RECYCLING DIGESTED SLUDGE TO REDUCE FAT OIL AND GREASE BUILD-UP IN PIPES

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ABSTRACT

The fat, oil and grease (FOG) in raw sewage tend to build-up and restrict flow inside a pipe. This is particularly pronounced in many domestic and industrial sewer networks and treatment plants around the world. Although there are methods to remove FOG from pipes and pump stations, this is an additional cost to operating the network and plants. A few years ago, the Rosedale Waste Water Treatment Plant (WWTP) was experiencing problems associated with FOG clogging in pipes.

Rosedale WWTP operates a gravity belt thickener (GBT) which is primarily used for thickening sludge from primary sedimentation tanks. Previously, FOG was an ongoing issue in the treatment process as it would build-up layers inside the GBT discharge pipe and restrict flow to the digester feed tank. Maintenance and cleaning of blocked pipe was required to maintain flow through the solid processing units at the plant. The plant also experienced pump failures due to blocked conveying lines.

To minimize FOG build-up in GBT discharge and downstream pipes, digested sludge from an anaerobic digester was recycled back and mixed with thickened primary sludge to address the issue. The novel process has been implemented at minimal cost.

KEYWORDS

Wastewater treatment plant, pipe, process, fat, oil and grease build-up

1 INTRODUCTION

The FOG deposits in pipes are one of the major problems in wastewater treatment process. Generally, FOG from industries and households are simply drained down into sewer lines without proper treatment. As wastewater flows through the sewer lines, temperature decreases and FOG form deposits in pipes. In 2013, utility company Thames Water removed 15 ton of “fatberg” from London sewer line. It was believed that wrongly flushed down festering food fat and wipes caused the problem in a sewer drain. The remaining FOG in wastewater arrives at a treatment plant and cause clogging issues in downstream of the treatment process, especially in solid processing lines. The solid process consists of settling down suspended solids in primary sedimentation tanks and thickening solids through gravity thickeners. Some of the major FOG build-up issue was identified in various sludge lines after the thickening process.

2 CONTROLLING FOG BUILD-UP

Generally, grease interceptor is installed for removing FOG from wastewater at source of generation. The grease interceptor removes liquid FOG before it reaches sewer pipes. As shown in the figure below, lighter FOG floats to the surface of the grease interceptor while wastewater flows under the FOG mat and flows over to the sewer.

Figure 1: Grease interceptor overview (Goslyn Ontario)

However, residual FOG in wastewater still makes its way down to wastewater treatment plants and form deposit in pipes. Therefore, many of the wastewater municipalities utilize high pressure water jet to break up the deposit and clear the pipes. The cleaning process takes time and it can be cumbersome depending on number of cleanings required.

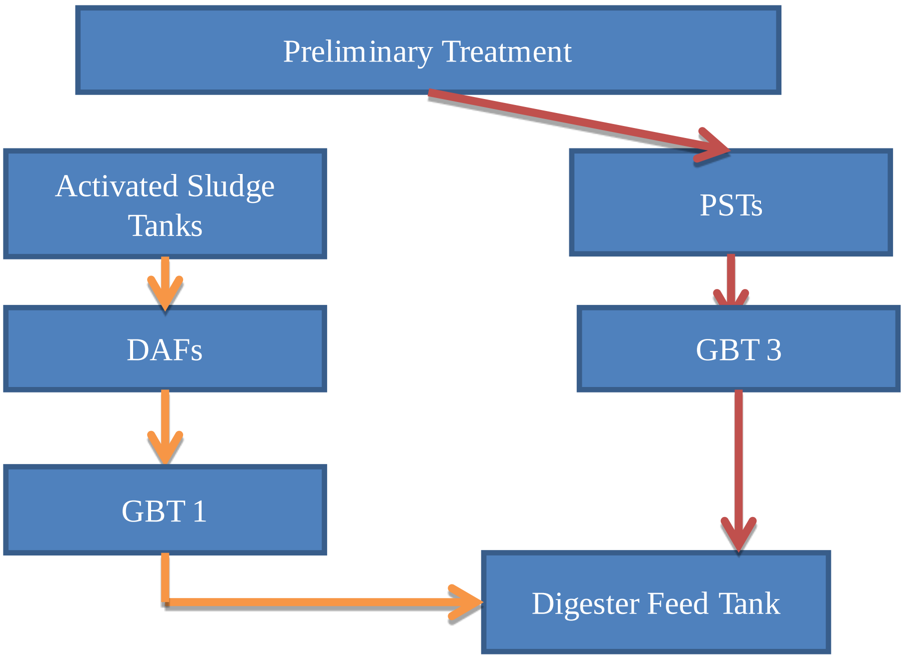
3 ROSEDALE WWTP SOLID STREAM PROCESS OVERVIEW

Rosedale WWTP operates 6 primary sedimentation tanks (PST). PSTs remove raw sludge by settling suspended solids at the bottom of the tank and use scrapers to push the sludge towards a sump. The sludge in the sump is then pumped to the Gravity Belt Thickening (GBT) process. Scum and other floatable solids are removed by the scum collection/removal system and then pumped to the anaerobic digesters.

Waste activated sludge (WAS) from the activated sludge process is pumped to dissolved air floatation units (DAFs) and sludge from the DAF units are pumped to a gravity belt thickener for further thickening.

There are two operational GBTs in Rosedale plant and each GBTs handle different type of sludge. GBT 1 is used for thickening waste activated sludge whereas GBT 3 is used for thickening primary sludge. After the GBT process, thickened primary sludge and waste activated sludge are combined in a digester feed tank (refer to Figure 2).

Figure 2: Rosedale WWTP solid stream process overview

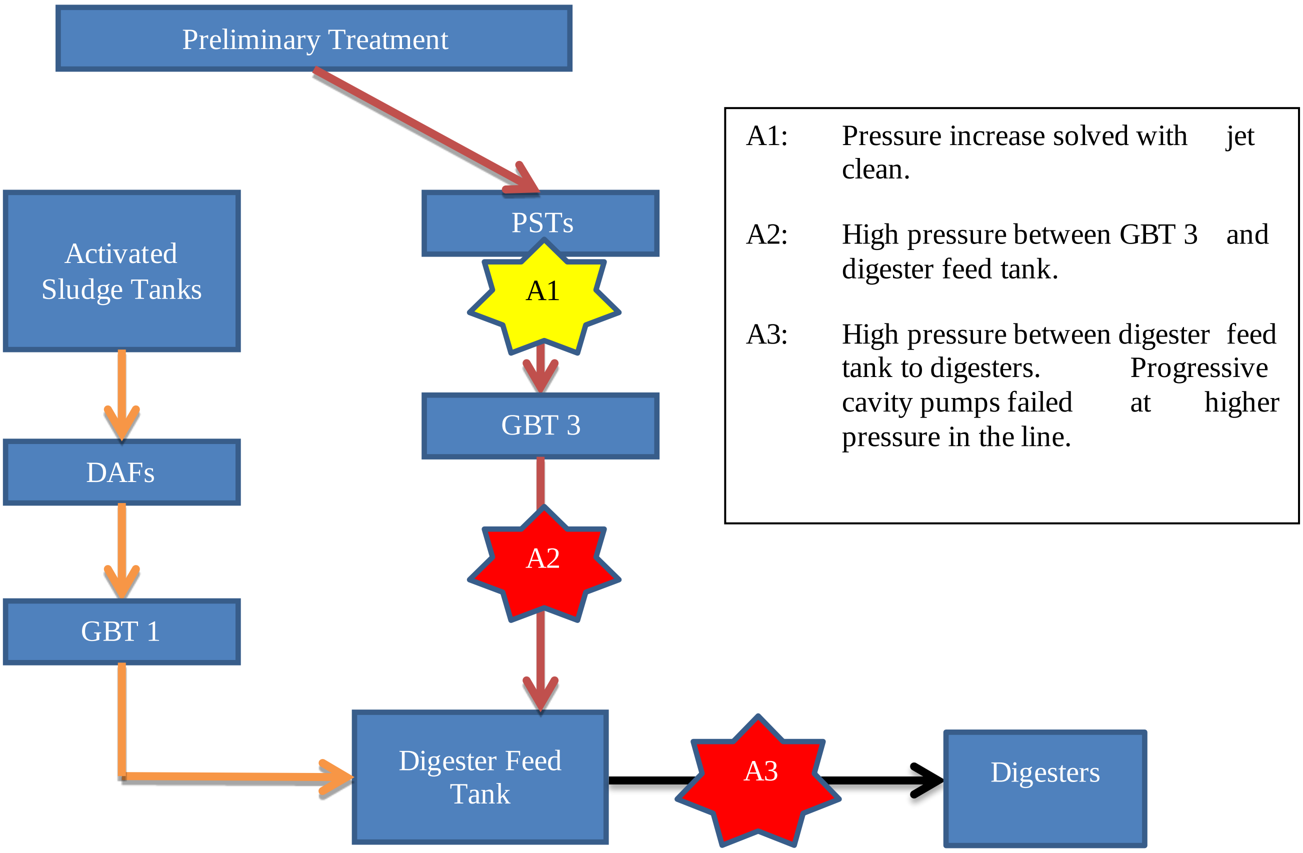


4 FOG BUILD-UP IN ROSEDALE WWTP SLUDGE PIPES

Prior to the year 2010, FOG build-up was an ongoing issue in pipes between GBT 3 to digester feed tank and digester feed tank to digesters (refer to A2, A3 in Figure 3). It was observed that pressure inside these sludge pipes would increase to a point where digester feed pumps were unable to deliver consistent feed to the digesters.

FOG build-up was slower in upstream process lines such as primary raw sludge pipes and GBT feed pipes (refer to A1 in Figure 3. It did not have major impact on treatment process as these lines were occasionally cleaned with high pressure jet water. However, digester feed lines were often clogged with fats and the line cleaning was no longer efficient for clearing the fat deposit.

Figure 3: Location of the FOG build-up issues in solid process lines



5 PLANT OPERATIONAL CHALLENGES DUE TO FOG BUILD-UP

Wastewater treatment is a 24 hours continuous process therefore FOG build-up in pipes can lead to disasters such as sludge leak through the pipes, overflows in storage tanks, septic and odor problems. Frequent build-up can lead to inconsistent sludge flow through pipes and upset wastewater treatment process. Anaerobic digestion is one of the important parts of the treatment process and it can be negatively impacted by the inconsistent feed flow.

5.1 ANAEROBIC DIGESTER PROCESS INSTABILITY

Rosedale WWTP operates mesophilic anaerobic digesters and the digester temperatures are maintained at about 35°C. As previously mentioned, FOG build-up in digester feed pipes caused disturbances in digester feed system.

The Rosedale WWTP digester feed system is controlled by the digester cover levels and the feed timers but there is no control over the exact sludge volume fed to the digesters. When digester feed pumps fail due to the pressure build-up in pipes, varying volume of sludge is fed to the digesters and some digesters would receive more sludge than others. This can result in lower solids retention time (SRT) in digesters and it can have negative impact on following anaerobic digestion process.

1. Hydrolysis: The first step of digestion process is hydrolysis where particulate materials such as lipids, protein, polysaccharides are converted into smaller molecules such as amino acids and fatty acids.
2. Acidogenesis: In acidogenesis process, microorganisms further degrade products from the previous reaction and produce hydrogen, carbondioxide, propionate and butyrate. The propionate and butyrate is further degraded to hydrogen, carbondioxide and acetate.
3. Methanogenesis: Methanogens create methane from the final products of acidogenesis. Also some of the intermediate products from previous reactions are converted into methane. (Tchobangoglous et al., 2010)

Converting acid intermediate products to biogas takes longer than hydrolysis or acidogenesis process. Therefore, reducing sludge retention time in anaerobic digesters will not provide sufficient time to convert acid products to methane gas and eventually build-up acid-intermediate products in digesters. It could upset the equilibrium conditions in biological reactions and pH drop can lead to digester failure. Anaerobic digesters can take several months to restore its normal operating conditions and while digesters are upset, it will greatly reduce the sludge digestion capacity. In worst case scenarios, sludge would have to bypass digesters which cab result in odor problems and additional cost for disposing biologically unstable products

The performance of anaerobic digesters can be monitored by conducting pH, alkalinity and volatile acid tests on digested sludge samples. When anaerobic digesters experience problems, volatile acid contents will build-up in the system causing pH and alkalinity to drop.

5.2 EXCESSIVE DIGESTER FOAMING ISSUE

Some literatures provided examples of how inconsistent feed to digesters could cause excessive foaming on top of the digesters. The Morris Forman WWTP in Louisville, Kentucky had experienced excessive foaming in their digesters whenever a large amount of volatile solids (VS) were pumped into the digesters. The foaming issue was controlled after the feed rate was controlled. Also WWTP in South Carolina experienced recurring foaming issue in their anaerobic digesters. The primary cause was inconsistent organic loading of thickened primary sludge (PS) and waste activated sludge (WAS). (Massart.N et al., 2006)

5.3 ROSEDALE WWTP OPERATION & MAINTENANCE DISRUPTION

At Rosedale WWTP, high pressure water jet is used for clearing FOG from pipelines. However, the cleaning process can take several hours since operators have to isolate plant equipment and maintenance fitters are required to disconnect valves, flanges and pipes. Operators have to ensure that upstream tank levels are maintained at a lower level and make appropriate adjustments in the plant to optimize the process.

Two digester feed pumps located on discharge side of the digester feed tank had issue with FOG build-up. The pressure in the line from digester feed tank to digesters would often increase and damaged progressive cavity pumps and needed spare parts for a repair. The majority of the treatment process had to stop for cleaning pipes and replacing parts.

6 PREVIOUS METHODS TO MAINTAIN PIPE

The fat build-up in digester feed or GBT 3 discharge pipe (refer to Figure 3 A2, A3) is usually indicated by a pressure sensor which is located on discharge side of the pump. Normally, pressure in the pipe is approximately 100 kPa. However, when discharge pressure is higher, 200 -300 kPa, this could be an indication that the pipe is getting clogged with FOG.

6.1 METHOD 1: HIGH PRESSURE WATER JET CLEANING

The high pressure water hose is fitted a nozzle at the front and the nozzle is jet blasting through a pipe, breaking up the hardened solids in the pipe. The main advantage of this option is that it is relatively easy to clear fat from the pipes. Disadvantages are that it takes several hours to prepare for the cleaning process since operators have to isolate plant equipment and drain pipes. Also, it will increase plant operating cost, depending on number of cleanings required. At the Rosedale WWTP, a high pressure water jet clean was performed every 3 - 4 days.

6.2 METHOD 2: HOT WATER FLUSH

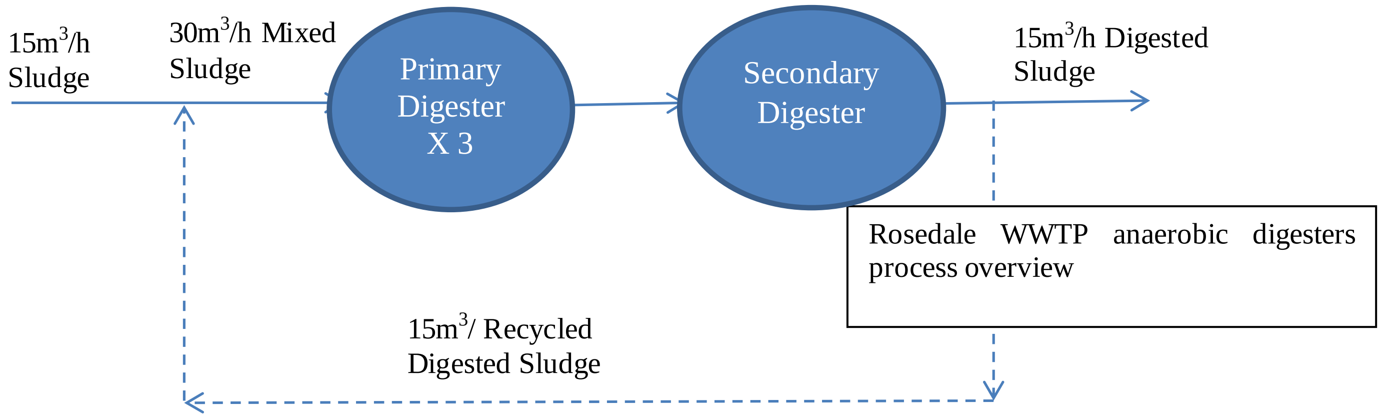
Hot water flush was implemented to reduce fat build-up in pipes. Heated water from digester heat loop is stored in a hot water tank near GBTs and temperature is kept at about 80°C. Initially, the hot water was used for cleaning belts on GBTs but the flow can be diverted to GBT 3 discharge hopper to flush the line with hot water. The hot water flush reduced the line cleaning frequency down to once every three weeks.

6.3 CURRENT METHOD TO MAINTAIN PIPE: RECYCLED DIGESTED SLUDGE

The hot water flush reduced fat build-up in pipes. However, water was added back to the thickened sludge and reduced solids retention time in the digesters. To remove FOG build-up in pipes, while minimizing negative impact on the digesters, digested sludge recirculation was proposed by Nigel Sanders as a solution to the problem.

As shown in the figure below, there are three primary digesters and one secondary digester in Rosedale WWTP. Most of the digestion takes place in primary digesters and secondary digester is used for combining digested sludge. The digested sludge was recycled from secondary digester and approximately $15m^3/h$ of recycled digested sludge was mixed with 30 m^3/h of fresh sludge (5 m^3/h PS, 15 m^3/h thickened WAS) and total sludge retention time in digesters were approximately 28 days. To transfer the recycled digested sludge, a temporary pipe was set up between the mixing pump and the discharge of GBT 3. A Polyvinyl Chloride (PVC) pipe was used since it's easy to transport, install and resistant to pressure. However, the mixing pump was unable to transport the digested sludge due to a frictional loss through the pipe. An additional pump was installed on top of the mixing pump which was able to pump and recycle digested sludge in the discharge line.

Figure 5: Recycling digested sludge



- Hydraulic retention time in digesters: 10200m3 / 15m3/h = 680h = 28 days

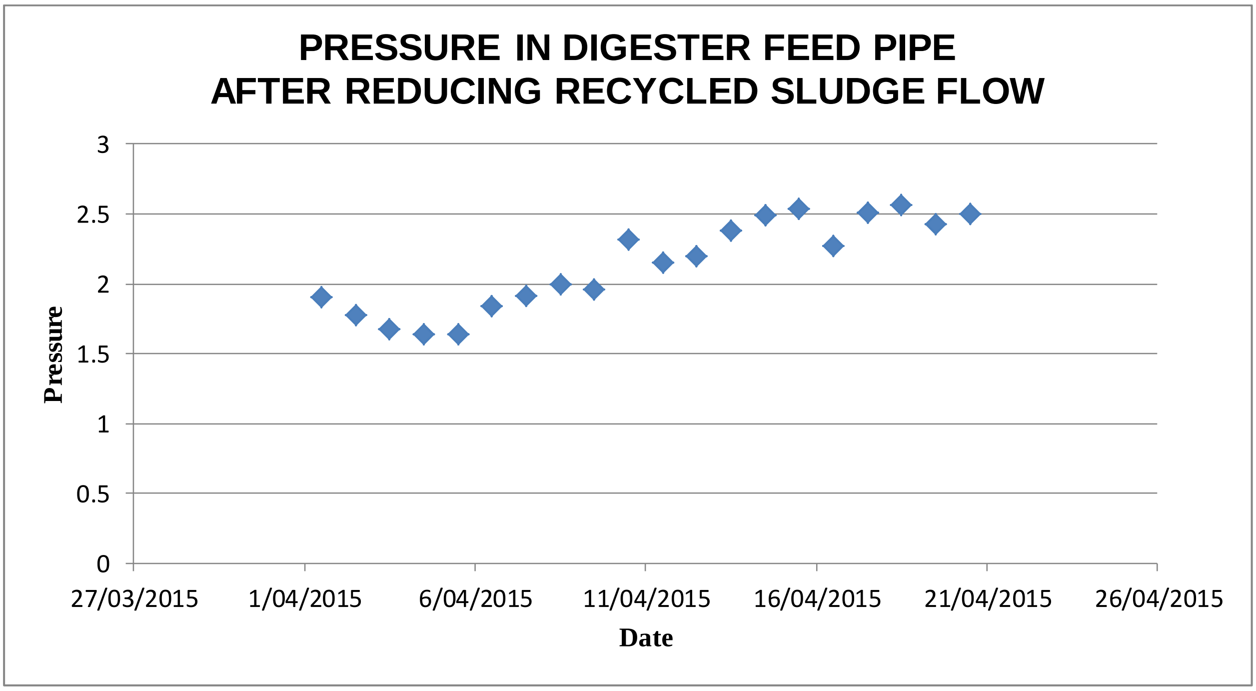
Currently, recycling digested sludge in GBT 3 discharge is still in use and following improvements were observed.

- Reduced plant operating cost: Prior to recycling digested sludge, line cleaning was carried out every 4 - 5 days interval and the cost was on average about $3,500 per clean. After recycling digested sludge, the number has dropped down to 1 - 2 line cleans per year which has saved approximately $280,000 in operational costs per year.
- Reduced maintenance cost: FOG build-up issue is no longer causing pressure increase in transfer pumps and maintenance cost has also reduced by recycling digested sludge.
- Improved flow through GBT discharge pump: Recycling digested sludge in a GBT discharge line, may have reduced viscosity of the thickened sludge therefore GBT discharge pump could transfer thicker sludge.

7 PRESSURE TESTING AND DISCUSSION

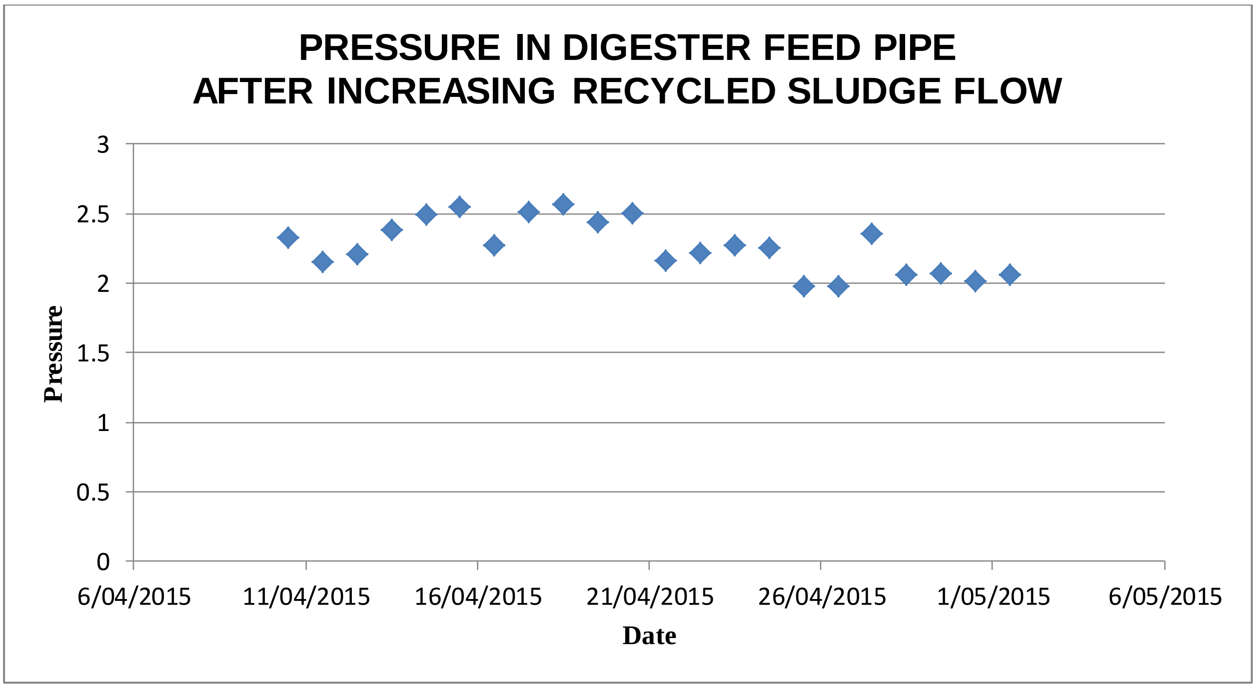
The digested sludge recycle was implemented in year 2010 and it has reduced FOG build-up in pipes. To demonstrate FOG build-up in digester feed pipe, recycled digested sludge flow rate was reduced from 16m3/h to 12m3/h and pressure in the pipe was monitored. Initially, the sludge flow rate was consistent with pressure less than 200 kPa and it seemed that digester feed pipe was clear of any FOG build-up. However, the pressure in the pipe started to increase and indicated that FOG deposit was gradually restricting the sludge flow through the pipe.

Figure 6: Pressure increase in digester feed pipe after reducing recycled digseted sludge flow rate



To reduce pressure in digester feed pipe, recycled digested sludge flow rate was increased from 12m3/h to 14m3/h. As shown in the figure below, pressure in the feed pipe was also reduced from 2.3 bar down to 2 bar.

Figure 7: Pressure decrease in digester feed pipe after increasing recycled digseted sludge flow rate



Normally, digested sludge has lower concentration of FOG than raw sludge due to microorganisms breaking down organic compounds and converting it into inert materials. Therefore it's possible that total FOG concentration was reduced by diluting raw sludge with digested sludge. Under normal operating condition, digested sludge is pumped at $15m^3/h$ whereas raw PS is pumped at $5m^3/h$. Therefore recycling higher volume of digested sludge may have reduced the rate at which the deposit is formed in the pipes.

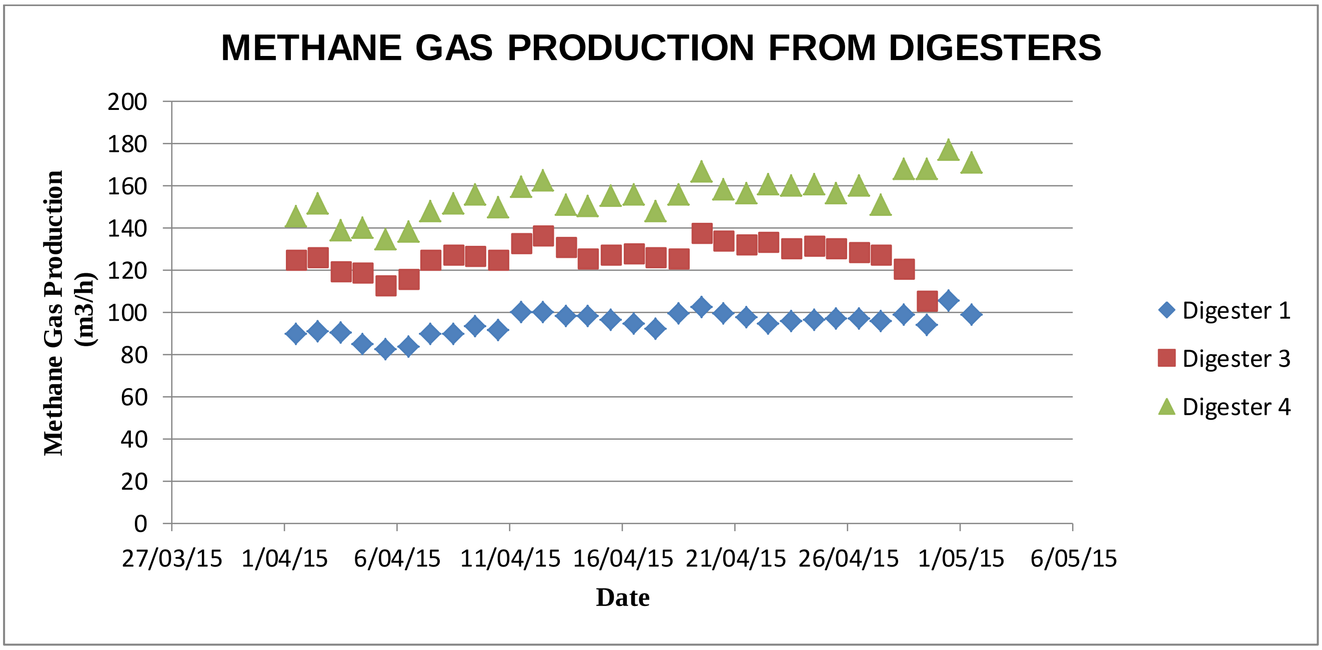
Also the temperature of mixed digested and fresh sludge may have helped with preventing FOG build-up in pipes. Digested sludge is kept warm inside the digesters to create an environment that is suitable for mesophilic microorganisms to grow. Normally digested sludge temperature is at about 35 -37°C and when larger volume of digested sludge is mixed with fresh feed sludge, the temperature of combined sludge would still be closer to the temperature of the digested sludge. An increase in temperature of the sludge could have helped reducing the fat build-up in pipes.

8 DIGESTER PROCESS MONITORING

The performances of anaerobic digesters were monitored by observing pH, alkalinity and volatile acid concentration in. It was observed that pH was consistent at about 7 and volatile acid concentration was less than 10mg/L, while alkalinity was maintained at about 3000 – 4000mg/L. This is normal working conditions for anaerobic digesters and it showed that recycling digested sludge didn't upset the digestion process.

One of the concerns regarding recycling digested sludge was reducing sludge retention time in digesters therefore reducing the amount of methane gas produced from the digesters. However, recycling digested sludge didn't have negative impact on methane gas production rate. The figure below shows that gas production was relatively constant, regardless of the change in recycled digested sludge volumetric flow rate.

Figure 8: Rosedale WWTP biogas production rate over the pressure testing period



Digesters 3 and 4 were producing larger volume of gas than digester 1 and this was expected since capacity of digester 1 is less than other two digesters. However, the gas productions from all three digesters were constant throughout the trial period.

9 CONCLUSIONS

Many wastewater treatment plants have problems associated with FOG build-up in primary raw sludge pipes. High pressure water jet is commonly used to clear deposits inside clogged pipes but frequent line cleanings can increase operational expenses and it can result in digester failures. To reduce the FOG build-up in pipes, digested sludge can be recycled and pumped back into digesters with fresh sludge. The results showed that recycled digested sludge reduced FOG build-up in interior surface of the pipes while maintaining stable digestion process.

ACKNOWLEDGEMENTS

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