CONTROL OF ACTIVATED SLUDGE FILAMENTOUS BULKING THROUGH OPERATION AT VERY HIGH MLSS CONCENTRATION

A. Abusam[1,] and F. Al-Salameen[2]*

1. Wastewater Treatment and Reclamation Technology (WTRT) Program, Water Research Center, Kuwait Institute for Scientific Research, Kuwait. P.O. Box 24885 Safat, 13109 Kuwait
E-mail: aabusam@kisr.edu.kw
2. Department of Biotechnology, the Environment & Life Sciences Research Center, Kuwait Institute for Scientific Research, Kuwait. P.O. Box 24885 Safat, 13109 Kuwait E-mail: fslamian@kisr.edu.kw

ABSTRACT

Filamentous sludge bulking problems are worldwide common operational problems for activated sludge systems. If not controlled, excessive sludge bulking can lead to a complete failure of the entire wastewater treatment process. This paper presents the control of filamentous sludge bulking at Umm-Al-Haiman activated sludge system, in Kuwait, through operation at mixed liquor suspended solids (MLSS) concentration higher than 7000 mg/l. Weekly samples of wastewater and sludge were collected and analyzed for nine months to determine the wastewater quality, operating variables of the activated sludge system, and the dominant filamentous bacteria. Despite the growth of various types of filamentous bacteria, which have been identified and quantified through VIT method (a molecular biology technique), the sludge volume index (SVI) was steadily less than 150 l/mg. Also the effluent was of high quality. That is, the control strategy used (MLSS > 7000 mg/l) had prevented filamentous sludge bulking from occuring. The paper also discusses the advantages and disadvantages of this control strategy.

Keywords: Wastewater, Activated sludge systems, Filamentous bacteria, Sludge bulking, Control measures.

1 INTRODUCTION

The activated sludge processes are the most globally used biological wastewater treatment processes (MetCalf, and Eddy, 2003). Filamentous sludge bulking and foaming problems are the most common operational problems of these systems (MetCalf and Eddy, 2003; Kragelund et al., 2010; Soltysik et al, 2011). If not properly controlled, excessive sludge bulking and foaming can lead to a complete failure of the entire wastewater treatment process (Soltysik et al, 2011).

There are several specific (long-term) and non-specific (temporary or short-term) measures for controlling sludge bulking and foaming problems (Goldwyn et al., 2010). Specific measures attempt to eliminate the root causes of the problem, whereas nonspecific measures are sort of quick-fix (temporary) solutions. Nonspecific (temporary) control measures include: addition of chemicals (organic polymers or disinfectants) and arbitrary change of some of the system operating variables (e.g. RAS and WAS). Specific control measures address the root causes of the problem. The most successfully applied specific control measures are addition of nutrients and use of selectors. However, change or modification of the reactor design and operation, e.g., reducing SRT and loading, adjusting DO concentration, reducing sulfide concentration in the influent, increasing RAS, increasing WAS, increasing operating temperature and changing reactor design from completely mixed to plug flow were also found to be successful measures (Azimi and Zamanzadeh, 2006; Yin et al., 2009, Areli et al., 2009; Yang et al., 2009; Kumari et al., 2009; Wang et al., 2009).

This paper presents how sludge bulking at Umm-Al-Haiman activated sludge system was avoided through operating the system at a very high MLSS concentration.

2 MATERIALS AND METHODS

2.1 Samples Collection and Handling

1000 ml grab samples were collected weekly in sterile bottles from the following four locations along the influent, the aeration tank, the secondary effluent and the tertiary effluent streams of Al-Haiman activated sludge system. After in-situ measurement of temperature (Temp.), electrical conductivity (EC) and hydrogen ion concentrations (pH), the samples were placed in an ice-box and transported for analysis with 24 h at the laboratories of Sulaibiya Research Plant (SRP) of Kuwait Institute for Scientific Research (KISR).

2.2 Filaments Identification and Quantification

Filamentous bacteria in the aeration tank were identified and quantified using the following Vermicon Identification Technology (VIT) kits: VIT-1851, VIT-H. hydrossis, VIT-Nocardiaform, VIT-021N/Thiothrix, VIT-N. Limicola II and VIT-M. parvicella. Identification and quantification of the dominant filaments were conducted within 24 h from the samples collection and according to Vermicon's instructions. Leica LS2 fluorescence microscope was used to investigate the presence and/or absence of filamentous bacteria. Images of the filaments were captured and visualized using Leica DFC295 digital colored camera system at standard resolution of 2048 x 1536 pixels (3 megapixels). The abundance of the identified filaments was then quantified using VIT proposed scoring scale which ranges from zero to five (0: None, 1: few, 2: some, 3: many, 4: abundant and 5: excessive). To confirm the filament identification and abundance level, all of the microscopic investigations and scoring of identified filaments were conducted independently by two observers.

2.3 Wastewater Quality Determination

According to the standard methods for water and wastewater examination (APHA, 2012), the following 16 parameters were determined for the collected wastewater samples: temperature (Temp.), pH, electrical conductivity (EC), dissolved oxygen (DO), total suspended solids (TSS), volatile suspended solids (VSS), chemical oxygen demand (COD), five-days biochemical oxygen demand (BOD_5), volatile fatty acids (VFAs), oil and grease concentration (O&G), Total Nitrogen (TN), ammonia nitrogen (NH_4), nitrate nitrogen (NO_3), nitrite nitrogen (NO_2), total phosphorous (TP) and hydrogen sulfide (H_2S).

3 RESULTS AND DISCUSSIONS

3.1 Dominant Filaments

Figure 1 presents the abundance of the identified filaments in the collected samples. It shows that the filaments had started from almost nil (scale 0 or scale 1) in the first half of January 2014 and rapidly, in only few weeks, had became abundant (scale 4) or even excessive (scale 5). This figure also shows that concentrations of Microthrix had the highest rate of fluctuations over time. However, this filament seems to be adversely impacted by the sharp increase in water temperature during the hottest months (June, July and August), summer season.

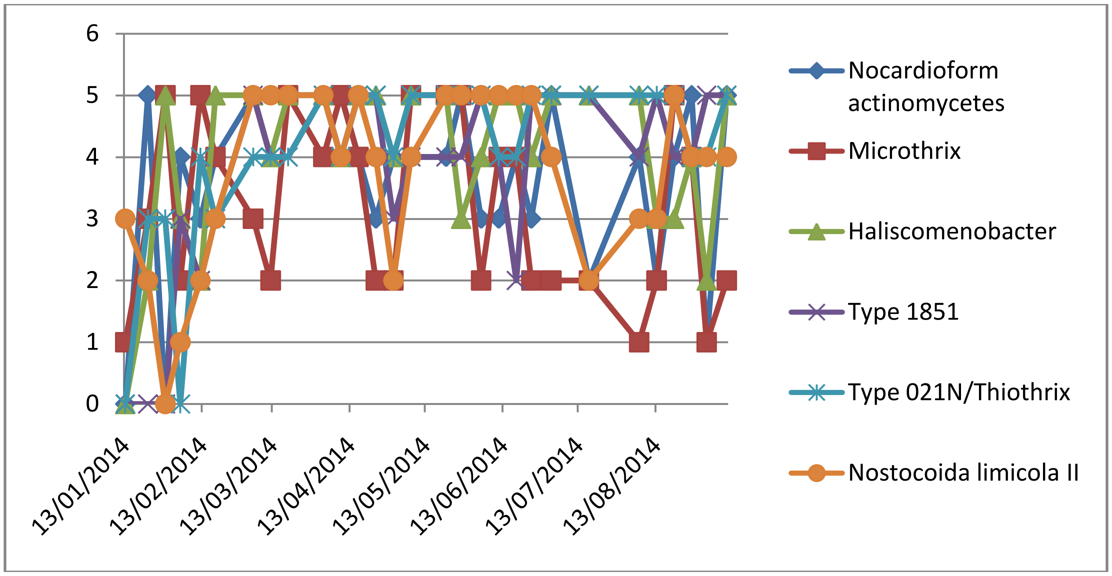

Figure 1. Score of filamentous bacteria identified in Umm Al-Haiman aeration tank

Fig. 2 compares the dominant filaments (> 70% of time) to secondary filaments found in the aeration tank of Umm Al-Haiman activated sludge system. As shown in this figure, the descending ranking of the dominant filaments is as follows: Haliscomenobacter, Type 021n/Thiothrix, N. limicola II, Type 1851, H. Hydrossis, Nacordioform and Microthrix. However, the filaments were found to be more abundant during the summer season than during the winter season, except for Nacordioform and Microthrix (Fig. 3).

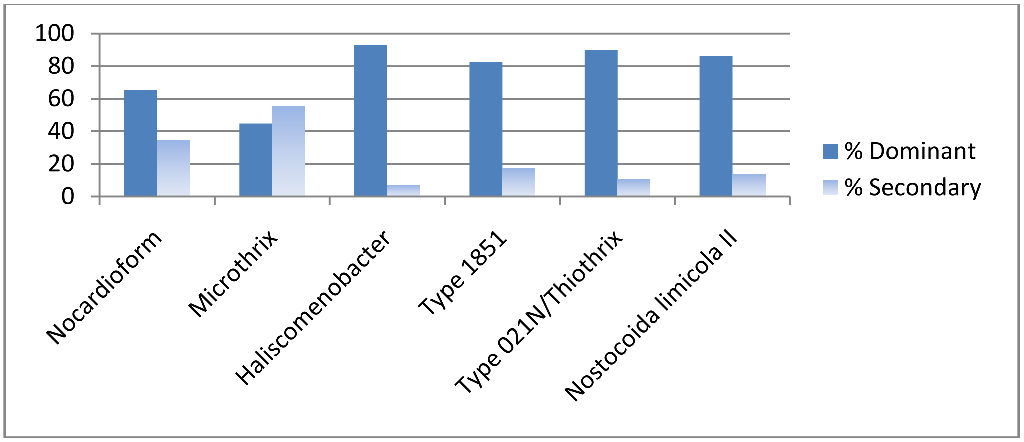

Figure 2. Comparison of dominant and secondary filaments in Umm Al-Haiman aeration tank during the whole sampling period

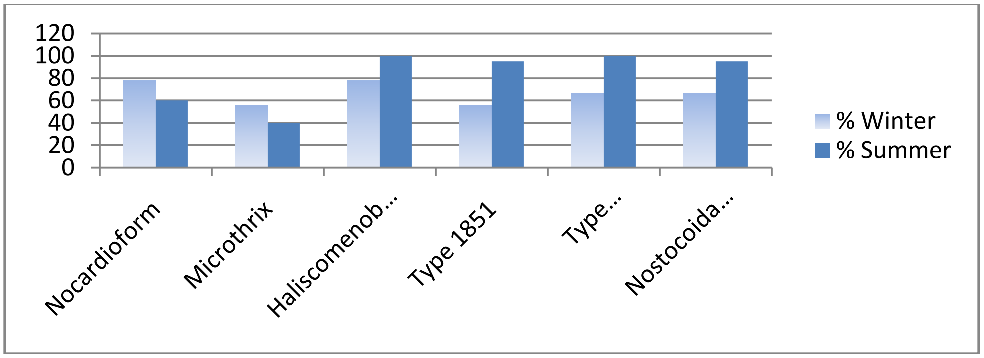

Figure 3. Comparison of dominant filaments in Umm Al-Haiman aeration tank during winter and summer seasons

3.2 System's Operation

Umm Al-Haiman activated sludge system is an oxidation ditch system designed to treat 20,000 m^3/d. Tables 1 and 2 show that during the study this system was operated at adequate DO (> 1.5), low organic loading (OL) and low food-to-microorganisms (F/M) ratio during both the winter and the summer seasons. However, it was operated at a very high mixed liquor suspended solids (MLSS) concentration. In fact, the MLSS concentrations during both the winter and summer seasons were 7566±627 and 7379±787 mg/l, respectively. Notice that the MLSS design value is only 3,000 mg/l. That is, the system was operated at MLSS concentration higher than double the design value. It was intentionally operated at such very high MLSS concentration to overcome the problem of sludge bulking usually associated with excessive growth of filamentous bacteria (Abusam et al., 2014). As indicated by values of sludge volume index (SVI) which were less than 150 mg/l, this strategy had completely controlled the sludge bulking despite the excessive growth of filamentous bacteria which is mentioned above. This control strategy is one of the current approaches for controlling filamentous bacteria (Pal et al., 2014). As shown below, this control strategy had helped in avoiding sludge bulking and thus having high quality final effluents. However, the main limitation of the this control strategy is the increase of the system's operational costs due to the excessive pumping of air (O_2) into the system to satisfy the needs of the large amount of biomass (MLSS).

Table 1. Operation data of Umm Al-Haiman activated sludge system during the winter season

Parameter	Design Value	Min	Max	Mean	STD
MLSS (mg/l)	3,000	6735	8490	7566	627
SVI (ml/mg)	---	103	126	111	7
DO (mg/l)	---	0.23	4.1	1.86	1.28
HRT (h)	11	29.8	42	34.9	4
OL (Kg/m3.d)	0.0917	0.1	0.4	0.2	0.1
F/M ratio	0.1	0.02	0.05	0.03	0.01

Table 2. Operation data of Umm Al-Haiman activated sludge system during the season

Parameter	Design Value	Min	Max	Mean	STD
MLSS (mg/l)	3,000	5440	8335	7379	787
SVI (ml/mg)	---	103	148	117	10
DO (mg/l)	---	0.38	2.31	1.54	0.62
HRT (h)	11	26.1	42.9	32.8	5.1
OL (Kg/m3.d)	0.0917	0.17	0.45	0.31	0.08
F/M ratio	0.1	0.03	0.07	0.04	0.01

3.3 System's Performance

It is apparent from Table 3 that the secondary effluents of the Umm-Al-Haiman plant were of high qualities during both the winter and summer seasons. This indicates that the system was working very well. The average COD removal rates were about 99%. The average nitrification (conversion of NH_4-N into NO_3-N) rate was about 99.8, while the average de-nitrification (biological conversion of NO_3-N into N_2) rate was 83%.

Table 3. Qualities of the influents and the secondary effluents of the Umm-Al-Haiman system during winter and summer seasons (Abusam et al., 2014)

Parameter	Influents				Effluents			
	Winter Season		Summer Season		Winter Season		Summer Season	
	Mean	STD	Mean	STD	Mean	STD	Mean	STD
pH (-)	7.2	0.2	7.3	0.1	7.3	0.3	7.7	0.1
EC (µS/cm)	1071	94	1387	177	934	72	1221	148
DO (mg/l)	0.9	0.3	0.7	0.3	2.5	0.7	3.7	2.4
TSS (mg/l)	162	27	155	28	0.9	0.5	1.7	2.0
VSS (mg/l)	133	27	135	26	11	5	11	4
COD (mg/l)	348	124	415	76	3	1	3	3
BOD_5 (mg/l)	173	74	141	40	17	19	8	13
VFAs (mg/l)	45	33	44	36	0	0	0	0
O&G (mg/l)	25	5.5	17	3	5	4	7	3
TN (mg/l)	30	9	29	5	0	0	1	1

NH_4-N (mg/l)	26	9	25	3	1	1	0	0
NO_2-N (mg/l)	1	1	0	0	5	3	6	3
NO_3-N (mg/l)	3	3	4	2	1	0	1	0
TP (mg/l)	2	0	2	0	0	0	0	0
H_2S (mg/l)	1.8	0.6	1.4	0.5	7.3	0.3	7.7	0.1

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CONCLUSIONS

- Using Vermicon Identification Technology (VIT), the filamentous bacteria dominating Umm-Al-Haiman activated sludge system were found to be: Haliscomenobacter, Type 021n/Thiothrix, N. limicola II, Type 1851, H. Hydrossis, Nacordioform and Microthrix.
- Despite the excessive growth of filamentous bacteria, the activated sludge system of Umm-Al-Haiman did not experienced sludge bulking incidences (SVI < 150). That is because the system was operated at a very high MLSS concentration (> 7000 mg/l).
- The main limitation of operating an activated sludge system at such a high MLSS value is the increase in the operation cost due to the need for a high aeration rate.

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