METHODS FOR ESTIMATION AND COMPARISON OF ACTIVATED SLUDGE SETTLEABILITY

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ABSTRACT

This project aimed to investigate the most frequently utilised methods of estimating activated sludge settleability. The three methods investigated are the settled volume, dilute settled volume and stirred settled volume. Results from these tests can be used to adjust the wasting and return rates and can also give an indication of effluent turbidity. It was found that the SSVI method, outlined in the *Standard Methods for the examination of water and Wastewater*, produced the most consistent and least variable results of the three methods. Although the settled volume and dilute settled volume methods had significant variations, their usefulness in monitoring the wastewater treatment process should not be discounted.

1.0 INTRODUCTION

Allconnex Water ran and managed a number of wastewater treatment plants in the Gold Coast, Logan and Redlands districts. Allconnex Water was committed to protecting the environment and ensured that treated wastewater surpassed the legislative requirements. An important aspect in achieving this goal is the monitoring of the solids in the activated sludge process as this gives a useful indication of the biological processes occurring and also prevents solids overflow into the environment.

Over the years, a number of different methods have been developed by operators to estimate the sludge volume index (SVI). According to the *Standard Methods for the examination of water and Wastewater*, there is only one recommended method for undertaking this examination. Therefore, this project aimed to investigate the different methods utilised by operators and linking them to the *Standard Method 2710 C*.

2.0 DISCUSSION

2.1 Wastewater Treatment

The wastewater treatment plants operated by Allconnex Water almost exclusively used the activated sludge treatment systems. The biological treatment of wastewater is by far a more cost efficient method when compared to chemical treatment. The process typically involves pre-treatment such as screening and chemical dosing. This is followed by biologically degrading the wastewater by utilising bacteria specific to the type of treatment required. The treated water is then pumped to the final clarifiers where the solid part of the waste (sludge) is separated from the liquid (effluent).

2.2 Sedimentation

The process occurring in the final clarifiers is simply gravity separation. The purpose of which is to collect the biological sludge which often settles quite rapidly due to their oxidised nature. However, in activated sludge systems there is the possibility that lighter, more buoyant flocs are formed. This results in a longer time for settling to occur and as a practical rule, the surface overflow rates should generally not exceed $33m^3/m^2/d$ in order to allow time for these buoyant particles to settle.

2.3 Particle Interaction

In the activated sludge process, biological floc often comes into contact with other floc particles causing an interaction to take place. In the final clarifier, 3 main types of settling occur:

Discrete (Type I settling)
Hindered (Type III settling)
Compression (Type IV settling)

In Type I settling, no interactions between particles take place and flocs settle increasingly faster until the terminal velocity of the particle is reached. The terminal velocity of the particles can be calculated by using Stoke's law. Type III settling involves particles moving as a block, thereby restricting fluid flow. This causes an increase in the drag force and may also increase the buoyant force acting on the particles. Type IV settling involves the particles physically interacting, compressing each other. Type II settling primarily occurs in water treatment, where flocculation is heavily utilised.

2.4 Sludge Volume Index

The sludge volume index (SVI) is the volume in millilitres occupied by 1 gram of a suspension after 30 minutes of settling. The measurement of biological suspension from the activated sludge process is primarily estimated by calculating the Sludge Volume Index (SVI). In order to calculate the SVI, the settled volume and the total suspended solids (TSS) has to be measured. TSS in this particular instance can also be referred to as the mixed liquor suspended solids (MLSS). Measurement of the settled volume allows for the determination of the return activated sludge (RAS) flow rate and could also be utilised in determining when to waste sludge (WAS).

2.5 Settled Volume

The settled volume method was the first method developed to determine the SVI. This method involves settling one litre of sludge from the aeration basin in a graduated cylinder for 30 minutes. Equipment required for this test includes a one litre graduated cylinder, latex gloves and safety glasses. The aerated sludge sample is homogenised before being placed in the cylinder. The volume of sludge at t = 30 minutes was recorded as the settled volume. The SVI is calculated as per equation 1.

$$SVI\ (\text{mL/g}) = \frac{\text{Settled Volume (mL)}}{MLSS\ (\text{g})} \qquad \text{(Equation 1)}$$

2.6 Dilute Settled Volume

The dilute settled volume is a modification of the settled volume method. Equipment required for this test is the same as the settled volume method. In order to calculate the DSVI (Dilute Sludge Volume Index), an arbitrary sample volume of around 300-500 mL (varies between plants/operators) is collected from the aeration basin. Depending on the volume of sludge utilised, the graduated cylinder was filled with potable water. The aerated sludge was then homogenised, filled to the one litre mark on the cylinder and settled for 30 minutes. At t = 30 mins, the volume to which the sludge settled was recorded. The DSVI is calculated as per equation 2.

$$DSVI\ (\text{mL/g}) = \left(\frac{\text{Dilute Settled Volume (mL)}}{MLSS\ (\text{g})}\right) \times \left(\frac{\text{Final Volume (mL)}}{\text{Initial Volume (mL)}}\right) \qquad \text{(Equation 2)}$$

2.7 Stirred Settled Volume

The stirred settled volume is the method proposed in the *Standard Methods for the examination of water and Wastewater, method 2710 C*. This method requires a graduated cylinder with a motorised stirring rod, rubber gloves and safety glasses. The speed of the motorised stirring rod should be constant for the duration of the experiment and in the range of 1-5 RPM. A higher RPM than this range will begin to re-homogenise the sample. An aerated sample is collected from the aeration basin, homogenised and filled to the mark. The motor on the cylinder is turned on and left to settle for 30 minutes. The sludge volume is recorded at t=30 minutes. The SSVI is calculated using equation 1.

2.8 Determination of MLSS

The calculation of the SVI requires the MLSS be known. The procedure for the determination of the MLSS is outlined in *Standard Method 2540 D.* A homogenised aeration basin sample is vacuum filtered onto a pre-weighed filter paper. The filter paper is dried in an oven at 103-105^{o}C until a constant weight is obtained. The increase in weight of the filter paper is representative of the MLSS concentration.

2.9 Influencing Factors

A number of variables affect the settleability of sludge in the final clarifiers. These include filamentous bacteria, rain events and temperature. In large numbers, filamentous bacteria such as S.*natans* and *M.parvicella* affect activated sludge settleability by producing more buoyant flocs. Typically, a balance between floc forming and filamentous bacteria is desired. Too little filamentous bacteria in the sludge results in pin floc formation which is undesired as pin floc does not settle readily and can cause effluent short circuiting in the final clarifiers. This leads to turbidity issues later on in the treatment process.

Temperature can affect the settleability of solids as at a higher temperature, the SVI increases significantly. This is more noticeable during the summer and winter months. As a result, it is important to ensure that when conducting settleability measurements, a constant temperature is maintained.

2.10 Other Methods

Apart from the three main methods outlined, there are still some various methods which are being used to measure settleability; one of which involves the use of the Imhoff cone. The procedure *2540 F* in the *Standard Methods* is used to determining the settleable solids and involves the use of the Imhoff cone. This method is primarily used for the measurement of solids in very dilute mixtures. Results obtained from this method should not be used to calculate the SVI.

3.0 CONCLUSION

3.1 Experimental

Experiments were conducted at various wastewater treatment plants around the Gold Coast, Redlands and Logan districts. Aerated sludge samples were collected before the outlet of the aeration basin. The SVI measurement method at the wastewater treatment plants was compared with the SVI obtained using the SSV method. SSV cylinders were obtained from the HEAL Group Inc. This process was repeated for a number of treatment plants at room temperature (20-25°C).

3.2 Results

Results of the experiments were recorded and the SVIs determined. The results of experimentation can be found in Figure 1. It is impractical to compare WWTP performance based on SVI measurements.

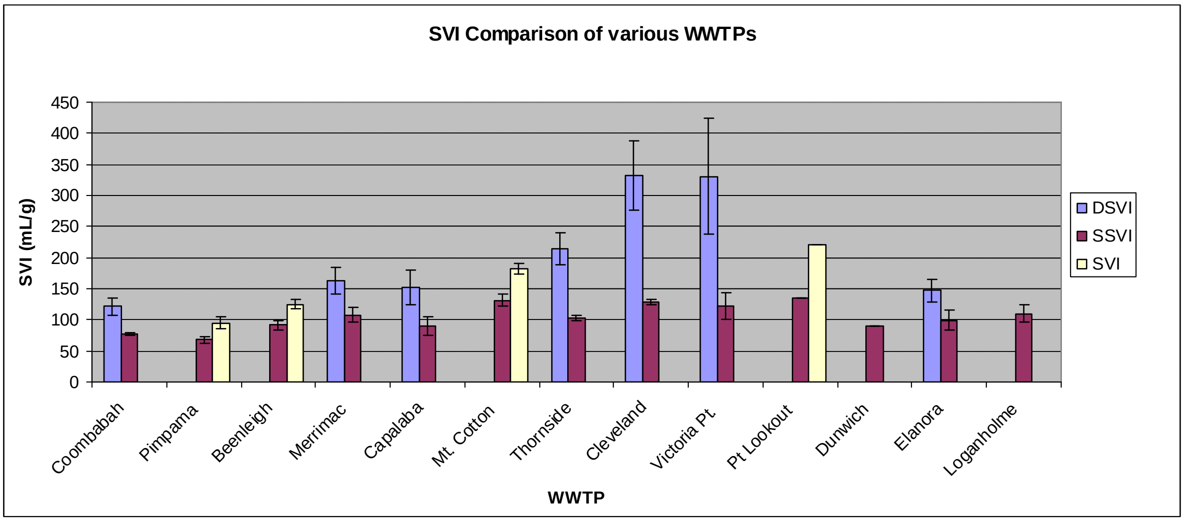

Figure 1: ***SVI values using the different methods at various WWTPS. n = 5****
****n= 1 for Dunwich and Pt Lookout WWTPs***

3.3 Data Interpretation Methods

Spellman's Standard Handbook for Wastewater Operators gives an in depth analysis of what typical SVI values should be and what they mean. This should be used to judge what further actions need to be taken for most favourable operation of the WWTP:

Table 1: ***Interpretation of SVI results***

SVI range	Expected Condition
< 100mL/g	Old sludge; possible pin floc; increasing effluent turbidity
100mL/g to 250mL/g	Normal operation; good settling; low effluent turbidity
> 250mL/g	Bulking sludge; poor settling; high effluent turbidity

Plotting SVI values over a time period allows for any trends to be identified. These trends allow for adjustments to be made on how much sludge is being wasted and returned from the final clarifiers.

Table 2: ***SVI Trends and Sludge Characteristics***

SVI Value	Sludge characteristics	Adjustment(s)
Increasing	• Less dense • Either young or bulking sludge • Slow settling • Compact less	• Decrease waste • Increase return rate
Decreasing	• More dense • Older sludge • Rapid settling • Compact more	• Increase waste rate • Decrease return rate
Constant	• Possesses current characteristics	• No Change

3.4 Analysis

The SSV method consistently produced lower results over the other methods (Figure 1). Using Table 1, the SSVI method produced a majority of results within the range of 100-150mL/g, indicating that the WWTPs are functioning at normal operation. The DSV method constantly overestimated the SVI which is most likely due to the effect of sample dilution. The SV method also consistently overestimated the SVI, however, this was not a large difference in comparison to the DSV method.

The SSV method produced more uniform SVI results whereas the SV and DSV methods both produced variable results. This may be due to the wall effects in the cylinder being negated by the constant stirring. At sludge concentrations of > 3000mg, wall effects and bridging between floc particles disrupts the settling rate of the sludge.

Overall, the SSV method would be the most suitable as it takes multiple variables into account and produces more uniform results. The DSVI and SVI produce more varied results but should not be discounted as they can still provide valuable information about sludge characteristics. Monitoring of the sludge settleability should also not be neglected as this can greatly help with the operation of WWTPs.

3.5 Limitations

The process of determining the SVI at wastewater treatment plants has a number of limitations. Firstly, the number of experiments carried out was too few to make any solid conclusions. The ever changing influent characteristics of the wastewater can affect the SVI. In addition, the time of sampling can cause SVI results to differ (peak flow vs. low flow). During this project, the zone settling velocity was not explored and could provide valuable information on effluent short circuiting.

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