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DEVELOPMENT OF AN IMPROVED COMPACT PACKAGE PLANT FOR SMALL COMMUNITY WASTEWATER TREATMENT

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ABSTRACT

The challenges facing the design and operation of small community wastewater treatment plants are discussed. The package plant concept is considered and the consequent development of a compact intermittently aerated activated sludge package plant is outlined. A four month trial period, comprising the first part of the evaluation, is described. Results from this trial show that the plant can serve communities of up to 300 p.e. and that treated effluent quality conforms to the General South African Standards. The compact design and unique operating regime offer reduced capital and running costs respectively.

KEYWORDS

Small community; package plant; activated sludge; intermittent aeration.

INTRODUCTION

The steady world-wide tightening of treated effluent standards has placed increased demands on small communities to treat their wastewaters to acceptable levels. Where previously legislation placed stipulations on effluent BOD and suspended solids, increasingly compliance levels are being imposed on effluent COD and ammonia concentrations. In some sensitive discharge areas nutrient (nitrogen and phosphorus) removal is also required.

Traditionally small community wastewater treatment has adopted the low technology/reliable operation approach. Such technologies include septic tanks, stabilization ponds and biological filtration. In many instances these treatment methods will not meet the required effluent standards. Compounded with legislative requirements is the nature of the small community wastewater itself. Two distinct flow conditions can be identified; relatively uniform flow and load (expected from permanent settlements) and sporadic high flow and shock load conditions (observed at motorway stopovers, hotels etc).

Over the last decade package plants have made significant advances in addressing the wastewater treatment needs of small communities. Their success can be attributed to reduced capital costs, innovative technology and ease of operation. Typically unit processes are factory made and assembled on site. Favoured technologies include:

a) fixed media systems (e.g. rotating bio-discs, biological filtration);

b) activated sludge systems (e.g. completely mixed continuously fed, intermittently fed, fill and draw, sequencing batch reactors etc);

c)combinations of a and b above.

For the compact package plant, the activated sludge process was selected as the appropriate treatment technology as it was considered the most reliable with regard to good effluent quality (Batchelor *et al.*, 1991).

PROCESS CONSIDERATIONS

The development of the compact package plant was prompted by the need to provide small communities with a wastewater treatment solution that requires low capital and running costs, operates reliably and guarantees acceptable treated effluent quality. Specifically effluent quality is to conform to the South African General Water Quality Standards (Government Notice No R991, 1984). Some of these standards are given in Table 1 below.

TABLE 1. South African Wastewater Standards After Purification

Water Quality Criterion*	General Standard	Special Standard
Chemical Oxygen Demand (COD)	< 75 mg/l	< 30 mg/l
Suspended Solids	< 25 mg/l	< 10 mg/l
Ammonia (as N)	< 10 mg/l	< 1 mg/l
Nitrates (as N)	no standard	< 1.5 mg/l
PO_4 (as P)	no standard	< 1 mg/l

* Not all criteria are listed

The compact package plant differs from other sewage treatment package plants in that all the unit treatment processes are housed within one 12m shipping container. Additionally construction costs are kept to a minimum by using commercially available tanks, equipment and materials. By assembling the compact package plant at a central point of manufacture the on-site requirements are (i) suitable foundation for the 12m container, (ii) appropriate electrical supply and (iii) a wet well and pump to deliver the wastewater flow to the inlet of the treatment plant. The wet well can take the form of a septic tank in which gross solids and rags would accumulate for periodic removal.

Housing all the unit processes in a 12m container saves construction costs and offers the following advantages:

- ease of transportation and installation
- reduced land requirements
- reduced noise levels
- containment of odours
- year-round heat conservation.

The WRC (1984) design equations were used to size the activated sludge process and secondary settling tank requirements. Due to the geometric and physical restraints of the 12m container the load to the package plant is restricted to around 25 kgCOD per day with a flow of 50 m^3/d. This approximates to a treatment capacity of two to three hundred p.e.

The unit processes of the compact package plant are

- primary sedimentation/flow balancing
- intermittently aerated activated sludge wastewater treatment
- secondary sludge settling.

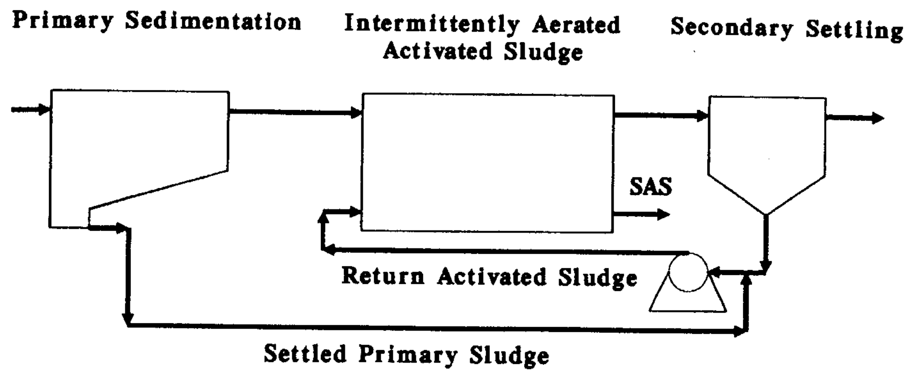

Fig.1. Schematic layout of the unit processes housed within a 12m container.

Settled sewage is gravity fed to the activated sludge tank whilst a single positive displacement pump continuously recycles secondary settled sludge to the activated sludge tank. At periods of low flow the sewage in the primary sedimentation tank is used as a substrate source and can be co- pumped with the secondary settled sludge to the activated sludge tank. This important feature obviates the need for primary sludge disposal.

The activated sludge process is contained in a single tank. Continuous and complete mixing is induced by two large diameter discs mounted on a horizontal drive shaft. A single air aspirator ($AerO_2$) oxygenates the mixed liquor.

An intermittent aeration cycle was chosen as it not only reduces running costs but also introduces an anoxic environment to the process for reduction of nitrate through denitrification. In laboratory scale continuously fed intermittently aerated reactors Warburton (1991) showed that the denitrification potential of such systems was nearly 20% larger than measured in compartmentalized systems.

Automatic operation of the unit processes is conducted from a central control board. Operator input is required on regular basis (2 to 3 times per week) to control the mixed liquor concentration (ideally 4.5 g/l). This is done by draining a predetermined volume of mixed liquor from the activated sludge tank to a small sludge drying bed. The mixed liquor concentration is needed to calculate the volume of surplus activated sludge (SAS) to be wasted.

PERFORMANCE EVALUATION

A four month trial period (August to November 1992) was conducted to evaluate the compact package plant's performance with regard to treated effluent quality, running costs and reliability.

Effluent Quality

The compact package plant was installed at a large municipal wastewater treatment plant in Pretoria. Pumped raw sewage was passed through a 'run down' type screen and gravity fed to the primary sedimentation tank. The results discussed in this paper cover the first phase of the evaluation in which the load to the plant was maintained between 15 to 35 kgCOD per day (see Fig. 2). Flow to the plant varied from 25 to 45 m^3/d. During the evaluation period influent and effluent samples were regularly taken for laboratory analysis. Additionally mixed liquor concentrations, sludge settleability and daily power consumption were also monitored.

From Fig. 2. (see below) it can be seen that for the most part the effluent COD concentration was well within the General limit of 75 mg/l. On day 22 an experimental flow balancing regime was introduced with the view to save running costs. A timer was fixed to the settled sludge recycle pump to allow intermittent sludge recycling. This modification was not successful and on day 46 continuous recycling was reintroduced. The decrease in effluent COD quality during this period is clearly visible in Fig. 2.

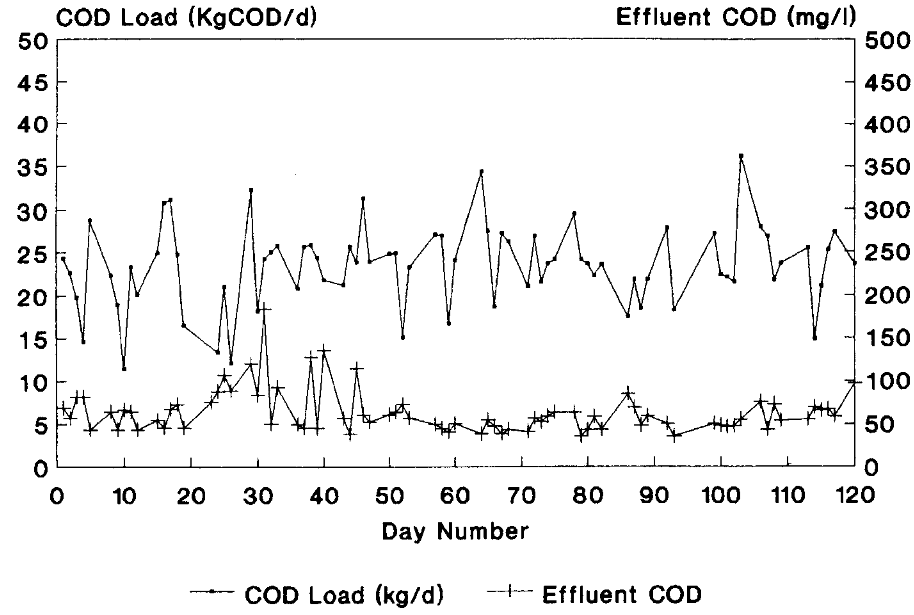

Fig. 2. Influent COD load (kgCOD/d) to the plant and effluent COD concentration (mgCOD/l).

The daily influent TKN load to the plant fluctuated between 1 and 2 kgTKN/d. Effluent TKN concentration is plotted as a percentage of time less than in Fig. 3. below and clearly all measured samples, by which effluent ammonia is implicit, were less than the 10 mg/l ammonia (as N) General Standard.

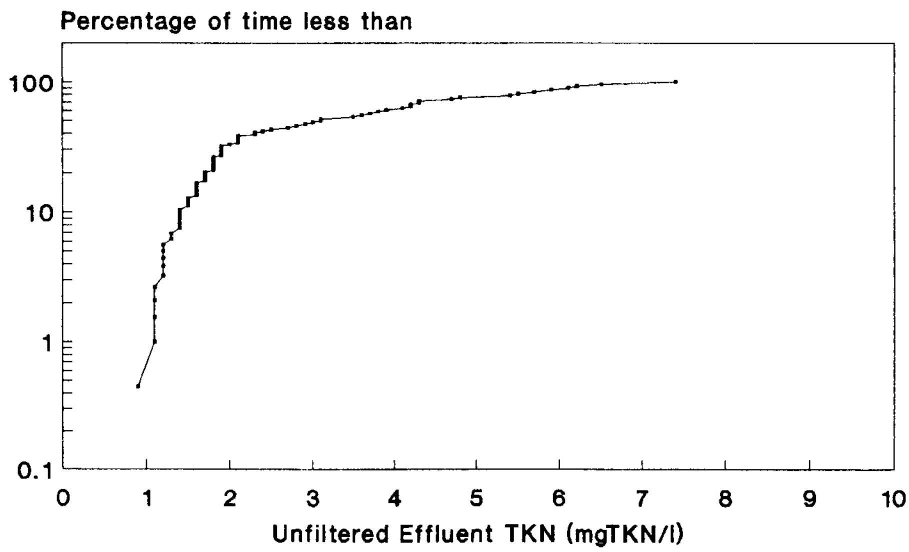

Fig. 3. Measured effluent TKN concentrations (mgTKN/l) expressed as a cumulative percentage of time less than.

A 10 minute intermittent aeration cycle was maintained during the course of the evaluation. In each 10 minute cycle air was sparged for the first 7 minutes. Thereafter the dissolved oxygen (DO) concentration progressively dropped for the remaining 3 minutes of the cycle. The $AerO_2$ surface aspirator induced a slight DO gradient through the depth of the activated sludge tank with typical base DO concentrations of 1 mgO/l and surface DO concentrations of 3 mgO/l.

The selected aeration cycle of 7:3 proved successful in removing COD and TKN, however from Fig. 4 below it is clear that nitrate reduction was not consistent. Effluent nitrate + nitrite concentrations were generally > 25 mg/l yet at times this figure dropped to as low as 1 mg/l (see Fig. 4. below). Clearly the anoxic fraction of the aeration cycle was insufficiently sized to ensure complete and sustained denitrification. The aeration cycle has since been changed to 7:5 in order to increase the anoxic fraction.

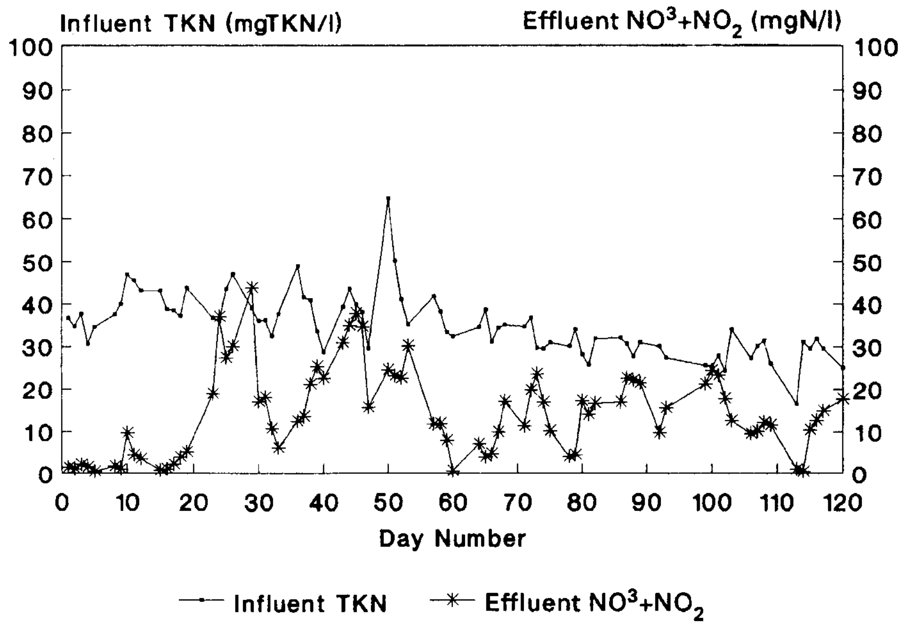

Fig. 4. Effluent $NO_3 + NO_2$ concentration (mgN/l) measured during the evaluation period.

Sludge settleability as measured by the DSVI (Dilute Sludge Volume Index) test ranged from 80 to 180 ml/g. This sort of settleability range can be expected from intermittently aerated systems with anoxic mass fractions less than 50% (Gabb *et al.*, 1989, Warburton *et al.*,1991).

Running Costs

The construction of the compact package plant took less than one month. Making use of commercially available tanks, equipment and materials proved to be both time and cost effective.

Throughout the evaluation period the total measured power supplied to the package plant was in the order of 45 kWh per day. This figure compares favourably with other energy saving technologies such as rotating bio- contact discs (Greaves *et al.*, 1990).

Reliability

During the four month evaluation period no stoppages occurred due to equipment failure. Other than to check and maintain equipment as and when necessary, operator input was required 2 to 3 times per week to control the activated sludge mixed liquor concentration.

SUMMARY

It was recognized that a low cost, reliable solution was needed to treat small community wastewaters to acceptable effluent standards. A compact intermittently aerated activated sludge package plant was developed in which all the treatment processes were housed within a 12m shipping container. Using commercially available tanks, equipment and materials construction costs were significantly reduced. The compact arrangement offers ease of transportation and installation.

The findings of a four month evaluation period showed that, with a flow and load from an equivalent population of up to 300, the package plant assures effluent quality well within the limits of the South African General Standards. Also from the evaluation it was observed that the mixing and aeration regimes successfully reduced the daily power requirements.

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