PERFORMANCE OF WASTE STABILIZATION POND SYSTEM - A CASE STUDY

by

Pathinather S and Rupasingha R A P

Introduction:

Waste Stabilization Ponds are considered as one of the low cost methods for treating wastewater, especially in warm climes. There are numerous research publications on Waste Stabilization Ponds (Arceivala 1986, Ellis and Rodrigues 1995), but still these Ponds remain as one of the most misunderstood treatment systems. Major processes that take place in the ponds include:

(a) Buffering of the organic and hydraulic loading fluctuations

(b) Settling of settleable solid forming sludge

(c) Algal photosynthesi to produce oxygen

(d) Aerobic/anaerobic oxidation of organic matter by bacteria

(e) Reduction of pathogenic organisms by several interactive processes.

A wide variety of microscopic plants and animals find the pond environment a suitable habitat. Organic matter in the wastes are metabolized by bacteria and saprobic protozoans as primary feeders. Secondary feeders include protozoans and higher animal forms, such as rotifers and crustaceans. Nutrients released during bacterial oxidation is used by algae in photosynthesis. Species diversity, seasonal variations, and plankton succession in ponds is dependent on organic load, temperature, daylight hours, pH, and grazing intensity of zooplankton.

Pond classification depends on factors such as loading, depth, operating conditions etc. Types can be:

(a) Aerobic, Anaerobic or Facultative according to biological activity.

(b) Based on influent wastewater, they may be called Primary, Secondary or Polishing/Maturation ponds.

(c) Depending on the mode of water loss, they can be Evaporation, Infiltration, or Flow Through ponds.

(d) According to physical layout, they may be called Series or Parallel connected ponds (Pond System).

In general ponds do not require mechanical equipment; they absorb shock loads, produce stabilized sludge and are relatively easy to operate and maintain. Disadvantages include large area requirements, potential odour and mosquito nuisance and high algal content in the effluent. In some cases modifications have also been made by growing water hyacinth, duckweed, phragmites and typha to reduce the problems related to large amount of algae in the effluent.

Inspite of several advantages, serious problems can crop up when the designers fail to understand the complexities of various biological and physical phenomena, which occur in different types of ponds. Among the mistakes made by some designers, the most serious ones are:

(a) Extrapolation of short-term tests or brief operational experience to predict long-term performance, and

(b) Inaccurate comparison between individual or series-connected units, which do not have biological-physical-chemical similarity.

Numerous methods for design have been proposed in literature, mainly based on empirical correlation between Waste Stabilization Pond performance and environmental or operational parameters. Many users claim (Agunwamba 1992) that more complex equations that include factors such as water temperature, light intensity, dispersion etc. are not quite successful in predicting the efficiency of Waste Stabilization Ponds.

Eng. S. Pathinather, Dip.SE(Delft), A Phi(Mora), AMIE(SL) Presently working as a Senior Lecture in Civil Engineering University of Moratuwa

Eng. R.A.P. Rupasinghe, Civil Eng., MIE (SL) Presently working as Technical Services Division, Mahaweli Authority of Sri Lanka

The main objective of this paper is to discuss the performance of the existing pond system at Digana Village, near Kandy in Sri Lanka in relation to the design and suggest methods for improving the efficiency/ performance of these units.

2. Materials and Methods

This study was conducted on the Waste Stabilization Pond System designed and commissioned in 1980 for the Digana Village. This Pond System consists of 6 units with inlet and outlet arrangements as shown in the layout diagram. These six ponds were to function as two parallel systems, each consisting of an Anaerobic, Facultative and Maturation ponds in series.

The system was designed to have an overall Hydraulic Retention Time of 21 days in order to produce a high quality effluent (De Silva, 1981). In order to estimate the designed organic loading and BOD & Bacterial removals, the following assumptions were used in this study:

Average BOD in the influent	= 180 mg/l
BOD removal rate constant	= 0.15/d at 20^0 C
Bacterial removal rate constant	= 2.6/d at 20^0 C

Average liquid temperature from records = 24.70^0 C
All cells/units behave as completely mixed reactors.

Out of the four inlet units, only the two units nearer the screens (inlets 1&2) are in working order. Accumulation of sludge over the years has reduced the capacity of the units, and therefore, a 5m-interval grid survey was carried out to determine the present capacity of the Pond System. The present population contributing to the Waste Treatment Plant is about 2150 (1150 residential and 1000 non-residential people from the housing complex for staff of the Victoria Dam Project). This housing complex consists of 300 residential houses with facilities such as a Hospital, School, Guesthouse, Shops, Recreation clubs etc. The wastewater coming to the treatment unit is mainly domestic in nature.

As there was no flow measurement facilities to the system, the flow was estimated by taking the average water usage from household meter readings, bulk water supply and the water demand of the population. It was also assumed that 85% of the water consumption reached the Wastewater Plant. As indicated in Figure 1, the study was conducted only on one-side, after closing the interpond connections to the 3 units on the other side. The arrows and sampling locations show the side investigated.

Grab Samples were collected at locations indicated, once in two weeks between 9.30 a.m. and 10.30 a.m from 18 December 1998 to 25 June 1999. Samples were tested regularly for pH, TSS, BOD_5^{20}, COD and DO. Tests for Sulphate, Nitrate, Phosphate and identification of algal species were also carried out on few samples. Laboratory tests were carried out at Peradeniya Water Supply & Drainage Board Laboratory as per procedures described in Standard Methods for Examination of Water and Wastewater (1995). Due to limited facilities at Digana Mahaweli Laboratory and the National Water Supply and Drainage Board Laboratory, no attempt was made to determine the type of organisms (other than algae) in the pond and the Coliform count. International Standard BOD_5^{20} is used in this work and reference to BOD implies BOD_5^{20} in this paper unless stated otherwise.

Meteorological data were obtained from the Victoria Meteorological Station and for the estimation of solar radiation, the chart provided by Samuel and Srikanthan (1982) was used.

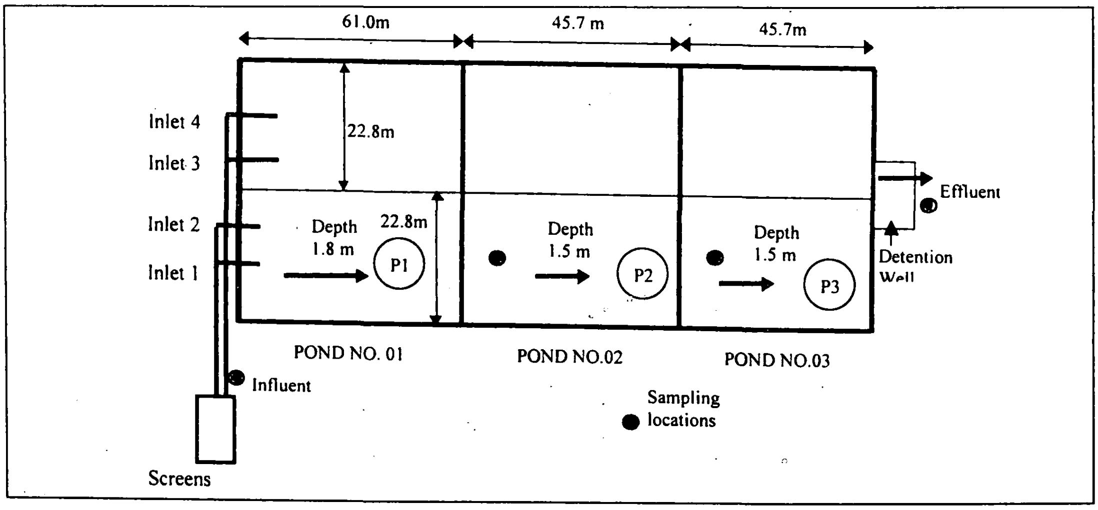

Fig. 1. Layout Diagram

3. Results and Discussions

Pond capacities, Hydraulic Retention Times, Surface areas as designed against the present values are presented in Table 1 for the designed and estimated (during the study period) flows of 230 m^3/d and 350 m^3/d respectively. The designed flow for the whole system was 460 m^3/d and 230 m^3/d for half the system.

BOD, COD and TSS measurements made in the ponds under investigations are plotted in figures 2, 3 and 4 respectively. Mean average temperature recorded was 24.70^0 C and the solar radiation estimated was 9 to 16 $MJ/m^2.d$, for the pond site.

Table 1
Comparison of the existing ground measurements: Only for units under operation

Description	Pond No (01)	Pond No (02)	Pond No (03)	Overall System
Capacity (m3)				
As designed	2140	1340	1340	4820
During study period	1040	755	400	2195
Reduction of Capacity	51%	44%	70%	54%
HRT (days)				
As designed (Q= 230 m3/d)	9.32	5.84	5.84	21.00
During study period (Q= 350 m3/d)	2.97	2.16	1.14	6.27
Areal loading in kg BOD/ha.d				
As Designed	300.0	-	-	-
During study period	390.0	-	-	-
Surface Area (ha.) at FSL				
As designed	0.14	0.10	0.10	0.34
During study period	0.14	0.10	0.09	0.33
Reduction of surface area	Nil	Nil	10%	3%

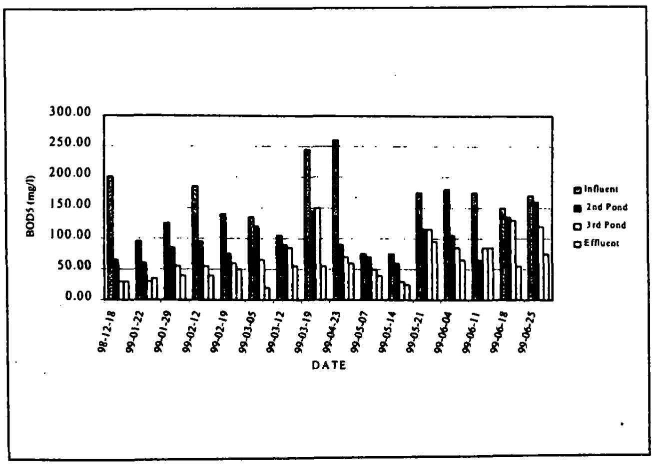

Figure 2: BOD Analysis in Ponds

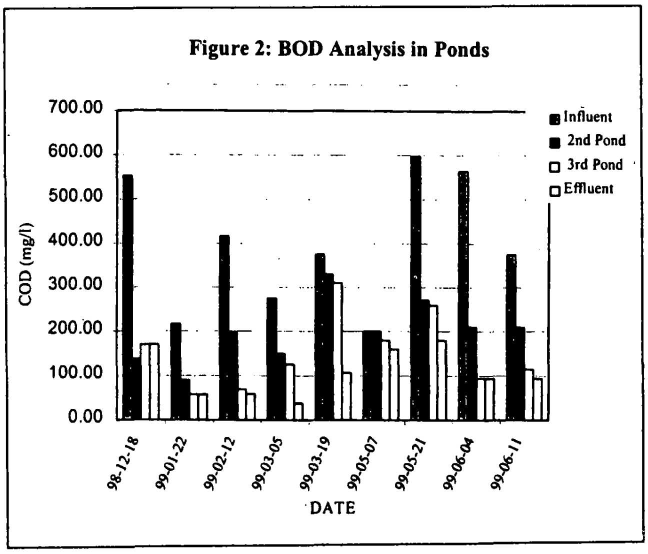

Figure 3: COD Analysis in Ponds

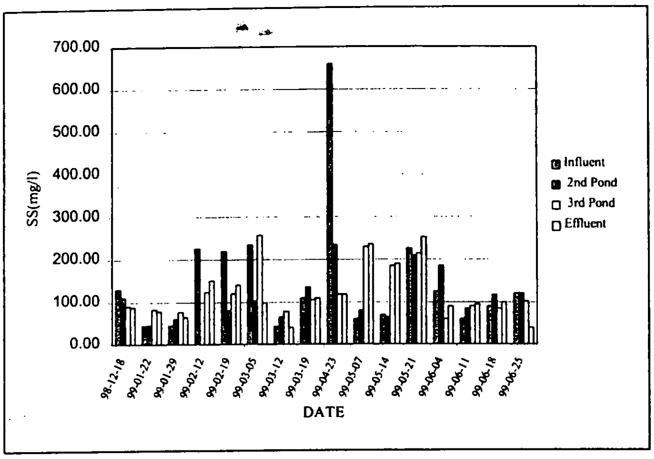

Figure 4: TSS Analysis in Pond

Designed flow of 460 m^3/d for the whole system used by the Designer would have been on the expectation that the population growth at Digana Village would be rapid. Estimated flow to the Treatment System during investigation in 1998/99 was only 350 m^3/day. The pond system would have produced a BOD of less than 20 mg/l and Coliform removal of more than 99.99%, with the estimated organic loading of 300 kg BOD/ha.d based on assumptions stated under materials & methods (Section 02).

For a pond to be anaerobic, it should be high loaded, deep and should have only a small area exposed to solar radiation. Since the designed organic loading (estimated) at 1.8m depth is low, it was very unlikely that the first pond would have been fully anaerobic (Pathinather 1989) and the study in 1998/99 shows that it behaves like a facultative pond. The BOD_5^{20}/ COD ratio indicates that the performance is not quite satisfactory during the period of study. Influent ratio 0.43 is very close to what can be expected in a normal domestic wastewater, but the ratio of 0.60 for the effluent recorded should have been lower, a ratio of around 0.2 would have been ideal (Bulusu et al 1969 and Wijeyesekara & Pathinather 1987). The BOD of the effluent also exceeded 50 mg/l on few occasions, in addition to high total suspended solids (TSS) contents. pH measurements given in Table 1 do not support intense algal photosynthesis in the ponds and this is further complicated by the absence of any desirable type of algae such as Chlorella, Euglena, Chlamydomonas etc., Only Spirulina and Microsystis were found in the pond system.

However, the BOD and COD analysis in the ponds as shown in Figures 2 and 3 demonstrate the capability of the pond system in reducing the pollutants from influent to final effluent. Even the higher loads experienced around March and April as indicated in BOD & TSS graphs did not affect the effluent quality. It is also interesting to note that the final effluent COD did not exceed 180 mg/l during the study period. Air temperature recorded and Solar Radiation estimated for the site is quite favourable to obtain good performance from the pond system. Sulphate measured (maximum recorded 3.84 mg/l) was also below the level at which algal activity will be affected.

Main reasons for the shortcomings in the ponds system are the reduction in capacity due to accumulation of sludge from 1980, absence of desirable types of algal species, which produce more oxygen and less toxic substances in Waste Stabilization Ponds (Hosetti and Frost 1998) and that the entire flow of 350m3/d is now treated using only one set of ponds. Steps should therefore be taken to clean and restore the ponds and the detention well to the original capacity. The anaerobic condition that exists in the detention well also contributes to the poor quality effluent. After cleaning, the ponds need to be seeded with desirable type of algae and monitored to ensure that these algal species get established in the pond system. With the present flow and organic loading, even after cleaning the first pond may function as a facultative pond and therefore the other two as maturation or polishing ponds. This system will not only produce good quality effluent with the present load, but is also capable of taking in additional hydraulic and organic loading without exceeding the minimum effluent quality standards (Sri Lanka). Tests carried out indicate that nitrogen, and phosphorus removal is not effective as given in Table 2&3, even though the concentrations in the effluent are not too high. It is recommended that this aspect should be studied further and remedial measures taken if necessary.

Much higher loadings have been used in tropical conditions according to McGarry & Pescod(1970) where an aerobic layer existed during daytime even at the loading of 1120 kg BOD/ha.d. Studies conducted in Sri Lanka using pilot plant and laboratory models by Wijeyesekera & Pathinather (1987), Pathinather (1989), Katugampola (1991) and Wijitha Kumara and Peiris (1992) confirmed that individual pond and pond system have high potential in treating wastewater under warm climatic conditions. The type of pond chosen depends on the treatment objectives and the location where it is needed. Ponds should be designed according to the requirement and more importantly, operated and maintained according to the design.

Table 1: pH

Date	pH			
	Influent	2nd Pond	3rd Pond	Effluent
98-12-18	6.50	6.90	7.20	6.90
99-01-22	6.90	6.50	6.50	7.00
99-01-29	7.30	7.60	7.80	7.60
99-02-12	7.30	7.80	8.60	7.80
99-02-26	7.20	7.30	7.20	7.30
99-03-05	6.65	7.90	8.00	7.50
99-03-12	6.70	7.10	7.30	7.60
99-03-19	6.20	6.50	6.80	6.30
99-04-23	6.25	6.70	6.75	6.80
99-05-07	7.10	6.35	7.00	7.30
99-05-14	7.01	7.07	7.05	7.15
99-05-21	7.10	7.10	7.15	7.15
99-06-04	6.50	6.80	6.40	6.80
99-06-11	7.10	6.80	6.40	6.70
99-06-18	6.60	7.10	7.40	7.50
99-06-25	6.90	6.30	6.10	6.50

Table 2: Phosphate

Date	Phosphate (PO^{-}_4)mg/l	
	Influent	Effluent
99-01-29	6.80	1.50
99-02-12	10.40	3.70
99-02-19	3.80	5.60
99-03-05	1.70	2.35
99-03-12	8.30	7.40
99-03-19	4.80	8.50
99-04-23	5.70	5.00
99-05-07	6.30	3.30
99-05-14	6.10	6.10
99-05-21	7.10	8.45
99-06-04	3.30	4.40
99-06-11	5.70	3.10
99-06-18	5.25	4.00
99-06-25	4.90	5.60

Table 3: Nitrogen

Date	Nitrate(NO^{-}_3)mg/l	
	Influent	Effluent
99-02-26	3.00	0.08
99-05-07	2.11	0.28
99-05-14	2.20	0.94

4. Conclusions

Based on this study the following conclusions are made:

The pond system under investigation was designed as an anaerobic pond, followed by facultative and maturation ponds. The performance of the pond system is reasonably good inspite of the existence of the unfavourable conditions such as reduction in capacity, absence of desirable algal species, lower retention time and the anaerobicity in the detention well.

Microcystis and Spirulina were the dominant algal species present in the Digana Waste Stabilization ponds during the period of investigation. Action should be taken to seed the ponds with desirable type of algae.

The Pond System has been designed for the effluent BOD_5^{20} quality of 20 mg/l and the combined Retention Period of 21 days for both compartments. But it was observed that at present the effective combined retention period in the working compartment is only 6.27 days. Therefore, the entire pond system should be restored to the original condition by effecting cleaning and repairs.

Depth and organic loading expected are inadequate to maintain the first pond fully anaerobic.

Nutrient (N&P) levels in the effluent are not too high at present, but further study should be conducted to determine the possibility of improving nutrient reduction in the effluent.

5. Acknowledgements

The authors are grateful to the University of Moratuwa and the Mahaweli Authority of Sri Lanka for providing funds and other facilities to carry out this investigation.

6. References:

- Arceivala S.J (1986) - Wastewater Treatment for Pollution Control -Tata Mc Graw-Hill publ. Company Ltd. pp 115-143.
- Agunwamba J.C (1992) - Field Pond Performance and Design Evaluation Using Physical Models, Wat. Res., Vol.26, No.11 pp 1403-1407
- Bulusu K.R, Thegaonkar V.P, Pathak B.N (1969) - The relationship between COD and BOD of organic substrates, Proc. Sympos. On Low Cost Waste Treatment, NEERI, Nagpur, India.

- De Silva R.A.C.(1981) -Waste Stabilization Ponds with particular reference to the pond constructed at Digana Housing Complex, The Consultant Magazine published by the CECB Engineers Association, pp 4-6.
- Ellis K.V and Rodrigues P.C.C (1995) Multiple Regression Design Equations for Stabilization Ponds, Wat. Res., Volume 29, No 11 pp 2509 - 2519.
- Hosetti B. and Frost S. (1998) - A Review of the Control of Biological Waste Treatment in Stabilization Ponds, Critical Reviews in Environmental Science and Technology, pp. 193-218.
- Katugampola PI, Jayasingha D and Gnanathilake G (1991) - Study of a Pond System, B.Sc. Eng., Final year Project Report, University of Moratuwa.
- Mara D.D, Pearson H.W, Alabaster G.P and Mills S.W (1997) - An Evaluation of Waste Stabilization Ponds in Kenya, Research Monograph No.11 in Tropical Public Health Engineering (ODA).
- McGary M.G & Pescod M.B (1970) -Stabilization Pond Design Criteria for tropical Asia in the Proc. of 2nd National Symposium for waste treatment lagoons, Kansas City, Missouri.
- Pathinather S. (1989) - The Performance of a Deep Primary Waste Stabilization Pond, MPhil Thesis, University of Moratuwa, Sri Lanka.
- Samuel T.D.M.A & Srikanthan R.(1982)-Solar Radiation Estimation for Sri Lanka, Institution of Engineers Sri Lanka- Transactions.
- Silva S.A, De Oliveira R. and Mara D.D (1996) - Performance of Waste Stabilization Ponds in Northeast Brazil, Research Monographs No.09 in Tropical Public Health Engineering (ODA).
- Standard Methods for the Examination of Water & Wastewater (1995) by APHA, AWWA and WEF-19th Edition.
- Wijitha Kumara T.D and Peiris G.L.S (1992) - Low Loaded Algal Pond for Wastewater Treatment, B.Sc Eng., Final year Project Report, University of Moratuwa.
- Wijeyesekara D.S. and Pathinather S. (1987) - Performance of a High Loaded Deep Primary Waste Stabilization Pond - Engineer, J/IESL Vol: XV No 2, June, 1987,pp 10-21