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# Study of the secondary settler capacity at Gryaab

Master of Science Thesis in the Master's Programme

Infrastructure and Environmental Engineering

Yue Zhou

Department of Civil and Environmental Engineering

Water Environment Technology

CHALMERS UNIVERSITY OF TECHNOLOGY

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Yue Zhou

Department of Civil and Environmental Engineering
*Division of Water Environment Technology*
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Yue Zhou



Examiner: Britt-Marie Wilén

Chalmers University of Technology
University of Gothenburg
Department of Civil and Environmental Engineering
Division of Water Environment Technology
SE-412 96 Göteborg
Sweden
Telephone + 46 (0)31-772 1000

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# Abstract

When the activated sludge process is applied, the secondary settler is often the most critical treatment step. The secondary settler is one of the most important processes in the wastewater treatment plant, it should produce a particle free effluent and a thickened sludge that can be returned to the influent of the activated sludge tank. Based on the comprehensive assessment of historical data and state point theory, this thesis focuses on researching the secondary settler operational capacity at the Rya wastewater treatment plant (Gryaab). First the properties of the activated sludge flocs were analyzed. Parameters such as stirred sludge volume index (SSVI), mixed liquor suspended solids (MLSS), zone settling velocity (ZSV), effluent suspended solids concentration, non-settleable solids concentration and turbidity are effective ways to define the settling properties of activated sludge in wastewater treatment plants. There was a clear correlation between MLSS and both SSVI and ZSV during the experiments data. It is better to operate a plant with a low SSVI value due to the good settling properties of activated sludge. However, this might lead to increased concentration of suspended solids in the effluent. Secondly the functions and characteristics of the secondary settlers were theoretically analyzed, and then according to the sedimentation test data, state point figures were plotted together with the observation of appearance of activated sludge flocs the operational situation at the Rya wastewater treatment plant was assessed. The experimental result shows that the shape of the solids flux curve is wide and high, and the state point is well below the curve. Consequently there is a big buffering rang of solids flux in the secondary settler which then could be loaded at least 50% more. On the basis of state point theory, polymer addition test and degassing test were carried out in order to see there are any optimization measures that could be used in at this plant to increase the secondary settler capacity.

**Keywords:**

activated sludge, sludge volume index, settling, flocculation, sedimentation, zone settling velocity, solids flux, concentration of sludge, polymer, degassing.

## Glossary

| | | |
|---|---|---|
| SST | - | Secondary settling tank |
| SSVI | - | Stirred sludge volume index |
| MLSS | - | Mixed liquor suspended solids |
| TSS | - | Total suspended solids |
| SS-out | - | Suspended solids in the effluent |
| $Q_{es}$ | - | Flow into secondary settler |
| $Q_R$ | - | Recycle sludge flow |
| ZSV | - | Zone settling velocity |
| HLR | - | Hydraulic loading rate |
| SLR | - | Solids loading rate |
| $G_{apply}$ | - | Application value of solids flux |
| $G_L$ | - | Limiting value of solids flux |
| $X_L$ | - | Limiting value of sludge concentration |
| $X_{RAS}$ | - | Return sludge concentration |

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# 1 Introduction

## 1.1 Background

Nowadays, environmental protection plays a role which becomes more and more important all over the world. Air, soil and water are the main three phases in this fast-developing area. Wastewater treatment is especially important due to the closely associated relationship of water with human's daily life. The two aspects, domestic and industrial waste water treatment have been developed into an active industry and protect our human beings from the danger of poison of contaminated water. Sweden is one of the leading countries in the world in treating waste water and the history of waste water treatment is very long.

## 1.2 The Rya WWTP

The Rya wastewater treatment plant is located in Göteborg, Sweden. The plant is operated by Gryaab AB, a company owned by seven municipalities in the Göteborg region is used for treating the waste water from the Göteborg area. The plant serves about 830,000 population equivalents. The flows can range from 175,000 to 1,425,000m3/d and the average daily flow is approximately 350,000$m^3$/d. The Rya wastewater treatment plant has high flows at wet weather flows and it has relatively highly loaded secondary settlers. At the latter half of the 1990s, the Rya WWTP was extended with secondary sedimentation tanks in two layers and with biological nitrogen removal including pre-denitrification and post-nitrification processes. For this plant, the wastewater from the secondary settlers must be recirculated to the trickling filters for nitrification. In 2010 the plant was further extended with a post-denitrification moving bed biofilm reactor (MBBR). A part of the effluent from the trickling filters can flow into the MBBR system for post-denitrification. Disc filters were also installed in 2010 where effluent from the secondary settlers and

MBBR are filtered through 15 µm cloths (Fig 1). The bottle-neck of the process is often the secondary settler capacity. At high flows into the treatment plant, less water can be recycled to the trickling filters as the secondary settlers have limited hydraulic capacity. Poor clarification in the settlers also leads to clogging of the disc filters.

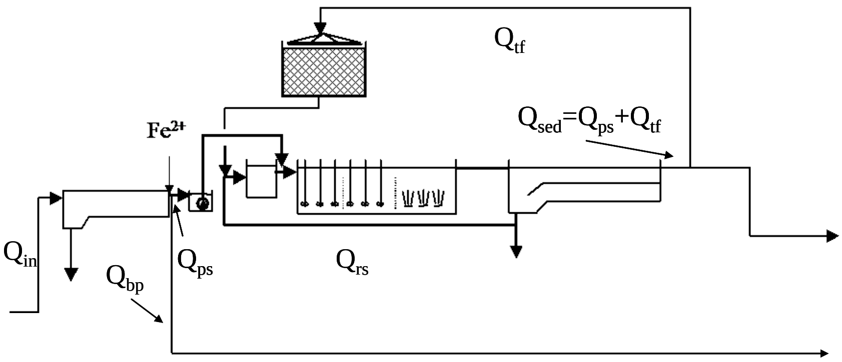



Figure 1. Schematic drawing of process at Gryaab.

## 1.3 Aims and objectives

The ultimate aim of this project is to find solutions to be able to operate the secondary settlers at higher hydraulic loading rates. More specifically this will be done by analysis of the characteristics of the flocs and settling and compaction properties of the activated sludge as well as assessing the load of the secondary settler at the Rya WWTP. The solid flux curve theory will be applied to research the settling capacity of the secondary sedimentation tanks. By studying the effluent properties such as suspended solids concentrations and turbidity a better understanding of the clarification properties will be assessed. Full scale process data will also be assessed to find correlations between operational parameters. The possibility to get better settling properties, and hence improved solids flux, by either adding synthetic polymers to the sludge or to expose the sludge to vacuum in order to remove dissolved gas in the sludge is also to be assessed.

# 2. Literature review

## 2.1 Activated Sludge Process

In the activated sludge process, the microorganisms form flocs, which are suspended in the wastewater. From the activated sludge tank, the wastewater-sludge mixture flows into the secondary sedimentation tank, where sludge is separated from the purified wastewater. The main part of the settled sludge is transported back to the activated sludge tank as return sludge, while a smaller part is removed as excess sludge and treated subsequently. Purified wastewater is discharged into the receiving watercourse (Fig 2). [1]

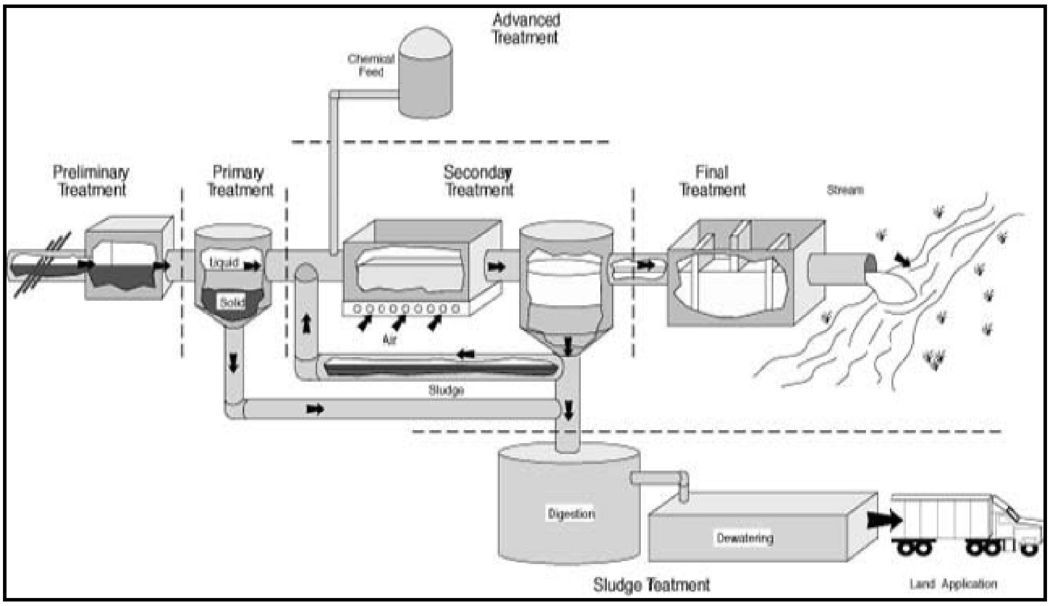



Figure 2. Schematic drawing of a typical wastewater treatment plant. [1]

## 2.2 Main activated sludge parameters

The sludge volume index (SVI) is the volume in milliliters taken up by 1g of mixed liquor suspended solids after 30 min settling. SVI is a common way to analyze the flocculation and sedimentation properties of activated sludge. A low SVI value stands for a well-flocculated sludge with good settling and compaction properties [2]. The stirred specific volume index (SSVI), is used in this thesis. Slow stirring is then applied to reduce wall effects during sedimentation in the cylinder.

MLSS is the concentration of mixed liquor suspended solids in an aeration tank during the activated sludge process. MLSS is an important part of the activated sludge process since there must be a sufficient quantity of active biomass available to consume the applied quantity of organic pollutant at any time.

## 2.2 State Point Analysis Theory

The state point analysis method is an extension of the solid flux theory. It is a convenient and effective analytical method to use as a tool to analyze and optimize the secondary settlers.

### 2.2.1 Solids Flux Theory

The solids flux theory is the theoretical basis to determine the secondary settling tank volume. Coe and Clevenger proposed the theory already for thickening, which is using solids load to determine the area of thickener tanks [3]. In 1969, according to the theory of traditional thickening concept by Coe and Clevenger, Dick proposed the method by using solids flux theory to determine the secondary settling tank area and a mathematical expression linking ZSV (m/h) with the solids concentration X (kg/m3) [2]. He assumed that in ideal secondary settlers, solids flux is in a state of dynamic balance which means that at the same time, the mass of solids flux entering the secondary settler equals the mass of the solid flux discharge from the settler. The downward flux consists of gravity settling and transport due to the underflow which is being pumped out and recycled:

$$G = XV_0e^{-nX} + Xq_R \quad (kg/m^2h)$$

$$\mathrm{U}_R = \frac{Q_R}{A}$$

Where:

X = solids concentration ($kg/m^3$)

$U_R$ = underflow rate (m/h)

$Q_R$ = recycle flow rate ($m^3$/h)

A = SST surface area ($m^2$)

n, $V_0$= Vesilind constants

G = solids flux (kg/$m^2$h)

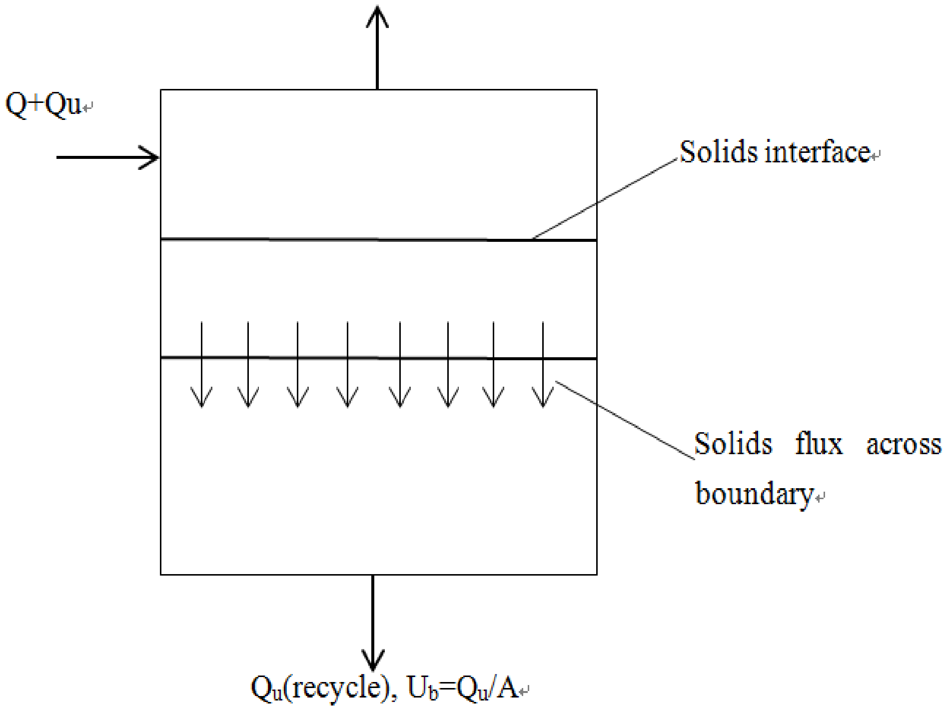



Fig 2.1 Definition sketch for a settling basin operating at steady state [4]

As shown on Fig 2.1, in a settling basin that is operating at steady state, a constant flux of solids is moving downward. In this tank, the downward flux of solids is brought about by gravity settling and by bulk transport due to the underflow that is being pumped out and recycled. [4]

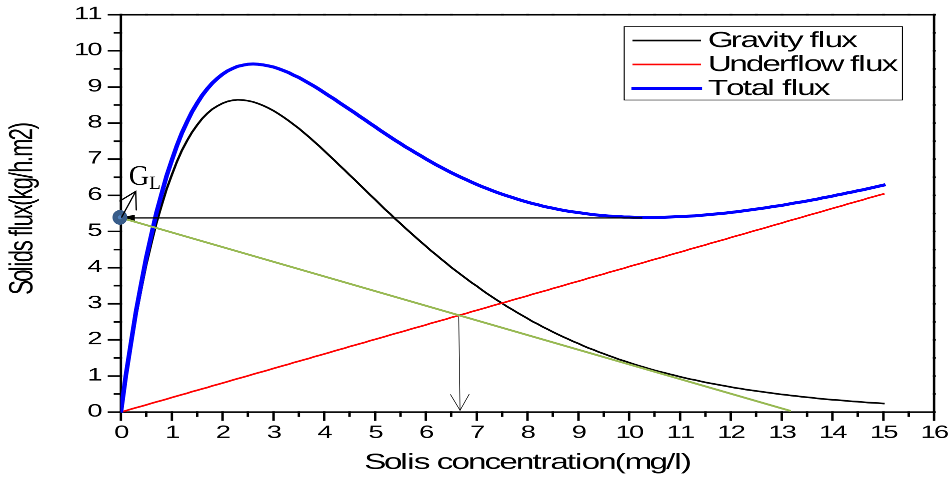



Fig 2.2 Definition sketch for the analysis of settling data using solids flux method.

Gravity flux is the mass flux of solids due to gravity settling and depends on the concentration of solids and the settling property of the solids at that concentration. It is can be obtained through several settling tests at different mixed liquor suspended solids concentrations. Underflow flux is the mass flux of solids due to movement of return sludge flow, which is associated with the operational mode of settling basins. It is a linear function of the concentration. The total flux is the sum of gravity flux and underflow flux. The green line corresponds to the underflow flux and touches the gravity flux curve at the inflection point and its intersection with the Y-axis gives the limiting flux. [4]

As shown on Fig 2.2, if a horizontal line is drawn tangent to the inflection point on the total flux curve, its intersection with the Y-axis represents the limiting solids flux $G_L$ that could be handled in the settling basin. The required area necessary to handle the limiting flux can be expressed as:

$$A = \frac{(Q + Q_u)C_0}{G_L}$$

Where:

A = cross-sectional area, ($m^2$)

$Q+Q_u$ = total volumetric flow rate to settling basin (overflow+underflow), ($m^3/h$)

$C_0$ = concentration of sludge in the aeration tank ($kg/m^3$)

$G_L$ = limiting solids flux, ($kg/m^2h$)

### 2.2.2 State point analysis

Fig 2.3 consists of settling flux curve, overflow rate operating line and the underflow rate operating line, the intersection of overflow rate operating line and overflow rate operating line is defined as a state point, which reflects the flow balance relation in secondary settler. [5] Gravity flux curve could be used to analyze the operational state of an activated sludge system in every moment. Therefore, it is better to do the on-line settling test to get accurate data in order to ensure the accuracy of the analysis results.

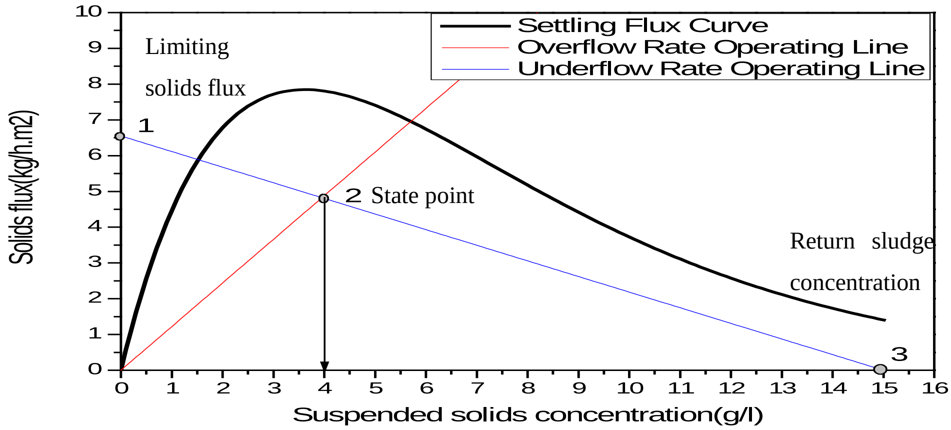



Fig 2.3 State point analysis in a secondary settler

Referring to Fig 2.3, the slope of overflow rate represents upward water flow in the settling basin and the velocity is equal to the ratio of inflow of secondary settler with the total area of the tank. Point 1, 2 and 3 represents the limiting solids flux, state point and return sludge concentration, respectively.

$$U_b = \frac{Q_{es}}{A}$$

Where:

$Q_{es}$ = inflow of secondary settler ($m^3/h$)

A = SST surface area ($m^2$)

$U_b$ = water overflow velocity (m/h)

The slope of underflow rate represents downward flow in the settling basin and the velocity is equal to the ratio of return sludge flow rate with the total area of the tank. The negative sign means the direction of velocity is downward.

$$U_R = -\frac{Q_R}{A}$$

Where:

$Q_R$ = return sludge flow ($m^3/h$)

A = SST surface area ($m^2$)

$U_R$ = downward water flow (m/h)

In addition, in Fig 2.3, point 1 represents the value of solids flux G, which stands for the mass of solid flux entering the secondary settler in a unit of time. When the operation of secondary settlers is in a stable condition, the value of G is equal to Solid Loading Rate (SLR). Point 2 stands for the actual MLSS concentration. Point 3 stands for underflow concentration. [5] An example of a settling flux curve with underflow rate operating lines is shown on Fig 2.4. An under loaded (1), critically loaded (2) and overloaded (3) secondary settler with respect to settling can be identified in a state point analysis by the position of the state point and the underflow rate operating line relative to the descending limb of the settling flux curve.

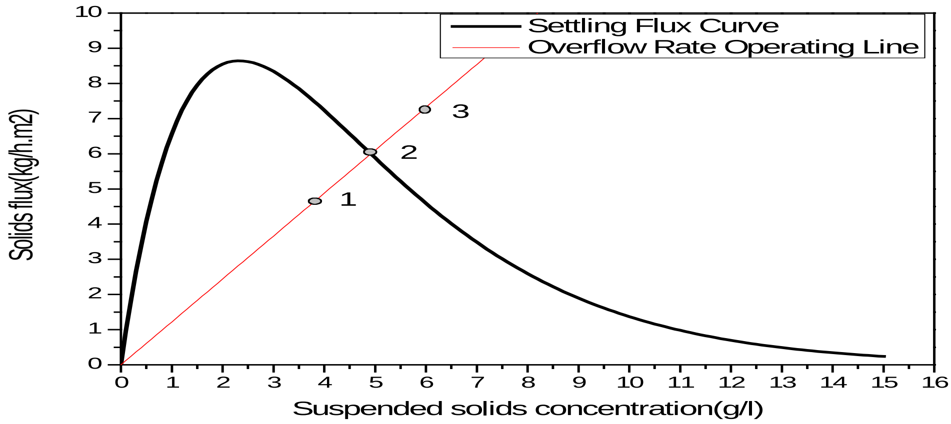



Fig 2.4 State point analysis for assessing clarifier operating

The clarification effect on secondary settler has been decided by both solids flux and mixed liquid suspended solid concentration as shown on Fig 2.4. The state point 1 is below the settling flux curve, the secondary settler is under loaded and the operation is stable. The state point 2 is on the settling flux curve, the secondary settler is critical load, in this condition the clarification effect on secondary settler will be influenced when there is peak discharge. The state point 3 is above the settling flux curve, the secondary settler is overloaded. Which means the effluent velocity is higher than settling velocity, then the sedimentation of solid is not enough, solid particles could be taken away by the outflow of secondary settler tank, which leads to a worsened clarification effect on secondary settler tank as well as heavy loss of biomass from the system.

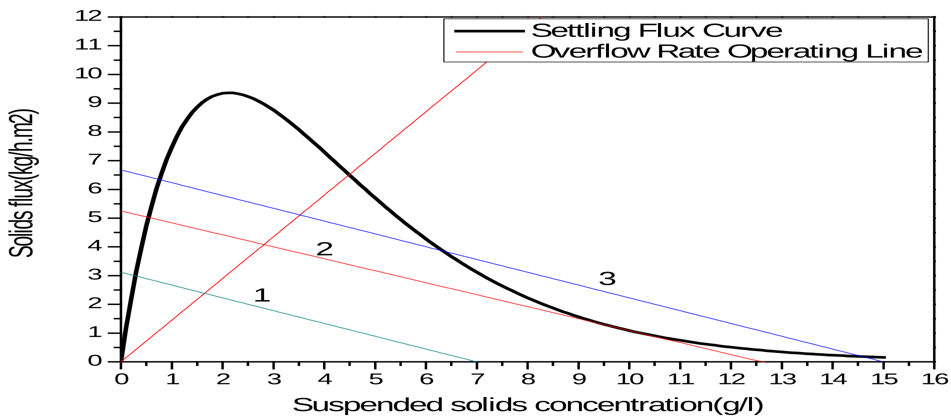



Fig 2.5 State point analysis for assessing thickened operating

The compression effect on secondary settler has been decided by both solids flux and underflow rate as shown on Fig 2.5. The underflow rate line 1 is below the settling flux curve: the secondary settler is under loaded and the solids which enter the secondary settler tank could be settled to the bottom completely in order to avoid sludge layer formation on the bottom.

The underflow rate line 2 is tangent to the settling flux curve: the secondary settler is critically loaded, which means the amount of solids which enters the secondary settlers is a bit larger than the amount of sludge discharged. However, it is not a big problem for the effluent water quality due to the self-regulation of secondary settlers.

The underflow rate line 3 intersects the settling flux curve: the secondary settler is overloaded. Activated sludge accumulates constantly and will exceed the storing capacity of the secondary settler; as a result, the suspended solids in the outflow will increase.

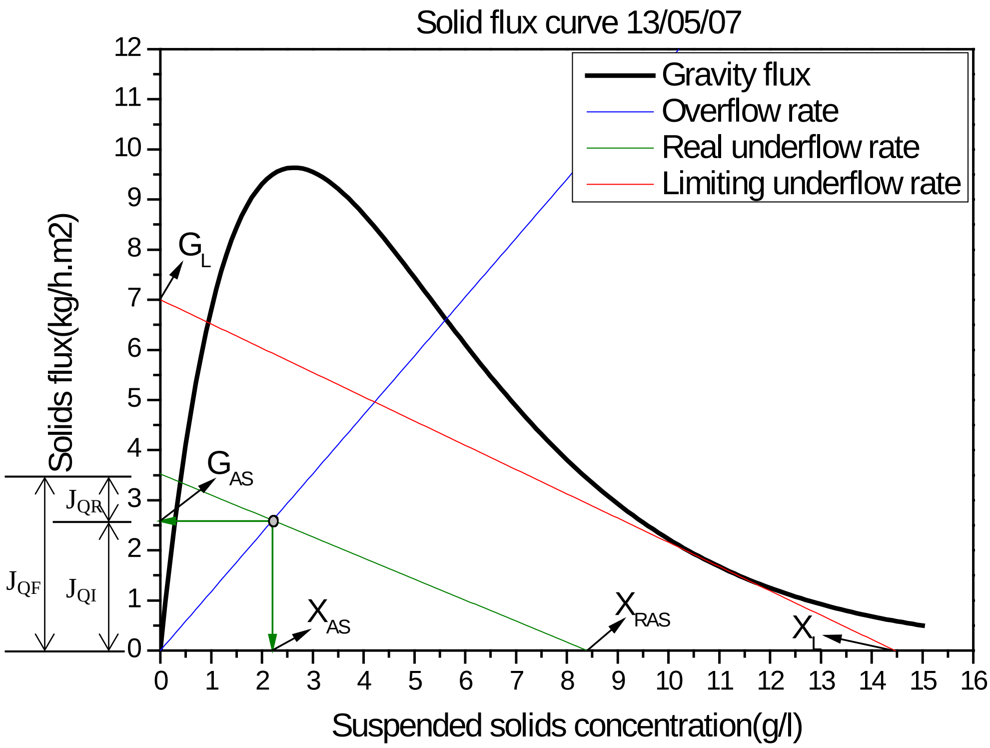



Fig 2.6 Definitions of the settling flux curve and state point analysis of SST operation

Where:

$J_{QF}$: The total solids loading rate

$J_{QI}$: The solids loading rate imposed on the SST by the influent flow

$J_{QR}$: The solids loading rate imposed on the SST by the RAS flow

$X_{AS}$: mixture suspended solid concentration

$X_{RAS}$: return sludge suspended solids concentration

$X_L$: limiting return sludge suspended solids concentration

$G_L$: limiting gravitational solids flux

$G_{AS}$: real gravitational solids flux

State point reflects the relationship between inflows of secondary settler (Qes), area of settler tank (A), mixture suspended solid concentration ($X_{AS}$), return sludge suspended solids concentration ($X_{RAS}$) return sludge ratio (R) and sludge volume index (SSVI).

### 2.2.3 The influence factors of state point

**1. Effects of changes in the influent flow (Qes)**

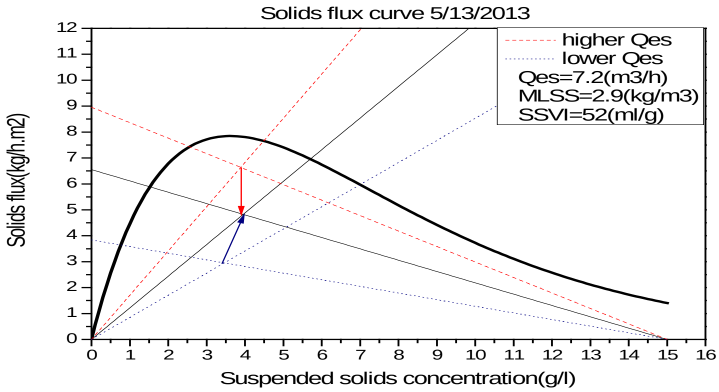



Fig 2.7 Effect on influent flow into secondary settler

If the amount of inflow to the secondary settler (Qes) changes, the slope of the overflow rate operating line and the slope of the underflow rate operating line will change as follows: in case of a higher inflow of the secondary settler, the solids flux will increase as well as the state point will moves up. On the other hand, the state point moves down when the inflow decreases (Fig 2.7).

**2 Effects of changes in the feed concentration ($X_R$)**

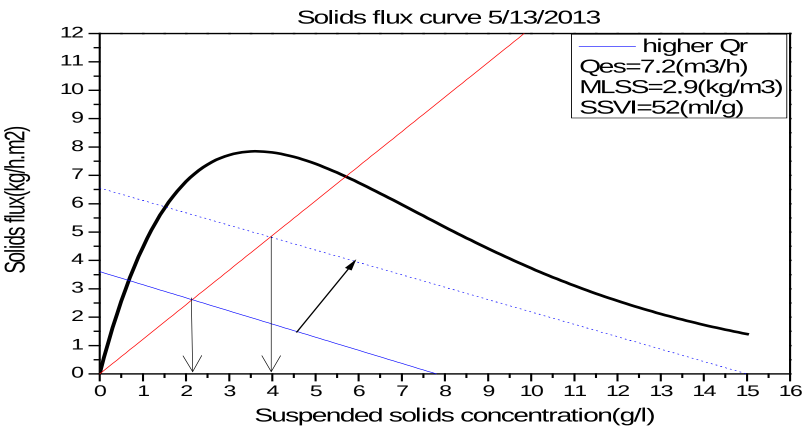



Fig 2.8 Effect on feed concentration

Mixture suspended solid concentration determines the intercept of the underflow operating rate line with X-axis. With the increase of mixture suspended solid concentration, the solid loading rate and expected underflow concentration will increase too. The state point will move to the upper right.

## 3 Effects of changes in the return sludge flow ($Q_R$)

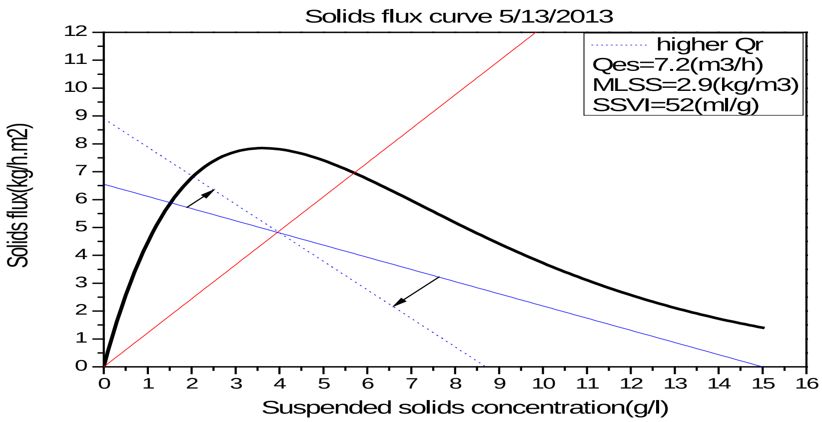



Fig 2.9 Effect on return sludge flow

The return sludge ratio is expressed as the percentage of the influent wastewater flow. This determines the flow rate and concentration of return sludge, If other factors remain constant, with the increase of return sludge ratio, the return sludge quantity and flow rate will increase. Then the slope of underflow operating rate line will increase and the expected return sludge concentration decreases. [6]

If the slope becomes very small, it is possible that the underflow rate operating line will be tangent to the solids flux curve and SST will get critically loaded. This would happen with lower sludge recirculation.

## 4 Effects of changes in stirring sludge volume index (SSVI)

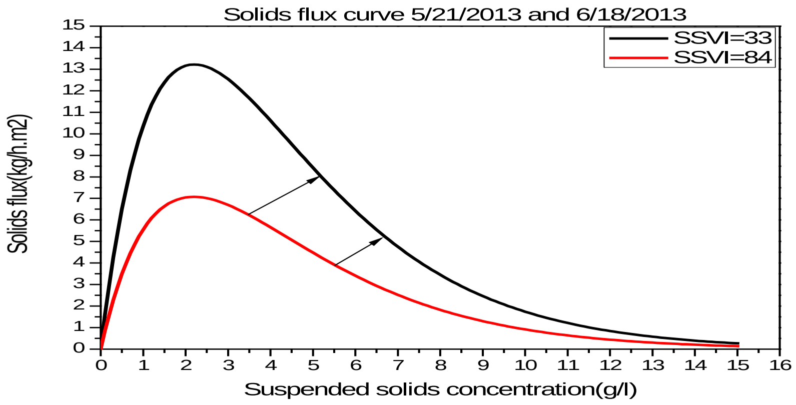



Fig 2.10 Effect on stirring sludge volume index

Stirring sludge volume index (SSVI) is indication measure of the sludge compressibility and settleability in the final clarifier. [2] As shown on Fig 2.10, a good settling sludge with low SSVI, will have a greater area below the solids flux curve, the curve is high and wide, which is good for separation of sludge. The effluent of the final clarifier is then good. In the case of high SSVI, the solids flux curve is lower and narrower.

## 2.3 Vesilind model

Generally speaking, different settling velocities will be obtained for different concentrations of mixed liquor. Different initial settling velocities are obtained for the same sample by changing the sludge concentrations. [7] At low sludge concentration, the movement of solids is mainly due to gravity and to a lesser extent due to interaction with other sludge particles. At very high solids concentrations, the settling velocity approaches zero. In order to get settling curves, the data is fitted to the Vesilind model. Two parameters are needed to be able to apply the Vesilind model namely the settling velocity and sludge concentration.

$$V_{ZS} = V_0 e^{-nX}$$

Where:

$V_{ZS}$= the initial settling velocity (m/h)

X= the concentration of the sludge (g/l)

n, $V_0$=Vesilind constants

$V_{ZS}$ of the sludge is obtained from a solid-liquid interface depth-time plot. It is given by the slope of the straight line part of the interface height and time curve. The $V_{ZS}$ decreases as the concentration increases. By changing the concentration of sludge, the $V_{ZS}$ at different X values is obtained.

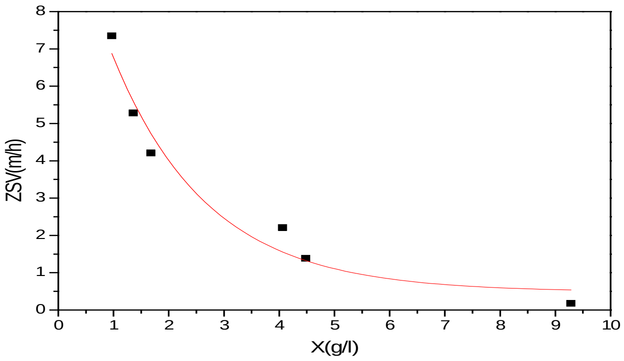



Fig2.11 Example curve of the Vesilind model

$$V = 10.102e^{-0.43X}$$

$$R^2 = 0.9897$$

In the example in Fig 2.11 the value for $V_0$ is 10.102 m/h and n is 0.43 l/g, so the initial settling velocity can be obtained for any concentration of sludge given, by fitting settling data to the Vesilind model. Hence a smooth settling curve can be plotted by using this formula. This is very useful when plotting the solids flux curve. [7]

## 2.4 Degassing technology

By subjecting the activated sludge to a strong vacuum pressure, the amount of gas bubbles in the water is reduced and thereby also improved compaction and settling properties are achieved.

## 2.5 Characteristics of activated sludge

Activated sludge flocs characteristics have a strong influence on the processes of the biological wastewater treatment, such as the settling abilities and the flocculation. The characteristics of activated sludge flocs are changing very fast depending on changing operation conditions. The appearance of flocs is determined by composition of microorganisms. To achieve a fast and efficient sedimentation, it is important that the activated sludge has good flocculation and sedimentation ability.

There are some important groups of bacteria and protozoa in activated sludge, the most common protozoa include flagellates amoebas and ciliates. They eat bacteria swimming around in the waste water then produce clear water. Their presence could be an indication of the state of the system, for instance, ciliates occur in long sludge age and in short sludge age there would contain more flagellates and amoebas. [9] Filamentous microorganisms are a type of bacteria which grows as long threads.

Some sedimentation problems are related to occurrence of various types of microorganisms such as enhanced growth of filamentous microorganisms and reduced flocculation properties. [9] The most common sedimentation problems are sludge bulking, foaming and formation of floating sludge.

# 3. Methodology

## 3.1 Historical data obtainment

On-line historical data as well as process data, such as stirred sludge volume index (SSVI), zone settling velocity (ZSV), mixed liquor suspended solids (MLSS), effluent suspended solids, turbidity, non-settable solids and amount of influent flow into settlers were taken from the Rya wastewater treatment plant operational system. By using historical data, the variation of performance of the process during recently years could be investigated. Process data from 2011 to mid-2013 were used.

## 3.2 Solid flux curve measurements

During a two months period, twelve solids flux experiments were carried out.

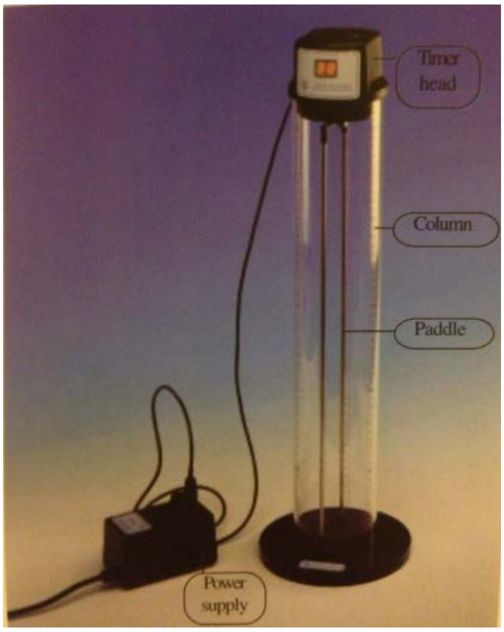



Fig 3.1 The Triton-WRc settling apparatus

Two 3 litres settling cylinders (50 cm high) were used for the settling experiments. During the test, an agitator with slow stirrers, around 1 rpm, was used to prevent the formation of floc adherence to the cylinder wall. The experiments were carried out during 30 minutes and the height of the sludge interface was recorded every minute. After that, the settling velocity and SSVI could be calculated by the residual settled sludge volume.

Each testing day, six experiments at different concentrations of sludge were carried out during a period from April until June 2013. Five of the samples were taken from the aeration tank and the last sample was taken from the recycle sludge stream. All of the samples were either thickened or diluted with effluent from the secondary settlers in order to get desired suspended solids concentration.

The six samples were obtained as follows:

- 2 times diluted: 2 litres of sludge from the aeration tank + 2 litres of effluent.
- 3 times diluted: 2 litres of sludge from the aeration tank + 4 litres of effluent.
- Original: 4 litres of sludge from the aeration tank.
- 1.5 times thickened: sludge from the aeration tank was settled and $1/3$ of a the supernatant was removed.
- 2 times thickened: sludge from the aeration tank was settled and $1/2$ of the supernatant was removed
- Return sludge: 4 litres of sludge from the returned sludge.

The sludge concentration and sludge volume index were measured after the settling test. Depending on different concentrations of the samples, either 10 ml or 5 ml of the mixed liquor was filtered through a Munktell (1.2 µm) filter paper and heated in a microwave oven during 8 minutes. The dried filter paper with the dried sludge was placed in a ventilated place for 30 minutes. The mass of sludge which remains on the paper filter, divided by the volume of sample that had been filtered is the mixed liquor suspended solids concentration of the sample (g/l).

By using the Vesilind model settling curves where correlations between $V_{ZS}$ and X can be obtained by best fit to settling data. This can then be used to calculate gravitational flux with different suspended solids concentrations (0 to 15mg/l).

Solids flux curve measurements were performed several times when the sludge properties were different. These data will be compared with the actual loading conditions at the plant by assessing on-line data from these particular days. In this way, the state point can be determined and compared with the limiting flux to assess whether the secondary settlers should be able to handle more flux or not.

Combined with the solids flux analysis, flocs have been studied with the help of microscopy in order to judge their properties and estimate morphology and size distributions to investigate how this affects the settling and compaction properties.

## 3.3 Polymer test

Two full scale experiments were carried out in the same day in order to keep similar process conditions in the activated sludge tanks. For the first experiment, samples were collected from the ordinary activated sludge sampling point, located where the effluent from the three parallel activated sludge tanks are mixed, which is after the polymer dosage point. For the second one, samples were collected in the channel before the polymer dosage point. Solids flux curves were then performed as before.

## 3.4 Degassing test

Activated sludge samples were taken at the same sampling point as for the solids flux analysis. Sludge samples were taken three times during one day at 10:30am, 11:45am and 14:30pm, respectively. For every experiment, two tests were performed at the same time. Four liters of sample was poured in a glass cylinder reactor up to a height of 45 cm. The sludge was degassed under stirring for 1min.  Another cylinder reactor was filled with non-degassed sample. In order to calculate the initial settling velocity the downward moving sludge level was read every 5 minutes during the first 30min of the analysis and then read every 10 minutes until 60min settling.

## 3.5 Characteristics of activated sludge

In this study, some parameters such as flocs size and flocs distribution, structure of the flocs and shape of the flocs were analyzed with the help of microscopy. Digital image analysis was used to determine flocs structures. Parameters like flocs size and flocs size distribution, morphological parameters such as structure of the flocs, shape of the flocs, and filaments could be observed from the digital images of activated sludge samples. Some pictures from different days were compared at different magnifications in order to evaluate the characteristics of the flocs.

# 4. Analysis of processing data from Gryaab

In this chapter, the on-line and laboratory process data obtained from Gryaab are analyzed. The chapter consists of three sections. In the first section, the historical data is analyzed, in order to achieve a complete understanding regarding the evolution of the settling properties at the plant. In the second and third section, the activated sludge properties and hydraulic loading data from 2011 to 2013 are investigated in detail, respectively.

## 4.1 Historical process data analysis

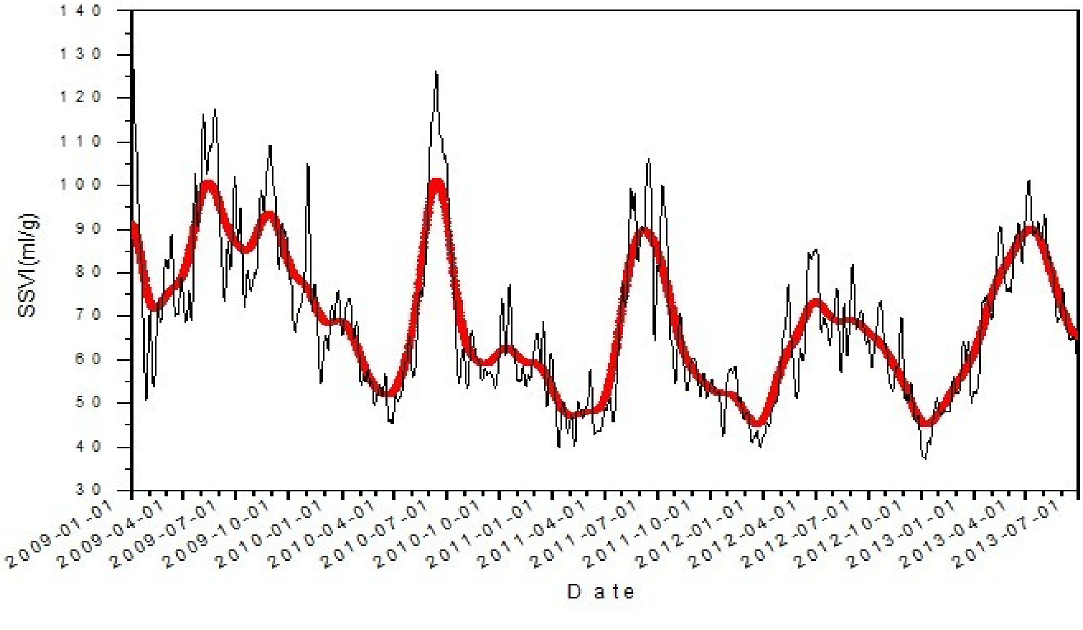



Fig 4.1 Evolution of SSVI from 2009 till 2013.

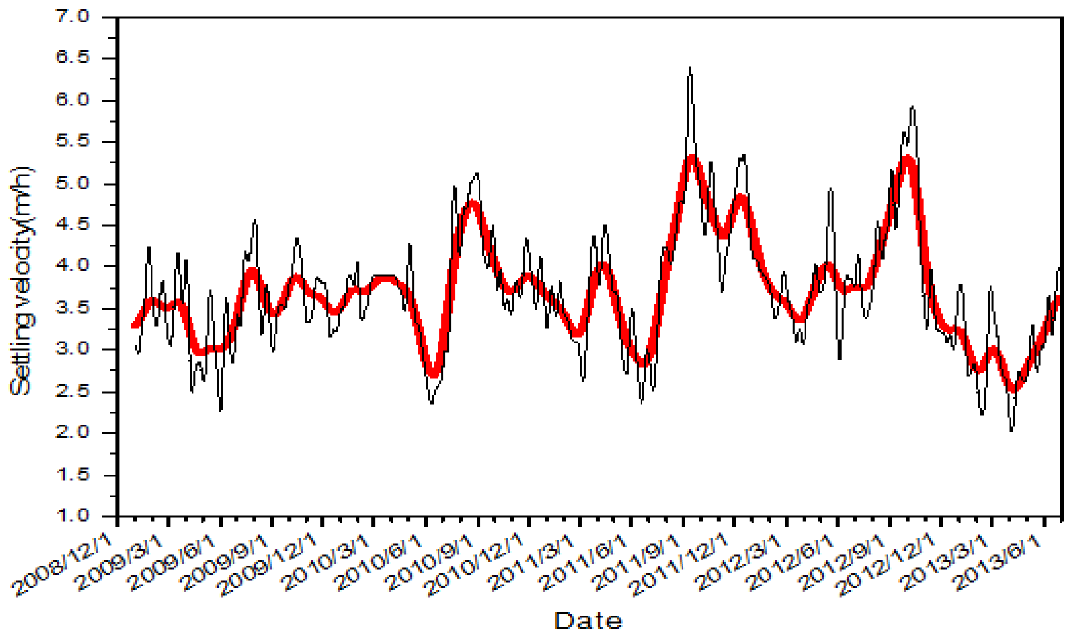



Fig 4.2 Evolution of ZSV from 2009 till 2013.

The changing trend in SSVI is shown in Fig 4.1, based on a series of data from five years (2009-2013). All the four SSVI peaks are at late spring/beginning of summer periods. According to Fig 4.2, the presence of three obvious peaks in ZSV is observed in September each year.

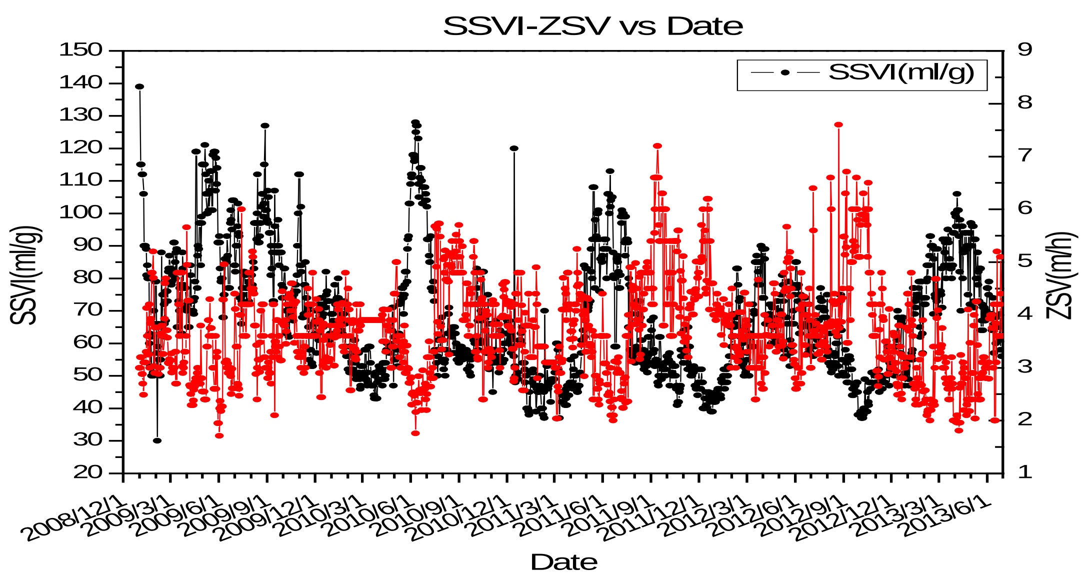



Fig 4.3 Evolution of SSVI and ZSV from 2009 to 2013.

A schematic diagram of the two changing trends of SSVI and ZSV are displayed in Fig 4.3, where it clearly can be seenthat there is an opposite trend between SSVI and ZSV, where the value of ZSV decreases as the SSVI value increases.

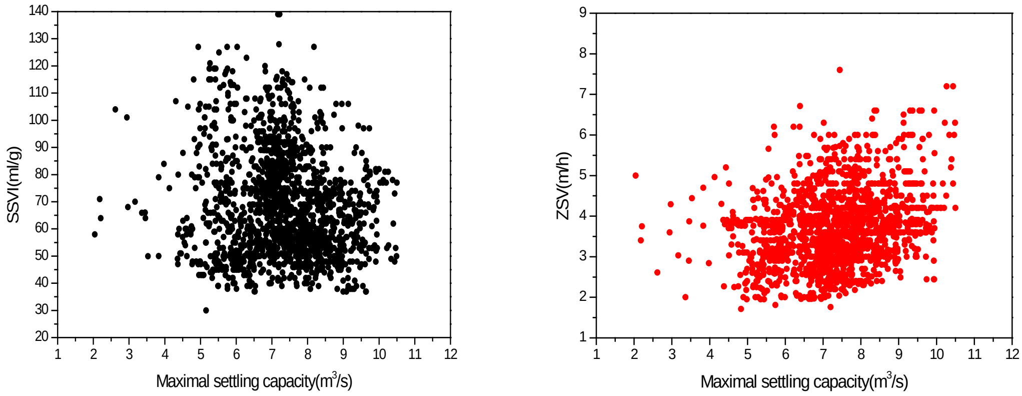



Fig 4.4　Relation between maximal settling capacity and SSVI, ZSV

The maximal settling capacity was found to be correlated to both SSVI and ZSV; when the SSVI is low and ZSV is high, the secondary settlers could be loaded with higher solids flux due to better settling properties (Fig 4.4).

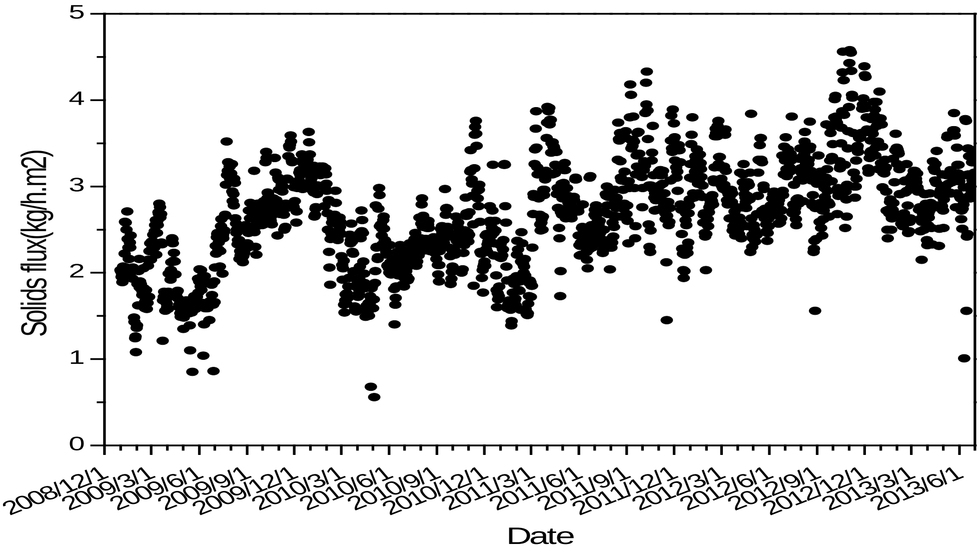



Fig 4.5　Evolution of Solids Flux from 2009 till 2013.

As can be seen in Fig 4.5, the settling properties obtained during the last 5 years show an increasing trend. Between 2009-2011, the average value of solids flux was 2.3 $kg/h.m^2$, but in the recent two years, the solids flux values stable rose to around 3 $kg/h.m^2$ approximately (Fig 4.5).

## 4.2 Analysis of the activated sludge data from 2011-2013

This thesis will be focus on the detailed data from the last three years (2011 and half of 2013). Process data obtained from the Gryaab laboratory were used to evaluate and analyze the sedimentation properties of the activated sludge.

### 4.2.1 Analysis of the effect of SSVI

There are several parameters that have an effect on the SSVI value. The wastewater composition always influences SSVI since it affects the sludge properties. Other affecting parameters are hydraulic conditions, sludge age, dissolved oxygen concentration among others. Moreover, the addition of polymers is also a very important factor since it can affect the settling properties directly.

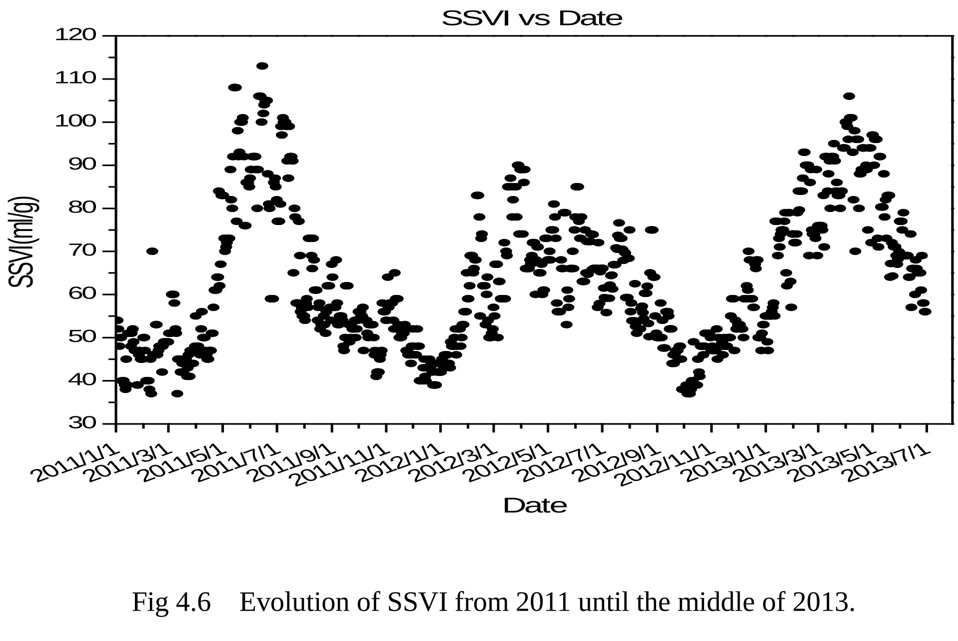



Fig 4.6 Evolution of SSVI from 2011 until the middle of 2013.

From the SSVI value during this period, the average value is 65 ml/g, which means the activate sludge has good settling properties. However the values of SSVI were changing substantially over the year. In general, the poor settling properties occurred in the spring (high SSVI). After that the trend was increasing until the summer, and then it started to go down.

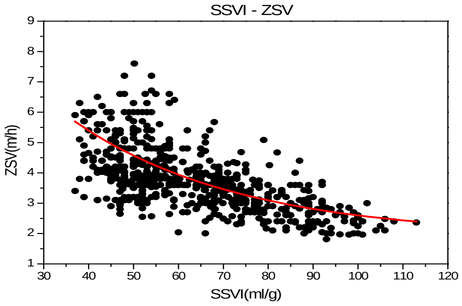



Fig 4.8 Relation between ZSV and SSVI

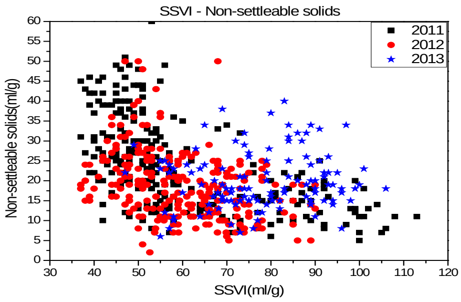



Fig 4.9 Relation between Non-settleable solids and SSVI

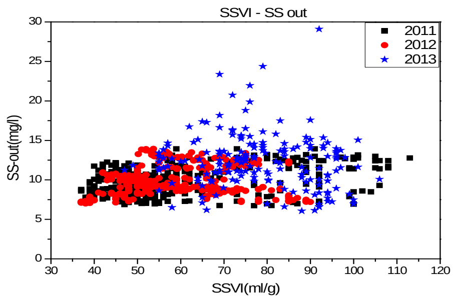



Fig 4.10 Relation between SS-out and SSVI

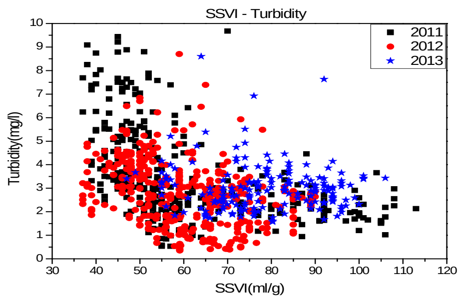



Fig 4.11 Relation between Turbidity and SSVI

The correlation between ZSV and SSVI is presented in Fig 4.8. In Fig 4.9 the relation between SSVI and non-settleable solids is illustrated where different colors show data for the last three years. There is a clear correlation between SSVI and non-settleable; for low SSVI, the concentration of non-settleable solids is higher, which means that when SSVI is high and ZSV is low, the non-settleable solids concentration is low. Therefore, to achieve an optimized operation in treatment plant, a balance between these two factors is necessary.

As shown on Fig 4.10 the suspended solids concentration value in the effluent is rather stable in 2011 and 2012 whereas there is more variation during 2013. There is no evident correlation to SSVI. The effluent suspended solids concentration varied less compared to the non-settleable solids during sedimentation test in a cylinder. In a full-scale secondary settler, the sludge flocs are probably more re-flocculated during the transport into the settler. Also a larger fraction of the sludge is transported directly to the sludge pocket, which is located near the inlet to the settler and hence, the major part of the settler is occupied by less amount of sludge. Another reason to the stable effluent suspended solids concentration is that during periods of poor clarification, polymers are added to the sludge mixture in the channel before the secondary settlers. From turbidity the correlation with SSVI is similar to suspended solids concentration where higher SSVI value leads to lower turbidity value.

### 4.2.2 Analysis of the effect of MLSS

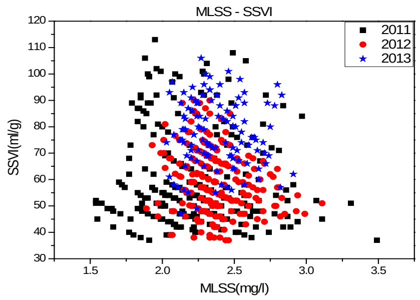



Fig 4.12 Relation between MLSS and SSVI

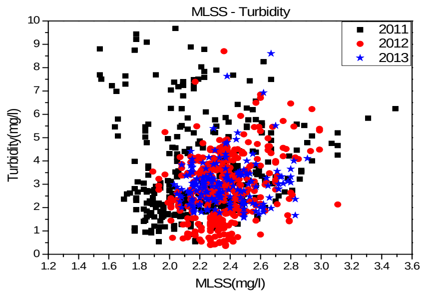
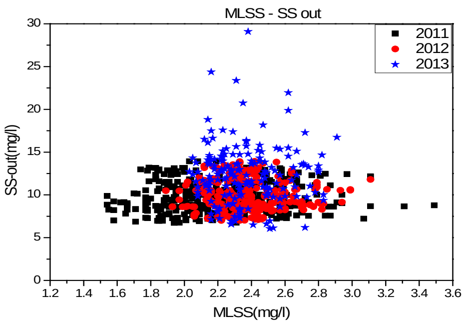



Fig 4.13 Relation between Turbidity and MLSS

It does not exist an evident correlation between MLSS concentration in the aeration tank and SSVI (Fig 4.12). When looking at the turbidity it can be seen that with an increase of the MLSS concentration, the turbidity in the effluent value does not change much. Therefore low MLSS concentration could not lead to a high turbidity value.



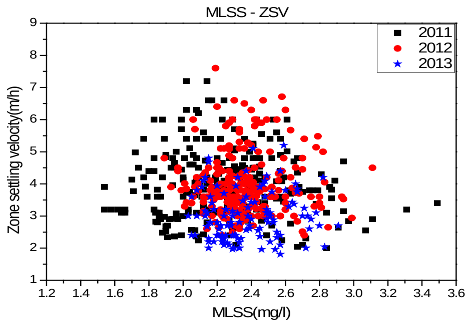



Fig 4.14 Relation between MLSS and SS-out    Fig 4.15 Relation between MLSS and settling velocity

In the same way as shown before there is no clear correlation between the MLSS concentration in the aeration tank and the SS-out (Fig 4.14). There is also no correlation between the MLSS concentration and the zone settling velocity (Fig 4.15).

## 4.3 Analysis of the hydraulic load data from 2011-2013

The amount of the different influent flows to the Rya WWTP is also a factor to study in order to understand the flocculation and sedimentation process. Apart from the influent flow, the flow coming from the trickling filters and return sludge flow also has to be considered when assessing the hydraulic condition in the secondary settler.

### 4.3.1 Analysis of the effect of influent

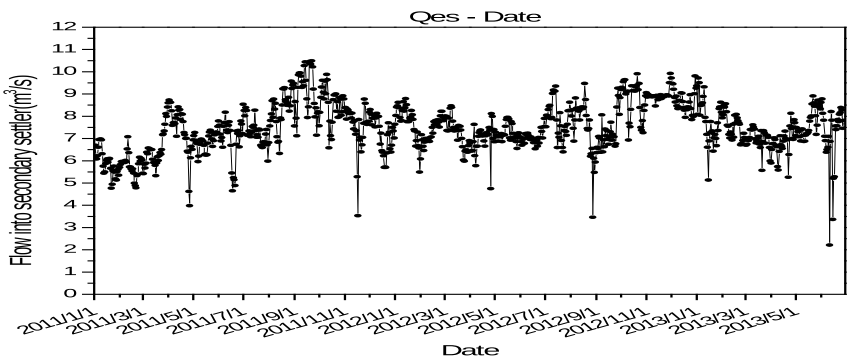
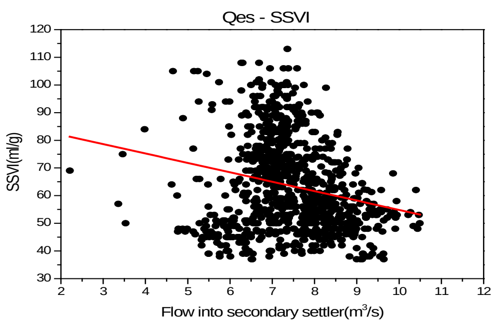



Fig 4.16  Evolution of Qes from 2011 till half of 2013.



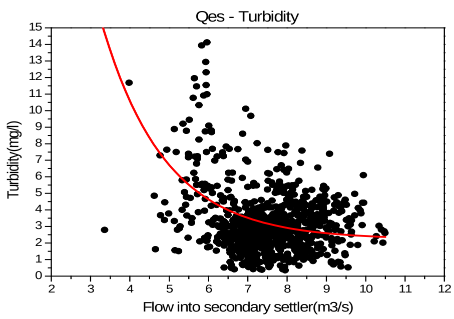




Fig 4.17  Relation between Qes and SSVI    Fig 4.18  Relation between Qes and turbidity

According to Fig 4.16, the value of inflow to the secondary settlers is around 7.5m$^3$/s. There is a clear correlation between the SSVI, turbidity and amount of flow into secondary settlers of the plant. It can be seen that for higher SSVI, less flow can be transported to the secondary settlers. On the other hand, flow could not be the reason to the settling problems but when the settling properties are poor less water can be passed through settlers. However, increased flow to the secondary settler may lead to decreased turbidity in the effluent, probably as a result of scouring of the sludge blanket.

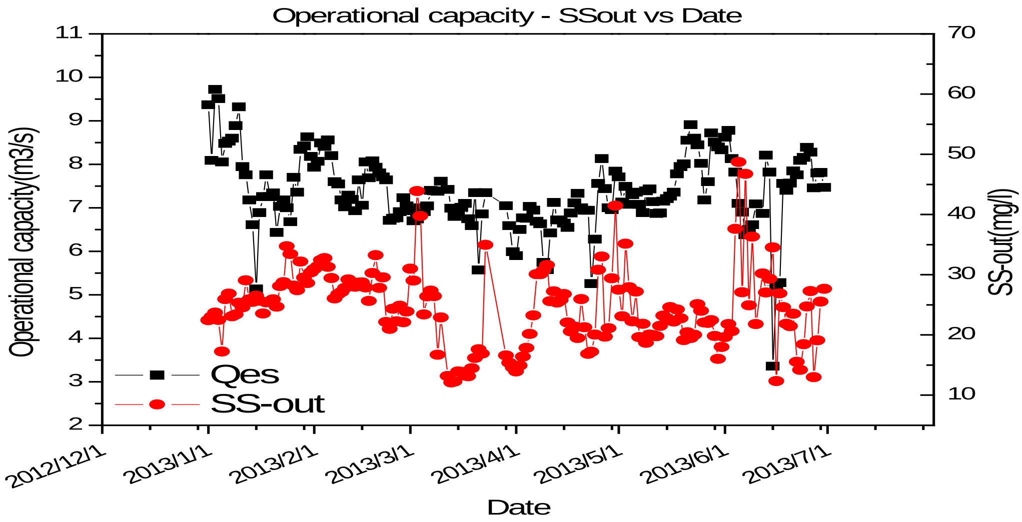
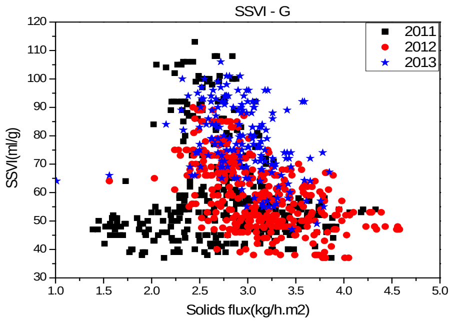



Fig 4.19 Evolution of operational capacity and SS-out in 2013

The value of operational capacity is the same as Qes. The correlation between operational capacity and suspended solids in the effluent is not very evident (Fig 4.19). Sometimes, for low values of operational capacity, the suspended solids concentration is higher. Sometimes it is the opposite. This is because suspended solids concentration is effected by the activated sludge properties. If the particles have poor sedimentation properties the suspended solids concentration will be high. Moreover, when the influent flow was changing, the value of suspended solids also will be affected.

### 4.3.2 Analysis of the effect of solids flux

The amount of solids flux that can be loaded on the secondary settlers is also a way to study the process performance of the plant. The solids flux theory is used in the experimental part of this thesis and there will be more detail in chapter 5.



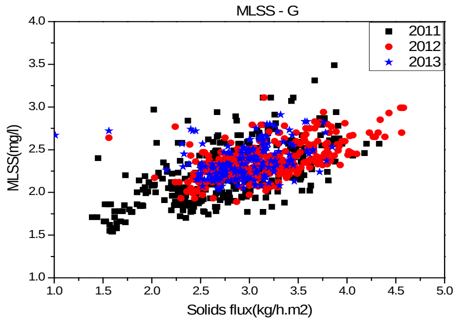




Fig 4.20 Relation between SSVI and Solids flux   Fig 4.21 Relation between MLSS and Solids flux

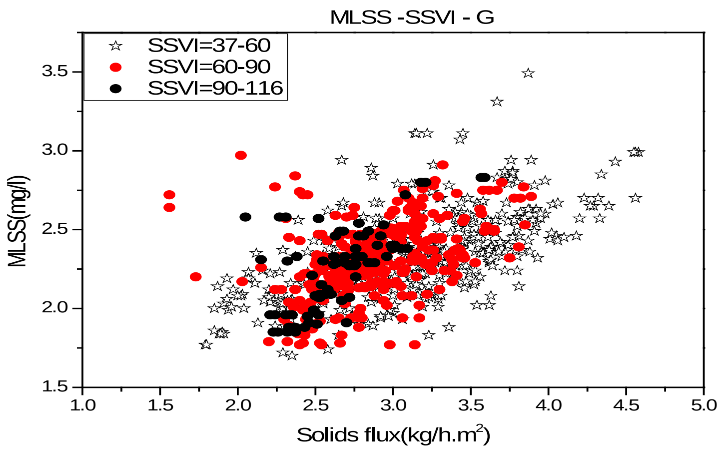



Fig 4.22 Relation between MLSS, SSVI and Solids flux

The solids flux is clearly correlated to the SSVI and MLSS concentrations (Fig 4.20 and 4.21). It seems that working with lower SSVI and higher MLSS is a good way to get better secondary settler operability. The SSVI value is concentrated at a range of 37 to 116 ml/g. At higher SSVI less solids flux can be handled in the secondary settler at a certain suspended solids concentration (Fig 4.22).

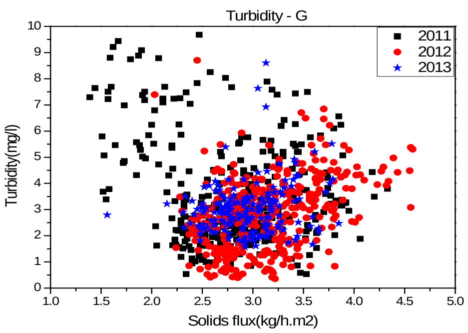



Fig 4.23 Relation between Turbidity and Solids flux

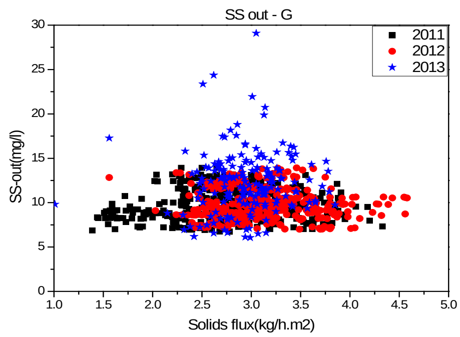



Fig 4.24 Relation between SS-out and Solids flux

The correlation between operational capacity and suspended solids in the effluent is not very evident (Fig 4.24). But there is a general trend that the effluent turbidity increases at higher solids fluxes Fig 4.23. Suspended solids concentration does not change much during the years of 2011 and 2012, therefore the value were not affected by changing the amount of solids flux.

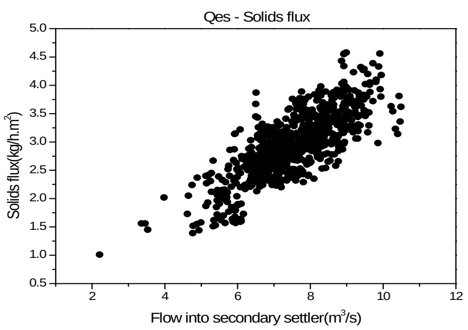



Fig 4.25 Relation between Qes and Solids flux

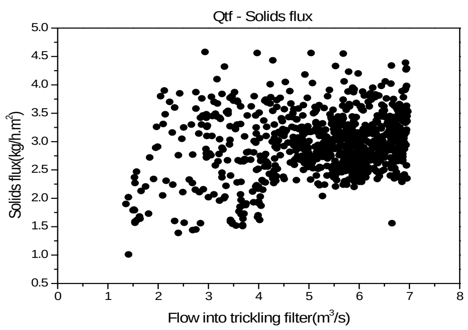



Fig 4.26 Relation between Qtf and Solids flux

The amount of solids flux also stands for operational capacity of the plant, for more amount of inflow of secondary settler, the value of solids flux is higher (Fig 4.25). At the Rya WWTP, the effluent flow from the secondary settlers flow is partly recycled to the trickling filters. In order to improve the capacity of the system, it is necessary to make the outflow from the trickling filters as high as possible as this will increase the nitrogen removal capacity of the plant there is. However, no correlation between the flow to the trickling filters and the solids flux applied on the secondary settlers can found (Fig 4.26).

### 4.3.3 Analysis of the recirculation ratio ($Q_{es}/Q_{ps}$)

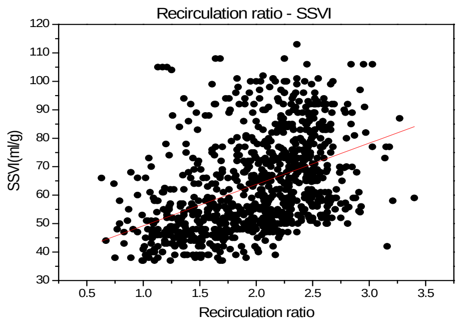



Fig 4.27 Relation between R and SSVI

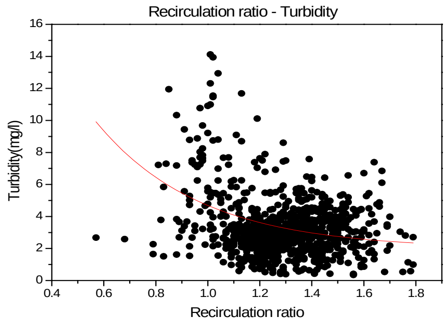



Fig 4.28 Relation between R and turbidity

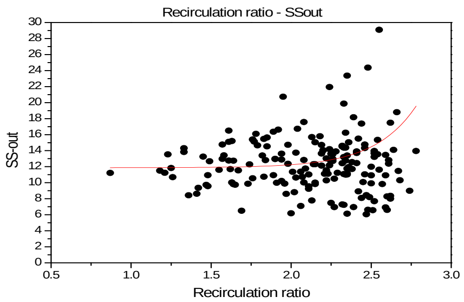



Fig 4.29 Relation between R and SS-out

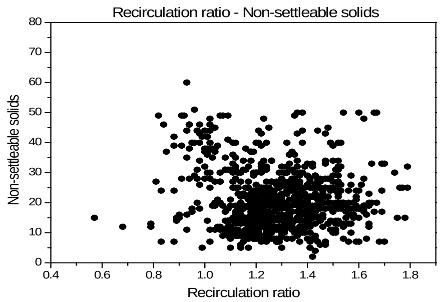



Fig 4.30 Relation between R and Non-settleable solids

The recirculation ratio describes the portion of the outflow of trickling filter to the outflow from primary settlers. This parameter describes how much flow that is recirculated from the trickling filters every day. According to the figures above, if the SSVI of activated sludge is higher, the recirculation ratio is higher. But the changing trend of turbidity is opposite. It is because when the recirculation ratio is high, the flow through the secondary settler is relatively lower. The relation between suspended solids concentration out and non-settleable solids concentration with recirculation ratio is not evident from Fig 4.29 and Fig 4.30. At higher recirculation ratio the relatively less wastewater goes through the activated sludge step and that might be the reason to the lower turbidity at higher recirculation rations.

### 4.3.4 Analysis of the hydraulic loading rate

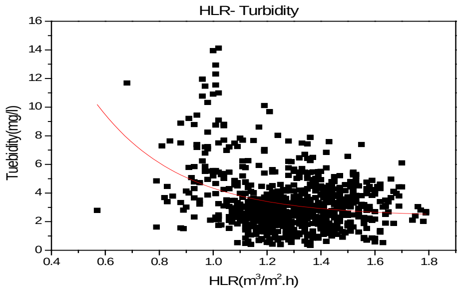



Fig 4.31 Relation between HLR and turbidity

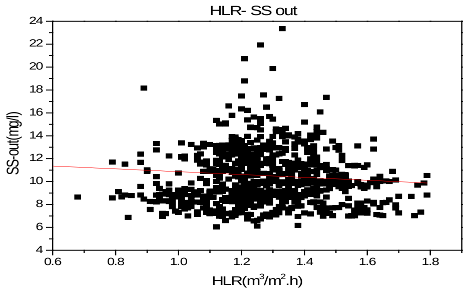



Fig 4.32 Relation between HLR and SS-out

At increasing hydraulic loading rates the values of effluent turbidity appear to go up slightly whereas there is no significant effect on the suspended solids.

# 5 Experiment results analysis

## 5.1 The influence factors of settling velocity

The settling velocity of activated sludge depends on many factors, such as sludge concentration, stirring sludge volume index, water temperature and the sludge properties.

### 5.1.1 The influence of the MLSS concentration (X)

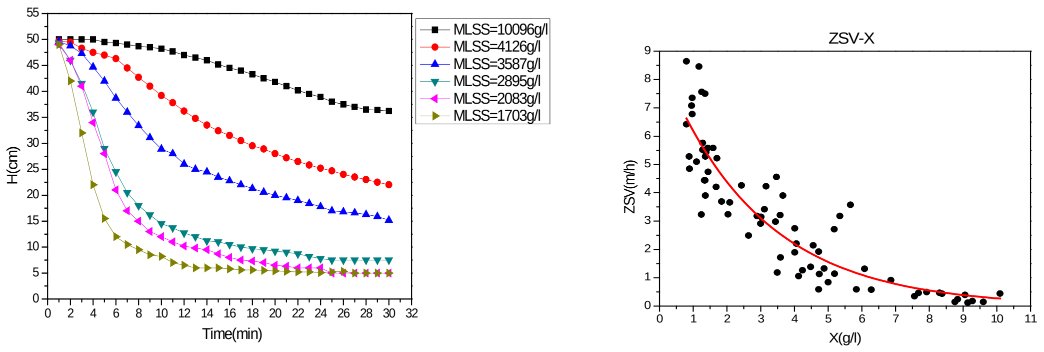



Fig 5.1　Analysis of effect on MLSS concentration

Solids concentration affects the settling velocity as shown in Fig 5.1. If the concentration of solids is low, the settling velocity is high and the time period of hindered settling is short (i.e. the straight line of the curve). The hindered settling phase is generally less than 10 minutes. On the other hand, if the concentration of solid is high, the settling velocity is low and the time of hindered settling is longer.

### 5.1.2 The influence of the stirring sludge volume index (SSVI)

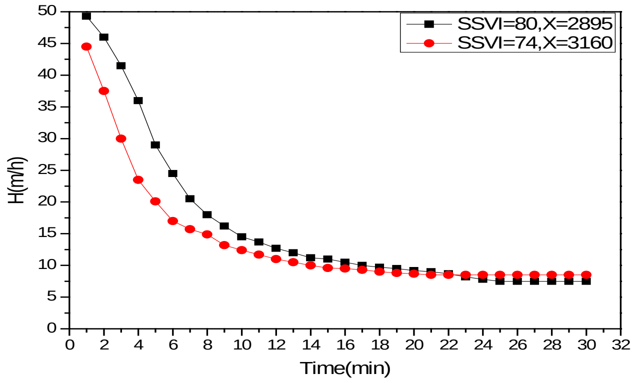
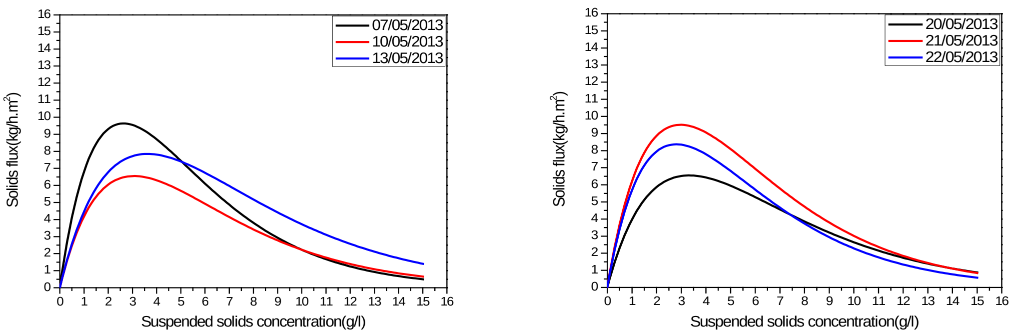



Fig5.2 Analysis of effect on stirring sludge volume index

Sludge volume index reflects the sludge compaction characteristics and quality. For settling test, when the concentrations of the samples are similar as well as when the sludge volume index value of the sample is higher, the settling velocity is lower, and at the same time the settleability is poor (Fig 5.2).

## 5.2 Changes on the settling process from May to June of 2013

During the period from May to June 2013, there were 12 experiments carried out.



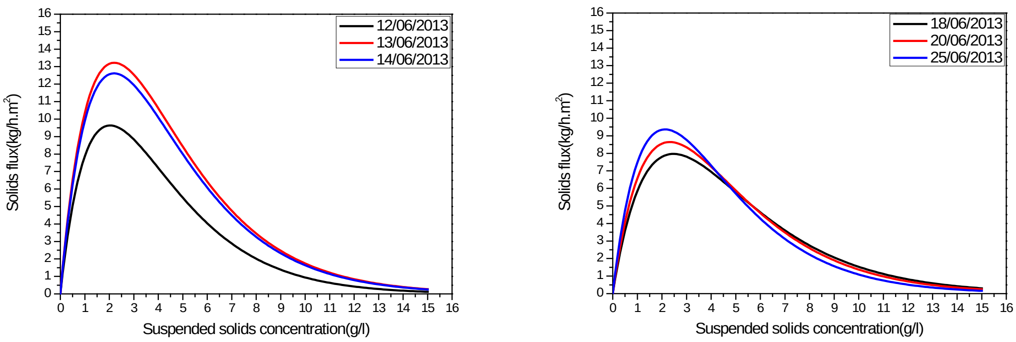



Fig5.3 Relation between solids flux and concentration of sludge(2013)

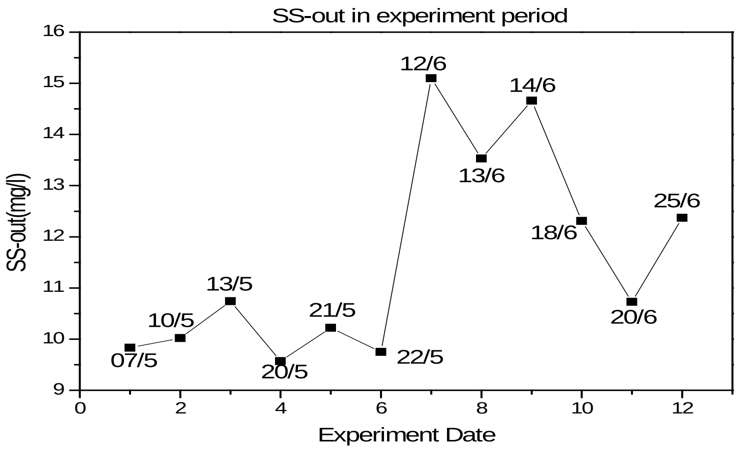



Fig 5.4 Evolution of SSVI in experiment period

In these curves the relation between the solids flux and concentration of sludge could be obtained (Fig 5.3). The shape of the curves reflects the settling properties of the sludge. The solids flux curve can be used to analyze the solids transport through secondary settlers and optimize the activated sludge process in terms of operational conditions of the secondary settlers. From Fig 5.3, it seems that the settling properties were stable during these two months, but in early June the settling properties had improved a little bit. At the same time, the large solids flux in the process lead to an increasing value of suspended solids out, as shown in Fig 5.4. The reason of the improvement of solids flux loading is possible due to polymer addition or to improved sludge properties.

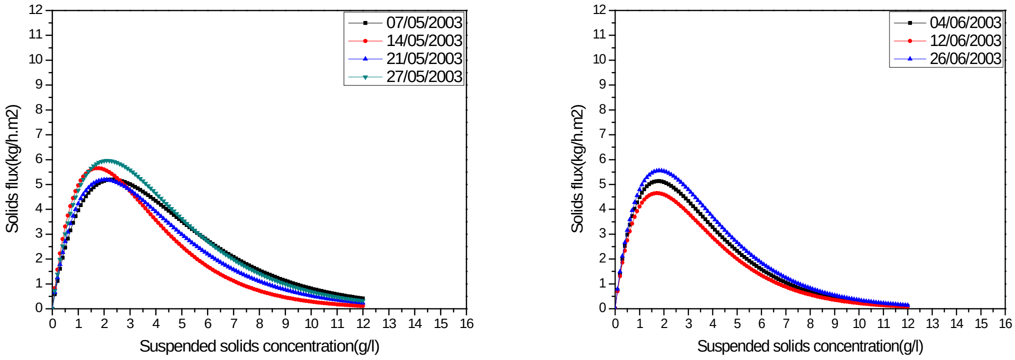



Fig 5.5 Relation between solids flux and concentration of sludge (2003)

There is a significant improvement of operational capacity of plant compared to ten years ago according to Fig 5.5. The solids flux curve was substantially higher in 2013 than in 2003. During the experiment period in 2013, the average value of maximum solids flux was 9.15 kg/h.m$^2$ and in the year of 2003, the value was 5.33 kg/h.m$^2$.

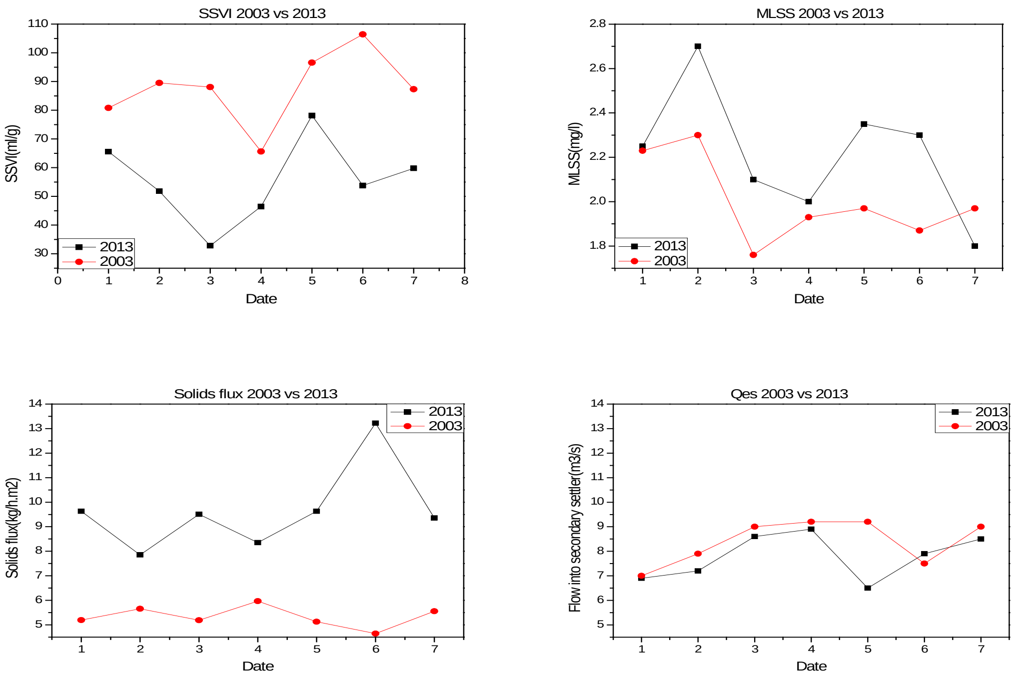



Fig 5.6 Relation of parameter between 2003 and 2013

The different parameters SSVI, MLSS, solids flux and flow through secondary settlers were compared for similar sampling days from 2003 and 2013 and as shown in Fig 5.6 the parameters differed quite a lot. In order to avoid error, the samplings which were got from 2003 and 2013 are almost in the same date of the year.

It can be seen clearly that settling property of the plant has improved in 2013 compared to ten years before when the values for SSVI were higher and the MLSS were lower. Therefore, some improvements of the solids flux were observed. But for the amount of influent flow into secondary settlers, the value does not change much. The disc filter was built in 2010, which could separate particle more efficiency thereby secondary settlers could be loaded more than before.

## 5.3 Test data processing

### 5.3.1 Effects of SSVI changes on settling properties

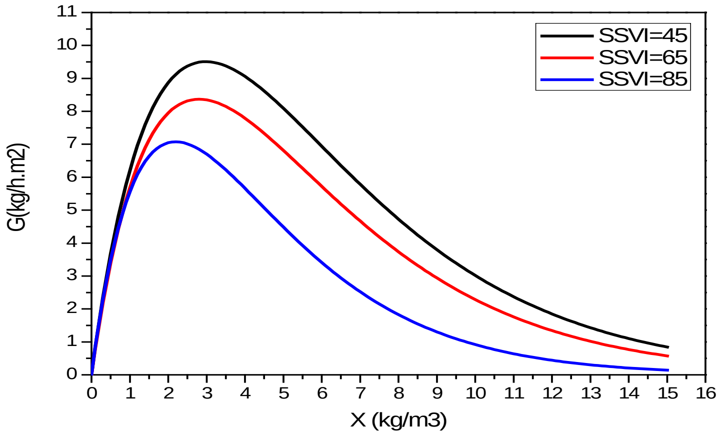



Fig 5.7 Compared with different stirring sludge volume index

Fig 5.7 shows the results of experiments in 22nd (SSVI=45), 07th (SSVI=65) of May and 18th (SSVI=85). Because of the different value of SSVI, the width and height of three settling curves are different. During this period of experiments, SSVI has been in the range between 45 ml/g and 85 ml/g.

Normally, activated sludge in nutrient removal plants have higher SSVI values between 70 ~ 100 ml/g. [4] Sometimes, value of SSVI is related to water quality, when there is more organic matter in the waste water, the SSVI value is higher.

Sludge property and temperature are also factors that could affect SSVI value. As the result of experiments show, the SSVI value at the Rya WWTP can be considered as low, therefore the activate sludge has good settling properties.

### 5.3.2 Effects of Influent flow changes on settling properties

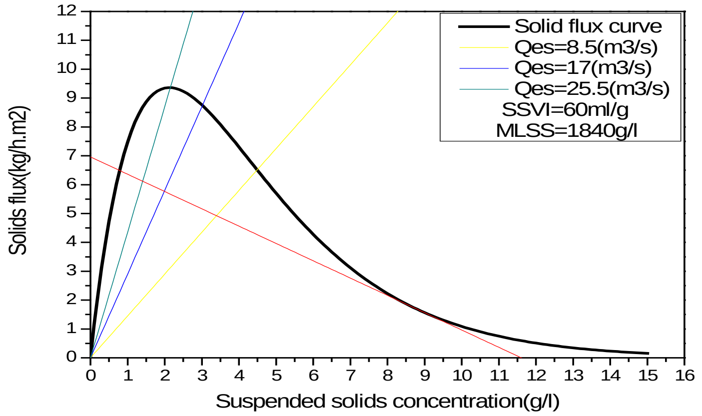
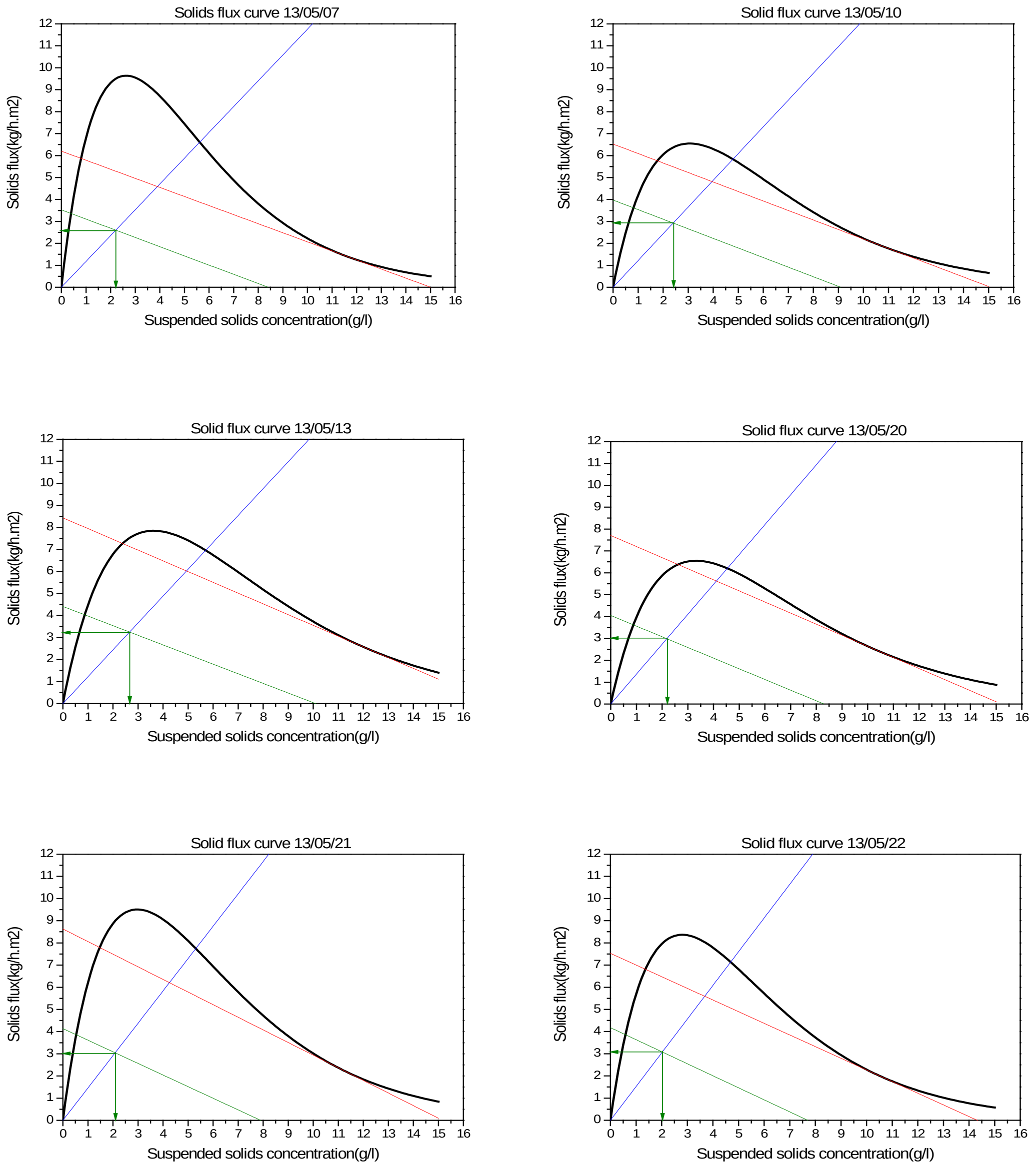



Fig 5.8 Compared with different inflow in secondary settler

In this example, the influent flow to the plant increases, which results in new overflow rate operating line. If there is a higher inflow in the secondary settler, the more solids flux should be loaded and the state point will move upwards. Normally, if the overloading condition exists for longer time, the amount return sludge flow must be increased due to the limit self adjusting capacity of settlers to improve the activate sludge concentration in aeration tank, in order to reduce the load of settlers. In this way the effluent quality could be kept stable. During this period of experiments, the amount of flow into secondary settler has been in the range between 6.88m$^3$/s and 8.55m$^3$/s and the maximum value has been in the range between 12.35m$^3$/s and 23.86m$^3$/s. The average value of influent flow into secondary settlers is 7.69m$^3$/s. The maximal value All of these parameters in secondary settler are under loaded and the operation is stable.

## 5.4 State point analysis of the experiments based on solids flux theory

The curves below show that the state-point of operation of the secondary settlers for different dates (Fig 5.9). The value of solids flux ($G_{AS}$) imposed on the settlers due to influent flow into secondary settler is around 3 kg/h·m$^2$. The total solids flux is given by the intercept of the line with slope $Q_{RAS}/A$ with the y-axis due to sum of influent flow of secondary settler and return sludge. From these curves, it can be seen that both in terms of settling and thickening, the secondary settlers are under loaded.



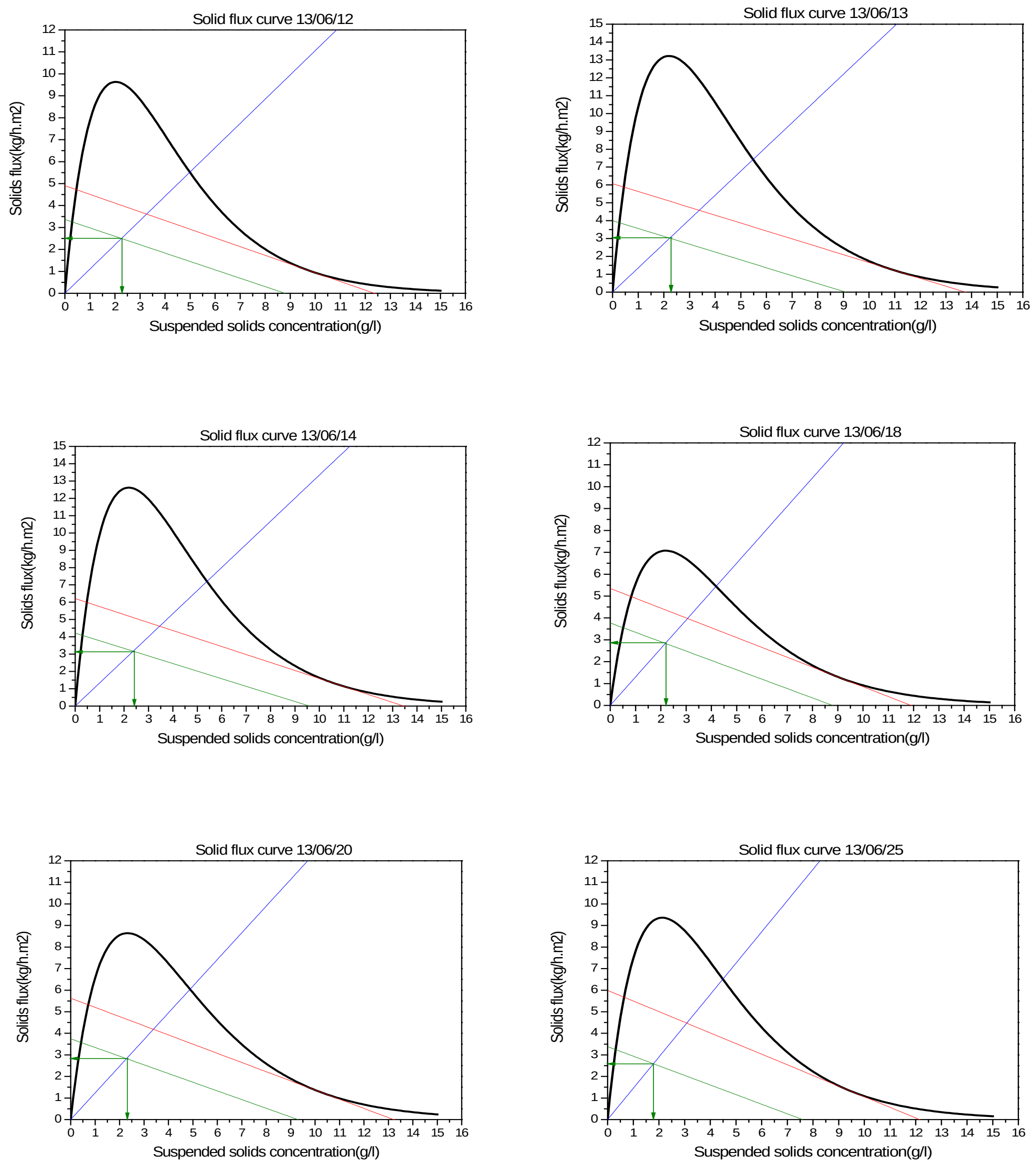



Fig 5.9 Solids flux curves with determination of the state point.

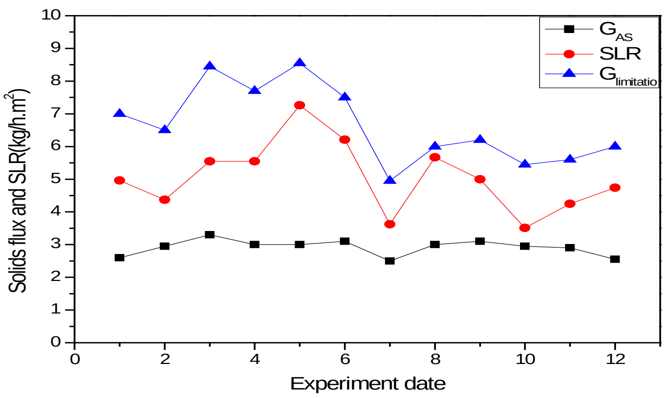



Fig 5.10 Relation of applied solids flux value, limitation solids flux value and solids loading rate

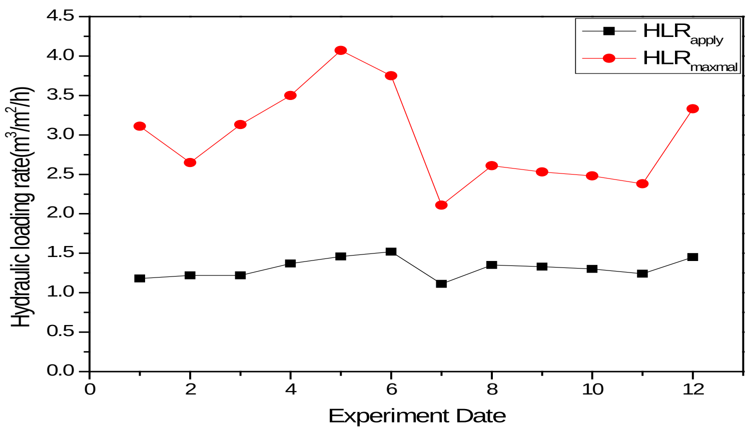



Fig 5.11 Relation of maximal hydraulic loading rate and real hydraulic loading rate

According to Fig 5.10, there is a big buffer between $G_{apply}$, solid loading rate and $G_L$. The system was operated quite below the limiting solids flux and a higher solids flux could be loaded to the secondary setters. The methods such as changing the feed concentration ($X_{AT}$), variations in the return sludge flow ($Q_R$) or in the influent flow ($Q_{ES}$) could be used for controlling and optimizing the run of secondary settlers. The relation between $G_{apply}$ and solids loading rate describes the different between them is whether the return sludge flow was added or not. SLR relates to the thickening function of final sedimentation basins.

The mean value of hydraulic loading rate in operation is 1.31 $m^3/m^2{\cdot}h$. It is a lot under the maximal hydraulic loading rate. Considering the maximal hydraulic loading rate, the system should be able to handle 2 times higher load than that applied.

**Table 1 Summary of the experimental data**

| ***Sample period*** | ***ZSV*** *(m/h)* | ***SSVI*** *(ml/g)* | ***Vesilind*** *$V_0$(m/h)* | ***Parameters*** *$n(m^3/kg)$* | ***Correlation coefficient*** | ***$G_L$*** *$(kg/h.m^2)$* | ***$X_L$*** *(g/l)* | ***$G_{AS}$*** *$(kg/h.m^2)$* | ***$X_{AS}$*** *(g/l)* | ***$X_{RAS}$*** *(g/l)* |
|---|---|---|---|---|---|---|---|---|---|---|
| 2013/5/7 | 3.42 | 65.59 | 9.954 | 0.38 | 0.9614 | 7 | 14.5 | 2.6 | 2.25 | 8.4 |
| 2013/5/10 | 2.49 | 75.76 | 5.804 | 0.326 | 0.8653 | 6.5 | 15 | 2.95 | 2.45 | 9 |
| 2013/5/13 | 3.18 | 51.81 | 5.8874 | 0.276 | 0.8581 | 8.45 | 16.5 | 3.3 | 2.7 | 10 |
| 2013/5/20 | 2.914 | 56.69 | 53,589 | 0.301 | 0.8982 | 7.7 | 15 | 3 | 2.2 | 8.3 |
| 2013/5/21 | 3.9 | 32.79 | 8.6843 | 0.336 | 0.7725 | 8.55 | 15 | 3 | 2.1 | 7.9 |
| 2013/5/22 | 3.15 | 46.51 | 8.1195 | 0.357 | 0.8305 | 7.5 | 14.2 | 3.1 | 2 | 7.6 |
| 2013/6/12 | 4.26 | 78.19 | 12.886 | 0.492 | 0.986 | 4.95 | 12.2 | 2.5 | 2.35 | 8.6 |
| 2013/6/13 | 4.23 | 53.80 | 16.317 | 0.454 | 0.8408 | 6 | 13.6 | 3 | 2.3 | 9 |
| 2013/6/14 | 4.56 | 51.87 | 15.64 | 0.456 | 0.962 | 6.2 | 13.4 | 3.1 | 2.45 | 9.5 |
| 2013/6/18 | 3.24 | 83.74 | 8.7698 | 0.456 | 0.9584 | 5.45 | 12 | 2.95 | 2.2 | 8.8 |
| 2013/6/20 | 4.206 | 83.33 | 10.102 | 0.43 | 0.9897 | 5.6 | 13.2 | 2.9 | 2.35 | 9.3 |
| 2013/6/25 | 3.69 | 59.78 | 11.962 | 0.47 | 0.9596 | 6 | 12.1 | 2.55 | 1.8 | 7.5 |

As the SSVI changed from 32.79 to 83.74 ml/g, the limiting gravitational solids flux ($G_L$) that can be decreased from 8.55 to 4.95 $(kg/h.m^2)$.

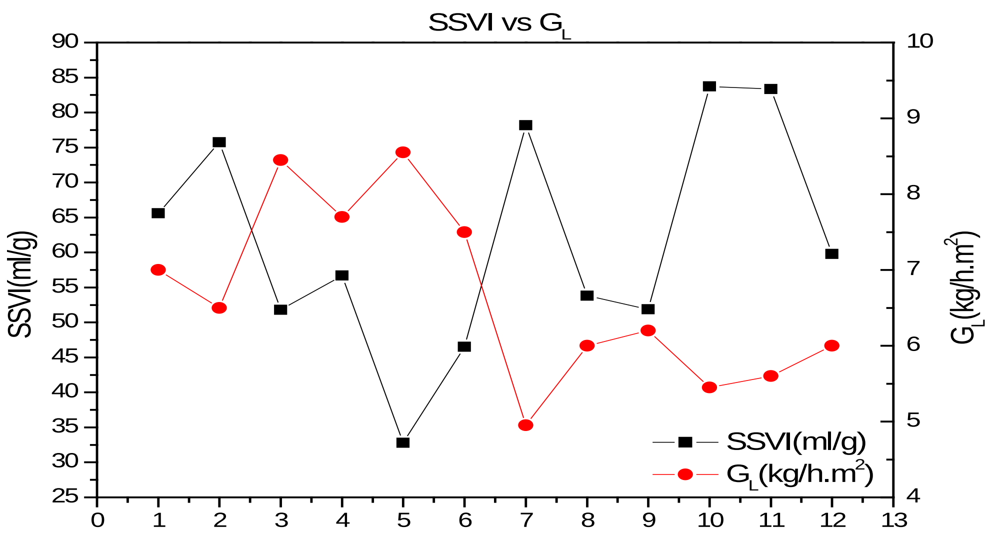



Fig6.12 Relation of SSVI and limitation solids flux

The trends of SSVI and solids flux value are opposite to each other.

## 5.5 Polymer test

The addition of polymer is one of the more common ways for the treatment plant to solve the poor sludge settling problem immediately. Therefore, it is evident to survey the effects of polymer on the activated sludge. In this study, polymer was dosed to the activate sludge system to control suspended solids concentrations in the effluent. The polymer test took place on the 26th of June, and polymer was added from 7:23am to 13:20pm with a dose of 0.5l/s.

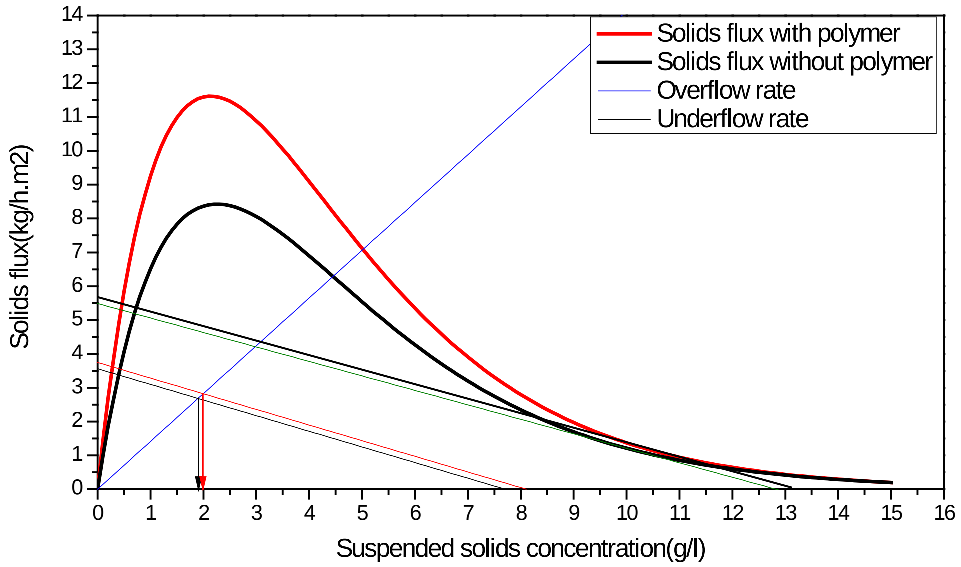



Fig 5.13 Solids flux curves with determination of the state point in the polymer test

According to the result of solids flux curve, the solids flux curve of the sample which was analyzed after polymer addition shows higher and wider shape. On the contrary, the solids flux curve of the sample which is without polymer addition shows lower and narrower shape. There are some reasons that explain why the underflow loading rate did not change, first is since the solids flux mainly assess the thickening properties of the sludge which means when the curve at higher solids concentrations, the limiting flux will be rather similar and other one is because the samples were got in the same point in a same day.

**Table 2 Summary data of the Polymer test**

| ***Sample period*** | ***ZSV*** *(m/h)* | ***SSVI*** *(ml/g)* | ***Vesilind*** $V_0$*(m/h)* | ***Parameters*** $n(m^3/kg)$ | ***Correlation coefficient*** | $G_L$ $(kg/h.m^2)$ | $X_L$ *(g/l)* | $G_{AS}$ $(kg/h.m^2)$ | $X_{AS}$ *(g/l)* | $X_{RAS}$ *(g/l)* | ***SLR*** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| polymer | 4.44 | 56.07 | 14.778 | 0.468 | 0.9602 | 5.7 | 13.1 | 3.7 | 2.00 | 8.0 | 15.8 |
| no-poly | 3.46 | 73.24 | 10.147 | 0.443 | 0.9722 | 5.5 | 12.7 | 3.5 | 1.80 | 7.6 | 12.7 |

From Table 2, polymer dosing could decrease the SSVI and increase the settling velocity, which stands for the settling capacity of sample with polymer addition is better the one without polymer addition. Therefore it could be confirmed that dosing the polymer into poorly-flocculated sludge could present a remarkable effect on improving the flocculation and settling property of activated sludge.

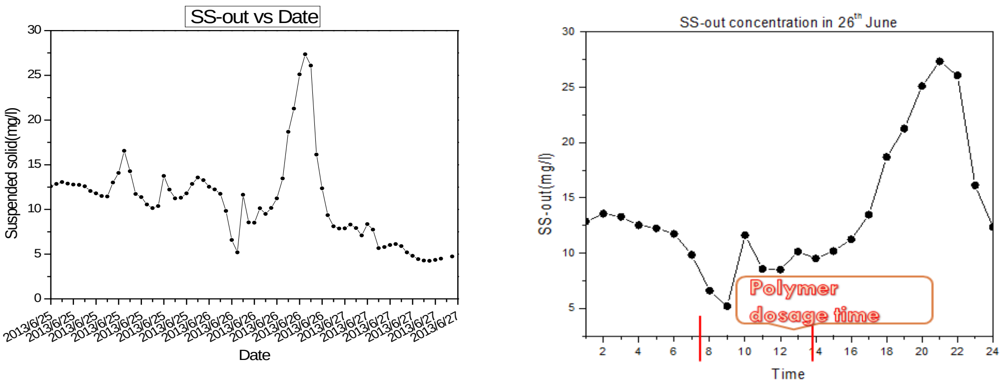



Fig 5.14 Suspended solids concentration in particular date

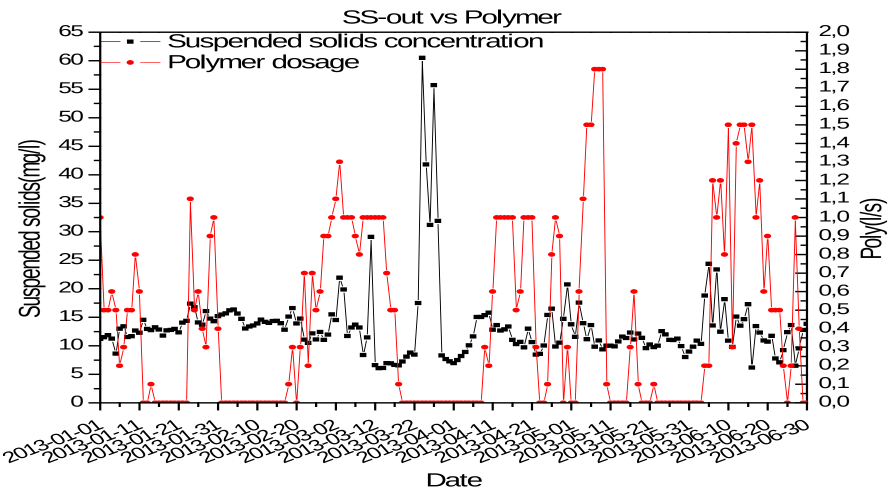



Fig 5.15 relation between Suspended solids concentration and polymer dosing

As mentioned before, the use of polymer is to control the suspended solids effluent concentration. Because of polymer addition, the sludge settles more readily and a clearer effluent was obtained. The suspended solids concentration in the effluent decreased to lowest value of 5.20 mg/L at 9:00am, and then the suspended solids concentration rose to an average value of 10.40 mg/L until 17:00pm (Fig 5.14). After that there is a sharp increase of suspended solids concentration and reached largest value of 27.35 mg/L at 21:00pm.

It is unusual for such high value of suspended solids concentration in the effluent, especially after polymer addition in the same day. There are some reasons that could be assumed. The first one is in 26$^{th}$ June, only 22 of 24 settlers were in operation. Secondly, the value for operation capacity on the plant was changed from 8.7m$^3$/s to 7.5m$^3$/s, as a result the particle separation was not sufficient in the settlers. Finally, the sedimentation properties particles are not same every day, even every hour. These subjects will go to trickling filter and further to activated sludge tank and secondary settler. Another possible reason the sharp increase in effluent suspended solids concentration could be due to poor dewater ability of the digested sludge at the moment of the experiment and the reject water which was high in suspended solids was pumped directly into the activated sludge tank instead of to the trickling filters. As shown in Fig 5.15, the relation between polymer dosing and suspended solids concentration is less clear. It is because the sedimentation properties of particles are not stable. The particles are easier to be influenced by many kinds of factors.

# 6 Degassing of Activated Sludge

## 6.1 Result of degassing test

From the Fig 6.1 below, any significant differences in sedimentation ability of degassed sample compared with non-degassed samples could be seen. During the experimental period, both samples settled well and no sludge floated in the supernatant after the sedimentation occurred.

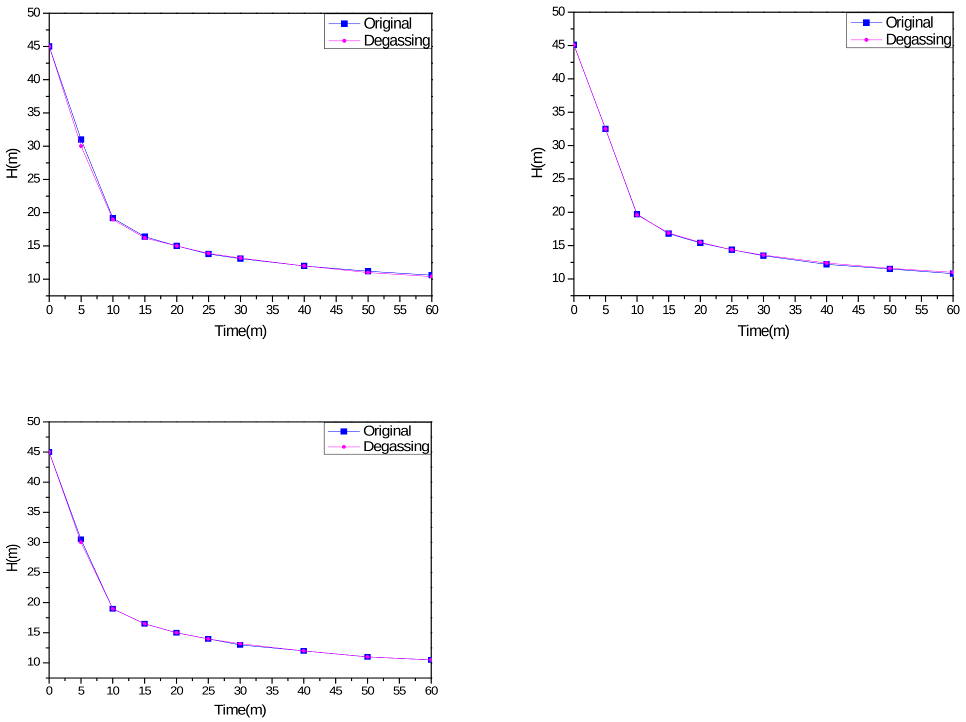



Figure 6.1 Comparison of the zone settling velocity between non degassed sample and degassed sample

**Table 3 Summary data of the degassing test**

| | ***1*** | ***2*** | ***3*** |
|---|---|---|---|
| Time | 10:30 | 11:45 | 14:00 |
| Q ($m^3$/h) | 25992 | 25992 | 25920 |
| Temp. (°C) | 14.02 | 14.08 | 14.19 |
| SS (mg/L) | 2335 | 2155 | 2330 |

| | | | |
|---|---|---|---|
| $O_2$ (mg/L) | 1.93 | 2.12 | 2.29 |
| Sludge age (Days) | 2.6 | 2.6 | 2.59 |
| SSVI (ml/g) | 82 | 82 | 82 |
| ZSV (cm/min) | 2.4 | 2.4 | 2.4 |
| Turbidity (NTU) | 15 | 14 | 14.5 |
| Pressure (mbar) | 50-70 | 50-70 | 50-70 |

As the Table3 summarized, there were also no significant differences in sludge volume index and concentration between the samples taken the same day. Based on experimental results performed, the degassing technology does not improve settling characteristics of activated sludge at the Rya WWTP.

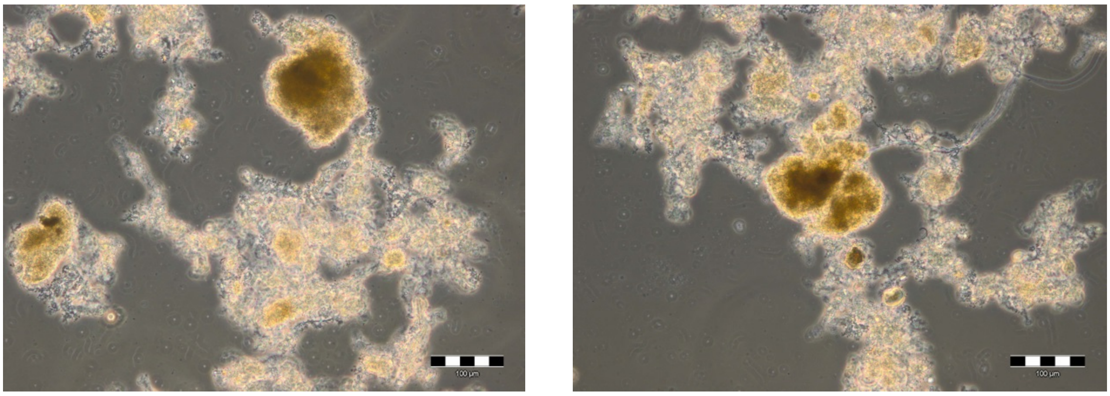


Fig 6.2 Microscopic pictures of the non-degassed and degassed flocs, respectively

There is no difference between degassed flocs and non-degassed flocs in terms of compactness and shape.

# 7 Characterisation of Flocs

## 7.1 Analysis of flocs characteristics

During the period of experiments carried out, samples of activated sludge were analyzed by microscopy in order to research the influence of the characteristics of the flocs on the sedimentation properties and the flocculation ability. Some microscopic pictures of sludge from different sampling days are presented below in order to see the characteristics of the flocs such as size, structure and shape.

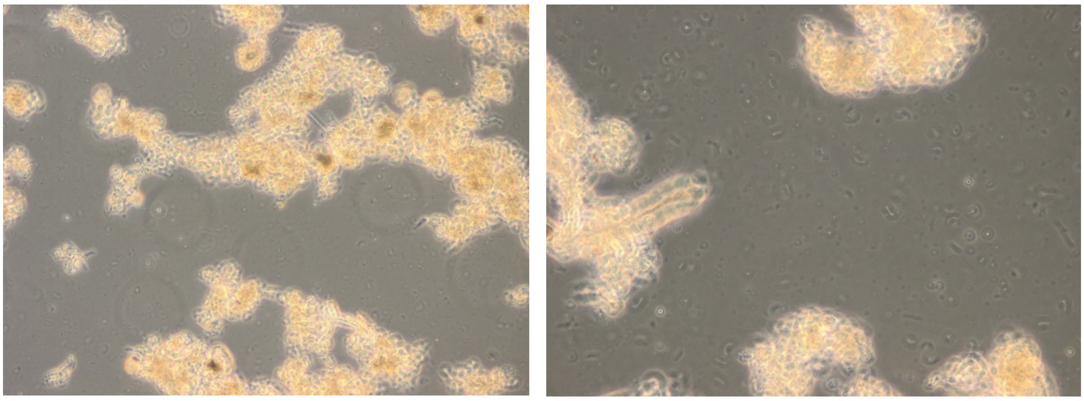


Fig 7.1 Microscopic pictures of the flocs at 10x and 20x, respectively (13/5).

The flocs distribution in 13th May, from the picture at 10x, the flocs are compact and the number of small particles is not significant and the flocs seem to be not quite regular. From the picture at 20x, the flocs are very compact and the shape is irregular and with different sizes. Some small floc fragments (pin-point flocs) and free bacteria can be seen in the supernatant surrounding the flocs. In this day, the value of SSVI is around 80 ml/g and a high ZSV of 4.25 m/h. The flocs contain no or very few filaments.

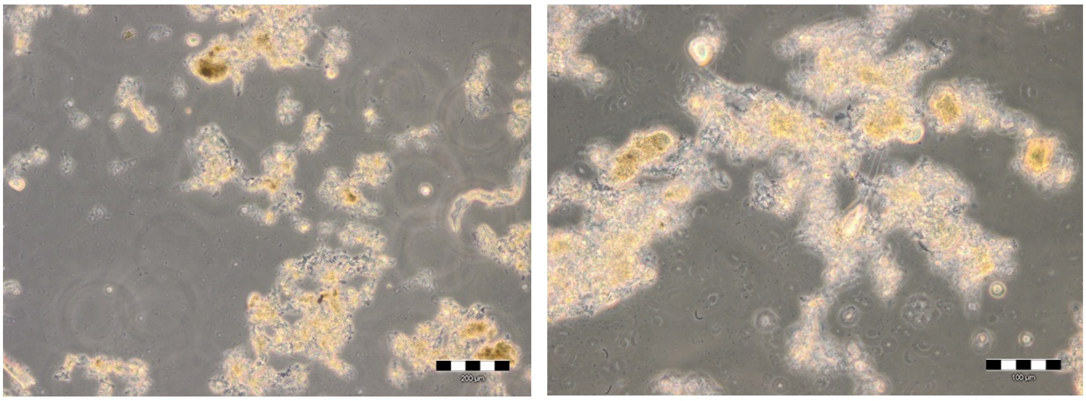


Fig 7.2 Microscopic pictures of the flocs at 10x and 20x, respectively (21/5).

From the picture taken the $21^{st}$ of May at $10^{x}$, the number of small particles is a little bit higher than previous case and the flocs seem to be not quite regular. From the picture at $20^{x}$, the flocs are compact and with irregular shapes. In this day, the settling conditions seemed to be quite good with a SSVI around 64 ml/g and 2.80 m/h of ZSV.

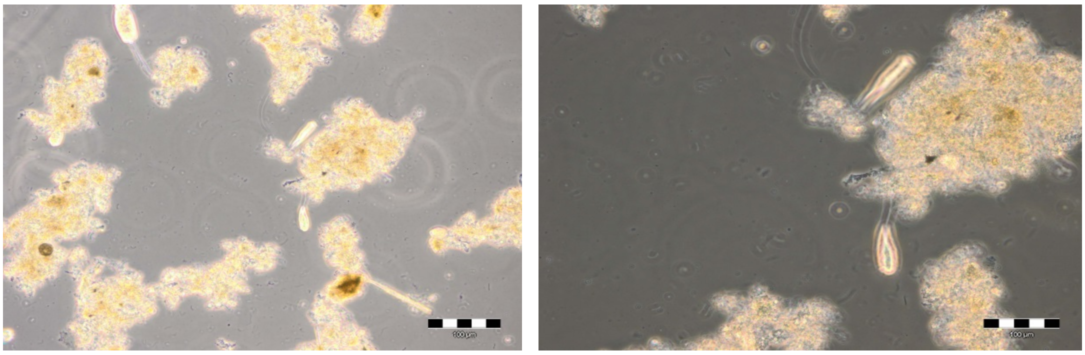


Fig 7.3 Microscopic pictures of the flocs at 10x and 20x, respectively (22/5).

The shape of the flocs in Fig8.3 taken the $22^{nd}$ of May is round and the structure is compact. From the strength point of view, flocs are firm. There are more flagellate and free-living cells could be observed in the pictures.

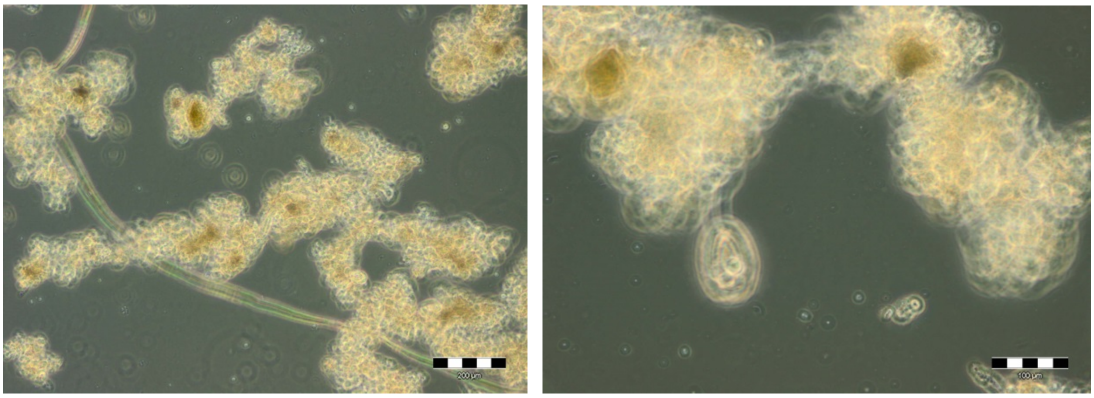


Fig 7.4 Microscopic pictures of the flocs at 10x and 20x, respectively (12/6).

In Fig 7.4 taken the 12th of June, the flocs are not as round as comparing with former days, but it also could be regarded as rounded flocs. It is also compact. There are some filamentous bacteria could be seen clearly.

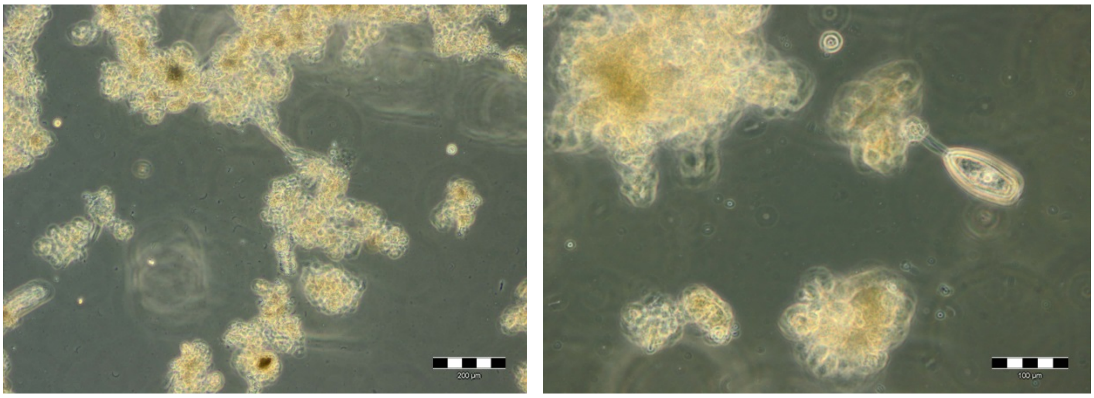


Fig 7.5 Microscopic pictures of the flocs at 10x and 20x, respectively (13/6).

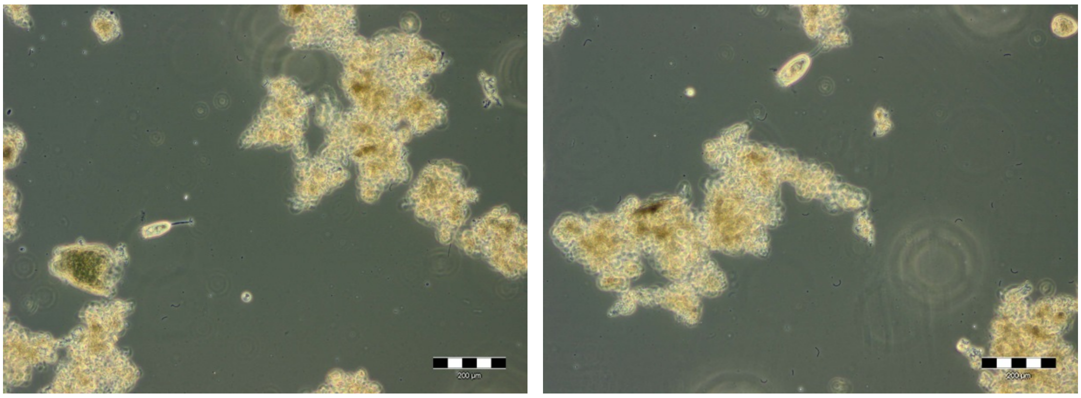


Fig 7.6 Microscopic pictures of the flocs at 10x and 20x, respectively (14/6).

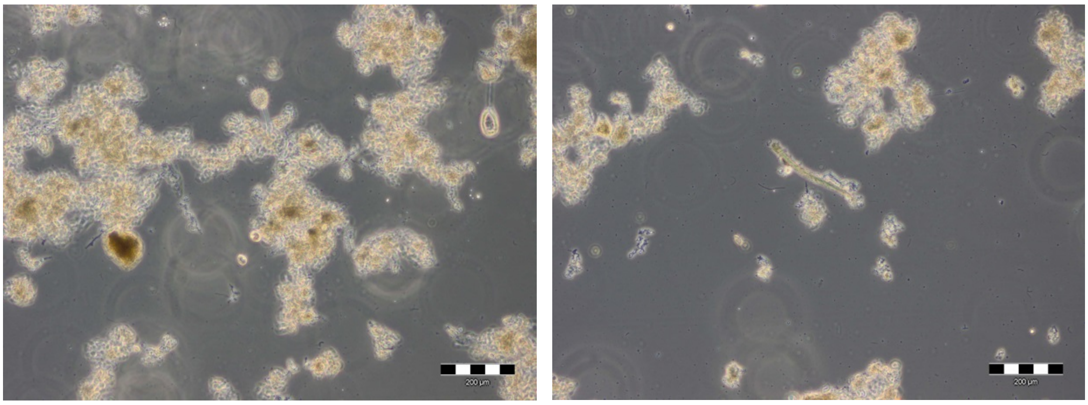


Fig 7.7 Microscopic pictures of the flocs at 10x and 20x, respectively (25/6).

From all appearance of pictures of flocs in the Rya wastewater treatment plant, there is no much difference every day. They have compact structure and the strength of them is firm. In the activated sludge, there are some filamentous bacteria and flagellates present. In addition, the number of free-living cells is high in the supernatant surrounding the flocs.

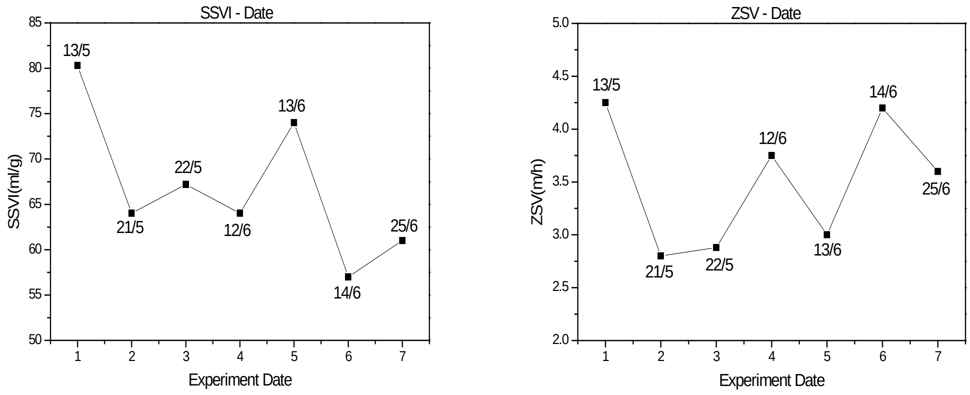



Fig 7.8 Evolution of SSVI and ISV during the period of experiments

From the Fig 7.8 shown above, in $14^{th}$ of June, the sludge has good settling capacity, the SSVI is even lower but the ZSV is not so high. This shows that SSVI and ZSV are not always linked. Comparing the sludge appearance with others, the flocs structure is compact and there is no much amount of small particles. There are some ciliates in the sludge but in relatively low numbers. The sludge age is very short in this plant, 2-4 days, and this might explain the relative low numbers of higher microorganisms such as protozoa.

In summarize, the sharps of activated sludge flocs are more or less round, thereby the settling velocity of flocs is high. The structure of flocs presents compact and the flocs are brown mostly, which means the combination of diffused air aeration and the sludge load is appropriate. In the strength point of view, the flocs belong to firm flocs, which means the floc itself and the liquid surrounding are separated markedly. The strength of flocs is determined by the sludge loading, if the sludge loading is higher, the flocs are weaker. The activated sludge flocs are composed of many species of micro-organisms. There are some filamentous bacteria and flagellate present, in addition, a large number of free-living cell exist in liquid.

# 8 Conclusion

In conclusion, flocculation and sedimentation properties are varying all the time, not only in different plant, but also in different periods in the same plant. The variability is affected by many different factors, such as chemical and physical conditions, hydraulic factors and weather conditions. By analyzing data from the Rya wastewater treatment plant, SSVI, SS-out, non-settleable, MLSS or turbidity are good parameters to define the quality of the effluent and the settling properties. The relation between SSVI with other parameters is clear. It is better to operate a plant with a low SSVI value due to the good settling properties of activated sludge. However, in this condition, the concentration of non-settleable solids will be high. Suspended solids value is a complicated parameter to work with, because it is not only influenced by SSVI but also by many other factors. In addition, changing the concentration of the activated sludge (MLSS) is also a good way to optimize the activated sludge properties.

From the hydraulic loading point of view, the amount of flows into the plant is also one critical factor that affects the settling process. Recirculation ratio is also an influencing factor for turbidity and suspended solids in the effluent. The solids flux also depends on the operational capacity of the plant and also be affected by other parameters. Moreover polymer addition also has a significant impact on the quality of the settling capacity.

Theoretically, the solids flux value is influenced by influent flow into secondary settler and the concentration of activated sludge in aeration tank. The shape and height of the solids flux curve is depending on the changes of sludge property, such as the value of SSVI and ZSV. The calculation of the state point of solids flux is an important point of the experimental part. From the graph in previous chapter, the state point is quite below the curve, so there is enough range to increase the solids flux load into the settlers.

In November of 2012, the hydraulic capacity of the disc filter unit had been increased due to improved flushing routines. It leads to the secondary settlers can be accepted higher loading particles. For the improvement of treatment plant, there are some benefits. Firstly, less water will be by-passed biological treatment during high flow conditions. Secondly the activated sludge tank could be operated at a higher suspended solids concentration.

There is no impact on improvement of settling properties in Rya wastewater treatment plant by degassing technology in terms of settling velocity and compactness and shape of the flocs. However, the settling property of activated sludge in Rya wastewater treatment plant is very good.

## Acknowledgements

Many people have supported my thesis work. I would like to express my acknowledgements to all of them:

Firstly, appreciation is given to my supervisor and examiner Britt-Marie Wilén. Thanks her for giving me such a great opportunity to study in Gryaab. Her experience and knowledge was very valuable and play a key role in my personal and professional development during my thesis.

Many thanks to the staff at the Rya WWTP assisted me with equipment and access to their database. Special thanks to Joana Nunes, Ann Mattsson and the staff in the laboratory. Special thanks are given to Joana Nunes for kindly helping me solve problems I faced in my daily work.

Finally, I would like to thank my family for their endless supporting, encouragement and love in my whole master period.

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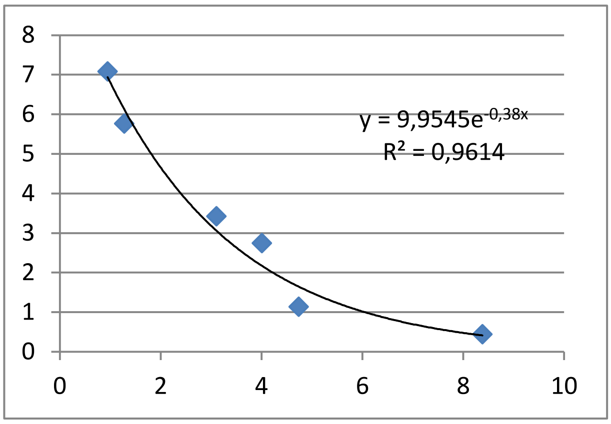
# Appendix

1 Experiment 07/105/2013

| Time | Original | Thickened(1) | Thickened(2) | Dilution(1) | Dilution(2) | Return |
|---|---|---|---|---|---|---|
| 1 | 47 | 49.5 | 48.5 | 45 | 46 | 50 |
| 2 | 40 | 49 | 43.5 | 36 | 34 | 49.9 |
| 3 | 33.5 | 48 | 38.5 | 24 | 21 | 49.8 |
| 4 | 27 | 47 | 33 | 17 | 11 | 49.6 |
| 5 | 25 | 45.5 | 29.5 | 13.5 | 9 | 49.5 |
| 6 | 22.5 | 44 | 26 | 11 | 7.4 | 49.3 |
| 7 | 20 | 42 | 23.8 | 9.5 | 6.5 | 49 |
| 8 | 19 | 40.2 | 22 | 8.5 | 5.5 | 48.5 |
| 9 | 18 | 38 | 20.5 | 7 | 5.3 | 48.2 |
| 10 | 17.2 | 36.3 | 19.5 | 6.8 | 5 | 48 |
| 11 | 16.5 | 34.5 | 18.7 | 6.5 | 4.8 | 47.2 |
| 12 | 16 | 33.5 | 17.2 | 6.3 | 4.7 | 47.1 |
| 13 | 15.5 | 32.3 | 16.8 | 6 | 4.7 | 46.6 |
| 14 | 15 | 31 | 16.4 | 6 | 4.6 | 46 |
| 15 | 14 | 30 | 15.7 | 6 | 4.5 | 45.5 |
| 16 | 13.7 | 29 | 15.2 | 6 | 4.5 | 45 |
| 17 | 13.2 | 28 | 14.7 | 6 | 4.5 | 44.3 |
| 18 | 13 | 27.5 | 14.3 | 6 | 4.5 | 43.5 |
| 19 | 12.5 | 26.7 | 13.8 | 6 | 4.5 | 42.7 |
| 20 | 12 | 25.7 | 13.4 | 6 | 4.5 | 42 |
| 21 | 11.8 | 25.1 | 13.2 | 6 | 4.5 | 41.2 |
| 22 | 11.7 | 24.2 | 12.7 | 6 | 4.5 | 40.5 |
| 23 | 11.5 | 24 | 12.2 | 6 | 4.5 | 39.8 |
| 24 | 11.3 | 23.7 | 12.1 | 6 | 4.5 | 39 |
| 25 | 11.2 | 23.2 | 12 | 6 | 4.5 | 38.5 |
| 26 | 11.1 | 22.5 | 11.5 | 6 | 4.5 | 37.7 |
| 27 | 10.5 | 22.2 | 11.5 | 6 | 4.5 | 37.2 |
| 28 | 10.2 | 22 | 11.5 | 6 | 4.5 | 36.5 |
| 29 | 10.2 | 21.3 | 11.5 | 6 | 4.5 | 35.8 |
| 30 | 10.2 | 21 | 11.5 | 6 | 4.3 | 35.3 |

| | MLSS | ZSV | G | SSVI | SV |
|---|---|---|---|---|---|
| 1 | 0.95 | 7.08 | 6.726 | 90.53 | 86 |
| 2 | 1.28 | 5.76 | 7.3728 | 93.75 | 120 |
| 3 | 3.11 | 3.42 | 10.6362 | 65.59 | 204 |
| 4 | 4.01 | 2.74284 | 10.9987884 | 57.36 | 230 |
| 5 | 4.74 | 1.134 | 5.37516 | 88.61 | 420 |
| 6 | 8.38 | 0.438 | 3.67044 | 84.25 | 706 |

| | | |
|---|---|---|
| **Qu** | 2.46 | (m3/s) |
| **QES** | 6.9 | (m3/s) |
| **Qest** | 6.9 | (m3/s) |
| **SLR** | 5.0 | (kg/m2/h) |
| **SF(limit)** | 10.7 | (kg/m2/h) |
| **HLR** | 1.175545 | (m3/m2/h) |
| **MLSS** | 3.11 | (kg/m3) |
| **Qmax** | 20.21625 | (m3/s) |
| **QES,max** | 17.75625 | (m3/s) |
| **R** | 0.590133 | |
| **EUC** | 11.8 | (kg/m3) |
| **R2** | 0.419716 | |

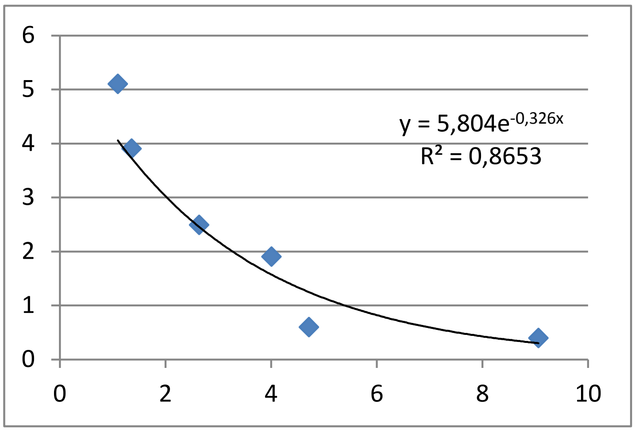


2 Experiment 10/05/2013

| Time | Original | Thickened(1) | Thickened(2) | Dilution(1) | Dilution(2) | Return |
|---|---|---|---|---|---|---|
| 1 | 49.5 | 49.9 | 49.4 | 49 | 49.5 | 50 |
| 2 | 47.5 | 49.7 | 48 | 47.5 | 47 | 50 |
| 3 | 44 | 45.5 | 45.5 | 41 | 40 | 50 |
| 4 | 40 | 48.8 | 42.2 | 33.5 | 33 | 50 |
| 5 | 35.5 | 48.3 | 39 | 29 | 25 | 49.7 |
| 6 | 31 | 47.1 | 35.5 | 20 | 12 | 49.5 |
| 7 | 28 | 46.8 | 32.5 | 15.5 | 11 | 49 |
| 8 | 25 | 46.2 | 30 | 13.5 | 10 | 48.7 |
| 9 | 23 | 45 | 27.9 | 12 | 9.5 | 48.6 |
| 10 | 21 | 44.1 | 26.1 | 11.5 | 9 | 48.5 |
| 11 | 19.5 | 43 | 24.7 | 10.2 | 8.3 | 48 |
| 12 | 18.2 | 41.5 | 23.6 | 9.5 | 8 | 47.7 |
| 13 | 17.4 | 40.5 | 22.6 | 8.7 | 7.5 | 47.5 |
| 14 | 16.5 | 39.3 | 21.7 | 8.2 | 7.1 | 47 |
| 15 | 15.5 | 38.2 | 21 | 7.8 | 6.7 | 46.4 |
| 16 | 15 | 37.1 | 20.5 | 7.5 | 6.2 | 46 |
| 17 | 14.3 | 36 | 19.3 | 7 | 5.8 | 45.3 |
| 18 | 14 | 35.3 | 19.1 | 6.7 | 5.4 | 44.7 |
| 19 | 13.5 | 34.4 | 18.5 | 6.3 | 5 | 44 |
| 20 | 13 | 33.1 | 18 | 6 | 5 | 43.5 |
| 21 | 12.6 | 32.7 | 17.5 | 5.5 | 5 | 42.7 |
| 22 | 12.2 | 32 | 17 | 5.5 | 5 | 42 |
| 23 | 12 | 31.3 | 16.7 | 5.5 | 5 | 41.5 |
| 24 | 11.7 | 30.5 | 16.4 | 5.5 | 5 | 40.9 |
| 25 | 11.5 | 30 | 16 | 5.5 | 5 | 40 |
| 26 | 11.3 | 29.7 | 15.5 | 5.5 | 5 | 39.5 |
| 27 | 11 | 28.7 | 15.2 | 5.5 | 5 | 39 |
| 28 | 10.5 | 28 | 15 | 5.5 | 5 | 38.7 |
| 29 | 10.2 | 27.6 | 14.6 | 5.5 | 5 | 38.3 |
| 30 | 10 | 27 | 14.3 | 5.5 | 5 | 37.5 |

| | MLSS | ZSV | G | SSVI | SV |
|---|---|---|---|---|---|
| 1 | 1.1 | 5.1 | 5.61 | 90.91 | 100 |
| 2 | 1.36 | 3.9 | 5.304 | 80.88 | 110 |
| 3 | 2.64 | 2.49 | 6.5736 | 75.76 | 200 |
| 4 | 4.01 | 1.8972 | 7.607772 | 71.32 | 286 |
| 5 | 4.72 | 0.59202 | 2.7943344 | 114.41 | 540 |
| 6 | 9.06 | 0.39426 | 3.5719956 | 82.78 | 750 |

| | | |
|---|---|---|
| **Qu** | 2.56 | (m3/s) |
| **QES** | 7.1 | (m3/s) |
| **Qest** | 7.1 | (m3/s) |
| **SLR** | 4.4 | (kg/m2/h) |
| **SF(limit)** | 7.9 | (kg/m2/h) |
| **HLR** | 1.218199 | (m3/m2/h) |
| **MLSS** | 2.64 | (kg/m3) |
| **Qmax** | 17.54615 | (m3/s) |
| **QES,max** | 14.98615 | (m3/s) |
| **R** | 0.411215 | |
| **EUC** | 10.0 | (kg/m3) |
| **R2** | 0.436777 | |

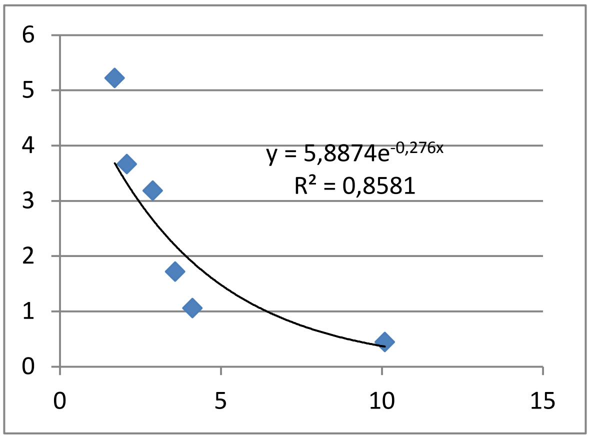


3 Experiment 13/05/2013

| Time | Original | Thickened(1) | Thickened(2) | Dilution(1) | Dilution(2) | Return |
|---|---|---|---|---|---|---|
| 1 | 49.3 | 49.7 | 49.6 | 49 | 49 | 50 |
| 2 | 46 | 49.5 | 48.8 | 42 | 46 | 50 |
| 3 | 41.5 | 48.3 | 47.3 | 32 | 41 | 50 |
| 4 | 36 | 47.5 | 44.7 | 22 | 34 | 50 |
| 5 | 29 | 47 | 42 | 15.5 | 28 | 49.5 |
| 6 | 24.5 | 46.3 | 38.7 | 12 | 21 | 49.3 |
| 7 | 20.5 | 44.5 | 36 | 10.5 | 17 | 49 |
| 8 | 18 | 42.7 | 33.4 | 9.5 | 15 | 48.7 |
| 9 | 16.2 | 41 | 31.1 | 8.5 | 13 | 48.5 |
| 10 | 14.5 | 39.2 | 28.9 | 8.2 | 12 | 48.2 |
| 11 | 13.7 | 37.8 | 28 | 7 | 11 | 47.7 |
| 12 | 12.7 | 36.2 | 26 | 6.5 | 10.2 | 47 |
| 13 | 12 | 34.8 | 25 | 6 | 9.8 | 46.5 |
| 14 | 11.2 | 33.5 | 24.5 | 6 | 9.5 | 46 |
| 15 | 11 | 32.4 | 23.5 | 6 | 8.7 | 45.2 |
| 16 | 10.5 | 31.5 | 22.8 | 5.8 | 8 | 44.5 |
| 17 | 10 | 30.5 | 22 | 5.6 | 7.5 | 44 |
| 18 | 9.7 | 29.5 | 21.3 | 5.6 | 7.3 | 43.3 |
| 19 | 9.5 | 28.9 | 20.6 | 5.5 | 7 | 42.5 |
| 20 | 9.2 | 28 | 20 | 5.4 | 6.5 | 41.8 |
| 21 | 9 | 27.2 | 19.5 | 5.3 | 6.3 | 41 |
| 22 | 8.7 | 26.5 | 19 | 5.2 | 6 | 40.2 |
| 23 | 8.2 | 25.8 | 18.4 | 5.2 | 6 | 39.5 |
| 24 | 7.8 | 25.2 | 17.8 | 5.1 | 6 | 38.9 |
| 25 | 7.5 | 24.7 | 17 | 5.2 | 5 | 38 |
| 26 | 7.5 | 24 | 16.8 | 5.3 | 5 | 37.5 |
| 27 | 7.5 | 23.5 | 16.6 | 5 | 5 | 37 |
| 28 | 7.5 | 23 | 16.3 | 5 | 5 | 36.5 |
| 29 | 7.5 | 22.5 | 15.9 | 5 | 5 | 36.4 |
| 30 | 7.5 | 22 | 15.2 | 5 | 5 | 36.2 |

| | MLSS | ZSV | G | SSVI | SV |
|---|---|---|---|---|---|
| 1 | 1.703 | 5.22 | 8.88966 | 58.72 | 100 |
| 2 | 2.083 | 3.66 | 7.62378 | 48.01 | 100 |
| 3 | 2.895 | 3.18 | 9.2061 | 51.81 | 150 |
| 4 | 3.587 | 1.716 | 6.155292 | 84.75 | 304 |
| 5 | 4.126 | 1.056 | 4.357056 | 106.64 | 440 |
| 6 | 10.096 | 0.44 | 4.44224 | 71.71 | 724 |

| | | |
|---|---|---|
| **Qu** | 2.56 | (m3/s) |
| **QES** | 7.2 | (m3/s) |
| **Qest** | 7.2 | (m3/s) |
| **SLR** | 4.8 | (kg/m2/h) |
| **SF(limit)** | 9.4 | (kg/m2/h) |
| **HLR** | 1.219905 | (m3/m2/h) |
| **MLSS** | 2.895 | (kg/m3) |
| **Qmax** | 19.07044 | (m3/s) |
| **QES,max** | 16.51044 | (m3/s) |
| **R** | 0.402027 | |
| **EUC** | 11.0 | (kg/m3) |
| **R2** | 0.436777 | |

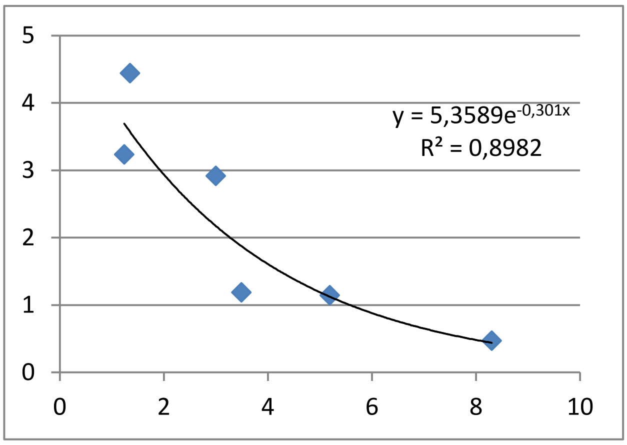


4 Experiment 20/05/2013

| Time | Original | Thickened(1) | Thickened(2) | Dilution(1) | Dilution(2) | Return |
|---|---|---|---|---|---|---|
| 1 | 49 | 49.8 | 49.7 | 49 | 49 | 49.9 |
| 2 | 45 | 49.6 | 48 | 44 | 42 | 49.7 |
| 3 | 40 | 49.3 | 47.2 | 37 | 36 | 49.5 |
| 4 | 35 | 48.7 | 44.4 | 30 | 30 | 49.4 |
| 5 | 30 | 48.2 | 41.8 | 21 | 23 | 49.2 |
| 6 | 25 | 47 | 39.2 | 15 | 18 | 49 |
| 7 | 21 | 45.6 | 36.6 | 12.5 | 9 | 48.7 |
| 8 | 19 | 44.2 | 34.5 | 10.8 | 8 | 48.5 |
| 9 | 17.5 | 42.4 | 32.5 | 9.5 | 7 | 48.3 |
| 10 | 16.5 | 41 | 30.7 | 8.5 | 6.2 | 47.7 |
| 11 | 15.5 | 39.1 | 29 | 8 | 5.3 | 47 |
| 12 | 14.7 | 37.6 | 27.5 | 7.4 | 5 | 46.5 |
| 13 | 14 | 35.8 | 25.7 | 6.2 | 4.5 | 45.7 |
| 14 | 13.4 | 33.7 | 23 | 6 | 4 | 44.5 |
| 15 | 13 | 31 | 21.3 | 5.9 | 4 | 43.5 |
| 16 | 12.5 | 29.3 | 19.5 | 5.7 | 4 | 43 |
| 17 | 12 | 27 | 18 | 5.4 | 4 | 42.5 |
| 18 | 11.5 | 25.6 | 16.8 | 5 | 4 | 42 |
| 19 | 11.2 | 23 | 15.4 | 5 | 4 | 41 |
| 20 | 11 | 21.5 | 14.8 | 5 | 4 | 40 |
| 21 | 10.7 | 20.2 | 14.4 | 5 | 4 | 39 |
| 22 | 10.5 | 19.5 | 14.1 | 5 | 4 | 38.2 |
| 23 | 10 | 18.5 | 13.8 | 5 | 4 | 37.5 |
| 24 | 9.7 | 18.2 | 13.6 | 5 | 4 | 36.5 |
| 25 | 9.5 | 17.9 | 13.4 | 5 | 4 | 35.7 |
| 26 | 9.3 | 17.8 | 13.3 | 5 | 4 | 35 |
| 27 | 9 | 17.6 | 13.1 | 5 | 4 | 34.5 |
| 28 | 8.7 | 17.5 | 13 | 5 | 4 | 34 |
| 29 | 8.6 | 17.5 | 13 | 5 | 4 | 33 |
| 30 | 8.5 | 17.5 | 13 | 5 | 4 | 32.3 |

| | MLSS | ZSV | G | SSVI | SV |
|---|---|---|---|---|---|
| 1 | 1.24 | 3.2357 | 4.012268 | 64.52 | 80 |
| 2 | 1.35 | 4.44 | 5.994 | 74.07 | 100 |
| 3 | 2.999 | 2.9143 | 8.7399857 | 56.69 | 170 |
| 4 | 3.49 | 1.1862 | 4.139838 | 74.50 | 260 |
| 5 | 5.19 | 1.1437 | 5.935803 | 67.44 | 350 |
| 6 | 8.3 | 0.46764 | 3.881412 | 77.83 | 646 |

| | | |
|---|---|---|
| **Qu** | 2.86 | (m3/s) |
| **QES** | 8.0 | (m3/s) |
| **Qest** | 8.0 | (m3/s) |
| **SLR** | 5.5 | (kg/m2/h) |
| **SF(limit)** | 8.2 | (kg/m2/h) |
| **HLR** | 1.366635 | (m3/m2/h) |
| **MLSS** | 2.99 | (kg/m3) |
| **Qmax** | 15.995 | (m3/s) |
| **QES,max** | 13.135 | (m3/s) |
| **R** | 0.565742 | |
| **EUC** | 11.4 | (kg/m3) |
| **R2** | 0.487962 | |

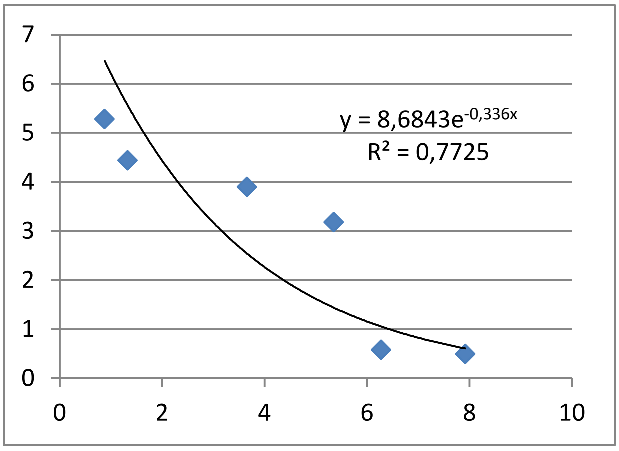


5 Experiment 21/05/2013

| Time | Original | Thickened(1) | Thickened(2) | Dilution(1) | Dilution(2) | Return |
|---|---|---|---|---|---|---|
| 1 | 49 | 49.7 | 49 | 49.5 | 49.5 | 49.9 |
| 2 | 44 | 49.5 | 45 | 44 | 47 | 49.8 |
| 3 | 38 | 49.3 | 40 | 38 | 40 | 49.6 |
| 4 | 32 | 48.8 | 34 | 30 | 32 | 49.4 |
| 5 | 24 | 48 | 29 | 22 | 24 | 49.2 |
| 6 | 18.5 | 47.5 | 24 | 15 | 11 | 49 |
| 7 | 15.5 | 46.8 | 20 | 12 | 9 | 48.5 |
| 8 | 13.5 | 46 | 18 | 10.5 | 7.7 | 48 |
| 9 | 12.2 | 44.5 | 16.5 | 9.5 | 6.9 | 47.5 |
| 10 | 11 | 43.2 | 15.5 | 8.3 | 6.5 | 47 |
| 11 | 10 | 42.4 | 14.5 | 7.5 | 5.8 | 46 |
| 12 | 9.8 | 40.4 | 13.5 | 7 | 5.5 | 44.5 |
| 13 | 9.3 | 39.3 | 13 | 6.4 | 5 | 43.6 |
| 14 | 8.9 | 38 | 12.3 | 6 | 4.7 | 42.5 |
| 15 | 8.5 | 36.5 | 11.3 | 5.7 | 4.5 | 41.7 |
| 16 | 8.2 | 35.5 | 11 | 5.5 | 4 | 40 |
| 17 | 8 | 34.5 | 10.7 | 5.3 | 3.5 | 39.5 |
| 18 | 7.6 | 33.5 | 10.3 | 5 | 3.5 | 38.3 |
| 19 | 7.4 | 32.5 | 9.8 | 4.7 | 3.5 | 37 |
| 20 | 7.1 | 31.5 | 9.5 | 4.5 | 3.5 | 36.2 |
| 21 | 7 | 30.7 | 9.2 | 4.5 | 3.5 | 35.3 |
| 22 | 6.7 | 30 | 8.9 | 4.5 | 3.5 | 34.5 |
| 23 | 6.6 | 29.2 | 8.5 | 4.5 | 3.5 | 33.7 |
| 24 | 6.4 | 28.5 | 8.3 | 4.5 | 3.5 | 33 |
| 25 | 6.3 | 27.7 | 8 | 4.5 | 3.5 | 32.5 |
| 26 | 6.2 | 27.3 | 7.8 | 4.5 | 3.5 | 31.5 |
| 27 | 6.1 | 26.5 | 7.3 | 4.5 | 3.5 | 30.7 |
| 28 | 6 | 26 | 7.3 | 4.5 | 3.5 | 30.2 |
| 29 | 6 | 25.3 | 7.3 | 4.5 | 3.5 | 29.6 |
| 30 | 6 | 25 | 7.3 | 4.5 | 3.5 | 29 |

| | MLSS | ZSV | G | SSVI | SV |
|---|---|---|---|---|---|
| 1 | 0.88 | 5.28 | 4.6464 | 52.63 | 70 |
| 2 | 1.33 | 4.44 | 5.9052 | 67.67 | 90 |
| 3 | 3.66 | 3.9 | 14.274 | 32.79 | 120 |
| 4 | 5.35 | 3.18 | 17.013 | 27.29 | 146 |
| 5 | 6.28 | 0.5814 | 3.651192 | 79.62 | 500 |
| 6 | 7.92 | 0.4944 | 3.915648 | 73.23 | 580 |

| | | |
|---|---|---|
| **Qu** | 3.07 | (m3/s) |
| **QES** | 8.6 | (m3/s) |
| **Qest** | 8.6 | (m3/s) |
| **SLR** | 7.3 | (kg/m2/h) |
| **SF(limit)** | 11.3 | (kg/m2/h) |
| **HLR** | 1.458768 | (m3/m2/h) |
| **MLSS** | 3.66 | (kg/m3) |
| **Qmax** | 18.01842 | (m3/s) |
| **QES,max** | 14.94842 | (m3/s) |
| **R** | 0.859155 | |
| **EUC** | 13.9 | (kg/m3) |
| **R2** | 0.523791 | |

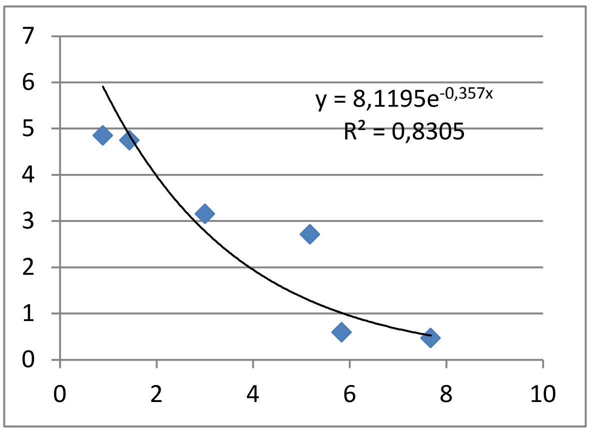


6 Experiment 22/05/2013

| Time | Original | Thickened(1) | Thickened(2) | Dilution(1) | Dilution(2) | Return |
|---|---|---|---|---|---|---|
| 1 | 49 | 49.8 | 49.3 | 48.5 | 49 | 50 |
| 2 | 46.5 | 49.5 | 47.5 | 42 | 47 | 49.7 |
| 3 | 42 | 49 | 43 | 33 | 40 | 49.5 |
| 4 | 36.5 | 48.6 | 39.5 | 26 | 32 | 49.1 |
| 5 | 30 | 48 | 35 | 18 | 24 | 48.8 |
| 6 | 25.5 | 47.7 | 31 | 14.5 | 15 | 48.5 |
| 7 | 21 | 46.5 | 27.5 | 12.5 | 7 | 48.1 |
| 8 | 18.5 | 45.6 | 24.5 | 10.9 | 6.5 | 47.6 |
| 9 | 16.5 | 44.5 | 22.5 | 9.5 | 5.7 | 47 |
| 10 | 15 | 43 | 21 | 8.6 | 5 | 46.3 |
| 11 | 14 | 41.6 | 19 | 8 | 4.6 | 45.5 |
| 12 | 13 | 40.3 | 18.6 | 7.4 | 3.8 | 44.5 |
| 13 | 12.5 | 39 | 17.7 | 6.9 | 3 | 43.5 |
| 14 | 12 | 37.5 | 17 | 6.5 | 3 | 42.7 |
| 15 | 11.4 | 36.2 | 16.3 | 5.8 | 3 | 41.5 |
| 16 | 11 | 35 | 15.5 | 5.6 | 3 | 40.5 |
| 17 | 10.5 | 34 | 15 | 5.3 | 3 | 39.5 |
| 18 | 10.1 | 33 | 14.5 | 5 | 3 | 38.5 |
| 19 | 9.7 | 32 | 14 | 4.7 | 3 | 37.6 |
| 20 | 9.5 | 31.3 | 13.5 | 4.5 | 3 | 36.8 |
| 21 | 9.1 | 30.4 | 13 | 4.5 | 3 | 36 |
| 22 | 8.9 | 29.6 | 12.3 | 4.5 | 3 | 35.2 |
| 23 | 8.5 | 29 | 12 | 4.5 | 3 | 34.5 |
| 24 | 8.3 | 28 | 11.7 | 4.5 | 3 | 33.7 |
| 25 | 8 | 27.5 | 11.6 | 4.5 | 3 | 33 |
| 26 | 7.8 | 27 | 11.5 | 4.5 | 3 | 32.5 |
| 27 | 7.7 | 26.2 | 11.2 | 4.5 | 3 | 31.7 |
| 28 | 7.5 | 25.7 | 11 | 4.5 | 3 | 31 |
| 29 | 7.3 | 25 | 10.6 | 4.5 | 3 | 30.5 |
| 30 | 7 | 24.5 | 10.4 | 4.5 | 3 | 30 |

| | MLSS | ZSV | G | SSVI | SV |
|---|---|---|---|---|---|
| 1 | 0.89 | 4.85 | 4.3165 | 67.42 | 60 |
| 2 | 1.44 | 4.74 | 6.8256 | 62.5 | 90 |
| 3 | 3.01 | 3.15 | 9.4815 | 46.51 | 140 |
| 4 | 5.18 | 2.71 | 14.0378 | 40.15 | 208 |
| 5 | 5.84 | 0.59 | 3.4456 | 83.9 | 490 |
| 6 | 7.68 | 0.4629 | 3.555072 | 78.13 | 600 |

| | | |
|---|---|---|
| **Qu** | 3.18 | (m3/s) |
| **QES** | 8.9 | (m3/s) |
| **Qest** | 8.9 | (m3/s) |
| **SLR** | 6.2 | (kg/m2/h) |
| **SF(limit)** | 11.3 | (kg/m2/h) |
| **HLR** | 1.52019 | (m3/m2/h) |
| **MLSS** | 3.01 | (kg/m3) |
| **Qmax** | 22.01907 | (m3/s) |
| **QES,max** | 18.83907 | (m3/s) |
| **R** | 0.64454 | |
| **EUC** | 11.4 | (kg/m3) |
| **R2** | 0.542559 | |

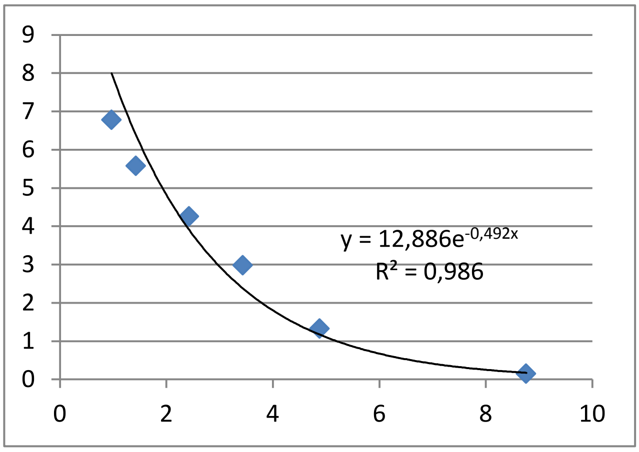


7 Experiment 12/06/2013

| Time | Original | Thickened(1) | Thickened(2) | Dilution(1) | Dilution(2) | Return |
|---|---|---|---|---|---|---|
| 1 | 45.5 | 49.2 | 46.5 | 44 | 46 | 49.9 |
| 2 | 38.5 | 48.5 | 41.5 | 36 | 34 | 49.8 |
| 3 | 30.5 | 47.2 | 35.5 | 24 | 23 | 49.8 |
| 4 | 24.5 | 45.5 | 30.2 | 17 | 12 | 49.7 |
| 5 | 20.4 | 43.5 | 26.7 | 12.5 | 7.7 | 49.6 |
| 6 | 17.8 | 41 | 23.6 | 11 | 6.5 | 49.5 |
| 7 | 15.8 | 38.7 | 21.4 | 10 | 5.9 | 49.4 |
| 8 | 14.5 | 36.5 | 19.5 | 9 | 5.5 | 49.2 |
| 9 | 13.5 | 34.4 | 18.3 | 8 | 5.2 | 49 |
| 10 | 12.6 | 32.1 | 17 | 7.5 | 5 | 48.7 |
| 11 | 11.8 | 31 | 16.3 | 7 | 4.7 | 48.6 |
| 12 | 11.3 | 29.5 | 15.5 | 6.5 | 4.5 | 48.5 |
| 13 | 10.9 | 28.5 | 14.2 | 6 | 4.3 | 48.4 |
| 14 | 10.6 | 27 | 14 | 5.8 | 4 | 48.3 |
| 15 | 10.2 | 26.2 | 13.5 | 5.6 | 3.8 | 48.1 |
| 16 | 9.7 | 25.5 | 13.2 | 5.5 | 3.5 | 48 |
| 17 | 9.5 | 24.3 | 12.9 | 5.5 | 3 | 47.6 |
| 18 | 9.4 | 23.5 | 12.5 | 5.5 | 3 | 47.5 |
| 19 | 9.3 | 23 | 12.1 | 5.5 | 3 | 47.4 |
| 20 | 9.3 | 22.2 | 11.9 | 5.5 | 3 | 47.2 |
| 21 | 9.3 | 21.6 | 11.7 | 5.5 | 3 | 47 |
| 22 | 9.3 | 21 | 11.5 | 5.5 | 3 | 46.8 |
| 23 | 9.3 | 20.3 | 11.3 | 5.5 | 3 | 46.7 |
| 24 | 9.3 | 20.1 | 11.2 | 5.5 | 3 | 46.4 |
| 25 | 9.3 | 20 | 11 | 5.5 | 3 | 46.2 |
| 26 | 9.3 | 19.7 | 10.8 | 5.5 | 3 | 46 |
| 27 | 9.3 | 19.3 | 10.7 | 5.5 | 3 | 45.7 |
| 28 | 9.3 | 19 | 10.6 | 5.5 | 3 | 45.5 |
| 29 | 9.3 | 18.7 | 10.5 | 5.5 | 3 | 45.3 |
| 30 | 9.3 | 18.5 | 10.5 | 5.5 | 3 | 45 |

| | MLSS | ZSV | G | SSVI | SV |
|---|---|---|---|---|---|
| 1 | 0.97 | 6.78 | 6.5766 | 72.16 | 70 |
| 2 | 1.43 | 5.58 | 7.9794 | 76.92 | 110 |
| 3 | 2.43 | 4.26 | 10.3518 | 78.19 | 190 |
| 4 | 3.44 | 2.982 | 10.25808 | 61.05 | 210 |
| 5 | 4.88 | 1.326 | 6.47088 | 75.82 | 370 |
| 6 | 8.76 | 0.15 | 1.314 | 102.74 | 900 |

| | | |
|---|---|---|
| **Qu** | 2.24 | (m3/s) |
| **QES** | 6.5 | (m3/s) |
| **Qest** | 6.5 | (m3/s) |
| **SLR** | 3.6 | (kg/m2/h) |
| **SF(limit)** | 10.4 | (kg/m2/h) |
| **HLR** | 1.131826 | (m3/m2/h) |
| **MLSS** | 2.43 | (kg/m3) |
| **Qmax** | 25.08041 | (m3/s) |
| **QES,max** | 22.84041 | (m3/s) |
| **R** | 0.383886 | |
| **EUC** | 9.5 | (kg/m3) |
| **R2** | 0.38218 | |

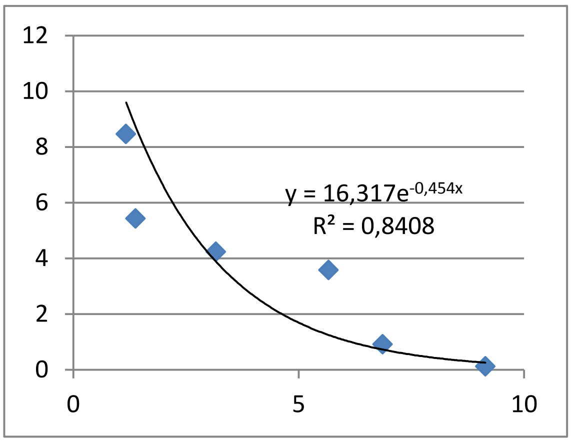


8 Experiment 13/06/2013

| Time | Original | Thickened(1) | Thickened(2) | Dilution(1) | Dilution(2) | Return |
|---|---|---|---|---|---|---|
| 1 | 44.5 | 49.7 | 44.5 | 44.5 | 49 | 50 |
| 2 | 37.5 | 49.2 | 37.5 | 34.5 | 33 | 49.9 |
| 3 | 30 | 48.6 | 30.7 | 25 | 18 | 49.8 |
| 4 | 23.5 | 47.8 | 24.9 | 17.5 | 7 | 49.6 |
| 5 | 20.1 | 46.7 | 21 | 13.8 | 5 | 49.4 |
| 6 | 17 | 45.4 | 18.5 | 11.5 | 4 | 49.3 |
| 7 | 15.7 | 44 | 17 | 10.1 | 3.5 | 49 |
| 8 | 14.9 | 42.3 | 15.5 | 9.6 | 3.3 | 48.9 |
| 9 | 13.2 | 40.6 | 14.5 | 9 | 3.2 | 48.7 |
| 10 | 12.4 | 39.1 | 13.5 | 8.5 | 3.1 | 48.6 |
| 11 | 11.7 | 38 | 12.9 | 8.2 | 3 | 48.5 |
| 12 | 11 | 36.2 | 12.3 | 7.8 | 3 | 48.4 |
| 13 | 10.5 | 35.1 | 11.8 | 7.5 | 3 | 48.1 |
| 14 | 10 | 34 | 11.2 | 7.4 | 3 | 48 |
| 15 | 9.6 | 33 | 10.5 | 7.3 | 3 | 47.7 |
| 16 | 9.5 | 32 | 10.2 | 7.2 | 3 | 47.5 |
| 17 | 9.3 | 31 | 10 | 7.1 | 3 | 47.3 |
| 18 | 9 | 30.2 | 9.8 | 7 | 3 | 47 |
| 19 | 8.8 | 29.5 | 9.5 | 6.8 | 3 | 46.7 |
| 20 | 8.7 | 28.6 | 9.4 | 6.6 | 3 | 46.5 |
| 21 | 8.5 | 28 | 9.2 | 6.5 | 3 | 46.3 |
| 22 | 8.5 | 27.4 | 9 | 6.4 | 3 | 46 |
| 23 | 8.5 | 26.7 | 8.8 | 6.3 | 3 | 45.7 |
| 24 | 8.5 | 26.2 | 8.7 | 6.2 | 3 | 45.5 |
| 25 | 8.5 | 25.7 | 8.7 | 6.1 | 3 | 45.2 |
| 26 | 8.5 | 25 | 8.7 | 6 | 3 | 45 |
| 27 | 8.5 | 24.5 | 8.7 | 5.9 | 3 | 44.6 |
| 28 | 8.5 | 24 | 8.7 | 5.8 | 3 | 44.3 |
| 29 | 8.5 | 23.5 | 8.7 | 5.7 | 3 | 44 |
| 30 | 8.5 | 23.5 | 8.7 | 5.6 | 3 | 43.7 |

| | MLSS | ZSV | G | SSVI | SV |
|---|---|---|---|---|---|
| 1 | 1.17 | 8.46 | 9.8982 | 56.41 | 66 |
| 2 | 1.38 | 5.43 | 7.4934 | 79.71 | 110 |
| 3 | 3.16 | 4.23 | 13.3668 | 53.8 | 170 |
| 4 | 5.66 | 3.576 | 20.24016 | 31.29 | 174 |
| 5 | 6.86 | 0.91542 | 6.2797812 | 68.51 | 470 |
| 6 | 9.14 | 0.12 | 1.0968 | 96.62 | 874 |

| | | |
|---|---|---|
| **Qu** | 2.58 | (m3/s) |
| **QES** | 7.9 | (m3/s) |
| **Qest** | 7.9 | (m3/s) |
| **SLR** | 5.7 | (kg/m2/h) |
| **SF(limit)** | 14.2 | (kg/m2/h) |
| **HLR** | 1.35469194 | (m3/m2/h) |
| **MLSS** | 3.16 | (kg/m3) |
| **Qmax** | 26.3197073 | (m3/s) |
| **QES,max** | 23.7397073 | (m3/s) |
| **R** | 0.52842809 | |
| **EUC** | 12.9 | (kg/m3) |
| **R2** | 0.44018957 | |

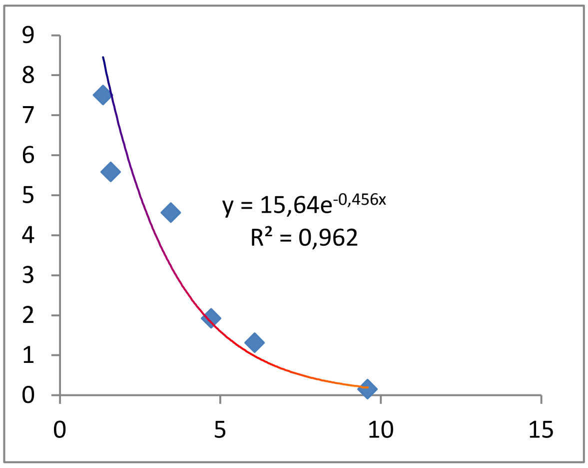


9 Experiment 14/06/2013

| Time | Original | Thickened(1) | Thickened(2) | Dilution(1) | Dilution(2) | Return |
|---|---|---|---|---|---|---|
| 1 | 45.5 | 49.5 | 48 | 42.5 | 43 | 50 |
| 2 | 38 | 48 | 46 | 32.5 | 32 | 49.9 |
| 3 | 29.5 | 46.4 | 42.6 | 22 | 18 | 49.8 |
| 4 | 23 | 44.5 | 39.2 | 15 | 6 | 49.7 |
| 5 | 19 | 42.5 | 36 | 12.4 | 4.3 | 49.5 |
| 6 | 16.2 | 40 | 33 | 10.8 | 4 | 49.3 |
| 7 | 14.5 | 37.7 | 30 | 9.5 | 3.5 | 49.1 |
| 8 | 13 | 35.5 | 28.5 | 8.5 | 3 | 49 |
| 9 | 12 | 33.5 | 27 | 7.9 | 3 | 49 |
| 10 | 11.5 | 31.5 | 25.5 | 7.3 | 3 | 48.8 |
| 11 | 10.3 | 30 | 24 | 6.8 | 3 | 48.6 |
| 12 | 10 | 28.6 | 23 | 6.5 | 3 | 48.5 |
| 13 | 9.9 | 27.5 | 22 | 6.2 | 3 | 48.3 |
| 14 | 9.7 | 26.5 | 21.5 | 6.2 | 3 | 48.2 |
| 15 | 9.3 | 25.5 | 20.4 | 6.2 | 3 | 48 |
| 16 | 9.2 | 24.5 | 19.7 | 6.2 | 3 | 47.9 |
| 17 | 9.1 | 23.6 | 19 | 6.2 | 3 | 47.6 |
| 18 | 9 | 23 | 18.5 | 6.2 | 3 | 47.5 |
| 19 | 9 | 22.3 | 18 | 6.2 | 3 | 47.2 |
| 20 | 9 | 21.5 | 17.5 | 6.2 | 3 | 47 |
| 21 | 9 | 21 | 17 | 6.2 | 3 | 47 |
| 22 | 9 | 20.5 | 16.5 | 6.2 | 3 | 46.9 |
| 23 | 9 | 20 | 16.3 | 6.2 | 3 | 46.6 |
| 24 | 9 | 19.5 | 15.8 | 6.2 | 3 | 46.3 |
| 25 | 9 | 19 | 15.5 | 6.2 | 3 | 46.1 |
| 26 | 9 | 18.5 | 15.2 | 6.2 | 3 | 46 |
| 27 | 9 | 18.2 | 15 | 6.2 | 3 | 45.9 |
| 28 | 9 | 18 | 15 | 6.2 | 3 | 45.6 |
| 29 | 9 | 17.8 | 14.8 | 6.2 | 3 | 45.3 |
| 30 | 9 | 17.6 | 14.6 | 6.2 | 3 | 45.1 |

| | MLSS | ZSV | G | SSVI | SV |
|---|---|---|---|---|---|
| 1 | 1.35 | 7.5 | 10.125 | 37.74 | 60 |
| 2 | 1.59 | 5.58 | 8.8722 | 77.99 | 124 |
| 3 | 3.47 | 4.56 | 15.8232 | 51.87 | 180 |
| 4 | 4.72 | 1.92 | 9.0624 | 61.44 | 290 |
| 5 | 6.08 | 1.31484 | 7.9942272 | 57.9 | 352 |
| 6 | 9.6 | 0.15 | 1.44 | 93.96 | 902 |

| | | |
|---|---|---|
| **Qu** | 2.57 | (m3/s) |
| **QES** | 7.8 | (m3/s) |
| **Qest** | 7.8 | (m3/s) |
| **SLR** | 5.0 | (kg/m2/h) |
| **SF(limit)** | 13.6 | (kg/m2/h) |
| **HLR** | 1.334218 | (m3/m2/h) |
| **MLSS** | 2.82 | (kg/m3) |
| **Qmax** | 28.22939 | (m3/s) |
| **QES,max** | 25.65939 | (m3/s) |
| **R** | 0.566069 | |
| **EUC** | 11.4 | (kg/m3) |
| **R2** | 0.438483 | |

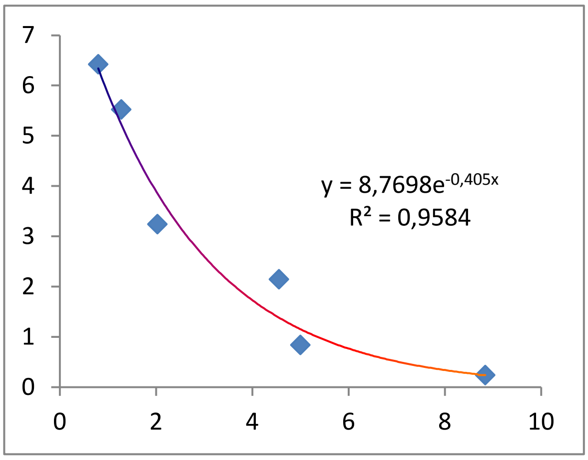


10 Experiment 18/06/2013

| Time | Original | Thickened(1) | Thickened(2) | Dilution(1) | Dilution(2) | Return |
|---|---|---|---|---|---|---|
| 1 | 48 | 49.5 | 49 | 49 | 49 | 50 |
| 2 | 43 | 49 | 46 | 42 | 41 | 49.8 |
| 3 | 37 | 48.5 | 43 | 32 | 33 | 49.7 |
| 4 | 31 | 47 | 39 | 21 | 20 | 49.5 |
| 5 | 26 | 45.2 | 35 | 13.5 | 6 | 49.4 |
| 6 | 21.5 | 44 | 31.5 | 10.5 | 5.5 | 49.3 |
| 7 | 18.5 | 42.5 | 28.7 | 9.1 | 4.8 | 49 |
| 8 | 16.5 | 41 | 26.3 | 8.2 | 4.3 | 48.8 |
| 9 | 15.3 | 40 | 24.5 | 7.5 | 3.8 | 48.6 |
| 10 | 14.2 | 38.5 | 23.3 | 6.9 | 3.5 | 48.4 |
| 11 | 13.3 | 37.5 | 22 | 6.4 | 3.3 | 48.2 |
| 12 | 12.6 | 36.3 | 21.3 | 6 | 3 | 48 |
| 13 | 12 | 35.3 | 20.2 | 5.7 | 3 | 47.8 |
| 14 | 11.6 | 34.5 | 19.4 | 5.5 | 3 | 47.6 |
| 15 | 11.2 | 33.5 | 18.7 | 5.3 | 3 | 47.5 |
| 16 | 10.8 | 32.7 | 18.2 | 5.1 | 3 | 47 |
| 17 | 10.5 | 32 | 17.6 | 4.8 | 3 | 46.8 |
| 18 | 10.1 | 31.4 | 17.3 | 4.8 | 3 | 46.6 |
| 19 | 9.9 | 30.3 | 16.7 | 4.8 | 3 | 46.3 |
| 20 | 9.7 | 30 | 16.3 | 4.8 | 3 | 46 |
| 21 | 9.4 | 29.5 | 16 | 4.8 | 3 | 45.6 |
| 22 | 9.2 | 29 | 15.6 | 4.8 | 3 | 45.3 |
| 23 | 9 | 28.5 | 15.3 | 4.8 | 3 | 44.9 |
| 24 | 8.9 | 27.8 | 15 | 4.8 | 3 | 44.5 |
| 25 | 8.7 | 27.5 | 14.4 | 4.8 | 3 | 44.1 |
| 26 | 8.7 | 27 | 14.4 | 4.8 | 3 | 43.7 |
| 27 | 8.6 | 26.5 | 14.4 | 4.8 | 3 | 43.5 |
| 28 | 8.5 | 26 | 14.4 | 4.8 | 3 | 43.2 |
| 29 | 8.5 | 25.7 | 14.4 | 4.8 | 3 | 42.8 |
| 30 | 8.5 | 25.3 | 14.4 | 4.8 | 3 | 42.5 |

| | MLSS | ZSV | G | SSVI | SV |
|---|---|---|---|---|---|
| 1 | 0.8 | 6.42 | 5.136 | 75.00 | 60 |
| 2 | 1.28 | 5.52 | 7.0656 | 75.00 | 96 |
| 3 | 2.03 | 3.24 | 6.5772 | 83.74 | 170 |
| 4 | 4.56 | 2.14284 | 9.7713504 | 63.16 | 288 |
| 5 | 5 | 0.84174 | 4.2087 | 101.20 | 506 |
| 6 | 8.84 | 0.24 | 2.1216 | 96.15 | 850 |

| | | |
|---|---|---|
| **Qu** | 2.51 | (m3/s) |
| **QES** | 7.6 | (m3/s) |
| **Qest** | 7.6 | (m3/s) |
| **SLR** | 3.5 | (kg/m2/h) |
| **SF(limit)** | 8.0 | (kg/m2/h) |
| **HLR** | 1.300095 | (m3/m2/h) |
| **MLSS** | 2.03 | (kg/m3) |
| **Qmax** | 23.14755 | (m3/s) |
| **QES,max** | 20.63755 | (m3/s) |
| **R** | 0.298091 | |
| **EUC** | 8.2 | (kg/m3) |
| **R2** | 0.428246 | |

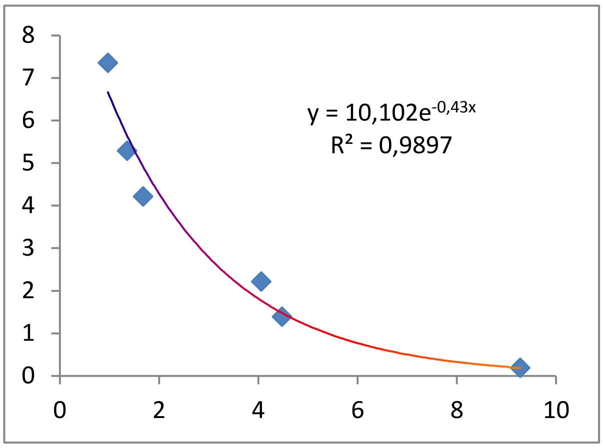


11 Experiment 20/06/2013

| Time | Original | Thickened(1) | Thickened(2) | Dilution(1) | Dilution(2) | Return |
|---|---|---|---|---|---|---|
| 1 | 46 | 49.4 | 48.7 | 43 | 43 | 49.9 |
| 2 | 39 | 47.6 | 40.5 | 32 | 31 | 49.8 |
| 3 | 30 | 45 | 36.5 | 22 | 15 | 49.7 |
| 4 | 23.5 | 43 | 32.7 | 17 | 7.5 | 49.6 |
| 5 | 18.7 | 40.5 | 29.5 | 12 | 6.2 | 49.5 |
| 6 | 15.8 | 38.1 | 27 | 10.4 | 5.5 | 49.4 |
| 7 | 14 | 36.1 | 25 | 9.4 | 5.2 | 49.3 |
| 8 | 12.5 | 34.2 | 23.2 | 8.5 | 4.7 | 49.1 |
| 9 | 11.9 | 32.5 | 22.2 | 7.8 | 4 | 49 |
| 10 | 10.7 | 31 | 21.1 | 7 | 3.3 | 48.8 |
| 11 | 10.2 | 29.7 | 20.3 | 6.5 | 3 | 48.7 |
| 12 | 9.5 | 28.7 | 19.5 | 6.3 | 3 | 48.6 |
| 13 | 9.3 | 27.9 | 18.5 | 5.8 | 3 | 48.5 |
| 14 | 9.1 | 26.9 | 18 | 5 | 3 | 48.3 |
| 15 | 8.7 | 26 | 17.5 | 5 | 3 | 48.1 |
| 16 | 8.4 | 25.3 | 17 | 5 | 3 | 48 |
| 17 | 8.2 | 24.5 | 16.5 | 5 | 3 | 47.6 |
| 18 | 8 | 24 | 16 | 5 | 3 | 47.5 |
| 19 | 8 | 23.5 | 15.5 | 5 | 3 | 47.5 |
| 20 | 8 | 22.7 | 15.2 | 5 | 3 | 47.2 |
| 21 | 8 | 22 | 15 | 5 | 3 | 47 |
| 22 | 8 | 21.6 | 14.5 | 5 | 3 | 46.8 |
| 23 | 8 | 21.2 | 14 | 5 | 3 | 46.5 |
| 24 | 8 | 20.7 | 13.8 | 5 | 3 | 46.3 |
| 25 | 8 | 20.5 | 13.5 | 5 | 3 | 46.2 |
| 26 | 8 | 20 | 13.2 | 5 | 3 | 45.8 |
| 27 | 8 | 19.5 | 13 | 5 | 3 | 45.6 |
| 28 | 8 | 19.3 | 12.8 | 5 | 3 | 45.5 |
| 29 | 8 | 19 | 12.7 | 5 | 3 | 45.5 |
| 30 | 7 | 18.5 | 12.7 | 5 | 3 | 45.5 |

| | MLSS | ZSV | G | SSVI | SV |
|---|---|---|---|---|---|
| 1 | 0.97 | 7.35 | 7.1295 | 61.86 | 60 |
| 2 | 1.36 | 5.28 | 7.1808 | 73.53 | 100 |
| 3 | 1.68 | 4.206 | 7.06608 | 83.33 | 140 |
| 4 | 4.06 | 2.208 | 8.96448 | 62.56 | 254 |
| 5 | 4.48 | 1.38342 | 6.1977216 | 82.59 | 370 |
| 6 | 9.28 | 0.18 | 1.6704 | 98.06 | 910 |

| | | |
|---|---|---|
| **Qu** | 2.36 | (m3/s) |
| **QES** | 7.3 | (m3/s) |
| **Qest** | 7.3 | (m3/s) |
| **SLR** | 4.2 | (kg/m2/h) |
| **SF(limit)** | 9.6 | (kg/m2/h) |
| **HLR** | 1.236967 | (m3/m2/h) |
| **MLSS** | 2.59 | (kg/m3) |
| **Qmax** | 21.65257 | (m3/s) |
| **QES,max** | 19.29257 | (m3/s) |
| **R** | 0.221053 | |
| **EUC** | 10.5 | (kg/m3) |
| **R2** | 0.402654 | |

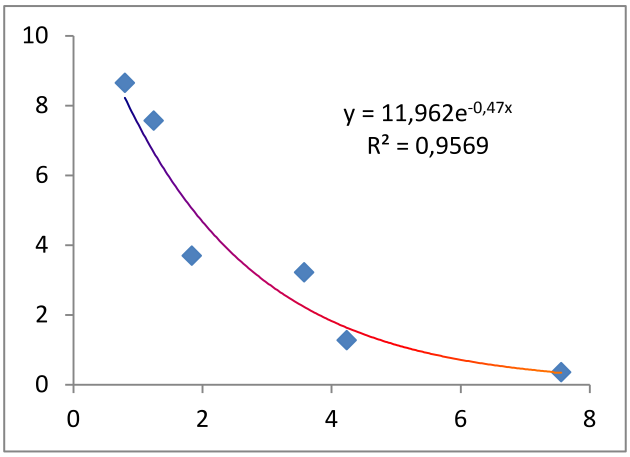


12 Experiment 25/06/2013

| Time | Original | Thickened(1) | Thickened(2) | Dilution(1) | Dilution(2) | Return |
|---|---|---|---|---|---|---|
| 1 | 49.4 | 49.5 | 48.5 | 48 | 49 | 50 |
| 2 | 44 | 48.8 | 43.5 | 39 | 35 | 49.9 |
| 3 | 38.5 | 47.5 | 38.5 | 21 | 17 | 49.5 |
| 4 | 32.5 | 45.5 | 33 | 12 | 7 | 49.3 |
| 5 | 25 | 43.6 | 27 | 10 | 6 | 49.2 |
| 6 | 20 | 41.5 | 22.5 | 8.5 | 5.5 | 49 |
| 7 | 16 | 39.2 | 20 | 7.5 | 5 | 48.8 |
| 8 | 13.5 | 37.2 | 17.5 | 6.2 | 4.5 | 48.5 |
| 9 | 12.5 | 35.2 | 16 | 6 | 4 | 48.3 |
| 10 | 11.5 | 33.9 | 14.8 | 5.8 | 3.5 | 48 |
| 11 | 10.4 | 32.2 | 13.8 | 5.5 | 3.2 | 47.6 |
| 12 | 9.5 | 31 | 13.2 | 5.1 | 3 | 47.3 |
| 13 | 9 | 29.8 | 12.5 | 4.5 | 3 | 47 |
| 14 | 8.5 | 28.9 | 11.9 | 4.4 | 3 | 46.5 |
| 15 | 8 | 28 | 11.5 | 4.4 | 3 | 46 |
| 16 | 7.5 | 27.2 | 11 | 4.4 | 3 | 45.6 |
| 17 | 7.3 | 26.5 | 10.5 | 4.4 | 3 | 45.3 |
| 18 | 7.2 | 25.5 | 10.3 | 4.4 | 3 | 44.5 |
| 19 | 6.9 | 25 | 10.1 | 4.4 | 3 | 44.1 |
| 20 | 6.7 | 24.5 | 9.8 | 4.4 | 3 | 43.5 |
| 21 | 6.5 | 23.9 | 9.5 | 4.4 | 3 | 43 |
| 22 | 6.4 | 23.2 | 9.3 | 4.4 | 3 | 42.9 |
| 23 | 6.3 | 22.8 | 9.1 | 4.4 | 3 | 41.8 |
| 24 | 6 | 22.3 | 9 | 4.4 | 3 | 41.2 |
| 25 | 5.9 | 21.8 | 8.8 | 4.4 | 3 | 40.6 |
| 26 | 5.8 | 21.5 | 8.7 | 4.4 | 3 | 40 |
| 27 | 5.6 | 21 | 8.5 | 4.4 | 3 | 39.8 |
| 28 | 5.5 | 20.5 | 8.4 | 4.4 | 3 | 38.9 |
| 29 | 5.5 | 20.1 | 8.4 | 4.4 | 3 | 38.3 |
| 30 | 5.5 | 19.8 | 8.4 | 4.4 | 3 | 37.6 |

| | MLSS | ZSV | G | SSVI | SV |
|---|---|---|---|---|---|
| 1 | 0.8 | 8.64 | 6.912 | 75.00 | 60 |
| 2 | 1.25 | 7.56 | 9.45 | 70.40 | 88 |
| 3 | 1.84 | 3.69 | 6.7896 | 59.78 | 110 |
| 4 | 3.58 | 3.21 | 11.4918 | 46.93 | 168 |
| 5 | 4.24 | 1.266 | 5.36784 | 93.40 | 396 |
| 6 | 7.56 | 0.348 | 2.63088 | 99.47 | 752 |

| | | |
|---|---|---|
| **Qu** | 2.61 | (m3/s) |
| **QES** | 8.5 | (m3/s) |
| **Qest** | 8.5 | (m3/s) |
| **SLR** | 4.7 | (kg/m2/h) |
| **SF(limit)** | 10.3 | (kg/m2/h) |
| **HLR** | 1.450237 | (m3/m2/h) |
| **MLSS** | 2.5 | (kg/m3) |
| **Qmax** | 24.14138 | (m3/s) |
| **QES,max** | 21.53138 | (m3/s) |
| **R** | 0.321678 | |
| **EUC** | 10.6 | (kg/m3) |
| **R2** | 0.445308 | |

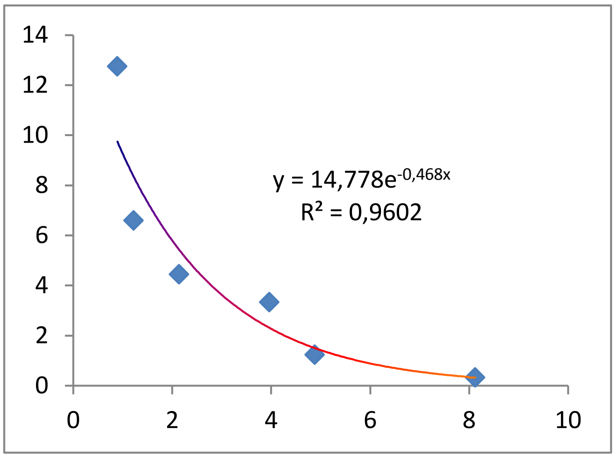


13 Experiment 26/06/2013

| Time | Original | Thickened(1) | Thickened(2) | Dilution(1) | Dilution(2) | Return |
|---|---|---|---|---|---|---|
| 1 | 47 | 49.5 | 47.7 | 45 | 48 | 50 |
| 2 | 40 | 48.7 | 43.5 | 34 | 25 | 49.9 |
| 3 | 32.5 | 47.6 | 38 | 23 | 5.5 | 49.8 |
| 4 | 24 | 46.5 | 32 | 12 | 5 | 49.6 |
| 5 | 18 | 44.5 | 27 | 10.5 | 4.8 | 49.4 |
| 6 | 14.5 | 42.5 | 23.5 | 9 | 4.8 | 49.2 |
| 7 | 12.9 | 40.5 | 20.5 | 7.7 | 4.7 | 49 |
| 8 | 11.4 | 38.3 | 18.7 | 6.8 | 4.5 | 48.8 |
| 9 | 10 | 36.5 | 17 | 6.3 | 4.4 | 48.6 |
| 10 | 9.5 | 35 | 15.6 | 5.7 | 4.2 | 48.3 |
| 11 | 8.6 | 33.5 | 15 | 5.2 | 4 | 48.1 |
| 12 | 8 | 32.5 | 14 | 5 | 3.7 | 47.9 |
| 13 | 7.6 | 31.2 | 13 | 4.8 | 3.4 | 47.6 |
| 14 | 7.4 | 30.1 | 12.5 | 4.6 | 3 | 47.3 |
| 15 | 7.1 | 29.5 | 12.2 | 4.4 | 3 | 47 |
| 16 | 6.8 | 28.6 | 12 | 4.1 | 3 | 46.7 |
| 17 | 6.5 | 27.7 | 11.5 | 4 | 3 | 46.1 |
| 18 | 6.4 | 27 | 11.3 | 4 | 3 | 45.7 |
| 19 | 6.3 | 26.5 | 11 | 4 | 3 | 45.4 |
| 20 | 6.2 | 25.6 | 10.7 | 4 | 3 | 45.1 |
| 21 | 6.1 | 25 | 10.5 | 4 | 3 | 44.5 |
| 22 | 6 | 24.5 | 10.2 | 4 | 3 | 44.1 |
| 23 | 6 | 24 | 10 | 4 | 3 | 43.6 |
| 24 | 6 | 23.5 | 9.7 | 4 | 3 | 43.2 |
| 25 | 6 | 23 | 9.5 | 4 | 3 | 42.6 |
| 26 | 6 | 22.5 | 9.3 | 4 | 3 | 42.1 |
| 27 | 6 | 22 | 9.3 | 4 | 3 | 41.5 |
| 28 | 6 | 21.5 | 9.3 | 4 | 3 | 41.1 |
| 29 | 6 | 21 | 9.3 | 4 | 3 | 40.5 |
| 30 | 6 | 21 | 9.3 | 4 | 3 | 40 |

| | MLSS | ZSV | G | SSVI | SV |
|---|---|---|---|---|---|
| 1 | 0.89 | 12.75 | 11.3475 | 67.42 | 60 |
| 2 | 1.22 | 6.6 | 8.052 | 65.57 | 80 |
| 3 | 2.14 | 4.44 | 9.5016 | 56.07 | 120 |
| 4 | 3.96 | 3.33 | 13.1868 | 46.97 | 186 |
| 5 | 4.88 | 1.236 | 6.03168 | 86.07 | 420 |
| 6 | 8.12 | 0.33 | 2.6796 | 98.52 | 800 |

| | | |
|---|---|---|
| **Qu** | 2.71 | (m3/s) |
| **QES** | 8.3 | (m3/s) |
| **Qest** | 8.3 | (m3/s) |
| **SLR** | 4.4 | (kg/m2/h) |
| **SF(limit)** | 12.6 | (kg/m2/h) |
| **HLR** | 1.412701 | (m3/m2/h) |
| **MLSS** | 2.32 | (kg/m3) |
| **Qmax** | 31.79587 | (m3/s) |
| **QES,max** | 29.08587 | (m3/s) |
| **R** | 0.35786 | |
| **EUC** | 9.4 | (kg/m3) |
| **R2** | 0.46237 | |



14 Experiment 26/06/2013(polymer)

| Time | Original | Thickened(1) | Thickened(2) | Dilution(1) | Dilution(2) | Return |
|---|---|---|---|---|---|---|
| 1 | 49 | 49.5 | 49 | 48 | 49.3 | 49.9 |
| 2 | 45 | 49 | 47.5 | 40 | 35 | 49.7 |
| 3 | 39.5 | 48.7 | 44 | 32 | 17 | 49.4 |
| 4 | 33.5 | 46.7 | 40 | 20 | 7 | 49.2 |
| 5 | 28 | 45.3 | 36.5 | 12 | 6.5 | 49.1 |
| 6 | 22 | 44 | 32.5 | 10 | 6.3 | 49 |
| 7 | 19 | 42.2 | 29.5 | 8.7 | 5.7 | 48.8 |
| 8 | 16.5 | 40.7 | 27 | 7.2 | 5.2 | 48.5 |
| 9 | 15 | 39 | 25 | 7 | 4.7 | 48.3 |
| 10 | 13.5 | 37.7 | 23.5 | 6.4 | 4.3 | 48.1 |
| 11 | 12.5 | 36.5 | 22.3 | 5.9 | 4 | 48 |
| 12 | 11.7 | 35.1 | 21 | 5.5 | 3.7 | 47.5 |
| 13 | 11 | 34.3 | 20 | 5 | 3.5 | 47 |
| 14 | 10.5 | 33.4 | 19.5 | 4.7 | 3.5 | 46.5 |
| 15 | 10 | 32.4 | 18.5 | 4.5 | 3.5 | 46 |
| 16 | 9.5 | 31.5 | 18 | 4.3 | 3.5 | 45.7 |
| 17 | 9.2 | 30.5 | 17.5 | 4 | 3.5 | 45 |
| 18 | 9 | 30 | 17 | 3.7 | 3.5 | 44.5 |
| 19 | 8.8 | 29.5 | 16.5 | 3.7 | 3.5 | 44 |
| 20 | 8.5 | 29 | 16 | 3.7 | 3.5 | 43.5 |
| 21 | 8.2 | 28.5 | 15.5 | 3.7 | 3.5 | 43 |
| 22 | 8 | 27.7 | 15.3 | 3.7 | 3.5 | 42 |
| 23 | 7.8 | 27.3 | 15.1 | 3.7 | 3.5 | 41 |
| 24 | 7.8 | 26.5 | 14.7 | 3.7 | 3.5 | 40.5 |
| 25 | 7.8 | 26 | 14.3 | 3.7 | 3.5 | 40 |
| 26 | 7.8 | 25.5 | 14 | 3.7 | 3.5 | 39.5 |
| 27 | 7.8 | 25 | 13.7 | 3.7 | 3.5 | 39 |
| 28 | 7.8 | 24.8 | 13.5 | 3.7 | 3.5 | 38.5 |
| 29 | 7.8 | 24.5 | 13.3 | 3.7 | 3.5 | 37.5 |
| 30 | 7.8 | 24 | 13 | 3.7 | 3.5 | 37 |

| | MLSS | ZSV | G | SSVI | SV |
|---|---|---|---|---|---|
| 1 | 0.82 | 8.694 | 7.12908 | 85.37 | 70 |
| 2 | 1.32 | 5.52 | 7.2864 | 56.06 | 74 |
| 3 | 2.13 | 3.46 | 7.3698 | 73.24 | 156 |
| 4 | 3.76 | 2.1 | 7.896 | 69.15 | 260 |
| 5 | 4.74 | 0.92 | 4.3608 | 101.27 | 480 |
| 6 | 7.72 | 0.39 | 3.0108 | 95.85 | 740 |

| | | |
|---|---|---|
| **Qu** | 2.71 | (m3/s) |
| **QES** | 8.3 | (m3/s) |
| **Qest** | 8.3 | (m3/s) |
| **SLR** | 4.4 | (kg/m2/h) |
| **SF(limit)** | 9.5 | (kg/m2/h) |
| **HLR** | 1.412701 | (m3/m2/h) |
| **MLSS** | 2.32 | (kg/m3) |
| **Qmax** | 23.97071 | (m3/s) |
| **QES,max** | 21.26071 | (m3/s) |
| **R** | 0.381038 | |
| **EUC** | 9.4 | (kg/m3) |
| **R2** | 0.46237 | |