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Seasonal variations of the growth of filamentous bacteria in Kuwait's wastewater treatment plants

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ABSTRACT

If not controlled, excessive sludge bulking can lead to a complete failure of the entire wastewater treatment process. Selection of an appropriate control measure requires information about the filaments type, level of dominance and the most probable causes. The main aim of this paper is to present the filamentous bacteria identified in Kuwait's wastewater treatment plants and to compare their seasonal levels of dominance. Wastewater samples were collected weekly from Riqqa and Um-Al-Haiman activated sludge systems in Kuwait for eight months. Vermicon identification technology, a molecular method, was used for the identification and quantification of the following six filamentous bacteria: Type 1851, H. hydrossis, Nocardioform, Type 021N/Thiothrix, N. Limicola and M. parvicella. The obtained results indicated that the rapid growth of the filaments was triggered by the sharp drop in water temperature during winter (January). Further, most of the filaments dominate the systems almost all through the year. Furthermore, Microthrix was found to have the highest rate of fluctuations.

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

1. Introduction

Kuwait has no natural freshwater resources other than scarce amounts of brackish groundwater that is over-exploited. Due to the scarcity of natural freshwater resources, Kuwait depended for a long time on the expensive processes of seawater desalination to satisfy almost all of its water demands. To maintain the sustainable development and lifestyle, therefore, Kuwait has recently adopted a vigorous campaign to reuse treated municipal wastewater in mainly agricultural and greenery landscape irrigations (Al-Shammari and Shahalam, 2005).

Kuwait treats the municipal wastewaters at four main activated sludge wastewater treatment plants located in Kabd, Riqqa, Sulaibiya and Umm Al-Haiman areas. All these plants, except the Sulaibiya wastewater and reclamation plant, are encountering severe filamentous sludge bulking and foaming problems particularly during the winter season. Sludge bulking and foaming usually results in poor effluent quality, odor nuisances and sludge management problems (Metcalf and Eddy, 2003; Nielsen et al., 2009; Posavac et al., 2010; Li et al., 2010). If not properly controlled, excessive sludge bulking and foaming can lead to even a complete failure of the entire wastewater treatment process (Soltysik et al, 2011).

Filamentous microorganisms grow naturally in activated sludge systems (Madoni et al., 2000). It provides a backbone for other types of bacteria to grow (Jenkins et al., 1993). However, the imbalance between the floc-forming and filamentous microorganisms often results in sludge bulking and foaming problems. In solving these problems, identification of the type of the dominant filaments and their cause is very important steps.

Sludge bulking and foaming problems are generally complex problems that are often caused by a multitude of interrelated factors. They can be linked to the substances

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in the influent, the plant operating variables and/or the environmental conditions (Chua and Le, 1994). Therefore, the correlation of filamentous bacteria types with specific causative conditions is very useful in developing specific control measures for sludge bulking and foaming episodes frequently encountered in activated sludge systems (Switzenbaum et al., 1992).

Considerable effort has been made worldwide to identify the dominant filamentous bacteria and their probable causes. This effort, however, is almost limited to cold developed countries such as European countries, United States of America, South Africa and Japan (Mino, 1995). In particular, there is very little information about the filamentous bacteria growing in activated sludge systems of the countries that are located in tropical and desert climatic zones. Published literature about the filamentous bacteria responsible for sludge bulking and foaming of the activated sludge plants in the Gulf region is limited to the preliminary studies done by Safar and Abusam (2007) and Faheem and Khan (2009). Safar and Abusam (2007) attempted to identify the filamentous bacteria dominant in Jahra plan in Kuwait, while Faheem and Khan (2009) tried to characterize the filaments abundant in Al-Aweer activated sludge plant in Dubai.

Identification of filamentous bacteria growing in wastewater treatment systems is usually achieved through conventional microscopic identification method which is based on the morphological characteristics of the filaments. This conventional method usually requires laborious preparation of pure culture inoculums from mixed cultures and lengthy microscopic characterization procedures. In addition, these methods have been recently proven to be unreliable (Mielczarek et al., 2012). In contrast, the molecular techniques, which have been developed in the last decades, have revolutionized the procedures of filamentous bacteria identification and tremendously increased the reliability of its results (Fourest et al., 2004; Sanz and Kochling, 2007).

To obtain accurate information about the filamentous bacteria proliferating Kuwait activated sludge systems, Vermicon identification technology (VIT), which is based the molecular biology techniques, was used in this study.

2. Materials and methods

1,000 ml grab samples of sludge-mixed liquor were collected weekly from three locations along the Riqqa and Umm Al-Haiman activated sludge systems during the period from January to September 2014. The sampling locations were: the influent stream, the aeration tank and the secondary effluent stream. In-situ measurements of temperature (Temp.), electrical conductivity and hydrogen ion concentrations (pH) were immediately carried out before transporting the collected samples to the laboratories of Sulaibiya Research Plant (SRP) of Kuwait Institute for Scientific Research (KISR) for further analysis. At SRP, filamentous bacteria were identified and quantified using VIT kits purchased from Vermicon Inc., Munich, Germany. At SRP routine wastewater quality parameters were also determined according to APHA (2012) standard methods. Finally, Excel software was used to carry out statistical analysis of the obtained results. More details of the analytical methods can be found in Abusam et al. (2016).

3. Results and discussion

Figs. 1 and 2 present the abundance profile expressed in VIT scores for the six filamentous bacteria found in Riqqa aeration tank samples. As shown in these figures, the identified filaments started from almost none (scale 0) in the first half of January 2014 and rapidly became abundant (scale 4) or even excessive (scale 5) in only few weeks. It is also clear from these figures that the concentrations of the filaments were fluctuating over time. Further, Fig. 1 shows that the concentrations of Microthrix and Nocardioform had the highest rate of fluctuations over time. Both figures, however, shows that, except for the abrupt drops in the scores of Microthrix and Nocardioform during the warmest months (June-August), there were no apparent seasonal shifts in population of the filaments.

Figs. 3 and 4 show that filaments identified for the samples collected from Umm Al-Haiman aeration tank had the same rapid trend of growth and almost the same flocculation in population dynamics as that for the filaments identified in the Riqqa aeration tank. Further, they also show that Microthrix and Nocardioform were highly affected by the increase in water temperature during the months June to August. Similar seasonal shift in the population of these filaments was also observed by Wanner et al. (1998).

Figs. 1–4 also shows that filamentous bacteria started to grow in the activated sludge systems of both Riqqa and Umm-Al-Hayman at the beginning of the winter season (January). That is to say, they were triggered by the drop

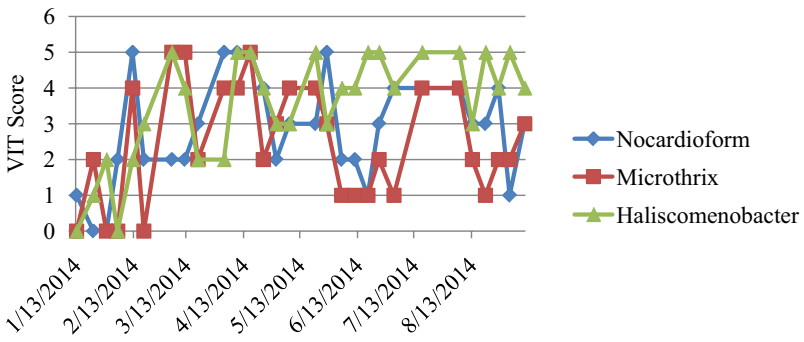

Fig. 1. Profile of Nocardiaform, Microthrix and Haliscomenbacter concentrations in Riqqa aeration tank.

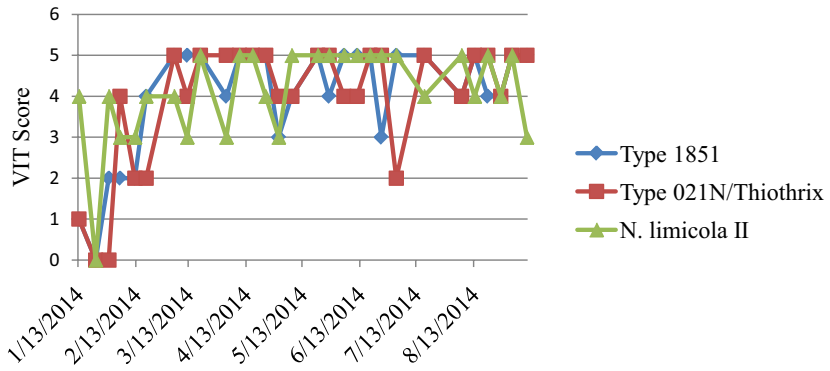

Fig. 2. Profile of Type 1851, Type 021N/Thiothrix and N. limicola concentrations in Riqqa aeration tank.

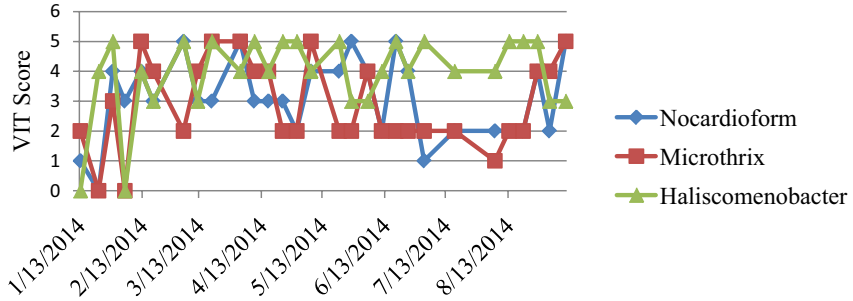

Fig. 3. Profile of Nocardioform, Microthrix and Haliscomenbacter concentrations in Umm Al-Haiman aeration tank.

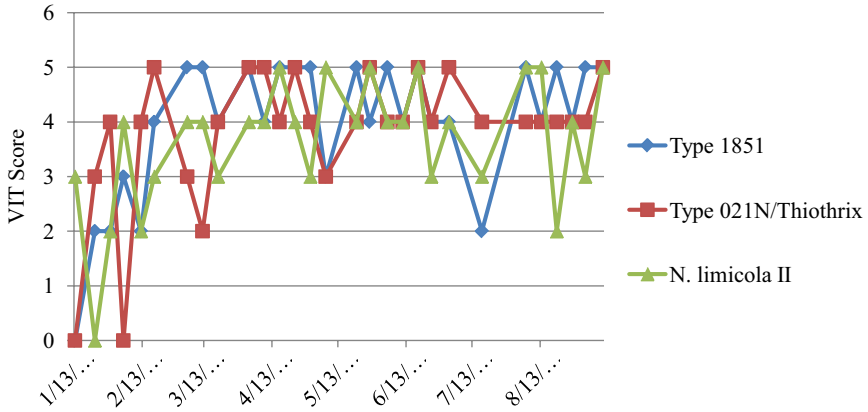

Fig. 4. Profile of Type 1851, Type 021N/Thiothrix and N. limicolla concentrations in Umm Al-Haiman aeration tank.

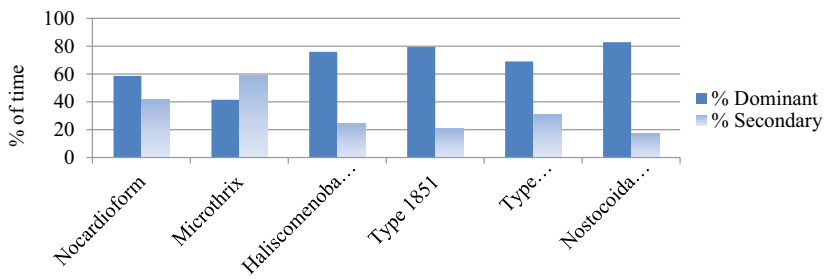

Fig. 5. Percent of time of dominant and secondary filaments in Riqqa Aeration Tank the whole sampling period.

of wastewater temperature drop to about 22°C. In contrast, filamentous bacteria were found to start grow in temperate conditions when wastewater temperature is well below 20°C (Wanner et al., 1998; Madoni et al., 2000; Graveleau et al., 2005; Cao and Lou, 2016).

Filaments are usually considered dominant when they score three or more. However, they are considered to be secondary when their score is less than three. Fig. 5 compares the percent of times when the filaments were dominant (score ≥ 3) to that when they were secondary (score < 3) in the aeration tank of Riqqa activated sludge system. It is clear from this figure that Nostocoida limicola II, Type 1851, Haliscombacter and Nacordioform were dominant for more than 70% of the time. Figs. 6 shows that the aforementioned findings were also true for the aeration tanks of Umm Al-Haiman activated sludge system. However, the only exception here is the dominance of Type 021N/Thiothrix in Umm Al-Haiman system during the entire period of sampling and analysis.

Figs. 7 and 8 compare the seasonal dominance of the filaments (score ≥ 3) as a percentage of time for Riqqa and Umm-Al-Hayman systems, respectively. It is clear that, for

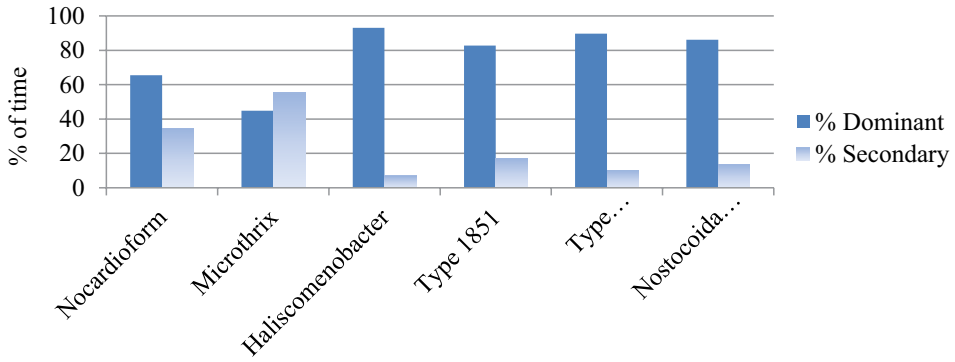

Fig. 6. Percent of time of dominant and secondary filaments in Umm Al-Haiman aeration tank.

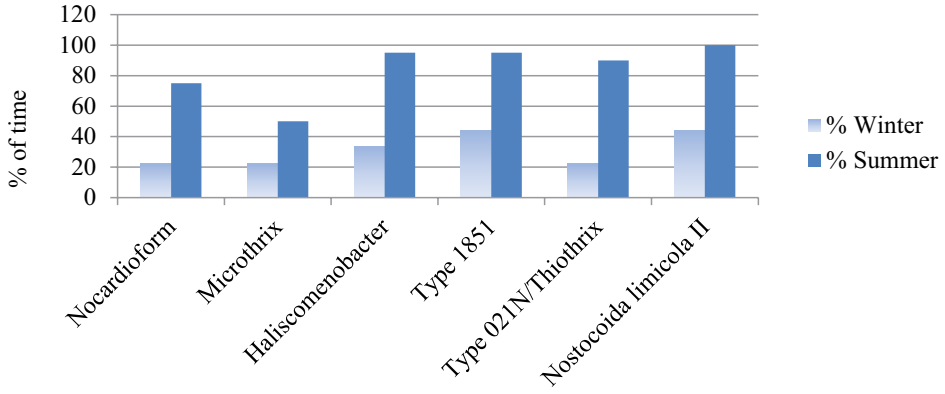

Fig. 7. Percent of time of winter and summer dominance of the filaments in Riqqa aeration tank.

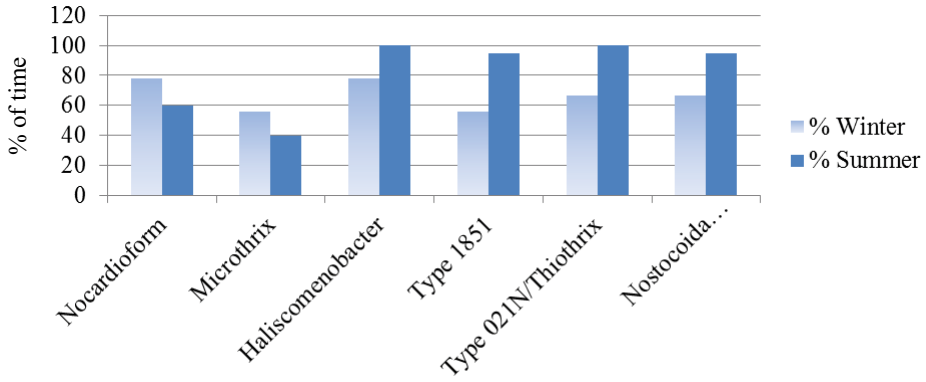

Fig. 8. Percent of time of winter and summer dominance of the filaments in Umm Al-Haiman aeration tank.

both systems, filamentous bacteria were more dominant during the summer season than during the winter season. The rank of the most dominant filaments (>70% of time) during the summer season were as follows: Nostocoida limicola II, Type 1851, Haliscombacter and Nacordioform.

Excessive growth of filamentous bacteria is usually correlated to the influent quality, the plant operating mode and/or the environmental conditions (Chua and Le, 1994). These correlations and the most probable causes are given in Abusam et al. (2017).

4. Conclusions

- The types of filamentous bacteria dominating in Riqqa and Umm Al-Haiman-activated sludge systems were identified using VIT kits (VIT, Munich, Germany).
- An analysis of the identification results obtained indicated that the following four types of filamentous bacteria were dominant (>70% of observation time) in both systems: N. limicola II, Type 1851, Haliscombacter and Nacordioform.
- Dominance of these filaments was found to be higher during the summer season than the winter season

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