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SELECTOR BASINS- DEVELOPMENT OF A COST EFFECTIVE DESIGN

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ABSTRACT

Since its design and construction in the early 1970's, flow and organic loads to the Alva wastewater treatment plant, operated by Scottish Water have changed considerably. Currently the plant receives a high flow but with a reduced strength wastewater and this has led to the proliferation of filamentous organisms in particular *Microthrix parvicella*, which in turn has resulted in high SSVI values. Consequently this has put final effluent compliance at risk. A number of capital intensive remedies were considered to increase the asset life including: chemically aided final settlement, incorporation of conventional selector basins and possible extensive modifications to the primary treatment stages. However an innovative approach to selector design was evaluated which took account of the variable nature of the sewage and endeavoured to ensure an adequate floc loading under most flow and load conditions. As a result the selector has a retention time of just 7.5 minutes at average flow (including RAS) and this resulted in the SSVI values reducing progressively from 150 ml/g to less than 75 ml/g over a 2 month operating period. This illustrates how experience in selector design can be modified to increase plant asset life and significantly reduce capital spend.

Keywords:

Selector, bulking, activated sludge, asset life, *M. parvicella*

INTRODUCTION

Many activated sludge plants built before the 1970's and 1980's have seemingly reached the end of their asset life in terms of the performance they can deliver compared to the increasingly rigid discharge consent standards with which they must comply. However over the past 30 years the flows and loads arriving at a treatment plant have varied greatly and the wastewater received today is likely to be very different to that envisaged in the original plant design. Consequently there is scope at any plant for a risk assessment of each unit operation based on the flow and load it actually receives, in order to evaluate the most cost effective uprating option.

Two factors have contributed synergistically to poor performance at many plants, namely a gradual deterioration in the organic load of the sewage, together with a gradual increase in the operating MLSS in order to achieve tighter consent standards. These two factors have led to a reduction in the operating F/M ratio at the treatment plant, allowing many filament types and in particular *Microthrix parvicella*, to predominate.

Table 1: The design flow and population equivalent for the Alva WwTw

Parameter	Alva WwTW
DWF(m^3/d)	2800
FFT (m^3/d)	8381
PE	9000
Storm Flow	3-6DWF primary settlement
Main industrialists	Brewery (keg washing only)

The consequences of *M. parvicella* proliferation are well known, with: an increase in the blanket height in the final clarifier increasing the risks of consent solids (and thus BOD) failures; a reduction in the return activated sludge suspended solids concentration leading to problems in maintaining reactor MLSS concentrations, and; increased volumes of waste sludge which are more difficult to thicken and dewater. At older works, all of these factors put increased pressure on the assets and may result in additional, sometimes unnecessary, refurbishment with its related capital spend, attempting to alleviate what appears to be a problem with an overloaded treatment plant. This paper reports on one such plant at Alva in the county of Clackmannanshire, Scotland which struggled to meet its consent and was likely to require a capital spend of up to £3 million, for a population equivalent of 9,000.

THE NATURE OF THE PROBLEM

The Alva WwTw comprises four stages of treatment, namely: preliminary treatment in the form of an inlet fine screen, primary sedimentation in Imhoff tanks, secondary treatment in oxidation ditches with conventional secondary clarification units and sludge storage. The site receives predominantly domestic wastewater but there is a small industrial contribution from a brewery and a prison. The design basis for the Alva plant is provided in Table 1 which shows a dry weather flow of 2,800 m^3/d and a population equivalent of 9,000, thus assuming a contribution of 311 litres/capita. The plant must meet a SEPA consent of 20 mg/l BOD and 15 mg/l ammonia at a 95 percentile (Table 2). There is presently no consent for suspended solids. This is easily within the capabilities of a well designed and operated oxidation ditch, indeed 15 mg/l BOD at a 95%ile are usually quoted for a typical UK sewage. However, large quantities of suspended solids in the final effluent will make the BOD consent hard to meet as each 10 mg of suspended solids will contribute from 2 to 12 mg of BOD. Thus improving the suspended solids removal will also make a big difference to the BOD removal efficiency and give an extra window of safety in consent compliance.

In July 2004 Scottish Water Solutions (SWS) Engineering commissioned Aqua Enviro to carry-out a process study at Alva WwTW. The agreed scope of works was as follows:

Table 2: SEPA consent conditions for the Alva effluent

Parameter	Value (95 %ile) mg/l
BOD	20
Ammonia	15
SS	NA

Table 3: Average load to the Alva site based on monthly data collected on six occasions between February 2001 and October 2003

Parameter	Concentration (mg/l)	Load (kg/d)
BOD	88	434
COD	230	1158
Suspended solids	114	593
Ammonia	16	85

- Carry out site visit & review current plant operation.
- Analyse all available historical data.
- Undertake microscopic examination to confirm the identity & abundance of filamentous bacteria.
- Evaluate potential engineering solutions.
- Recommend best options.
- Undertake 6-month service contract to evaluate effect of engineered solution.

The trials were also to establish if the secondary treatment stage could be made to work more efficiently with a weak pre-settled sewage or whether there was a requirement to bypass the existing upstream primary settlement tanks to increase the BOD loading to the works. Should a bypass be required then the additional scope of works would potentially involve conversion of the PSTs to sludge storage & storm tanks; construction of a SAS pumping station & installation of an additional inlet screen. This work had previously been costed at some £1m.

In addition to the above work there is also a contingency plan in place to provide additional chemical dosing facilities in order to aid final settlement. This was costed at an additional £0.15m.

OPTIONEERING

There are a number of possible permutations for optimizing the Alva oxidation ditches. Currently the plant operation is optimized for carbonaceous removal as the ammonia standard is achieved by a combination of influent dilution (as a result of high infiltration) and nitrogen assimilation by new biomass. However, due to a combination of planned improvements to the network infrastructure and additional load from new housing developments the plant will require to achieve complete nitrification. This will therefore necessitate the ditches to operate with increased operational sludge ages. There is also the possibility that the existing primary tanks may be removed and

Table 4: Operating parameters for the Alva WwTw at Average Flow and Load

Parameter	With Primary Sedimentation		Without Primary Sedimentation	
	BOD removal	Nitrification	BOD removal	Nitrification
BOD load (kg/d)	290	290	434	434
Ammonia load (kg/d)	13	13	16.4	16.4
Range of F/M (/d)	0.12-0.3	0.074-0.15	0.12-0.3	0.074-0.15
Sludge age (d)	9.2	15	9.2	15
Max MLSS (mg/l)	2,200	3,620	3,340	5,420
Total oxygen (kg/d)	291	353	458	536
Max $SSVI_{3.5}$ (ml/g)	>120	110	120	<70

Table 5: Maximum operating MLSS (mg/l) for the Alva oxidation ditch at a range of flow rates and operating SSVI3.5 values

SSVI$_{3.5}$ (ml/g)	Flow (m^3/d)			
	4,200	**6,300**	**8,400**	**10,000**
70	6820	5,400	4,470	**3,951***
80	6153	4873	**4033***	3565
90	5620	4450	3683	3256
100	5182	4103	3396	3002
110	4815	**3813***	3156	2790
120	4503	3566	2952	2609

** Worst case (maximum) MLSS necessary to achieve nitrification of settled sewage*

retrofitted as storm tanks, in which case the ditch would operate on screened raw sewage. Thus this gives four possible future operating scenarios.

With long term historic SSVI levels being in excess of 140 ml/g optimisation of the SSVI was therefore key. For carbonaceous only removal the maximum SSVI at average flow could be >120ml/g but at peak flow would be need to be 90 ml/g in order to prevent final effluent compliance problems. If nitrification was required at the lowest F:M ratio quoted above, the SSVI at average flow would need to be approximately 70ml/g and at peak flow significantly <<70 ml/g and so unlikely to be achieved in this case.

SELECTOR DESIGN FOR ALVA

The approach taken at Alva was to construct a selector tank, monitor the performance and then review the requirement for further capital work at the site.

The initial approach to selector design is to consider a selector that provides a hydraulic retention time of around 15 min at average flow and then to determine the instantaneous floc loading in this selector. The initial volume can then be adjusted up or down or alternatively the RAS rate to the selector can be adjusted, to bring the floc loading into the correct range. Thus with an average flow of 5453 m^3/d, the initial selector volume for Alva is 57 m^3.

Assuming that the influent COD is 230 mg/l, and the RAS is set at DWF and provides 10,000 mg/l MLSS and 60 mg/l COD, then the instantaneous conditions in the selector at average flow are: MLSS = 4,348 mg/l and COD = 156 mg/l. Thus the floc loading is 36 mg COD/ g MLSS which is a little low as a result of the weak sewage to the plant. In order to increase this, only half the RAS should be circulated to the selector thus giving conditions in the selector of MLSS =2,800 mg/l and COD = 204. Thus the floc loading in the selector is 73 mg COD/ g MLSS which is in the middle of the required floc loading and thus a sensible selector. The recommendation therefore is that the Alva ditch has two selectors installed, each of 28.5 m^3. The selectors are baffled into three zones each of 9.5 m^3 using under /over baffles. The first zone of the selector receives all of the incoming settled sewage into the first zone; in addition the first zone of each selector also receives RAS at a rate of 1050 m^3/d.

Note that the use of these design criteria required Scottish Water Solutions to obtain a specification waiver from Scottish Water. This is due to the fact that the Scottish Water functional specification requires a hydraulic retention time of between 10mins at flow to full treatment (including RAS) and 30mins at average daily flow (including RAS). The waiver was granted, demonstrating Scottish Water's receptive approach to innovation.

Table 6: Selector Design Summary

No. selector tanks:	2 (one per aeration tank)
Type:	Anoxic 3 chamber
Material of construction:	Concrete with stainless steel baffles
Working capacity	29m3 each
Dimensions:	2.12m(W) x 2.12m(TWL) x 6.4m (L) nominal
Design floc-loading rate:	75 mg.COD.g.MLSS
HRT (ex RAS)	15 min at ADF
HRT (inc RAS	7.5 min
RAS ratio	50% upstream of selector/50% downstream
FFT	48l/s (each tank)
DWF	24l/s (each tank)
ADF	32 l/s (each tank)
RAS flowrate (trial)	100% DWF
RAS flowrate (future)	50- 150% DWF

RESULTS

The installation of the selector tanks has resulted in a progressive improvement to the settleability of the sludge (figures 1 and 2, table 7) in the final settlement tanks over the trial period. Analysis has shown that the activated sludge SSVI has reduced from an average of over 140ml/g before the trial to an average of 70 ml/g in the final month.

Microscopic evidence collected from Alva indicates that the selectors to date have achieved the following changes to the activated sludge mixed liquor:

- Not changed the overall abundance levels of filamentous bacteria.
- Changed the dominant species present from Microthrix parvicella to Type 0041 and Type 1851.

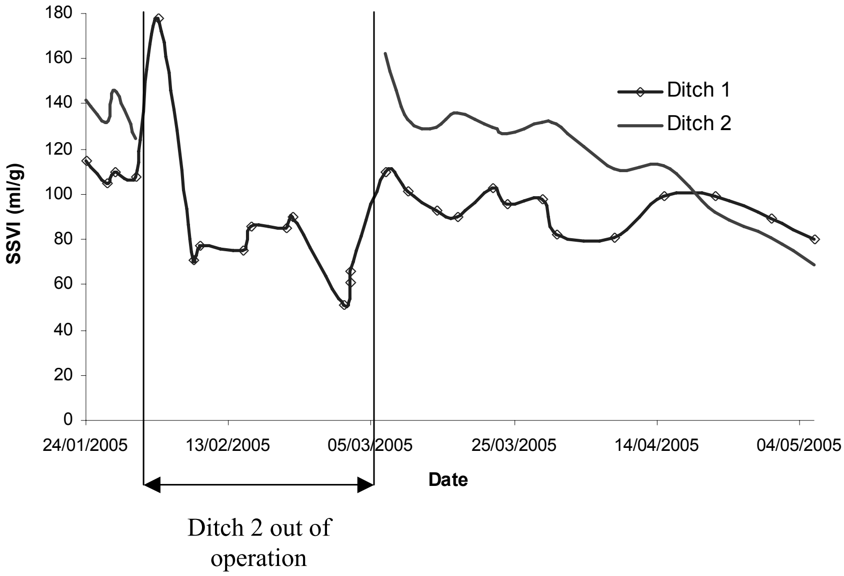

Figure 1: Improvement in SSVI

Table 7: Zone settling before and after selector installation

Time	28th Jan 2005	29th May 2005
	MLSS = 3147 mg/l	MLSS = 3230 mg/l
0	50	50
5	49	39.6
10	41.8	26.1
15	34	18.6
20	28.2	13.5
25	24.7	11.1
30	23	10.6
35	20.4	9.1
40	19	8.3
45	18.2	7.6
50	17.4	7.3
55	16.5	6.8
60	16.2	6.4

- Reduction in the length of filamentous bacteria present.
- Significantly improved the morphology of the flocs.

CONCLUSIONS

The installation of the selector tanks has resulted in a progressive improvement to the settleability of the sludge in final settlement tanks over the trial period. Analysis has shown that the activated sludge SSVI has reduced from an average of over 140ml/g before the trial to an average of 70 ml/g in the last month.

As one of the main aims of the trial was to reduce the SSVI value to below a target

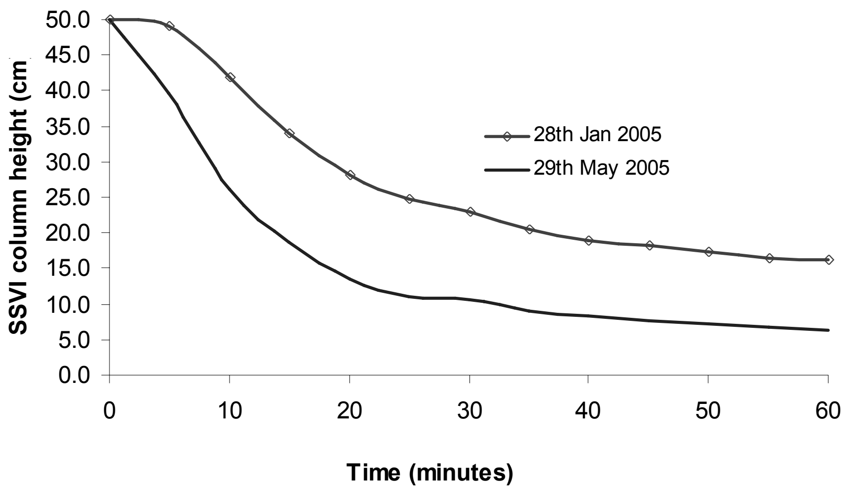

Figure 2: Zone settling velocities

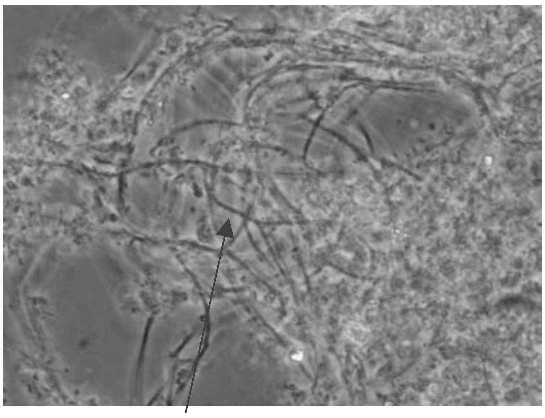

Figure 3: **July 2004: Large coils of Microthrix interfering with floc structure (x1000)**

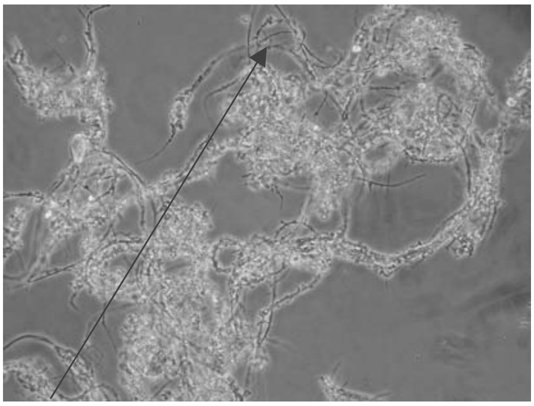

Figure 4: **January 2005: Type 1851 dominates, Microthrix absent, flocs remain poor (x100)**

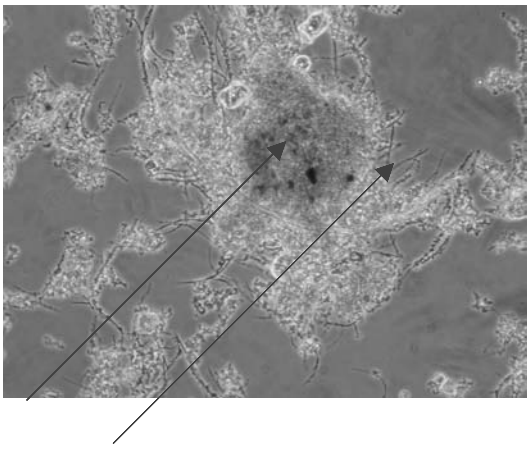

Figure 5: **July 2005: Compact dense flocs. Filament levels remain high but lengths are much shorter (under 500 um), (x100)**

value of 95 ml/g the trial can be seen as very successful.

It is thought likely that a reduction in the plant operational MLSS will reduce the mass flux on the final settlement tanks and hence further improve sludge blanket control. This will allow greater plant flexibility & provide increased process robustness.

The inclusion of a selector has not changed the overall abundance levels of filamentous bacteria but has changed the dominant species from *Microthrix parvicella* to Type 0041 and Type 1851. It has also resulted in a reduction in the length of filamentous bacteria present with a significantly improved floc morphology.

The selector tanks have improved the performance of the activated sludge plant to the extent where it is thought unlikely at the present stage of the trial that there will be a requirement to install any further equipment other than that already approved i.e. new inlet pumps, RAS pumps & new inlet screens.

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