DEVELOPMENT OF DESIGN PARAMETERS FOR AERATED WASTEWATER TREATMENT SYSTEMS (AWTS)

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Abstract

Aerated Wastewater Treatment Systems (AWTS) have been widely used in Australia in order to manage the waste from households that are not connected to urban sewer systems. However, there are very few studies that deal with the design of AWTS. This paper present the results of an experimental study conducted to determine the design parameters for appropriate sizing of the aeration tank and media in an AWTS. Though it is too early to propose any definite design criteria for AWTS, it appears that it may be possible to use some of the design criteria developed for low rate trickling filters when designing AWTS.

Keywords

Aerated wastewater treatment system, AWTS, design, hydraulic loading, nutrient removal, performance.

1 Introduction

Sewage treatment for many areas of Australia requires the development of on-site wastewater management systems. These on-site wastewater treatment systems have been operated in Australia for many years. Originally the systems comprised of basic septic tanks and leach fields. However, the greater awareness of environmental issues in recent times has lead to the replacement of such systems to incorporate biological treatment of wastewater flows. Aerated wastewater treatment systems (AWTS) have been available in Australia since 1983 (Dharmappa & Khalife, 1998) and are now commonly used in place of the traditional septic system. AWTS utilising either suspended, attached or hybrid growth bacterial populations are commonly found in practice. Performance studies of such systems have found that although the systems are designed with appropriate capacity, operating problems have lead to inadequate bacteria concentrations in the reactor (Dharmappa & Khalife, 1998). This has resulted in the ineffective treatment of wastewater. The specific objectives of this work are to:

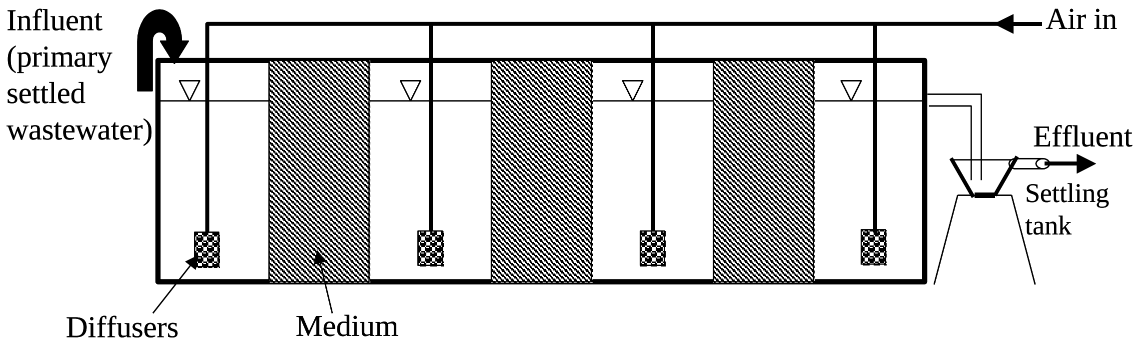
- measure the removal efficiency of a hybrid AWTS pilot plant utilising plastic medium for supporting biomass;
- determine the performance of AWTS pilot plant under different hydraulic loading;
- develop a relationship between surface area of support medium and BOD removal rate;
- provide valuable data related to the operation of hybrid AWTS in practice.

2 Experimental Setup

To fulfil the work objectives, it was necessary to design and operate a small hybrid AWTS pilot plant. This system is fed with the settled domestic wastewater (taken from the effluent channel of primary sedimentation tank) from the Wollongong sewage treatment works. The pilot plant system was designed to allow for the removal and addition of plastic support media.

The experimental setup is shown in Figure 1, indicating the reactor, which consisted of a long channel with three filter medium blocks. The three blocks were placed equidistant from each other. The filter media used was a "honey-combed cross-flow" type with a specific surface area of 226 m^2/m^3. The entire unit was covered using dark plastic sheet to prevent algal growth within the hybrid system.

Figure 1. Pilot Scale Experimental Setup



The experiments were conducted with 2 hydraulic loading rates of 40 mL/min and 50 mL/min. The influent and effluent wastewater qualities were monitored for 5 day biochemical oxygen demand (BOD_5), total suspended solids (TSS) and total Kjeldahl nitrogen (TKN). Other parameters such as turbidity, dissolved oxygen, pH and temperature were also monitored. However, the latter results are not presented here. Sampling was carried out over a period of 14 weeks between May and November 2000. The pilot plant was operated with a flowrate of 50 mL/min for a period of six weeks before reducing it to 40 mL/min for the next eight weeks. The BOD_5, TSS and TKN results are compared with the guidelines set by NSW Department of Health (1999), which are given in Table 1.

Table 1. Effluent Guidelines (NSW Department of Health, 1999)

Parameter	Limit, mg/L*
BOD_5	20
SS	30
TKN	20

* - 90% of the samples shall not exceed these values

3 Results and Discussions

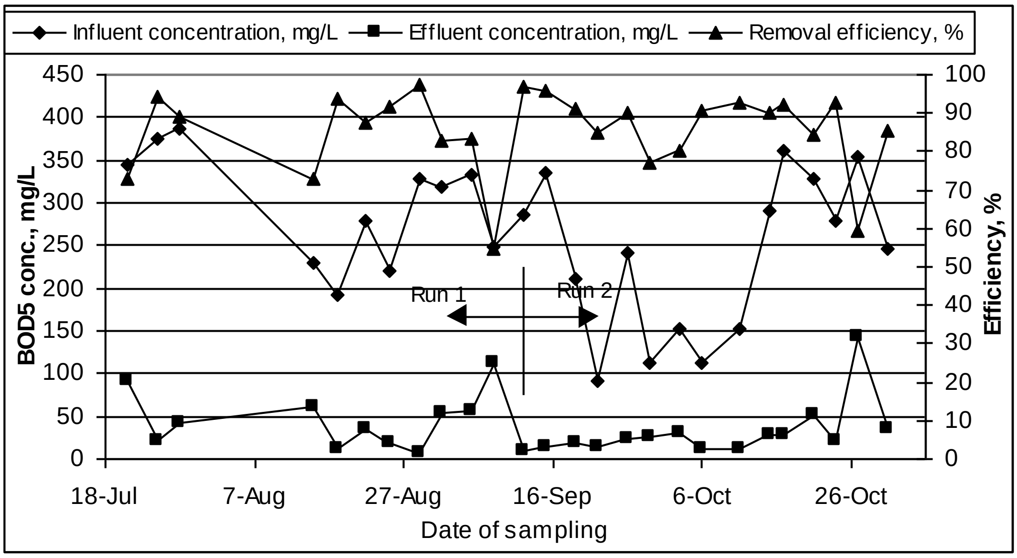
3.1 BOD_5 Removal

Run 1 (50 mL/min flowrate): Figure 2 (Figure 1 is the diagram above) shows the variations of influent and effluent concentrations and removal efficiency of BOD_5 for Run 1. The average BOD_5 of the influent obtained from the Wollongong Sewage Treatment Plant was found to be 296 mg/L during Run 1, with a range from 192 to 387 mg/L. This was consistent with the influent conditions commonly found for on-site AWTS influent. Khalife & Dharmappa (1996) found, through studies on 27 AWTS, that primary effluent from households had an average BOD_5 concentration of 242 mg/L.

The BOD_5 of the effluent exiting the settling chamber was found to be significantly higher than the 20 mg/L set by NSW Department of Health (Table 1). The average effluent concentration of 47 mg/L observed in this study is also higher than the average BOD_5 concentration (37 mg/L) reported for 27 AWTS tested by Khalife & Dharmappa (1996). The large value was due to high BOD readings on the 21st July and the 8th September. The first of these two high readings was during the initial set-up of the treatment plant, and thus resulted from the insufficient bacterial population in the aeration tank.

The second reading was likely a result of the high concentration of organic matter in the aeration tank, caused by the die-off of algae, which had developed during the initial stages of the experimental study. If these two readings were omitted as outliers, the average effluent BOD_5 concentration was found to be 34mg/L, which is still above the guideline (Table 1).

Figure 2. BOD_5 Removal with Time



Run 2 (40 mL/min flowrate): Figure 2 shows the variations of influent and effluent concentrations and removal efficiency of BOD_5 for Run 2. The BOD_5 of the influent for Run 2 was found to average 237 mg/L with a range of 91 - 360 mg/L. This was lower than the influent BOD_5 (296mg/L) observed during Run 1. However 46% of samples taken had a BOD_5 between 280 – 360mg/L, which is consistent with the Run 1 influent conditions.

The average effluent BOD_5 concentration of 31 mg/L observed for Run 2, is a significant improvement in the treatment efficiency compared to Run 1. If the extremely high value of 143 mg/L for BOD_5 on the 27^{th} October is omitted, effluent BOD_5 is reduced to 23 mg/L. However, this is still higher than the effluent standard set by NSW Department of Health (Table 1). High effluent concentration on 27^{th} October was caused by blocking of the air diffuser in the first suspended growth chamber of the aeration tank, which resulted in low dissolved oxygen levels in the subsequent aeration chambers.

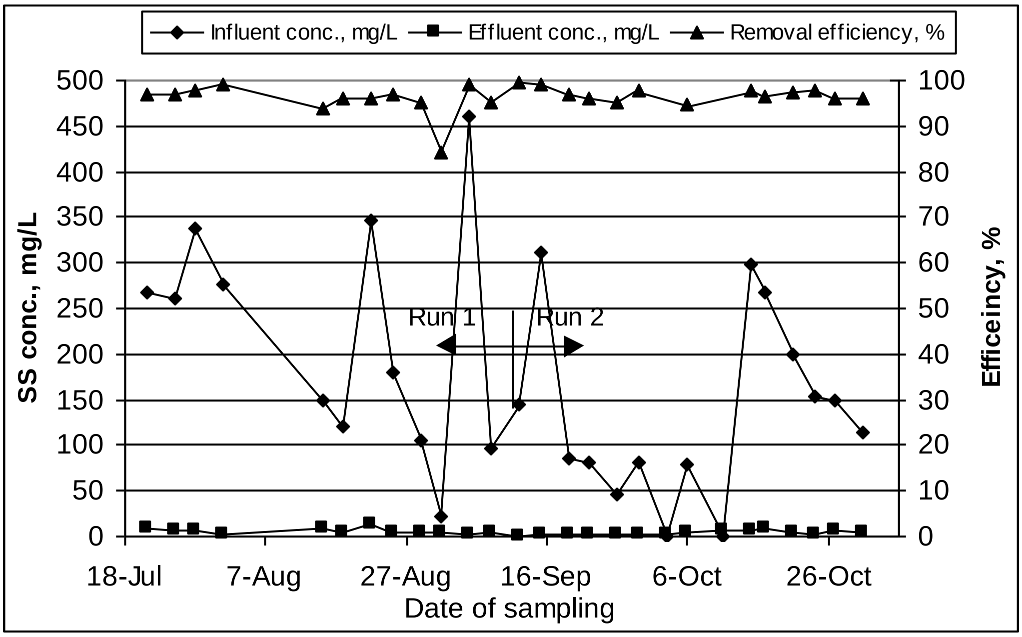
The average effluent BOD_5 obtained for Run 2 (31 mg/L) was significantly better than the 39 mg/L reported by Khalife & Dharmappa (1996). However the BOD_5 concentrations for 53% of effluent samples taken were still above the NSW Department of Health standard of 20 mg/L.

3.2 Suspended Solids (SS) Removal

Run 1 (50 mL/min flowrate): Figure 3 shows the variations of influent and effluent concentrations and removal efficiency of TSS for Run 1. The average total suspended solids concentration of 218 mg/L for the influent wastewater was observed during Run 1, which is similar to TSS concentration (220 mg/L) reported for the medium strength untreated household wastewater (Metcalf & Eddy Inc. *et al.*, 1991).

The pilot plant produced effluent with suspended solids concentration well below the required limit of 30 mg/L as shown in Figure 3. The removal of TSS was significantly greater for the pilot plant tested than the results obtained by Khalife & Dharmappa (1996) for 27 operating AWTS. The improved results were partly due to better quality influent wastewater and the absence of carry over solids from the primary settling chamber.

Figure 3. Total Suspended Solids (TSS) Removal with Time



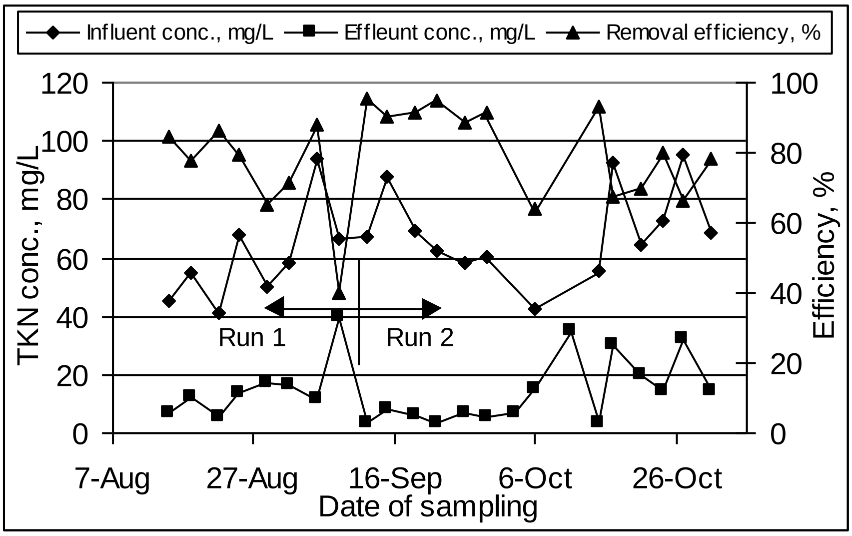
Run 2 (40 mL/min flowrate): Figure 2 shows the variations of influent and effluent concentrations and removal efficiency of TSS for Run 2. The concentrations of TSS for samples taken from the final chamber of the aeration tank and from the secondary clarifier were significantly lower for the 40 mL/min flowrate of Run 2. Average TSS concentrations of 165 and 4 mg/L were measured for the influent and effluent, respectively. Average TSS removal was observed to be 97%, which was slightly better than the value obtained for Run 1. This improvement in the treatment efficiency can be due to the 24% reduction in the influent TSS. The lower level of TSS in the influent waste stream of 165 mg/L was still consistent with typical household sewage but significantly lower than the 218 mg/L obtained in Run 1.

3.3 Total Kjeldahl Nitrogen (TKN) Removal

Run 1 (50 mL/min flowrate): Figure 4 shows the variations of influent and effluent concentrations and removal efficiency of TKN for Run 1. TKN is a measure of the combined concentration of ammonia and organic nitrogen in the wastewater. In this study a range of 41 – 94 mg/L with an average concentration of 60 mg/L was observed during Run 1. This range appears to be on higher side of expected values. Metcalf & Eddy Inc. *et al.* (1991) indicated a range of 20 – 85 mg/L for domestic wastewater and suggested that the higher range corresponds to medium to high strength wastewater. The influent BOD_5 values (Figure 2) obtained in this study indicate that the influent wastewater is of medium to high strength. Further the influent TKN values obtained in this study are significantly higher than those observed by Hazlewood (1999) for primary effluent from AWTS (32 and 37 mg/L). The results show that the treatment system provides conditions for significant nitrogen removal. An overall reduction of 74% in TKN was observed.

The average effluent concentration of 16 mg/L was observed for the pilot plant that met the TKN standard for effluent disposal from AWTS (Table 1). However, one observation exceeded the required limit of 20 mg/L. this may be attributed to the high influent TKN levels during the previous cycle of sampling.

Figure 4. Total Kjeldahl Nitrogen (TKN) Removal with Time



Run 2 (40 mL/min flowrate): Figure 4 shows the variations of influent and effluent concentrations and removal efficiency of TKN for Run 2. The results for nitrogen removal from second test run sampling showed a 9% decrease in the TKN concentration of the effluent wastewater with an average concentration of 14 mg/L compared to 16 mg/L in the case of Run 1. However, the NSW Department of Health standard given in Table 1 was not met as the effluent TKN concentration exceeded 20 mg/L for 25% of the samples collected. Nevertheless, the results showed a large improvement in performance compared with the concentrations found by Hazlewood (1999) during testing of actual AWTS. The high removal efficiency of the pilot plant system of 89% was most likely due to the increased hydraulic retention time (HRT) of the aeration tank during Run 2. The high average temperature of 17°C may have also contributed to the improved nitrification performance.

As shown in Figure 4, towards the later stages of Run 2, there was a significant drop in the performance of the system. The nitrification efficiency of the aeration tank dropped by 19% after the 3rd October with a corresponding 67% increase in the TKN concentration of the effluent. This significant reduction in the nitrification performance of the pilot plant was caused by the corresponding increase in the influent TKN. In fact, the influent, in addition to TKN, shows higher BOD_5 and SS concentrations.

3.4 Summary of Results

The influent and effluent concentrations and removal efficiencies for both Runs 1 and 2 are summarised in Table 2. As shown in the table, there are slight improvements in the performance of the pilot plant setup with respect to BOD_5 and TSS due to increased hydraulic retention time. Improvement in the performance can be partly attributed to the relatively lower strength of the influent wastewater supplied during Run 2.

Table 2. Summary of BOD_5, SS and TKN results

Parameters	Run 1 (50 mL/min)			Run 2 (40 mL/min)		
	Influent, mg/L	Effluent, mg/L	Removal, %	Influent, mg/L	Effluent, mg/L	Removal, %
BOD_5	296	47	84	237	31	87
SS	218	6	96	165	4	97
TKN	60	16	74	63	14	89

Table 3 summarises the design parameters for both Runs 1 and 2. Comparing Tables 1 and 2 it can be said that the improvement in the performance of the pilot plant can not, at this stage, be fully attributed to the change in the design criteria. Further studies are required to identify definite relationships between the performance and design parameters.

Table 3. Design Parameters

PARAMETERS	RUN 1	RUN 2	TRICKLING FILTER+
Flow rate, mL/min	50	40	
Hydraulic retention time, hr	30	37	
Hydraulic volumetric loading rate, m^3/m^3.d	0.92	0.74	
Hydraulic surface loading rate, m^3/m^2-media.d	0.014	0.011	
Organic volumetric loading rate, kg/m^3.d	0.27	0.17	0.08-0.4
Organic surface loading rate, g/m^2-media.d	4.0	2.6	
g BOD_5 removal/m^2-media.d	3.4	2.2	
BOD_5 removal rate, %	80-92	80-97	80-90
Nitrification	High	High	High

+ - values for low rate trickling filter from Metcalf & Eddy Inc. *et al.* (1991).

As shown in Table 3, some of the design criteria appear to have matched with those of low rate trickling filters. However, a thorough comparative study is needed before making any final conclusion in this regard.

4 Conclusions

This paper presents results from an experimental study, which is being conducted at University of Wollongong to develop design criteria for AWTS. The study was successful in achieving high average removal rates of 87 %, 97 % and 89 % for BOD_5, TSS and TKN, respectively. The study also indicated that by reducing the hydraulic loading rate, the performance of AWTS was enhanced. However, the effluent quality showed considerable amount of variability. Also, the performance enhancement achieved by reducing hydraulic loading rate was not up to the expected level. This may be due to the highly variable nature of the influent, which was fed to the pilot plant. Further studies are required to develop a definite relationship between the design parameters and AWTS performance.

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