Changes in waste stabilisation pond performance resulting from the retrofit of activated sludge treatment upstream: part II – management and operating issues


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Abstract Bolivar Wastewater Treatment Plant (WWTP) was originally commissioned with trickling filter secondary treatment, followed by waste stabilisation pond (WSP) treatment and marine discharge. In 1999, a dissolved air flotation/filtration (DAFF) plant was commissioned to treat a portion of the WSP effluent for horticultural reuse. In 2001, the trickling filters were replaced with activated sludge treatment. A shift in WSP ecology became evident soon after this time, characterised by a statistically significant reduction in algal counts in the pond effluent, and increased variability in algal counts and occasional population crashes in the ponds. While the photosynthetic capacity of the WSPs has been reduced, the concomitant reduction in organic loading has meant that the WSPs have not become overloaded. As a result of the improvement in water quality leaving the ponds, significant cost savings and improved product water quality have been realised in the subsequent DAFF treatment stage. A number of operating issues have arisen from the change, however, including the re-emergence of a midge fly nuisance at the site. Control of midge flies using chemical spraying has negated the cost savings realised in the DAFF treatment stage. While biomanipulation of the WSP may provide a less aggressive method of midge control, this case demonstrates the difficulty of predicting in advance all ramifications of a retrospective process change.

Keywords Activated sludge retrofit; waste stabilisation pond; operating changes; midge flies

Introduction

The waste stabilisation pond (WSP) system at Bolivar Wastewater Treatment Plant (WWTP) in Adelaide, South Australia, comprises the tertiary component in a four-stage process. The main plant was commissioned between 1964 and 1969 and comprised primary sedimentation, secondary trickling filters with recirculation, and waste stabilisation pond (WSP) treatment prior to marine discharge. A quaternary dissolved air flotation/filtration (DAFF) plant was commissioned in 1999 to treat a component of the WSP effluent for horticultural reuse (described in Buisine and Oemcke, 2003).

An activated sludge plant (ASP) was commissioned in February 2001 to replace the secondary trickling filters. This was part of a range of upgrades introduced at the site (including the introduction of the DAFF plant in 1999) as part of an Environmental Improvement Programme (EIP) to reduce odour emission from the site and reduce nutrient levels entering the marine environment. The ASP is of conventional design with intermittent anoxic zones for targeted nitrogen removal.

The WSP system consists of six large ponds arranged in two parallel streams of three ponds each. The system has a combined surface area of 346 ha and nominal depth of 1.4 m. Nominal mean residence time through the ponds is greater than 30 days, at 150 ML/day. Prior to the introduction of the ASP, WSP influent was not typically nutrient limited, and conditions in the first WSP in each stream were facultative. The final pond in each system was mainly used for pathogen removal, with a transition from facultative
to maturation behaviour in between. Since the introduction of the WSP, evidence exists that pond operation is, on occasions, nutrient limited (Cromar et al., 2005).

The EIP has been particularly successful in reducing odour emissions and associated complaints from local residents, and improving the quality and decreasing the quantity of treated wastewater discharged to sea. As a result of the EIP, however, a number of operating changes have been required and operating issues of varying severity have surfaced, predominantly due to the changes in the WSPs which have occurred as a result of the plant upgrade upstream of the WSPs.

Changes in operation and performance of Bolivar WWTP WSPs

Improved pond influent quality

Figure 1 shows the change in typical pond influent quality (median values) corresponding to the change in the secondary treatment stage at the WWTP. For the previous trickling filter configuration, effluent entering the pond was considerably higher in total nitrogen, particularly in the form of NH₃-N. Nitrification in the trickling filters occurred only during the warmer months. While phosphorus levels have also declined, the absolute improvement in removal of phosphorus through the ASP compared to the trickling filters is lower. The ASP has also been responsible for a significant reduction in organic loading levels in the pond influent.

Changes in pond effluent quality

Fung (2004) undertook a statistical study of the changes in algal concentration and speciation that have occurred in the ponds since the introduction of the ASP. Analysis of weekly algal counts demonstrated that, overall, algal cell counts in the first ponds of each series have not significantly changed. However, a statistically significant (α = 0.05) decrease in algal cell counts in the pond effluent leaving the last pond in each series was evident.

Plant operators have also observed that brief excursions in the DAFF raw water pH occur during the summer months. While typically between 7.8 and 9, since the introduction of the ASP daily pH averages above 10 have been recorded, with the instantaneous pH on some occasions exceeding 11. This may result from the reduction of nitrate to ammonia by algae in the WSPs.

Reduction in post-treatment (DAFF) operating costs

DAFF treatment consists of coagulation and flocculation, flotation, sand filtration and chlorination. Alum is used as the primary coagulant together with a cationic polyelectrolyte coagulant aid.

Improvements in WSP effluent quality have resulted in a reduction in the operating cost of the DAFF plant. The DAFF raw water turbidity (WSP effluent turbidity) and
filtered water turbidity (outflow from DAFF) are shown in Figure 2. Although seasonal fluctuations in the product water turbidity still occur, the quality of the DAFF product water has improved overall. The optimum coagulant dose in the DAFF plant has decreased from approximately 100 mg/L to 50 mg/L since the ASP was commissioned (Figure 3). Relative treatment costs, based on chemical and energy usage per volume of water treated, are also shown in Figure 3. These are indexed to inflation, and normalised with respect to the highest value recorded at the site, to show the relative cost at other times. It is apparent that the relative treatment cost has decreased by at least 50%, and that the decrease corresponds to the introduction of the ASP.

DAFF plant flowrate, which is driven by demand for irrigation, is seasonal in nature (Figure 4). Increasing yearly demand is also evident. Seasonal peaks in sludge production per volume treated equate to seasonal increases in algal numbers in the WSPs. While limited sludge production data are available for the period prior to the introduction of the ASP, it is evident that sludge production correlates well with the trends of raw water turbidity and optimum alum dose at the site. A reduction in sludge production at the site leads to savings in sludge pumping, digestion, dewatering and disposal costs.

![Figure 2](image2.png)  
**Figure 2** DAFF raw water and treated water turbidity at Bolivar WWTP, from plant commissioning in mid-1999 to early 2004. Date of activated sludge plant commissioning marked

![Figure 3](image3.png)  
**Figure 3** DAFF plant optimal alum dose and normalised treatment chemical cost, from plant commissioning in mid-1999 to early 2004. Date of activated sludge plant commissioning marked

![Figure 4](image4.png)  
**Figure 4** DAFF plant flowrate and dry mass sludge production per volume of wastewater treated at Bolivar WWTP, from plant commissioning in mid-1999 to early 2004. Date of activated sludge plant commissioning marked
Bird numbers at the site
Operational staff have commented on the significant increase in bird life at the site which has accompanied the improvement in water quality in the ponds, particularly in the primary WSP in each series. In addition to the potential for increased pathogens entering the ponds, this has meant that additional expenditure at the DAFF plant has been required for cleaning and the installation of bird netting.

Decreased pond capacity/robustness
With the increased variability in algal populations since the introduction of the ASP, insufficient photosynthetic oxygen production capacity in the WSPs has been identified as a potential problem. While sampling to date has shown that the primary ponds in each series have remained facultative, dissolved oxygen levels in the WSPs have decreased down to as low as 1 mg/L on occasions.

Midge fly nuisance
Since the introduction of the ASP, and the corresponding improvement in pond water quality, the increase in midge fly (Chironomidae) numbers at the site during summer months has emerged as one of the main operating issues. The pupal stage of the midge fly life cycle takes place in the upper layer of the pond sediment, and adult midges emerge through the pond surface on maturation. While the midge flies do not bite, and have a relatively short total lifespan of approximately three to five weeks, swarms of midge flies can cause a nuisance to local residents. This is particularly the case when wind conditions are amenable, or at night, when they are attracted to the lights of housing adjacent to the site. In addition to providing an airborne nuisance, dead midge flies rapidly accumulate around buildings at both the site (Figure 5), and the homes of local residents.

Midge fly problems were first reported at the site during the summer of 1967/1968, following commissioning of the WSPs in February 1967 (Peters, 1975). Insecticide dosing using Abate was initially used to control midge numbers. By the early 1970s, the midge flies were displaying evidence of insecticide resistance, and the control strategy shifted to prevention using operational strategies, involving an increase in the lagoon operating depth and the lagoon organic loading rate (accomplished by reducing the recirculation ratio of the secondary treatment). Both strategies were designed to reduce oxygen levels at the benthic interface. Peters (1975) suggested that larvae suppression was not directly due to oxygen deprivation, but rather by the action of some unestablished toxic byproduct of anaerobic digestion.

Since the commissioning of the ASP, the Australian Water Quality Centre has undertaken enumeration of midge larvae and emergent adult midge numbers in all six WSPs at the site (Madden, 2001). An example of the apparatus used for capturing emergent adult midges is shown in Figure 6. The sampling showed that emergent midge fly numbers during mid-2001 were similar to the levels experienced during the summer months by Peters in the 1970s. During 1973, the organic loading on the WSPs was approximately 10 kg BOD/ha d. Without any major changes in operating depth, by 2000 typical BOD loadings had increased to 40 kg BOD/ha d, and midge flies were no longer a problem at the site. Organic loadings fell to typical levels of 20 kg BOD/ha d after the commissioning of the ASP. During 2001–2003, midge emergence rates were highest in the latter WSPs in each stream, where loadings are lowest.

During 2001–2003, a number of solutions were trialed at the site. The aerial spraying of a chemical larvicide and two insecticides was tested, including Abate. Partial bypassing of secondary treatment was again trialed to increase organic loading rate. A number of portable light towers were installed at the site in an attempt to limit the migration of
midges outside the plant locality. Of these, only the larvicide Methoprene had a significant impact on emergent midge numbers, and it was concluded that aerial larvicide spraying is the most effective control strategy at the site. While a reduction in emergent midge numbers occurred after the organic loading was increased, it is possible that the reduction was in part due to other factors. Since the introduction of the ASP, no sampling of the WSP benthic interface has been undertaken to test the theory that it has become more aerobic. The increase in midge abundance may more directly result from other factors such as a reduction in ammonia levels, and therefore toxicity, in the WSPs.

Discussion

A considerable change in WSP ecology has occurred as a result of the introduction of the ASP at Bolivar WWTP. The ponds have undergone a shift from a more traditional facultative-maturation configuration to ponds in which are primarily used for pathogen disinfection, and to maintain a hydraulic buffer upstream of DAFF treatment.

The reduction in algal growth in the ponds and subsequent improvement in raw water turbidity entering the DAFF plant has led to significant reductions in both operating costs and sludge production of DAFF treatment. The treated wastewater from the DAFF plant is supplied to a horticultural reuse scheme. Improvements in treated water quality increase the value of this resource, and broaden the scope of uses to which it may be applied. The nature and scale of a number of negative impacts resulting from the changes were, however, not clearly evident prior to the commissioning of the ASP. Operating expenditure for midge control at the site has increased during the summer months. On a yearly basis, this cost of midge management using spraying has been of a similar order of magnitude to the saving in DAFF treatment costs. This is in addition to the expenditure associated with investigating these issues and revising operational practices. Currently, both the costs of operating the DAFF plant and controlling midge flies are subject to a high degree of variability, and from the available data it is not possible to conclude whether or not the lagoons have reached a new “steady state” phase of operation.

In an attempt to realise the full benefits of activated sludge secondary treatment at the site, it may be necessary to make further operational changes in the WSPs. A number of potential solutions have been considered, including biomanipulation of the ponds using shrimp or fish for midge control, or increasing the organic loading by only using a portion of the WSP system. The introduction of the ASP has demonstrated that the net benefits of large-scale changes can be difficult to predict. The impact of further operational

Figure 5 Accumulation of moribund midge flies at DAFF Plant. From Roder (2003)

Figure 6 Apparatus for sampling of emergent midge flies, with netting open at top. From Roder (2003)
changes on algal and zooplankton ecology, and pathogen levels in the WSPs, will have to be clearly understood prior to implementation.

Conclusions

Retrospective modifications of waste stabilisation pond pretreatment stages have the potential to produce significant benefits, as a result of changes in WSP operation. This has been the case at Bolivar WWTP, where the introduction of secondary activated sludge treatment has resulted in a significant improvement in the quality of treated wastewater produced at the site.

While still subject to large seasonal variation, the optimal alum dose for DAFF treatment of the lagoon effluent has reduced by approximately 50% since the introduction of the ASP. A similar reduction in water treatment costs has been achieved, along with reduced sludge production.

A number of operating issues have resulted from the change, the scope and impact of which could not be predicted prior to the change. In addition to capital expenditure associated with control of increased bird numbers on the WSPs, considerable ongoing operating costs are incurred for the management of midge flies at the site.

Biomanipulation of the ponds using aquaculture may provide a potential means to control midge numbers in the pond, however any such further changes which are likely to impact on the algal and zooplankton ecology, and pathogen levels in the pond, will require thorough investigation to ensure that they will be benign.

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References