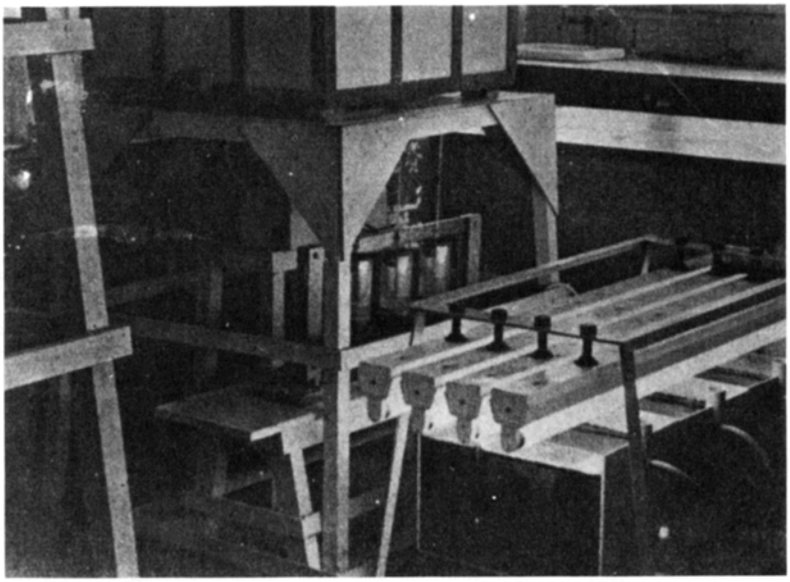

Figure 1. Indoor experimental set-up

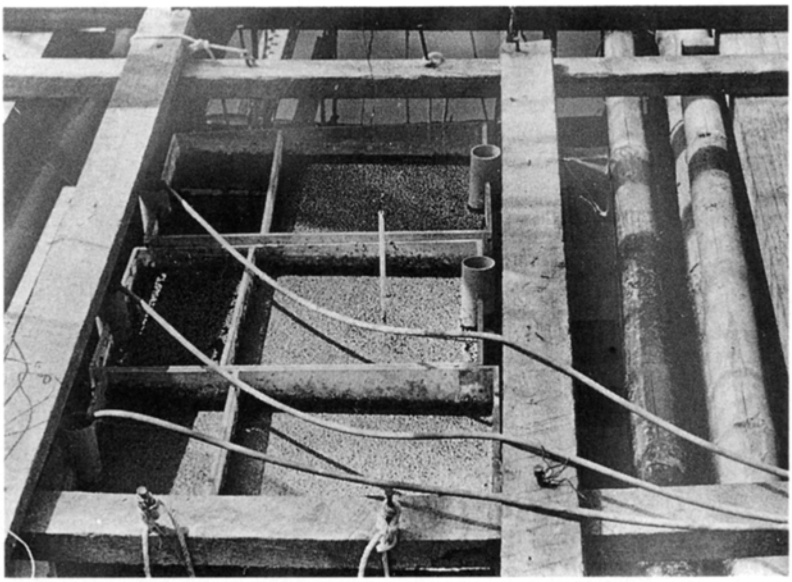

Figure 2. Outdoor experimental set-up

light intensities were 222 ft-cand indoors and 5,180 ft-cand outdoors.

Indoor and outdoor model pond performance were measured for each detention time. BOD_5, suspended solids (SS), total nitrogen and orthophosphate were analyzed weekly. Dissolved oxygen (DO), temperature, pH and alkalinity were measured daily. Predominant algae species were noted. All analyses were according to Standard Methods (1980) except where specifically stated. SS concentrations were determined using the glass filter disk method by Wyckoff (1964). DO was measured with a YSI Model 51 DO meter and the Winkler method for verification. A temperature recorder monitored the 24-hr temperature variation and a megatron selenium photocell was used for light intensity measurements.

RESULTS AND DISCUSSION

In both indoor and outdoor studies, BOD_5 removals increased as the detention period was lengthened (Table 2). At 0.8 d detention, the laboratory ponds removed 74.5% and 79.9% of the total and filtered BOD_5 with corresponding removals of 81.2% and 87.8% in outdoor ponds. With a detention time of 2.4 d, total and filtered BOD_5 removals increased to 88.0% and 93.6% indoors and 90.9% and 95.6% outdoors. For a given detention time, BOD_5 removal was greater outdoors than indoors. BOD_5 concentrations in the filtered effluent at detention times of 0.8, 1.2 and 2.4 d were, respectively, 7.4, 14.0, and 24.0 mg/L indoors and 4.4, 9.0, and 12.0 mg/L outdoors. This difference between total and filtered BOD_5 was due to algae and trace quantities of other suspended solids.

Outdoor ponds 1 and 2 showed a supersaturation of DO earlier during the run, with concentrations declining as the run progressed. Maximum DO levels were 30 mg/L and 25 mg/L, respectively, while minimum DO levels were 13 mg/L and 8 mg/L, respectively. In outdoor pond 3, with the shortest detention time, DO levels were reduced, ranging from 4-14.8 mg/L. In the laboratory, the DO levels in Pond 1 decreased to a low of 1.8 mg/L on the 12th day. Thereafter, the DO reached a maximum of 8.0 mg/L on the 18th d but subsequently decreased. In indoor pond 2, the DO concentration fluctuated from 0-3 mg/L, averaging about 1 mg/L. Pond 3 was devoid of DO most of the time.

Throughout the study period, the indoor pond water temperature ranged from 23°C to 26°C. The 24-hr temperature cycle varied only slightly in the

Table 2. Performance of indoor and outdoor aerobic stabilization pond models at different detention times.

Characteristic	Unit	Indoor			Outdoor		
		Pond 1	Pond 2	Pond 3	Pond 1	Pond 2	Pond 3
Detention period	days	2.4	1.2	0.8	2.4	1.2	0.8
Influent BOD	mg/L	100	100	100	100	100	100
Effluent BOD (filt)	mg/L	7.4	14.0	20.4	4.4	9.0	12.2
BOD removal	%	93.6	86.0	79.9	95.6	91.0	87.8
Effluent BOD (unfilt)	mg/L	12.0	17.6	24.5	9.1	13.3	18.8
BOD removal	%	88.0	82.4	74.5	90.9	86.7	81.2
Dissolved Oxygen	mg/L	1.8–8	0–3	0–1	13–30	8–25	4–14.8
Temperature	^0C	23–26	23–26	23–26	28–36	28–36	28–36
pH	–	7.1–7.4	7.0–7.2	6.8–7.1	8.1–8.6	7.3–8.4	7.0–8.2
Alkalinity, as $CaCO_3$	mg/L	280–360	280–370	300–450	210–280	210–290	260–390
Suspended solids (inf)	mg/L	148	148	148	148	148	148
Suspended solids (eff)	mg/L	23.5	18.0	11.7	23.3	23.0	43.0
Percent removal	%	84.2	87,8	88.3	84.3	84.5	61.0
Total nitrogen (inf)	mg/L	14.4	14.4	14.4	14.4	14.4	14.4
Total nitrogen (eff)	mg/L	4.7	6.9	8.9	4.1	5.0	5.2
NH_3–N (eff)	mg/L	0.6	0.9	2.0	0.2	0.5	1.2
NO_2–N (eff)	mg/L	nil	nil	nil	nil	nil	nil
NO_3–N (eff)	mg/L	0.17	0.16	0.0	0.3	0.15	0.1
Percent removal	%	67.6	52.4	38.3	71.6	65.6	63.9
Orthophosphate (inf)	mg/L	2.5	2.5	2.5	2.5	2.5	2.5
Orthophosphate (eff)	mg/L	0.9	1.2	2.0	0.9	0.9	1.5
Percent removal	%	64.0	52.0	20.9	64.0	64.0	40.0
Predominant organism	–	*Euglena*	*Scenedesmus*	Diatoms	*Euglena*	*Euglena*	*Euglena*

laboratory. In the outdoors ponds, the temperature varied from 28°C to 36°C, with a greater difference between the daily maximum and minimum (6°C to 8°C).

pH concentrations were higher in the outdoor ponds than in the laboratory ponds. Outdoors, the hydrogen ion concentration in Pond 1 reached its peak of 8.6, 2 d after the run started and persisted above 8.0 thereafter. This high pH was due to the removal of carbon dioxide by algae as represented by the equation:

$$2HCO_3^- \rightarrow CO_3^= + H_2O + CO_2 \text{ (to algal cells)}$$
$$Ca^{++} + CO_3^= \rightarrow CaCO_3$$

The removal of CO_2 shifted the equilibrium toward an increase in $CO_3^=$ concentration. The $CO_3^=$ ion precipitated the Ca++ present, forming $CaCO_3$, which settled to the bottom, causing a reduction in alkalinity. In Pond 2, pH values above 8.0 were observed until the 18th d but subsequently decreased to 7.2. Pond 3 attained a maximum pH of 8.2 on the second d of the run and declined to 7.0 thereafter. Indoors, the pH values varied from 7.1-7.4 in Pond 1, from 7.0-7.2 in Pond 2, and decreased to a minimum of 6.8 in Pond 3 (the same pH as the influent sewage).

Total alkalinity decreased as the detention time increased. In the laboratory, alkalinity ranged from 300-450 mg/L at the 0.8-d detention time but decreased to 280-360 mg/L at the 2.4-d detention time. Outdoors, alkalinity varied from 260-390 mg/L at 0.8-d detention but decreased to 210-280 mg/L at the 2.4-d detention time. For any given detention time, the total alkalinity concentration was lower in the outdoor pond than in the indoor pond, presumably as a result of greater algal growth outdoors.

Indoors, the suspended solids removal decreased as the detention time was lengthened while outdoors, the suspended solids removal at 0.8 d detention was low (61%) but increased at longer detention times (84.5%), The filtered suspensions in outdoor ponds were predominantly due to algae. Higher concentrations of suspended solids in the outdoor ponds were due to greater algal populations.

In both studies, higher removal of total nitrogen and orthophosphate was achieved as the detention time increased. Ammonia and organic nitrogen were low in the outdoor ponds but the nitrate contents were higher. With higher DO concentrations in the outdoor ponds, nitrification of ammonia to nitrate is possible.

In the laboratory ponds, *Euglena* was the most common algal type in Pond 1, while *Scenedesmus* was prevalent in Pond 2. In Pond 3, diatoms were the only type of algae present. In outdoor ponds, *Euglena* was dominant followed by *Chlorella*. *Scenedesmus* and diatoms were also present in insignificant amounts.

Better performance was achieved outdoors than indoors. Indoors, with an influent BOD concentration of 100 mg/L, aerobic conditions were attained at detention times of 1.2 d and 2.4 d. The shortest detention time of 0.8 d is not suitable for the laboratory pond to function properly. Algal growth was inhibited, and anaerobic conditions prevailed. Outdoors, aerobic conditions were attained at all detention times. Generally, BOD_5 removal efficiency and DO and pH levels were higher in outdoor ponds. Lower ammonia and higher nitrate concentrations indicate that nitrification is occurring, resulting in higher ammonia removal. Increased light intensity and warmer outdoor temperature accelerated algal growth and bacterial metabolism, thus improving the operational efficiency.

Based upon the results for all operational parameters, an outdoor pond with a detention time of 2.4 days (Pond 1) gave the optimum performance. Lowest total and filtered effluent BOD_5 concentration (9.1 and 4.4 mg/L) and highest BOD_5 removal efficiency (90.9 and 95.6%) along with highest DO levels (13-30 mg/L) occurred in this pond. While the suspended solids concentration (23.3 mg/L) and percent removal (84.3%) were not optimal in outdoor pond 1, the filtered suspensions were predominantly due to algae which indicates that algal growth is well-established.

Lowest concentrations of total and ammonia nitrogen and orthophosphate and highest removal efficiencies also occured in outdoor pond 1. If the effluent from a stabilization pond is discharged to a receiving water body (river or lake), ammonia can be potentially toxic to fish and other aquatic life particularly at high pH and temperature regimes, typical of the outdoor ponds. Hence, ammonia removal, through nitrification, would be an important operational consideration for aquatic life protection. Likewise, reduced orthophosphate concentrations would be beneficial since eutrophication poses a problem in the receiving water.

The stabilization pond models can be used as tool for prediction and evaluation of full-scale stabilization pond performance in the treatment of wastes of the same characteristics under a similar environment. The composition of synthetic sewage used in this study simulates that of Southeast Asian sewages. Several studies show that under similar operational conditions, performance of model ponds closely reproduce those measured for large-scale stabilization ponds (Hermann and Gloyna 1958; Bokil and Agrawal 1976; Mars 1979). Thus, the information obtained may be applied to full-scale stabilization pond treatment of actual sewages under a tropical climate such as in Southeast Asia.

Acknowledgments. This study was supported by the SEATO Graduate Fellowship Grant. Thanks to Dr. Roscoe Ward for his quidance during the course of the study.

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