

RECOMMISSIONING OF THE OPAL'S EGSB REACTOR USING ANOXICALLY STORED ANAEROBIC BIOMASS

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SUMMARY

Wastewater treatment using granular biomass is a comparatively new technology. Due to its cost-effective benefits, it is used all over the world. This study was initiated to prove the reuse of 49.5 tonnes of anoxically stored granular biomass for 22 weeks during the recommissioning of Opal's EGSB reactor. A biomass sample of 200 mL from 1.0 meter depth of the EGSB reactor along with 1800 mL of paper mill wastewater was continuously stirred at 290 - 340 rpm using a Cole-Parmer magnetic stirrer equipped with a hot plate. We proved that stored granular biomass under the starved anoxic conditions can be reused to recommission the Opal's EGSB reactor. Results showed that biomass recovered very quickly as evident from the 45% increase in the biomass activity after the first week of recommissioning. VFA¹ increase by 81% because of fasting which in turn triggered granular growth. Granule size grew 60%, showing a remarkable response to the feasting after prolonged fasting of 22 weeks.

Keywords: recommissioning, EGSB reactor, anaerobic granular biomass, biomass activity, VFA

¹ VFA (Volatile Fatty Acid)

APPLICATION

Secondary Water Treatment Plants (SWTP) are popular all over the world, particularly in the paper industry due to their cost-saving aspects linked with the disposal of untreated wastewater. During 2002-2007 almost 52% of EGSB reactors were sold worldwide (van Lier, 2008). Anaerobic EGSB reactors are popular due to their reduced energy requirements, energy production, and biomass production as a saleable commodity. Mill water is passed through the EGSB reactor where the undesired pollutants are eaten or consumed by the anaerobic bacterial biomass. Wastewater is then disposed of without any cost paid to the Environmental Pollution Agencies (EPA). The other benefit of SWTP is to make the environment clean by generating electricity by capturing the methane produced by the microbes in the Extended Granular Sludge Bed (EGSB) reactor. Opal Paper & Recycling Mill decided to reduce the cost of wastewater disposal paid to Sydney Waters. Therefore, Opal Paper and their Recycling Mill commissioned a SWTP per the EPA's stringent guidelines. A second objective was to generate electricity from the methane produced by the microbial activities as a result of the consumption of undesired pollutants present in the Paper Mill wastewaters. This plant was commissioned in Dec. 2017 but was decommissioned in Oct. 2019 due to some technical faults in the EGSB reactor. The third objective was to prove the viability of stored granular biomass during the recommissioning. Finally, in March 2020, SWTP was recommissioned to achieve the above-mentioned objectives.

Recommissioning the EGSB reactor was dependant on the biomass granular regrowth and their activities. Grotenhuis et al. (1991) also found a positive relationship between the granule diameter and the influent concentration. They found that granule diameter is probably controlled by substrate diffusion in the biomass. Lack of nutrient diffusion into the biomass will reduce bacterial growth and may cause cell lysis, which will weaken the granule and result in the breaking up of the structures.

Cho et al. (2005) further reported that factors such as biomass concentration, type, concentrations of substrate and mixing intensities significantly contribute to measured specific methanogenic activities.

METHODS

The granular biomass was stored for 22 weeks under starved anoxic environments in the storage tanks which have a capacity of 49.5T. Every fortnight, biomass samples were collected and analysed to examine the visual, physical, and chemical properties in the Opal Paper and Recycling Wet Chemistry Laboratory. All the samples were filtered through a 0.45-micron filter paper before the analysis.

A Eutech® pH meter equipped with combined electrodes was used to determine pH. The temperature was measured in situ using an LCD Digital thermometer. Analytical reagents grade urea and phosphoric acid were used to compensate for the macro nutritional requirements during the biomass activity determinations. Temperature and pH were maintained at 37 °C and 7.00 respectively, for five days. The pH was maintained by using analytical reagent-grade hydrochloric acid and sodium hydroxide. A homogeneous biomass sample of 200 mL from 1.0 meter depth of the EGSB reactor and a paper mill effluent sample of 1800 mL was continuously stirred at 290 - 340 rpm using a Cole-Parmer magnetic stirrer equipped with a hot plate. Biomass activity was measured using the following formula and the apparatus assembled in the Opal Wet Chemistry Laboratory as shown in Figure 1.

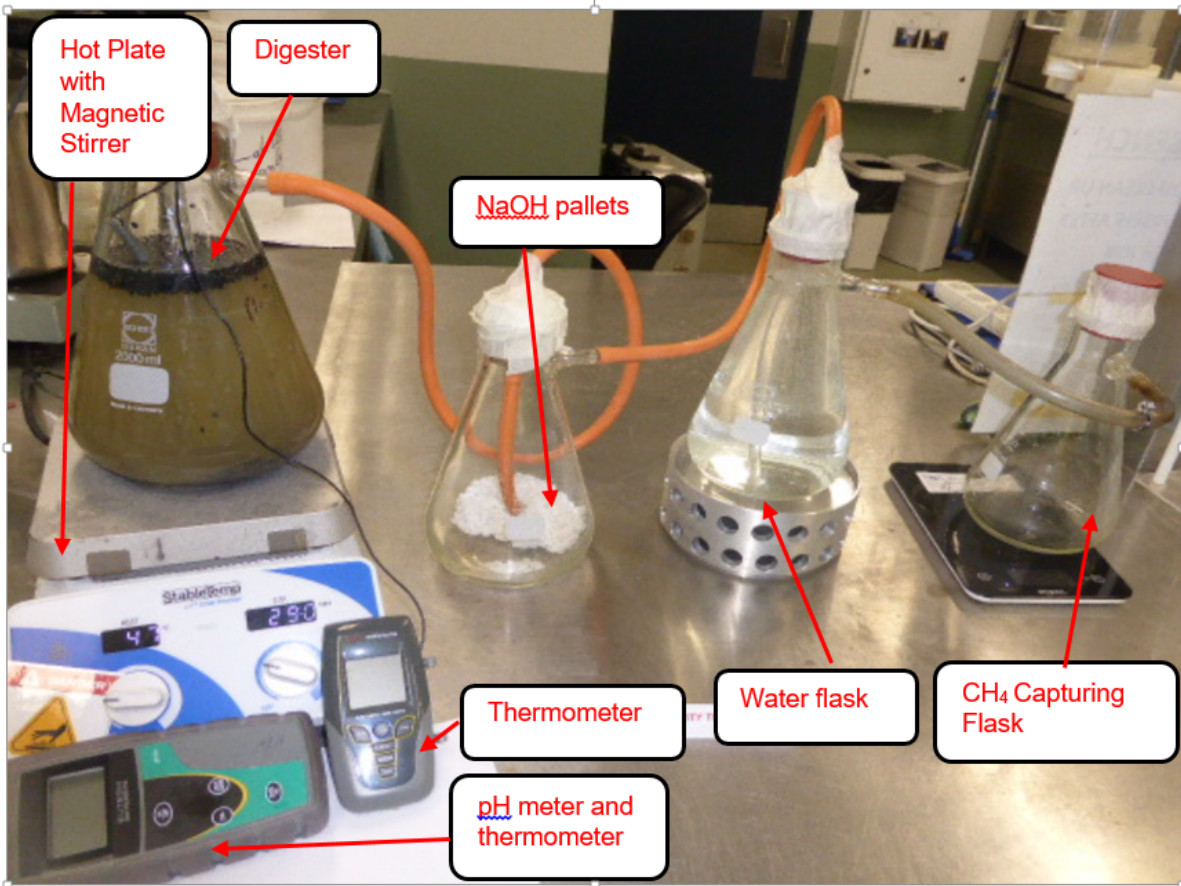


Figure 1 Apparatus used for the determination of biomass activity of the granular biomass during storage and recommissioning of the EGSB reactor.

$$\text{Biomass Activity (g/gVSS.d)} = \text{Volume of reactor} \times (\text{sCOD}_{t1} - \text{sCOD}_{t2}) \times 24 / (t1 - t2) \times \text{gram of biomass used}$$

A biomass activity trial was run at 6000 ppm sCOD to simulate the EGSB reactor conditions. The pH of the reactor contents was maintained using dilute NaOH and HCl.

Nutrients such as nitrogen in the form of Urea and phosphorous in the form of Phosphoric acid were also added to the reactor. Parameters such as Volatile Fatty Acids and Total Alkalinity were measured using a HACH® DR 3900 spectrophotometer. The granular size, shape, and colour were also measured using visual and photometric measuring techniques in the same laboratory.

RESULTS AND DISCUSSION

The amount of volatile fatty acids (VFA) increased 81% after the first week of recommissioning. The increase was due to the addition of paper mill wastewater into the EGSB reactor (Figure 2). It is important to note that during the 22 weeks of biomass starvation duration, VFA did not increase and remained more or less steady at 230 ppm. Under such stressed conditions, microbial biomass showed endurance against the anoxic and nutritionally deficient environment. During storage, VFA showed degradation from 400 to 200 ppm (50%) during 22 weeks of storage because available food for the microbes diminished with time. Wu et al. experimented on the VFA consumption with time at 22 °C for one month. Volatile fatty acids in the form of acetic acid decreased from 12 mM to zero within 20 hours.

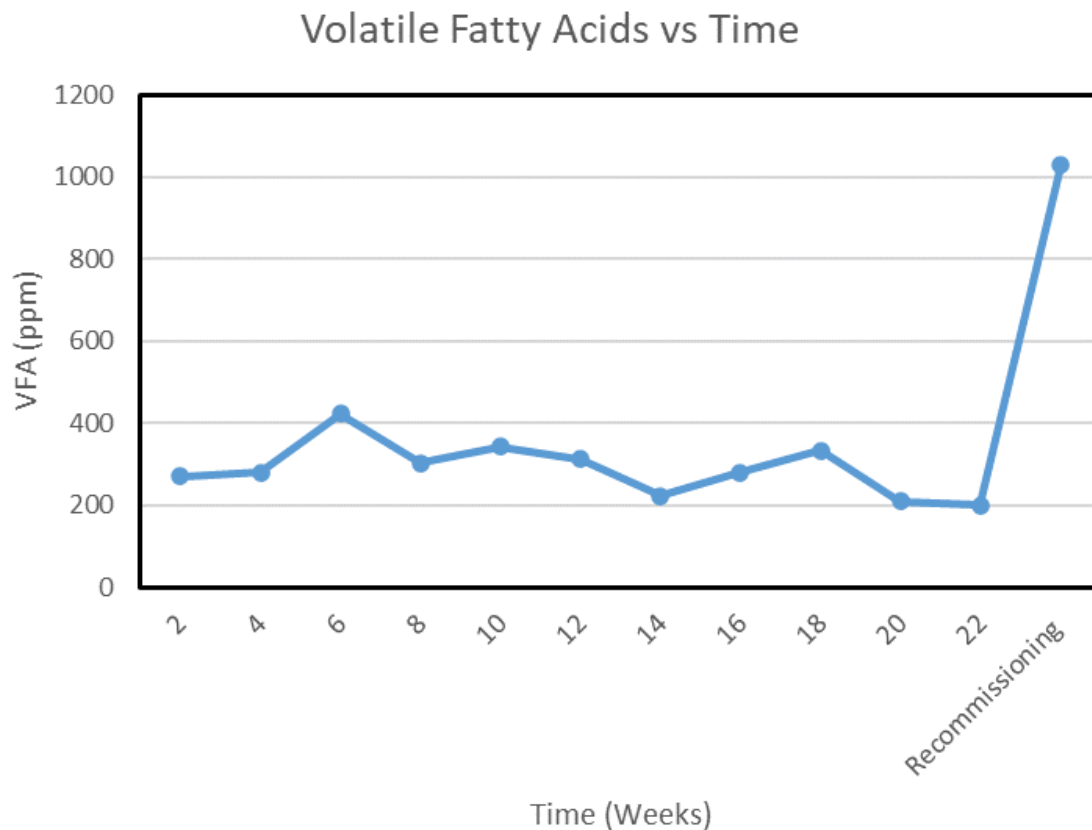


Figure 2 Volatile Fatty Acids (VFA) during biomass storage and recommissioning vs time.

Soluble chemical oxygen demand (sCOD) increased after seven days of recommissioning as shown in the Figure 3. Comparing Figure 3 with Figure 2 showed that volatile fatty acid addition through the mill wastewater triggered microbial growth. Increased mill wastewater supply into the conditioning tank at the time of recommissioning and the macronutrients intake triggered COD production. As a result of feasting, COD concentration increased by 8% after the first week of the start of the EGSB reactor. Semblante et al. (2014) also reported similar trends during

their experiments on anoxic anaerobic granules and the wastewater treatment performance but not during the recommissioning.

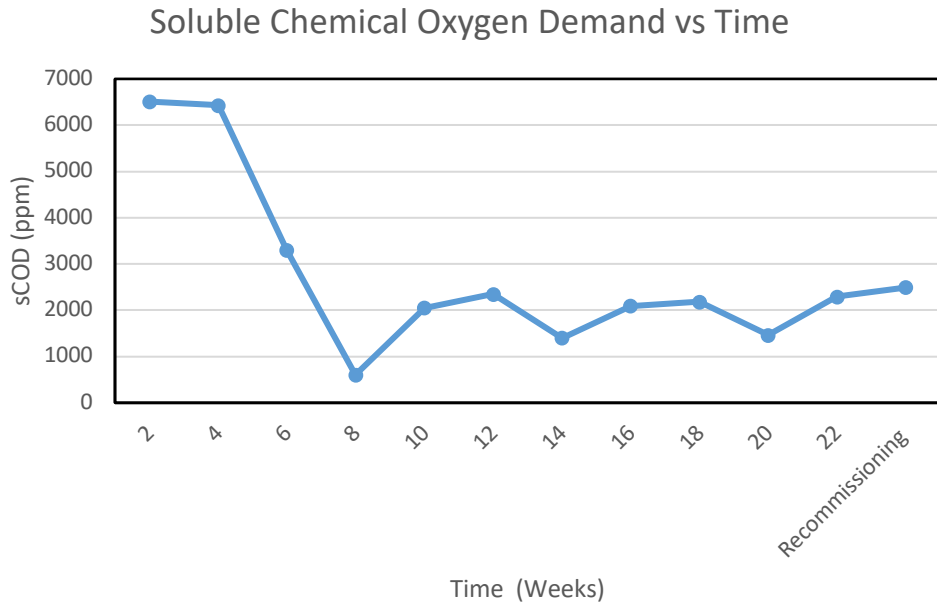


Figure 3 Soluble Chemical Oxygen Demand (sCOD) trend with time during the anoxic biomass storage and the recommissioning stage.

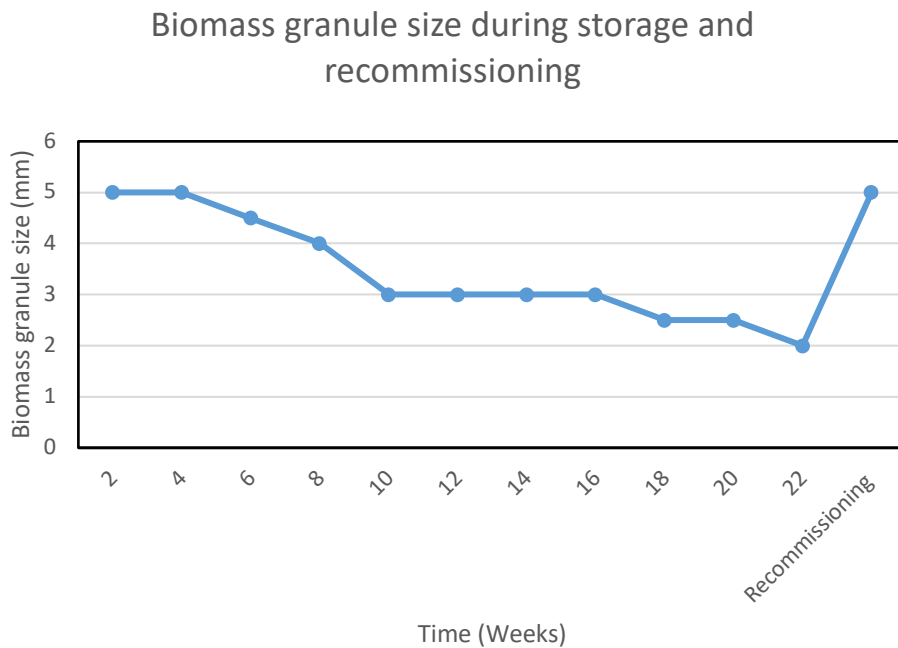


Figure 4 Growth of biomass granule size after one week of recommissioning of the EGSB reactor.



Figure 5 Size, shape, and color of biomass granules after the first week of recommissioning.

As a result of survival strategies such as cell lysis and mitochondrial rupture, granular size reduced during the starved storage conditions of 22 weeks. During the recommissioning phase, microbial biomass showed a response to the added nutrients and food through the mill wastewater. Hence granular size increased 60 % as shown in Figure 4.

Increased biomass granular size, shape, and color can be seen in Figure 5. Starved biomass granules utilized nutrients and food in the form of acetic acids and grew in almost round, shiny, and black granules. Granules regained their size of 0.5 mm within the first week's recommissioning of the EGSB reactor as shown in Figure 5.

In contrast, Zhu and Wilderer (2003) showed that the size and color of granules did not change during the 7 weeks anaerobic storage time. However, Beftink and Staugaard (1986) found that granular growth is related to bacterial health and growth.

Granular fraction showed 6 % growth thus proving the hidden effectiveness of biomass activity as shown in Figure 6. Granular fraction growth was further supported by the biomass activity, as shown in Figure 7. However, sufficient literature on granular biomass fraction production during recommissioning is not available. Therefore, our study significantly supported the reuse of anoxically stored biomass for quick biogas production and wastewater cost reduction.

During the recommissioning biomass, activity increased 45 % after 7 days of biomass transfer into the EGSB reactor. For the optimum growth of biomass, the pH and temperature of the reactor were maintained at 6.99 and 36 °C respectively, as shown in Figure 7. In our case increased biomass activity showed that stored biomass was not dead and was just inactive. Upon food availability, nutritionally starved biomass showed growth potential. Cho et al. (2005) found 0.85 gCOD/g VSS.d specific methanogenic activities. Wiegant et al.

(1983) concluded that methanogenic activity at 30 °C stored for 50 days reduced to 50 %. However, in the literature, scant data is available about biomass activity during recommissioning.

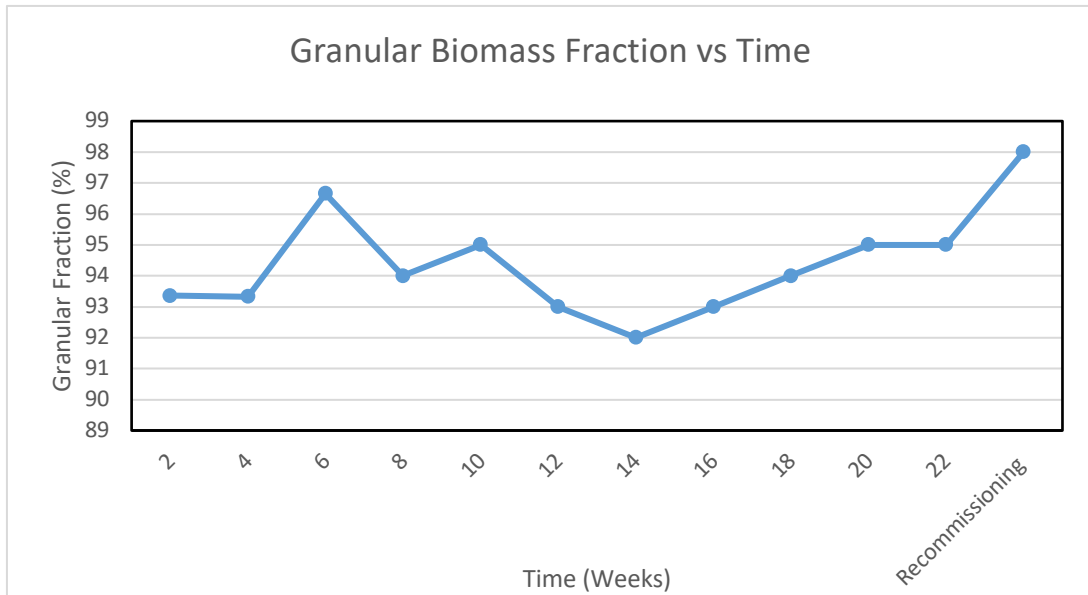


Figure 6 Granular biomass fraction growth after the first week of recommissioning.

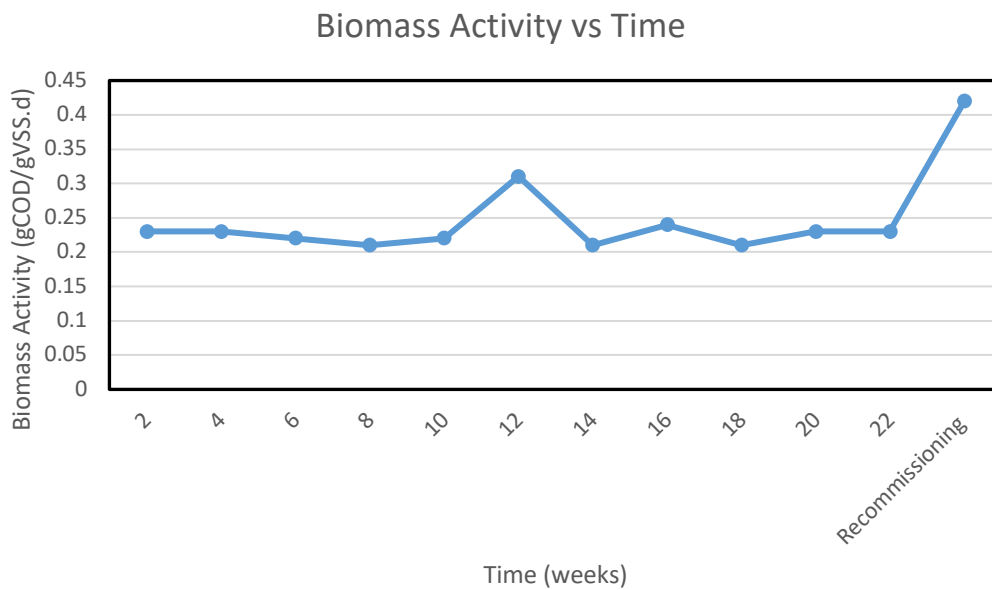


Figure 7 Granular biomass activity during storage and after recommissioning of the EGSB reactor.

CONCLUSIONS

In this research, we proved that biomass adopted survival strategies to strive through the long-term anoxic, starved, and highly stressed storage conditions under the natural environment. Biomass regained its granular size even after one week of recommissioning of the EGSB reactor.

Biomass activity increased to 45% after the start of the EGSB reactor showing the stored biomass survival and growth.

Cannibalism and cell lysis survival strategies: weaker biomass granules shrunk and finally ruptured their cells thus producing macronutrients such as phosphorus and nitrogen for the regeneration, growth, and survival of younger granules. In other words, younger and healthy biomass granules ate older and weaker biomass granules to survive.

Finally, the same biomass was used to recommission Opal's EGSB reactor of SWTP after repair. This research work not only helped to reduce the operational cost by reusing the stored granular biomass but also gave a head start to quickly produce methane gas used to run the gas engine and produce electricity.

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