



## Sludge concentration dynamic distribution and its impact on the performance of UNITANK

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### Abstract

UNITANK is a biological wastewater treatment process that combines the advantages of traditional activated sludge process and sequencing batch reactor, which is divided into Tank A, B and C. In this study, the sludge distribution and its impact on performance of UNITANK were carried out in Liede Wastewater Plant (WWTP) of Guangzhou, China. Results showed that there was a strong affiliation between Tank A and B of the system in sludge concentration distribution. The initial sludge concentration in Tank A could present the sludge distribution of the whole system. The sludge distribution was mainly influenced by hydraulic condition. Unsteady sludge distribution had an impact on variations of substrates in reactors, especially in decisive reactor, and this could lead to failure of system. Settler could partially remove substrates such as COD and NO<sub>3</sub>-N, but there was adventure of sludge deterioration. The rational initial sludge concentration in Tank A should be 4000–6000 mg/L MLSS.

**Key words:** UNITANK; sludge concentration; dynamic distribution; in-process study

### Introduction

UNITANK is a biological wastewater treatment process that combines the advantages of traditional activated sludge process and sequencing batch reactor (SBR). It is one rectangular reactor which is divided into three tanks, named as Tank A, B and C (Fig.1). The volumes of the three tanks are same and each tank is equipped with aeration and agitation systems. The process works according to a cyclic operation, of which Tank B works as reactor only, Tank A and C as either reactor or settler. The three tanks are connected with each other by pipe from bottom or via perforated wall. The wastewater is fed to Tank A, B and C alternatively and the cleaned water is discharged from Tank C or A. There are no primary settler and sludge return facilities.

UNITANK is commonly considered as modified SBR. However, it is quite different from SBR in configuration and hydraulic condition because both influent and effluent are continuous. In a sense, it is more similar to a normal multi-reactor process, such as A/O or UCT, but no sludge or mixed liquor returns. UNITANK is not special in configuration and its biological processes seem no difference from usual biological treatment mechanisms, such as degradation of organic carbon, transformation of nitrogen and removal of phosphorus (Barker *et al.*, 1997; Brdjanovic *et al.*, 2000; Henze *et al.*, 1987, 1995, 1999). The particular advantages of UNITANK include

construction-compact, space-saving, cost-effective, flexible operation and easy to maintenance. Alternate control can perform a cycle of the anaerobic, anoxic, aerobic and settling conditions in one tank to remove organic substrate and enhance biological nutrient removal.

Since the running scheme is flexible, it is difficult to analyze its performance. UNITANK, strictly saying, is not a steadily running system because sludge concentrations in all tanks, hydraulic condition and effluent quality are unsteady. How to estimate its characteristics is still unsure. The conclusions from lab-scale or pilot-scale experiments do not always work well in full-scale plant since they are quite different. Additionally, little attention has been given to UNITANK performance so the in-process study is necessary and useful to mend UNITANK. Since no sludge returns into the UNITANK reactors, the sludge distribution will be different in Tank A, B and C, and changes with operation time. This sludge distribution will influence the performance of UNITANK. Therefore, the sludge distribution in the tanks and its impact on UNITANK performance were investigated in this paper.

UNITANK process is used in Liede Wastewater Treatment Plant (WWTP) of Guangzhou City and the study was carried out in this plant in one year of 2004. The study was first focused on the sludge distribution in the tanks and then on the in-process performance of UNITANK.

### 1 Materials and method

#### 1.1 Full-scale UNITANK process

About 260000 m<sup>3</sup>/d of wastewater was treated by the

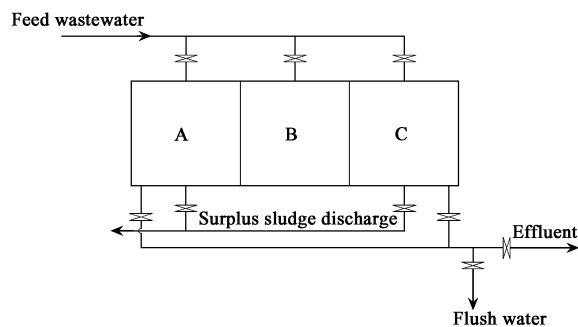


Fig. 1 Configuration of conventional UNITANK.

UNITANK process in Liede WWTP. The layout of UNITANK process is shown in Fig.2.

In this UNITANK process, there are eight independent UNITANK units, which form four groups (group 1–4), and each group includes two parallel UNITANK units (Fig.3). The inclined-tube systems are equipped in Tank A and C of each unit (Fig.1) to increase the efficiency of solid-liquor separation. Each unit has a total effective volume of about 14000 m<sup>3</sup>. The raw wastewater is lifted by pump with a mean flow rate of 1365 m<sup>3</sup>/h into each unit and the corresponding hydraulic retention time (HRT) is about 10 h.

## 1.2 Analytical methods

MLSS, MLVSS, SS, COD, BOD<sub>5</sub>, NH<sub>3</sub>-N, NO<sub>3</sub>-N and PO<sub>4</sub>-P were determined according to the standard methods (APHA, 1995). Fractions of COD, namely readily degradable-soluble COD(S<sub>S</sub>), inert-soluble COD(S<sub>I</sub>), slowly degradable-particulate COD(X<sub>S</sub>) and inert-particulate COD(X<sub>I</sub>) were determined in other ways (Henze *et al.*, 1995, 1999; Roelveland and van Loosdrecht, 2002).

MLSS was used as sludge concentration index. COD, NH<sub>3</sub>-N, NO<sub>3</sub>-N and PO<sub>4</sub>-P were chosen as substrate indices.

## 1.3 Operation conditions

### 1.3.1 Raw wastewater

The raw wastewater came from the municipal sewer and entered the UNITANK process via a grit chamber (Fig.2). Its characters are shown in Fig.4.

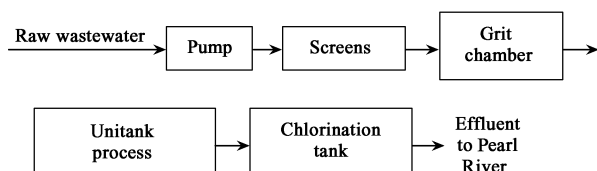


Fig. 2 Layout of wastewater treatment process in Liede WWTP.

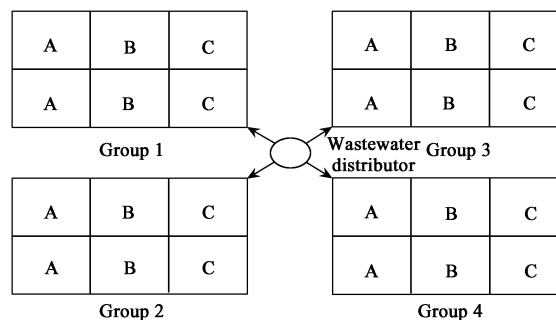


Fig. 3 Layout of UNITANK process in Liede WWTP.

With low substrate concentrations, the raw wastewater was typical in Southern China. BOD<sub>5</sub> was between 50 and 120 mg/L with average of 84 mg/L. COD was between 90 and 200 mg/L with average of 150 mg/L, of which S<sub>S</sub>, S<sub>I</sub>, X<sub>S</sub> and X<sub>I</sub> accounted for about 14%, 16%, 43% and 27%, respectively. SS was between 80 and 160 mg/L with average of 104 mg/L. NH<sub>3</sub>-N was between 10 and 40 mg/L with average of 22 mg/L. TP was between 1.7 and 3.5 mg/L with average of 2.6 mg/L, of which PO<sub>4</sub>-P accounted for about 70%–90%.

### 1.3.2 Running and sampling scheme

An operation cycle is composed of two half-cycles with same running schemes, in which the raw wastewater flows from Tank A to Tank C during the first half-cycle, and from Tank C to Tank A during the second. Therefore, only one half-cycle was researched in this study. This half-cycle scheme is shown in Table 1 and divided into four periods named as Period 1, 2, 3 and 4, respectively. In this scheme, Tank A and B worked as reactor, and Tank C as settler.

Eight sampling points were chosen in each tank and samples from these eight points were mixed as an instantaneous sample.

The sampling scheme of Tank A and B for MLSS is shown in Table 2. No sample in Tank A was taken from

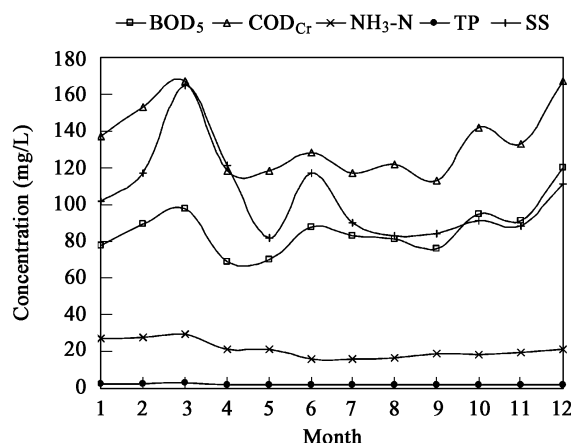


Fig. 4 Characters of raw wastewater in year 2004.

Table 1 First half-cycle scheme of UNITANK in Liede WWTP

Period	Start point	Period 1 (60 min)	Period 2 (120 min)	Period 3 (30 min)	Period 4 (30 min)
Tank A	Feed	Feed/Aerobic	Feed/Anoxic/Anaerobic	Aerobic	Settling
Tank B		Aerobic	Aerobic	Feed/Anoxic	Feed/Anaerobic
Tank C		Settling	Settling	Settling	Settling

**Table 2 Sampling scheme for MLSS in Tank A and B**

Series number	1	2	3	4	5	6	7	8	9
Tank A (min)	1	5	20	35	50	180	195	210	
Tank B (min)	1	30	60	90	120	150	180	210	240

the 60th to 180th min since inclined-tube system made the sample unrepresentative during anoxic or anaerobic period (Table 1).

Continuously changing sludge concentration would lead to variations in organic loads, oxygen concentration and efficiency of substrate removal. The effect of this change could be reflected by in-process study on variations of substrate. Tank B is decisive in whole UNITANK unit, so the variations of substrate in Tank B were studied. The substrates in effluent were also studied to analyze the efficiencies of biological treatment and settling.

The sampling scheme for in-process study is shown in Table 3. During this half-cycle, the raw wastewater quality was considered unchangeable. The samples from Tank A (not shown in Table 3), B and C represented the raw wastewater, variations of substrate and effluent, respectively.

**Table 3 Sampling scheme for water quality in Tank C and Tank B**

Series number	1	2	3	4	5	6	7
Tank C (min)	1	30	60	120	180	210	
Tank B (min)	1	30	60	120	180	210	240

### 1.3.3 Other conditions

During the whole study, the running scheme was unchanged. Temperature was between 13–27°C. The raw wastewater was weak alkali with pH value of 7.2–7.5. The controllable factors included soluble oxygen and initial sludge concentration in Tank A. During this experiment, the ratio of MLVSS and MLSS was almost stable.

## 2 Results and discussion

### 2.1 Sludge distribution

Figs.5a and 5b show the MLSS distribution in Tank A and B, respectively. S1–S7 were the test results in seven half-cycles.

Since the raw wastewater entered Tank A and its mixed

liquor flowed into Tank B, the MLSS in Tank A decreased continuously (Fig.5a). The higher the initial sludge concentration was, the more it reduced. The MLSS was 4000–13000 mg/L at the start and 3000–5000 mg/L in the end (Fig.5a). The reduction rate of MLSS was 4.8–38.1 mg/(L·min).

The change of MLSS in Tank B was quite different from that in Tank A (Fig.5b). At the start, the MLSS was higher in Tank A than in Tank B so that the MLSS accumulation was greater than the MLSS loss in Tank B. As a result, the MLSS in Tank B ascended quickly in the former 90 min. Between 90–150 min, the MLSS in Tank B began to descend because the MLSS in Tank A became lower and less MLSS entered Tank B. Between 150–180 min, the MLSS in Tank B descended more quickly since the MLSS became lower in Tank A than in Tank B. After 180 min, the MLSS in Tank B decreased much more quickly because no MLSS entered Tank B from Tank A, and the raw wastewater was fed into Tank B.

The test results from other UNITANK units showed that MLSS variations were similar to that in Figs.5a and 5b.

Theoretically, the mass balance equation of MLSS in Tank A or B is given by Leslie *et al.* (1999):

$$V \frac{dC}{dt} = FC_0 - FC + rV \quad (1)$$

Where,  $C$  is the MLSS in reactor (mg/L);  $C_0$  is the MLSS of influent, equal to SS in raw wastewater into Tank A or MLSS from Tank A into Tank B (mg/L);  $V$  is the effective volume of reactor ( $m^3$ );  $F$  is the flow rate ( $m^3/h$ );  $r$  is the reaction rate (mg/(L·h)).

The change of MLSS can be simulated according to Equation (1). Considering the raw wastewater quality stable and choosing S2 (Figs.5a and 5b) as target, the changes of the measured and simulated MLSS in Tank A and B are shown in Fig.6.

Evidently, the simulated results do not accord with the measured perfectly. From measured results and Equation (1), it can be concluded that the sludge distribution is influenced by not only HRT, initial sludge concentration,

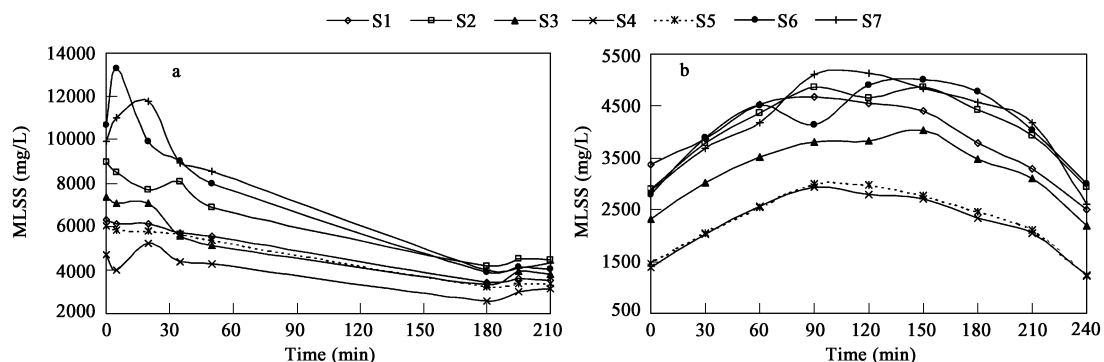


Fig. 5 MLSS change in Tank A (a) and Tank B (b) of UNITANK.

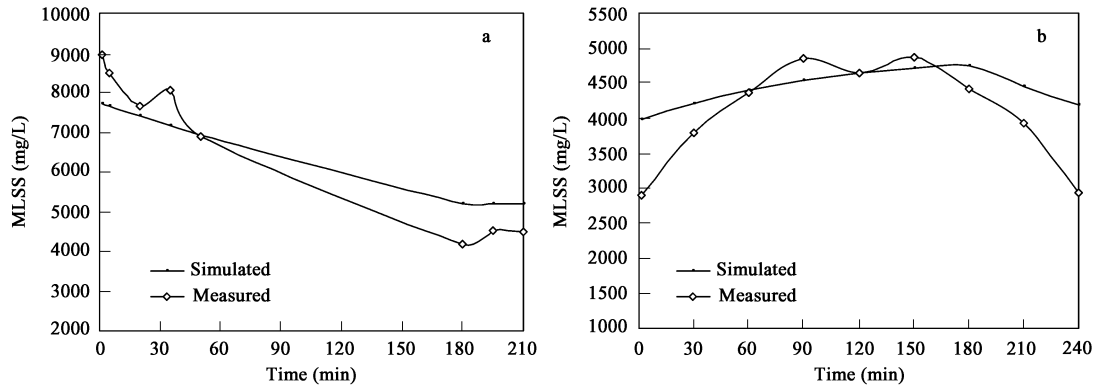


Fig. 6 Changes of measured and simulated MLSS in Tank A (a) and B (b).

sludge growth and discharge but the structure of reactor. For UNITANK, HRT plays the most remarkable role influencing the sludge distribution. It could be estimated that the sludge concentration in Tank A would be too low if the raw wastewater was fed to Tank A for a very long time, so did Tank B. Therefore, HRT and the half-cycle and feeding period should be well controlled.

## 2.2 Evaluation of SRT in UNITANK

Sludge retention time (SRT) plays an important role in BNR system (Yoshitaka, 1994; Peter, 1998; Ligerio *et al.*, 2001; Henze *et al.*, 2002; Liss *et al.*, 2002; Adeline *et al.*, 2003; Clara *et al.*, 2005). In general, it can be defined as Equation (2) (Leslie *et al.*, 1999):

$$\text{SRT(d)} = \frac{M_T}{M_d} \quad (2)$$

where,  $M_T$  is the total mass of sludge in system, and  $M_d$  is discharged mass of sludge everyday.

In most cases, intermittent sludge discharge is applied in UNITANK process. So specific calculating method of SRT for intermittent sludge discharge is introduced as:

$$\text{SRT(d)} = \frac{M_T \times t}{M_d \times 24} \quad (3)$$

Where,  $t$  is the time length of one half-cycle (h); 24 is 24 h of a day.

$M_d$  is an easily-controlled parameter via batch pumping of sludge from settling area.  $M_T$  is a troublesome parameter because MLSS varies in both reactor and settler so that total mass can not be determined easily. To calculate  $M_T$ , the relativity of MLSS between Tank A and B was investigated (Fig.7).

It is obvious that the MLSS in Tank B is corresponding to that in Tank A. In other words, the higher the initial MLSS in Tank A is, the higher the MLSS in Tank B is during the half-cycle. The initial MLSS of  $S_1$  in Tank A was about 13000 mg/L, the MLSS of  $S_1$  in Tank B increased from about 3000 mg/L of the initial to 5000 mg/L of peak value. The initial MLSS of  $S_2$  in Tank A was about 7000 mg/L, the MLSS of  $S_2$  in Tank B increased from about 2000 mg/L of the initial to 4000 mg/L of peak value. Furthermore, in Tank B, the final MLSS were basically same with the initial one. Results indicated that

this phenomenon was similar before or after this half-cycle for a considerably long time if excess sludge discharge was rational.  $M_T$  could then be evaluated according to the nearest half-cycles.  $M_T$  can be divided into three parts: (1) sludge mass in Tank A (SMST); (2) sludge mass in Tank B (SMMT) and (3) sludge mass in Tank C (SMSA).  $M_T$  can be calculated by:

$$M_T = \text{SMST} + \text{SMMT} + \text{SMSA} \quad (4)$$

According to the running scheme (Table 1) and results in Fig.5a, MLSS in Tank A was stable after 180 min until the end. So the SMST and SMMT can be calculated by the effective volume of Tank A or B and corresponding MLSS concentration at the end of this half-cycle. SMSA can be made certain as the initial MLSS in Tank C at next half-cycle.

For UNITANK, the evaluation of SRT could be based on Equations (3) and (4). In this study, the real SRT was mean value of ten nearest half-cycles' SRTs of same unit.

As discussed above, a steadily running UNITANK process keeps strong affiliation between Tank A and Tank B in sludge concentration. Given the initial MLSS in Tank A, the MLSS distributions in Tank A and B could be described. SRT could be easily-controlled if the on-line sensor and fuzzy monitor are used for manual control (Wong *et al.*, 2005; Chang *et al.*, 2003).

## 2.3 In-process study on variations of substrate

Only the initial sludge concentration in Tank A was tested since it could present the MLSS distribution basically.

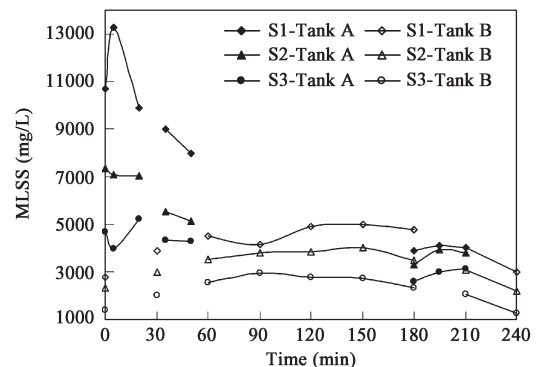


Fig. 7 MLSS relativity in UNITANK units.

Influent quality was considered stable during the tested half-cycle.

### 2.3.1 Variations of substrate in Tank B

Part precondition data are shown in Table 4. Variations of COD, NH<sub>3</sub>-N, NO<sub>3</sub>-N and PO<sub>4</sub>-P are shown in Figs.8a, 8b, 8c, and 8d, respectively.

Generally speaking, except PO<sub>4</sub>-P, the change trend of the rest was basically similar. This trend was accordant with that of MLSS in Tank B (Fig.5b). It could be explained by equation (Henze *et al.*, 1987, 1995, 1999; Leslie *et al.*, 1999):

$$r = \mu_{\max} \frac{S}{K_S + S} X \quad (5)$$

Where,  $r$  is the reaction rate (g/(L·d));  $\mu_{\max}$  is the maximum specific growth rate (d<sup>-1</sup>);  $K_S$  is the half saturation coefficient (mg/L);  $S$  is the substrate's concentration (mg/L) and  $X$  is the sludge concentration (g/L).

It should be mentioned that most NH<sub>3</sub>-N had been transformed into NO<sub>3</sub>-N and the change trend of NO<sub>3</sub>-N

was opposite to that of NH<sub>3</sub>-N. So only the change trend of NH<sub>3</sub>-N needs be analyzed.

In the first 90 min,  $S$  was very high and  $S/(K_S+S)$  changed little so that  $r$  increased with  $X$  ascended. As a result, the transformation of substrate speeded up and the  $S$  went down. Between 90–150 min,  $S$  was tended to be low and  $S/(K_S+S)$  began to decrease obviously. Although  $X$  continued to ascend,  $r$  decreased. So the transformation of substrate slowed down. Between 150–180 min,  $X$  began to descend but  $r$  and  $S$  were still low, leading to little change of  $S$ . After 180 min, the raw wastewater was fed to Tank B and  $X$  began to descend faster. On the other hand, the Tank B tended to be anoxic, which influenced  $r$  greatly. As a result, in Tank B, the entered  $S$  surpassed the transformed  $S$ , leading to the accumulation of  $S$ . For example, for NH<sub>3</sub>-N of C2 (Fig.8b),  $K_S$  is about 1 mg/L, changes of other parameters are shown in Table 5.

However, the transformation of substrate is so complex that Equation (5) could not describe it accurately. According to the observation, Equation (5) could explain the transformation of substrate rationally.

For PO<sub>4</sub>, its removal is accomplished mainly by two sequencing biological processes of anaerobic release and aerobic (anoxic) excess uptake and by process of chemical precipitation (Henze *et al.*, 1995, 1999; Rieger *et al.*, 2001). The efficiency of PO<sub>4</sub>-P removal is influenced by SRT, influent quality, COD/PO<sub>4</sub>-P, oxygen, alkalinity and NO<sub>3</sub>-N. The PO<sub>4</sub> varied between 0.2–0.5 mg/L (C2 and C3 in Fig.8d), which shows UNITANK process's potential to remove PO<sub>4</sub> efficiently. Further study should be conducted

Table 4 Partial precondition data for in-process study on Tank B

Series code	C1	C2	C3
Initial sludge concentration in Tank A (mg/L)	6959	6501	5801
SRT (d)	≈11	≈8	>20
COD of influent (mg/L)	285	223	118
NH <sub>3</sub> -N of influent (mg/L)	27.4	28.3	22.8
NO <sub>3</sub> -N of influent (mg/L)	0	0.2	0
PO <sub>4</sub> -P of influent (mg/L)	2.9	2.2	1.8

C1, C2 and C3 are the test results in several half-cycles.

Table 5 Changes of parameters in Equation (5) for NH<sub>3</sub>-N of C2

Time (min)	1	30	60	90	120	150	180	210	240
$S$	6.6	4.6	2.2	≈1.5*	0.4	≈0.2*	0.1	1.8	4.8
$X$	3.3	3.8	4.2	4.3	4.5	4.4	3.8	3.5	3.3
$S/(K_S+S)$	0.87	0.82	0.69	0.60	0.29	0.17	0.09	0.64	0.83
$r (\times \mu_{\max})$	2.86	3.12	2.88	2.58	1.29	0.73	0.35	1.35**	1.64**

\*Fitted data according to plotted curve (Fig.8b); \*\*the anaerobic (anoxic)  $\mu_{\max}$  is about 60% of the aerobic  $\mu_{\max}$

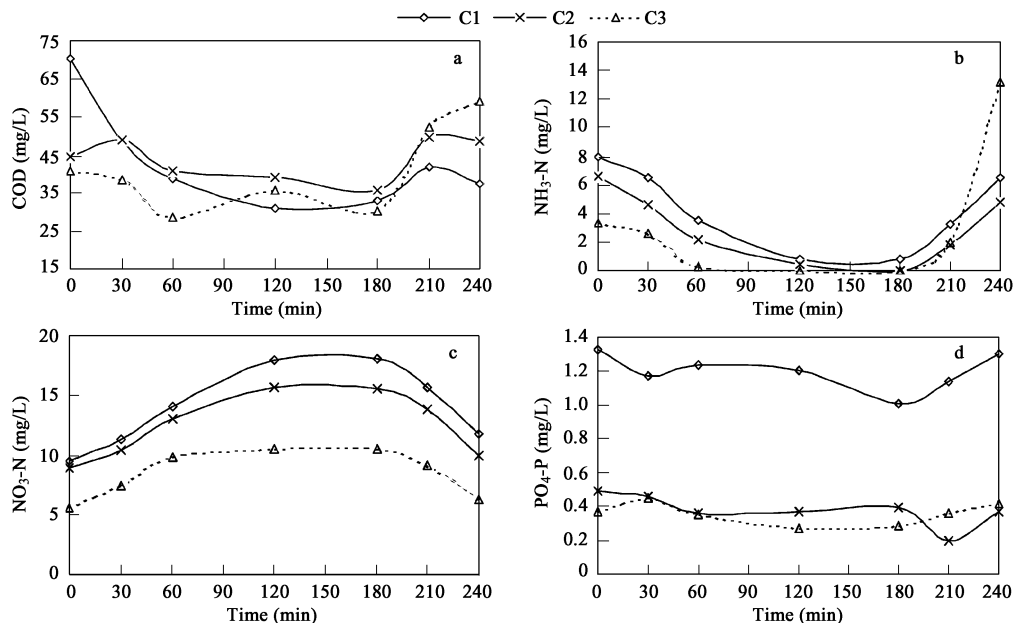


Fig. 8 Variation of COD (a), NH<sub>3</sub>-N (b), NO<sub>3</sub>-N (c) and PO<sub>4</sub>-P (d) in Tank B.

on  $\text{PO}_4$  removal.

Period 3 and 4 (Table 1) are two transitional stages during which, the raw wastewater must be fed into Tank B. As discussed above, the anoxic and anaerobic conditions are not good for substrate removal. Therefore, the decisive tank should not be anoxic or anaerobic. The impact of sludge concentration on substrates removal is not obvious but long SRT helps to remove  $\text{NH}_3\text{-N}$  (Table 4 and Fig.8b).

### 2.3.2 Variations of substrate in effluent

Table 6 shows part precondition data that were similar to that in Table 4. So the change trend of substrate in Tank B of this study should be accordant with that in Fig.5b. Between 210–240 min, both Tank A and C worked as settler so no sample was taken. Variations of COD,  $\text{NH}_3\text{-N}$ ,  $\text{NO}_3\text{-N}$  and  $\text{PO}_4\text{-P}$  are shown in Figs.9a, 9b, 9c and 9d, respectively.

**Table 6** Partial precondition data for in-process study on effluent

Series code	C1	C2	C3
Initial concentration in Tank A (mg/L)	6218	4708	5051
SRT (d)	$\approx 12$	$>20$	$\approx 7$
COD of influent (mg/L)	198	164	180
$\text{NH}_3\text{-N}$ of influent (mg/L)	26.7	17	23.6
$\text{NO}_3\text{-N}$ of influent (mg/L)	0	0	0
$\text{PO}_4\text{-P}$ of influent (mg/L)	2.1	1.7	2.9

C1, C2, and C3 are the test results in several half-cycles.

Usually, the settler is considered simple solid-liquor separator where no bio-chemical reaction happened (Henze *et al.*, 1987, 1995, 1999). Since intermittent sludge discharge is applied, there must be too much sludge accumulated in settler before it is discharged. As a result, the sludge possibly overflows into the effluent (Hasselblad *et al.*, 1998). Furthermore, the bio-chemical reactions, such as denitrification, could happen during settling (Kazmi *et al.*, 2000; Siegrist *et al.*, 1994).

Fig.10 shows the performance characteristic of settler.

The parameter of solid removal efficiency is introduced to describe the settler's characteristic. The maximum, minimum and mean values of removal efficiency were 99.89%, 99.27% and 99.68%, respectively. The results suggested that no obvious sludge overflowed and very few particulate substrates appeared in effluent. The sludge stayed in the settler for about 4 h before it was discharged. With addition and compaction of sludge, the sludge layer tended to be anoxic. The *in situ* measurements by sensor proved that the oxygen concentration in the sludge layer was approximately 0.1–0.8 mg/L and the denitrification would happened in this situation.

If the settler is considered simple solid-liquor separator, the change trend of substrate in effluent should be accordant with that in Tank B. Evidently, the change of substrate in effluent was not as sharp as that in Tank B. COD reached the lowest at about 120 min in Tank B (Fig.8a) but at about 30 min in the settler (Fig.9a). It indicated that the denitrifier consumed the biodegradable COD which was not degraded completely in Tank B, leading to COD reduction. At the same time,  $\text{NO}_3\text{-N}$  was transformed so it did not increase until 30 min (Fig.9c). Insufficient biodegradable COD made no further  $\text{NO}_3\text{-N}$  reduction since about 7.7 g COD is needed for transforming 1 g  $\text{NO}_3\text{-N}$  (Siegrist *et al.*, 1994). For example COD of C2 (Fig.9a),  $S_1$  in influent was about 26 mg/L and the initial COD in settler was 36 mg/L. So about 10 mg/L COD was available for denitrification and about 1.3 mg/L  $\text{NO}_3\text{-N}$  would be transformed. Unfortunately, the  $\text{NO}_3\text{-N}$  would not be transformed completely lacking of sufficient COD supply. After 30 min, the COD supply from Tank B reduced, so transformed  $\text{NO}_3\text{-N}$  reduced, leading to increasing  $\text{NO}_3\text{-N}$  in effluent.

Since the bio-chemical activity was going on in settler, the sludge would undertake endogenous respiration because of insufficient COD supply. As a result, the  $\text{NH}_3\text{-N}$  could be released (Henze *et al.*, 1987, 1995, 1999), which might make  $\text{NH}_3\text{-N}$  increasing in effluent. Fig.9b shows

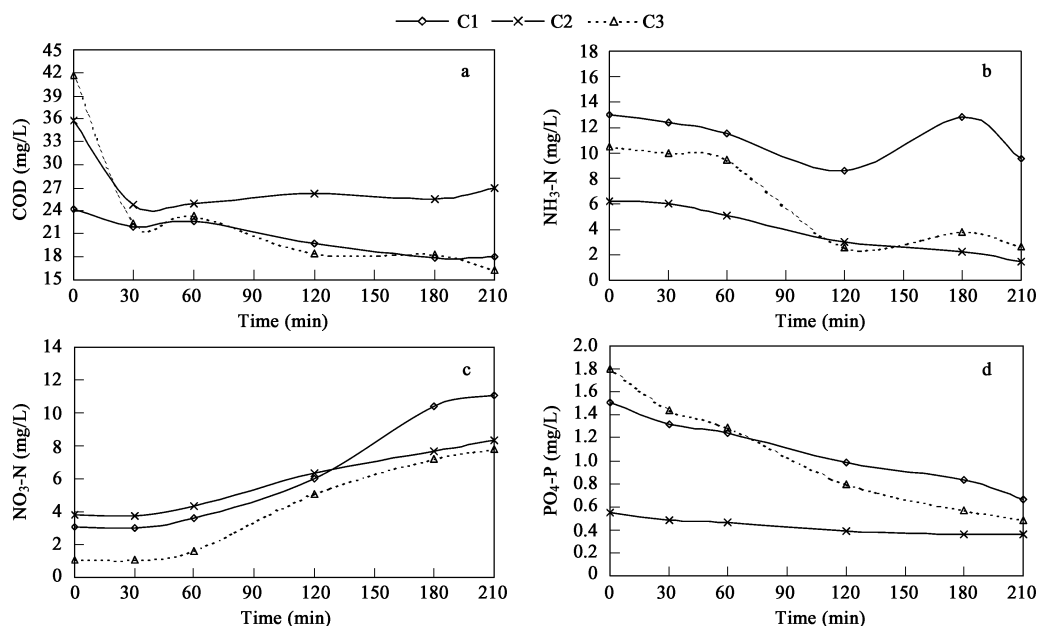


Fig. 9 Variation of COD (a),  $\text{NH}_3\text{-N}$  (b),  $\text{NO}_3\text{-N}$  (c) and  $\text{PO}_4\text{-P}$  (d) in effluent.

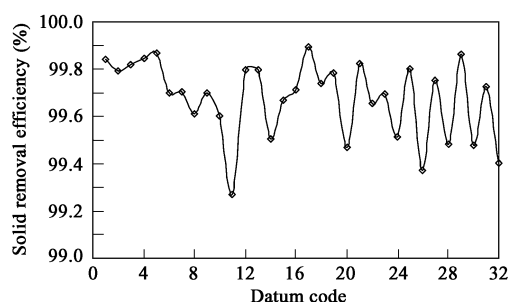


Fig. 10 Settler's characteristic of UNITANK.

that the  $\text{NH}_3\text{-N}$  changed unsteadily, which is different from that in Fig.8b. It indicated that the too high sludge concentration is bad for  $\text{NH}_3\text{-N}$  removal but long SRT and comparatively lower sludge concentration help to remove  $\text{NH}_3\text{-N}$  (Table 6 and Fig.9b).

It is still difficult to describe what happened on  $\text{PO}_4\text{-P}$ . In C3, the  $\text{PO}_4\text{-P}$  decreased from 1.8 to 0.6 mg/L and in C2,  $\text{PO}_4\text{-P}$  was between 0.4 and 0.6 mg/L (Fig.9d). But the high sludge concentration might release more  $\text{PO}_4\text{-P}$  into effluent (C1 and C2 in Fig.9d). Some explanations refer to 2.4.1.

### 3 Conclusions

The sludge distributions in Tank A and B are correspondent. Given the initial sludge concentration in Tank A, the sludge distributions in reactors could be described. The sludge distribution in reactors is mainly influenced by hydraulic condition. The HRT and lengths of half-cycle and feeding period should be well controlled.

The performance of UNITANK is influenced strongly by sludge distribution. Unsteady sludge concentration leads to the variations of substrates. Especially in decisive reactor, the conditions of sludge concentration and oxygen should be strictly controlled. Steady sludge concentration and aerobic situation are very important.

In settler, part COD and  $\text{NO}_3\text{-N}$  could be removed by denitrification, but there is adventure of sludge floating. Furthermore, the accumulated sludge in settler may release some substrate such as  $\text{NH}_3\text{-N}$ , so the sludge concentration should be rational. The initial sludge concentration in Tank A should be 4000–6000 mg/L MLSS.

Long SRT helps to remove  $\text{NH}_3\text{-N}$ . UNITANK is potential to remove  $\text{PO}_4\text{-P}$  but the mechanism should be studied further.

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