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A Case Study on Bulking Problems in Paper Recycling Effluent Treatment Plant in Malaysia

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Abstract: This study was conducted to investigate the cause of bulking problem at the effluent treatment plant (ETP) of a paper recycling plant in Malaysia. Hypothetically, the effluent is lacking nutrients and could induce the overpopulation of filamentous bacteria, and further cause the bulking problem during the effluent treatment using activated sludge process. Experiment to simulate treatment operations had been set up at laboratory. The simulation showed that the bulking started to occur after the first cycle of the fed-batch operation with the typical effluent. To make up the lacking of nutrients in the effluent, urea (N) and phosphate (P) were added as supplements with the ratio of BOD : N : P equal to 100 : 1.0 : 0.7. The supplemented effluent was again tested by a simulation study and showed that the bulking problem started to take place after the third cycle of feeding regime. Bulking problem also periodically took place in the actual operation when the same supplemented formula was applied; however the frequency of occurrence was lesser. Therefore, this study has shown that other than the lack of nutrients, there are other factors that could cause bulking problem.

Key words: Recycled paper mill effluent, activated sludge process, bulking, filamentous bacteria, nutrients supplement.

Introduction

Despite the lingo for paperless office by advances in information technology, the demand for paper still continues to be strong. The fact is that the world paper and paperboard demand was at 313.3 million metric tonnes (MT) in the year 2000 and the demand growth in Asia has been anticipated to account for a third of the world's paper consumption within the next 15 years (MPPMA, 2002). It is predicted that the demand for the paper in the region will grow at an annual average of 6% to 10% over the long term. Keeping up with the demand for paper, 20 paper mills have been set up in Malaysia (Sveriges Ambassad, 2004). Five of these plant operators have the production capacity of more than 100, 000 MT per year.

Pulp and paper industry is known to consume tremendous amount of water, which has been ranked as third, after the primary metals and the chemical industries (UNIDO, 1993). The demand for water in this industry will remain high until the principle for manufacturing process is changed. The water consumption varies with the type of paper being produced and the total consumption could reach as high as 60 m^3 per MT of paper produced. From this fact, in some paper mills in Malaysia, the demand for water could be estimated reaching at 20,000 m^3 per day. With such high amount of water consumption, high quality of treated wastewater is necessary. Discharge of non-compliance effluent will give significant impact to the receiving water body by the high amount of pollutant loading.

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Abbreviations

ASP : activated sludge process
BOD : biochemical oxygen demand
COD : chemical oxygen demand
DAP : diammonium phosphate
ETP : effluent treatment plant
HRT : hydraulic retention time
F : food
M : biomass
MCRT: mean cell retention time
MT : metric tonnes
N : nitrogen
NaOCl: sodium hypochlorite
P : phosphate
RAS : return activated sludge
TSS : total suspended solid
WAS : wasted activated sludge

Paper-recycling industry poses lesser threat to the environmental pollution based on the fact that it reprocesses a readily available raw material when compared to the primary pulp and paper processing (Thompson et al., 2001). This article explains the problem faced by one of the paper recycling plants in Malaysia, to keep their effluent discharge at required standards. The major issue faced by the operator is the occurrence of bulking problems in the secondary clarifier which is caused by the overpopulated filamentous bacteria and poor sludge settling condition. Bulking problem would discharge effluent with higher concentration of total suspended solids as the carried over. Finding solution without involving changes of the effluent treatment plant (ETP)'s operational design would be the priority. In recycled paper processing, the content of raw materials such as cellulose fibres and carbohydrates such as starch and sugars, as well as lignin, are much lesser compared to the primary paper and pulp processing. Considering these facts, hypothetically, this wastewater contains imbalanced nutrients which could lead to the overpopulation of filamentous bacteria due to different substrates preferences.

Effluent Treatment Operation

Overall effluent treatment operation in this case study is illustrated in Figure 1. The influent to the aeration basin carry the effluent of paper recycling and reproduction processes which need to pass through the cooling tower, and mixed with returned activated sludge (RAS). Prior to the entry, suspended solid was initially removed using the dissolved air floatation process.

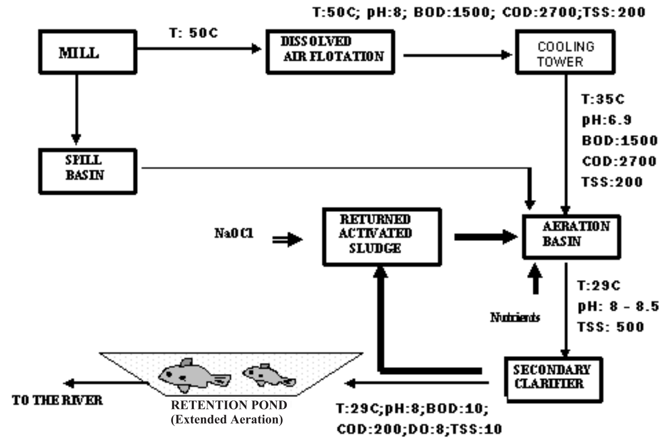

Figure 1: Schematic of effluent treatment processes at the recycled paper mill.

The aeration basin has eight mechanical surface aerators with a total volume of 18,700 m^3. It operates at 44 hours of hydraulic retention time (HRT). Depth of the aeration basin is 1.2 m, which is by design sufficient to deliver oxygen via surface aerators. The first three mechanical aerators by the incoming effluent from cooling tower are connected to draft tubes that are placed vertically from the surface of the basin towards the bottom of the basin. Therefore, this increases the aeration capacity and a high level of oxygen is maintained.

Flow rates at aeration basin, secondary clarifier overflow rates, RAS and wasted activated sludge (WAS) and the final discharge flows are automatically tracked by an online flow meter. The aeration basin with a size of 18,700 m^3 is operating at the average flow rate of 10,000 $m^3.d^{-1}$. Meanwhile the size of secondary clarifier is 3000 m^3 and running at the average flow rate of 13,000 $m^3.d^{-1}$. Dissolved oxygen (DO) in the aeration basin is monitored using an online DO probe, which is located 30 cm from the surface in the 1.2 m deep aeration basin. With an average of 44 hours of HRT in the aeration basin, the mixed liquor was streamed to the secondary clarifier for gravitational biomass separation. Overflow from the clarifier is directed into retention pond for extended aeration. Black tilapia fish is used in the extended retention pond as shown in Figure 1 as the biological indicator for the final effluent to be safely discharged.

Table 1 shows the effluent characteristics based on monthly average. All parameters for pH, biochemical oxygen demand (BOD), total suspended solid (TSS) except chemical oxygen demand (COD) for the final effluent within the three months period have complied with Standard A as required by Malaysian Environmental Quality Acts (LRB, 2001). Under certain circumstances,

Table 1: Monthly average parameters for effluent characteristics

Parameter	*Month 1*	*Month 2*	*Month 3*
Untreated effluent			
pH	7.1 ± 0.2	7.0 ± 0.2	7.1 ± 0.2
BOD (mg.L^{-1})	790 ± 20	820 ± 30	770 ± 10
COD (mg.L^{-1})	1650 ± 170	1740 ± 260	1780 ± 220
TSS (mg.L^{-1})	130 ± 50	130 ± 60	120 ± 40
Treated effluent			
pH	7.1 ± 0.2	7.0 ± 0.2	7.1 ± 0.2
BOD (mg.L^{-1})	4.0	4.0	3.0
COD (mg.L^{-1})	170 ± 20	190 ± 30	170 ± 30
TSS (mg.L^{-1})	16 ± 6	17 ± 5	14 ± 6

Malaysian authority would allow a non-compliance effluent to be discharged to the surrounding under a contravention licence. In this case, high COD concentration up to 190 mg.L^{-1} was allowed to be discharged whereas Standard A only allows the maximum of 50 mg.L^{-1}. This permission was given on the basis that the operator is continuously taking the effort to reduce this concentration.

Materials and Methods

A grace period of three months has been given to this research work by the ETP operator to conduct the investigation of bulking problems by the filamentous bacteria. In order to investigate the cause of bulking population during the operation, the inoculum sludge was prepared by removing high filamentous population with administration of sodium hypochlorite (NaOCl) into the supernatant for secondary clarifier.

Laboratory Studies

Laboratory study for the simulation of the actual ETP operation was designed according to actual operation. Inoculum for the simulation of activated sludge process was taken from RAS, while the fresh effluent was taken out from the sampling point at the cooling tower, prior to the entry of aeration basin. The simulation was carried out using simplified bench top experiment. A seven-litre capacity PVC tank was filled with five litres of mixed liquor sample to simulate an activated sludge process. Circulation and aeration were put in place with the recreational fish-aquarium kits. It was set up in duplicates to simulate the ETP processes in laboratory with HRT 1.8 days; however additional distilled water was added from time to time to make up the water loss by evaporation. Each cycle of the operation was on 24-hours basis according to the given HRT.

Three types of substrates were used to simulate the operation: the actual untreated effluent, untreated effluent with supplements and complete substrate prepared from a nutrient broth. Preparation of nutrient supplements was done by using the mixture of urea (43% N) and diammonium phosphate (DAP; 21.2% N and 23.5% P). Dosage of supplement was given in a concentrated solution by dissolving 200 g urea and 54 g DAP in one litre of water. The ratio of liquid stock supplement to the mixed liquor in the aeration tank was at 2:5000 to make up the ratio for BOD:N:P of 100:1:0.7 as suggested by ETP operator. Measurement of BOD was taken according to the average values in the record, which was at 800 mg.L^{-1}.

Settleability Test

Settleability test is one of the methods which could be used to monitor bulking properties (Ekama et al., 1986). It is a simple test which can be carried out in a 1000 ml measuring cylinder and is indicative of the settling characteristics of the sludge in the secondary clarifier. Settleability test was done by studying the settling rate versus time of 120 minutes, based on the sludge volume for interface of supernatant and settled sludge. The data was then plotted as settled sludge volume (mL) versus time (minutes).

Results and Discussion

Laboratory Studies

A "good" type of seeding sludge was used as the inoculum in laboratory simulation. This sludge was categorised to have a good compaction and settling rate. This was taken when the sludge blanket in the clarifier was at 1.17 metre high and no dosing of NaOCl was carried out at this stage.

For the study with a complete nutrient, a laboratory grade of nutrient broth for microbial work has been used as control. However, it was found that the media was not suitable to be used in this experiment when excessive foaming of the mixed liquor has taken place. High volumetric rate of air diffuser for oxygen supply was the cause of this foaming problem. No observation could be made on the bulking problem using complete nutrient substrates.

The simulation work with the actual effluent has shown that bulking problem would occur after the first "feeding" cycle, which took place at every 24 hours, to simulate an 1.8 days of HRT. Figure 2 shows the initial compacted volume of sludge at the fifth minutes at 500 ml. During the settleability test, the sludge was further compacted at the discreet settling rate. During the second cycle of feeding, the compaction and settling rates changed, the initial compaction volume was observed to occupy more than 900 ml. It indicated that the bulking problem has started to occur after 24 hours. The rapid changes of sludge settling rate has shown that the filamentous bacteria regularly do not represent the dominant metabolic bacterial group in the treatment plant.

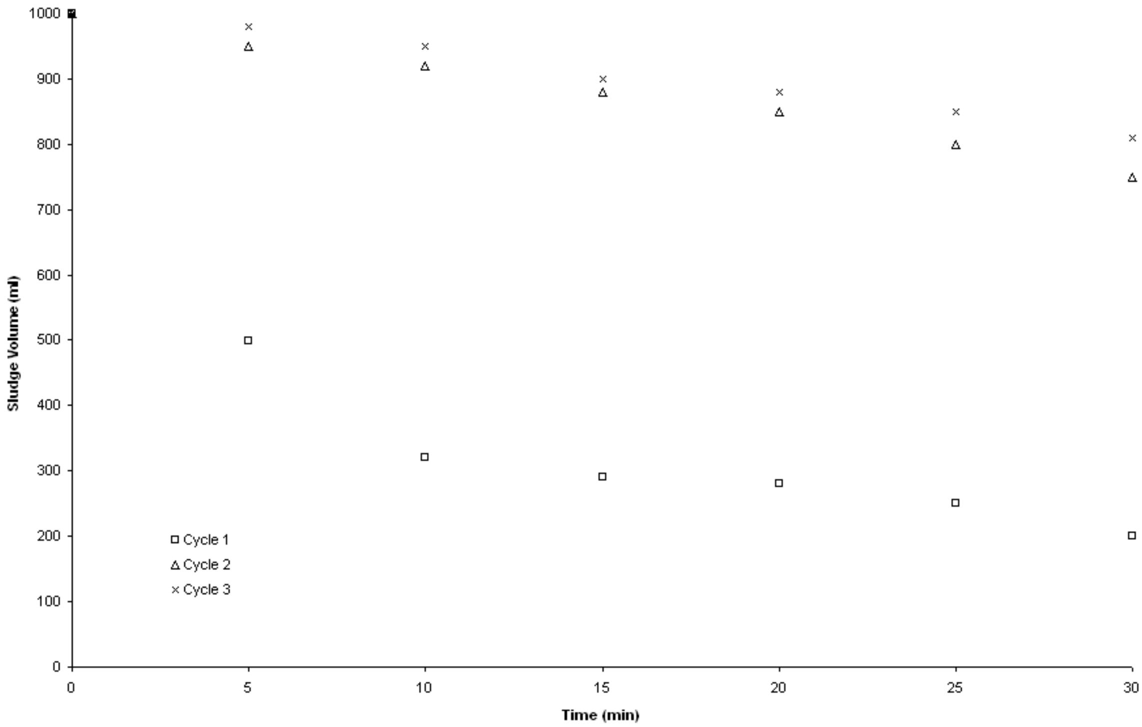

Figure 2: Volumetric sludge settling during the simulation of fed-batch treatment operation without supplements for paper mill effluent in laboratory.

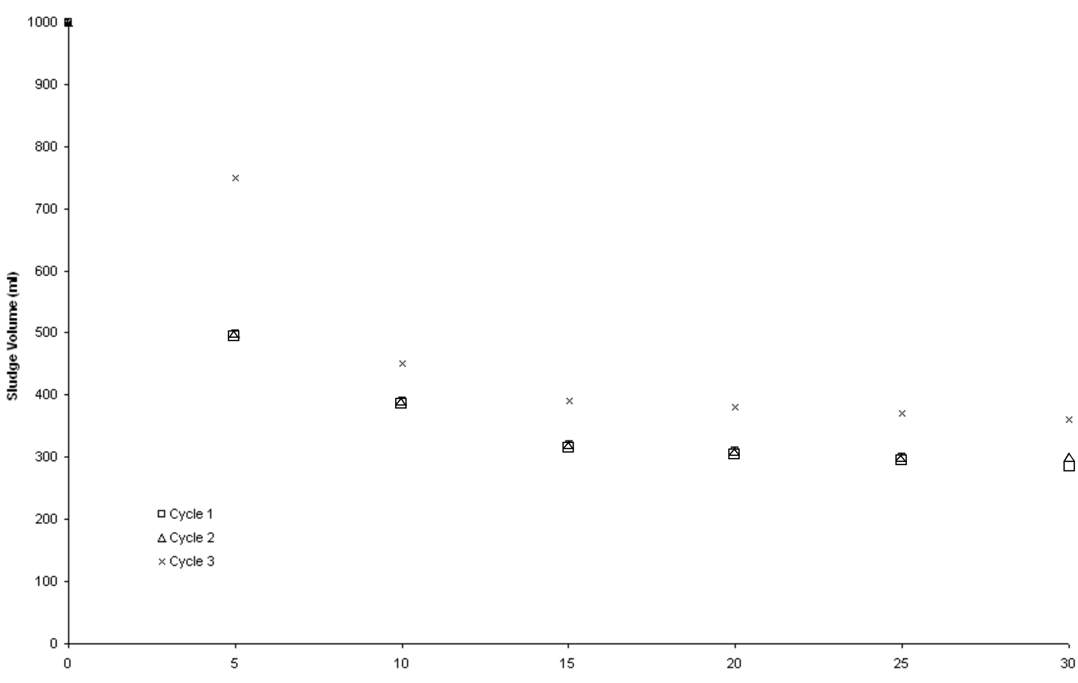

Figure 3: Volumetric sludge settling during the simulation of fed-batch treatment operation for paper mill effluent with supplements in laboratory.

When compared with Figure 3, it shows that the use of nutrient supplements could be potentially a good solution to solve bulking problem. However bulking problem started to appear after the third feeding cycle. The initial sludge compaction at five minutes occupied the volume of 750 ml, whereas "good" properties of sludge could give the compaction at 500 ml during the same first five minutes. Nevertheless, the bulking property for the supplemented effluent was not as poor as during the simulation with the unsupplemented effluent. At the end of settleability test, the final sludge compaction volume for the supplemented effluent was almost equivalent to earlier cycles (good property of sludge), which was between 300 and 400 ml.

The same ratio of C:N:P supplementation was also applied in the actual operation, and has resulted in lesser frequency of bulking problem in ETP when compared to the previous unsupplemented effluent. The actual cause for the changes is yet to be determined. Nevertheless the C:N:P should be increased to 100:5:1 as recommended (Droste, 1991), instead of current dosage at the concentration ratio of 100:1:0.7.

Despite much research, bulking sludge seems to be a continuous problem in operating wastewater treatment plants. Changes of dominant population are likely to be caused by several facts. Many filamentous bacteria are not available in pure cultures, preventing a detailed study to be performed on these organisms (Martins et al., 2004). The condition of the plant operation under which bulking sludge occurs is usually only marginally documented. One reason for not finding a good general solution to bulking sludge might be the absence of a consensus on the exact level at which the problem should be approached. For example, in this study, the bulking sludge was quantified based on the height of the sludge blanket in the clarifier. There has been a suggestion to use a separate compartment as the initial contact zone of aeration basin where the primary effluent and RAS are combined (Metcalf and Eddy, 1996). This concept entails the selective growth of floc-forming organism at the initial stage by providing a high food to microorganism ration at controlled dissolved oxygen levels. Nevertheless, this suggestion requires physical modification by the ETP operators, which is not a favourable choice.

Conclusion

Using nutrients supplement of nitrogen and phosphorus to overcome bulking problem, it was only successful at laboratory but not at actual scale for the ETP of recycled paper mill. Nevertheless, the laboratory study which had been conducted was not able to simulate the actual operation of the ETP. For instance, oxygen supply to aeration process was sufficient as the sizing of laboratory scale. The aeration for the actual scale was subjected to be sufficient according to the monitoring of oxygen which, however, was only done at the first selector of the aeration basin. Draft tube is included in the structure for the first three selectors but not at the other five selectors, which may cause the lack of oxygen supply within the high density of microbial population. Longer MCRT and HRT at the operational stage also could contribute to the poor settling of the sludge from the aeration basin. Simulating the actual operational process or at least at a pilot scale would help to identify whether the occurrence of bulking are caused by the design on the parameter of oxygen transfer and the volumetric flow rates for effluent, RAS and WAS, which affect the HRT and MCRT of the whole treatment process. The design should also include the study on the initial contact zone for RAS and fresh effluent.

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