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The stability of aerobic granular sludge treating municipal sludge deep dewatering filtrate in a bench scale sequencing batch reactor

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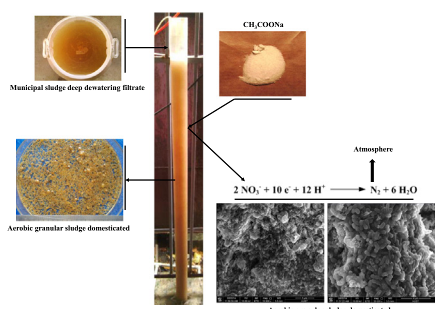
HIGHLIGHTS

- Wastewater quality of municipal sludge deep dewatering filtrate was analyzed.
- Aerobic granule treating real wastewater was successfully domesticated after 84 days.
- Effective denitrification was achieved through adding external carbon sources.

GRAPHICAL ABSTRACT



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ABSTRACT

Inoculated with mature aerobic granular sludge in a sequencing batch reactor, gradually increasing the proportion of municipal sludge deep dewatering filtrate in influent, aerobic granular sludge was domesticated after 84 days and maintained its structure during the operation. The domesticated AGS was yellowish-brown, dense and irregular spherical shape, average size was 1.49 mm, water content and specific density were 98.13% and 1.0114, the SVI and settling velocity were 40 ml/g and 46.5 m/h. After 38 days, NO_3^--N accumulated obviously in the reactor as lack of carbon sources. When adding 1–3 g solid CH_3COONa at 4.5 and 5.5 h of each cycle from the 57th day, the removal rate of TN rose to above 90% after 20 days, where effective COD removal and denitrification were realized in a single bio-reactor. Finally, the removal rates of COD, TP, TN and NH_4^+-N were higher than 95%, 88%, 96% and 99%.

1. Introduction

Municipal sludge deep dewatering filtrate (MSDDF) refers to the wastewater generated in municipal sludge deep dewatering process, where water content of the sludge cake was required to less than 60%, or 50% on special occasions. Usually, MSDDF is a kind of wastewater with high NH_4^+-N concentration. Meanwhile, the filtrate presented strongly alkaline or acidic by using different conditioners, such as CaO, H_2SO_4, $FeSO_4$ and so on (Liu et al., 2012a; Shi et al., 2013). At present, mechanical dewatering process (water content of the sludge cake is about 80%) is widely adopted by municipal wastewater treatment plant (MWTP) in China, where the filtrate is directly pumped back and treated together with municipal wastewater. However, with the improvement of sludge dewatering requirements, wastewater quantity increased significantly and the quality becomes more and more complicated. Thus, MSDDF gradually becomes a new pollution source of MWTP, which is adverse to the stability of the effluent quality. Additionally, the operational costs of MWTP will increase significantly with the increase of the pollutant load. In the case of this dilemma,

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the treatment of MSDDF separately is not a bad choice. So, research on economic and efficient treatment technology of MSDDF is accorded with development of the society.

Aerobic granular sludge (AGS) is a granular biological polymer formed by microbial self-agglomeration and proliferation in specific environment, which has many incomparable advantages towards activated sludge, such as regular shape, compact structure, high settling velocity and tolerance to toxicity (Tay et al., 2001; Moy et al., 2002; Morgenroth et al., 1997). Owing to these advantages, AGS has become a hot research topic in the field of wastewater treatment, and is considered to be one of the most prospective biological treatment technologies in the 21st century (Show et al., 2012). It was believed that good technical and economic benefits could be achieved by AGS technology for the treatment of wastewater. Extensive research work on aerobic granulation had been investigated, however, so many works were limited to easily degradable simulated wastewater (SW) (Beun et al., 1999; Peng et al., 1999; Etterer and Wilderer, 2001; Liu and Tay, 2002), the research results obtained had only theoretical guiding significance for engineering applications. Thus, the benefit of AGS should be testified by practical and complex wastewater for further development (Wang et al., 2007; Abdullah et al., 2011; Rosman et al., 2013; Othman et al., 2013; Zhu et al., 2013).

Synthesizing the above two aspects, inoculated with mature AGS in a bench scale sequencing batch reactor (SBR), and strategy based on gradually increasing the proportion of MSDDF in influent, AGS's performance and stability on treating MSDDF was studied, which committed to provide technical support for AGS's industrial application.

2. Methods

2.1. Equipment

Working volume of the cylinder sequencing batch reactor was 9 L (diameter of 8.4 cm, height of 163 cm and H/D ratio was 19.40), and exchange ratio was 60%. Fine air bubbles for aeration and mixing were supplied through a dispenser at the bottom of the reactor, and superficial gas velocity was 1.2–2 cm/s. SW and MSDDF were filled into the reactor from two head tanks separately (working volume was both 50 L). The reactor operated sequentially in 6 h per cycle which was controlled by a programmable logic controller (PLC) automatically, including 5 min of influent filling, 60 min of anaerobic period (no stirring), 289 min of aeration, 1 min of setting and 5 min of effluent withdrawal. The SBR worked at room temperature ranging from 16 °C to 37 °C.

2.2. Media

Influent was synthetic wastewater which adding a certain proportion of MSDDF in SW (Table 1), and the proportion of MSDDF (Table 2) gradually increased to 100% during the domestication. MSDDF was from a pilot sludge dewatering workshop of Tang Xun-hu MWTP in Wuhan, which characterized of low C/N ratio and high saltness. Dewatering process included sludge conditioning, mechanical dewatering and so on, and the sludge conditioner was the mixture of $FeSO_4$, NaS_2O_4 and CaO. Each stage of the influent quality of SBR was shown in Table 3, and the pH was adjusted to around 7 by NaOH solution before filling into the reactor.

Table 2
Wastewater quality of MSDDF from sludge dewatering workshop of Tang Xun-hu MWTP in Wuhan.

Indicator	Concentration	Indicator	Concentration
pH	5.87	Fe^{2+}	14.23 mg/L
COD	566.30 mg/L	Fe	18.48 mg/L
NH_4^+-N	67.40 mg/L	Conductivity	2.32 mS/cm
TN	75.56 mg/L	SS	27.00 mg/L
TP	1.89 mg/L	Zn	23.04 mg/L
NO_3^--N	0.40 mg/L	Pb	0.10 mg/L
NO_2^--N	0.22 mg/L	Cd	0.071 mg/L

2.3. Analysis methods

pH, COD, TN, NH_4^+-N, NO_2^--N, NO_3^--N, TP, MLSS, MLVSS, SVI, SS, Fe, Zn, Pb, Cd, specific gravity and conductivity were carried out according to the standard methods (APHA, 1998). Size distribution was measured by wet-sieving separation method. 300 ml sludge samples were taken out and filtered by a series of sieves with apertures of 4.0 mm, 2.0 mm, 1.43 mm, 1.0 mm, 0.6 mm and 0.3 mm. The size distribution could be obtained by recording the proportions of the granular sludge with a certain size of the total sludge's MLSS, and granulation rate was the proportion of the MLSS larger than 0.3 mm of the total sludge's MLSS. The average particle size was the diameter when proportion of filtered sludge and unfiltered sludge was both 50%, which could be calculated from the quality distribution curve. The settling velocity was measured by recording the time taken for individual granule, which was randomly taken out from the sieved granular sludge with different apertures, to fall from a certain height in a measuring cylinder. Water content was measured by the method suggested by Liu et al. (2012b). A heat extraction method was modified to extract extracellular polymeric substances (EPS) from activated sludge and granules suggested by Morgan et al. (1990). Polysaccharides (PS) content was determined using the phenol – sulfuric acid method (Gerhardt et al., 1994) with glucose as the standard. Proteins (PN) content was analyzed by a UV spectrophotometer (UV-1600(PC), MAPADA, China) following the modified Lowry method (Lowry et al., 1951). Thus, EPS was the sum of PS and PN.

Table 1
Composition of SW.

Composition of major element[a]	Concentration (mg/L)	Composition of minor element[b]	Concentration (g/L)
CH_3COONa	1172	H_3BO_3	0.05
NH_4Cl	382.1	$CoCl_2{\cdot}6H_2O$	0.05
KH_2PO_4	43.87	$CuCl_2$	0.03
$CaCl_2$	150.0	$MnSO_4$	0.05
$FeSO_4{\cdot}7H_2O$	30.0	$AlCl_3$	0.05
$MgSO_4{\cdot}7H_2O$	33.75	$ZnCl_2$	0.05
Conductivity[c]	1.01	$NiCl_2$	0.05
		$Na_2Mo_7O_{24}{\cdot}2H_2O$	0.05

[a] The corresponding COD, NH_4^+-N and TP concentration were 800 mg/L, 100 mg/L and 10 mg/L.
[b] Minor element's supplementation was 1 ml per 1 L simulated wastewater.
[c] Unit of conductivity was mS/cm.