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Hydraulic and Biochemical Profiles of Primary Settling Process

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Primary sedimentation; settling velocity; biodegradability

Abstract

The major part of wastewater treatment plants in Hungary face carbon deficiency regarding influent wastewater quality. However, both the decrease of bioreactor inlet organic load and the improvement of biogas production require enhanced removal efficiency in primary settlers. According to the diverse technological aspects, in order to appropriately understand, describe and determine the preclarification process, complex and thorough investigations of both hydrodynamic and biochemical parameters are crucial.

Introduction

Conventionally, the general aim of primary sedimentation is to lower the organic load of bioreactors, in order to increase sludge age and moderate air supply. Moreover, primary sedimentation has considerable effect on biogas yield. However, in Hungary the inlet BOD_5/TKN ratio shows severe deficiency or marginal availability of readily biodegradable carbon (Tardy et *al.*, 2012). PST (primary settling tank) models based solely on hydrodynamic parameters are insufficient to meet diverse technological aims and fulfill all requirements for efficient denitrification, excess biological phosphorous removal and biogas production, therefore biotechnological reconsiderations should be taken into account. The measurement method applied for secondary sedimentation tank (Patziger, 2007, Patziger et *al.*, 2012) was successfully adopted to investigate the hydrodynamic and removal efficiency in PSTs (Kiss, 2013) in order to set, calibrate and validate the PST hydrodynamic model.

The main purpose of the paper has been to explore and combine hydrodynamic and biochemical characteristics of PSTs for cost-effective design and optimization.

Hydraulic characteristics of raw wastewater settling

The settling properties of mechanically pretreated inlet wastewater (i.e. samples taken after screenings, grit and grease removal, directly before PST) were studied for the TSS (total suspended solids) range of 80-587 mg L^{-1} at three different large wastewater treatment plants (LWWTPs, i.e. Graz Municipal WWTP: GM WWTP, North-Budapest WWTP: NBP WWTP, Budapest Central WWTP: BC WWTP). The investigations were carried out in special settling cylinders (made of plexiglass, height: 1.0 m, diameter: 194 mm) by visual observations and sampling of different suspension layers along the vertical axis. Based on the obtained settling curves (i.e. settling velocity, turbulence) the parameter settings and calibration of transport equations in the hydrodynamic PST model can be successfully carried out.

Thereafter, the settling experiments were repeated for wider TSS range (41 - 9963 mg L^{-1}) and the emerged TSS profiles were examined. The results acquired at the BC WWTP (Figure 1) and those of the NBP WWTP (Figure 2) showed remarkable differences compared to each other. At NBP WWTP the mechanically pretreated raw wastewater applied for the experiments contained also recirculated biological sludge, while at BC WWTP purely primary sludge containing raw wastewater was used according to the full-scale operation conditions, respectively. At the end of the sedimentation the lower zone was the most concentrated and the lowest insoluble content was revealed in the middle zone. The TSS concentration of the highest thin layer of the upper zone was determined by the rising sludge in the supernatant and Figure 2 shows that it correlates closely with the average mixed sludge concentration.

Biochemical settling profiles

In order to determine the biochemical characteristics, further investigations were carried out. The representative sampling was crucial, therefore a special method was developed, and samples of four suspension layers (i.e. one taken from the upper, two from the middle and one from the lower zone) of the same cylinder were analyzed for COD (chemical oxygen demand) fractions, BOD (biochemical oxygen demand), TSS and VSS (total and volatile suspended solids) concentrations at the end of the sedimentation process. Figure 3 illustrates typical vertical BOD_5/COD ratio and TSS concentration profiles in the cylinder after 10 and 25 minutes of sedimentation. These results coupled by detailed measurement of COD fractions highlighted that concentration distribution of hydrolysable particulate and colloidal COD are highly depending on settling time. Besides readily biodegradable substrate content, these fractions influence strongly the biodegradability (e.g. denitrification capacity) of biology inlet wastewater. BOD_5/COD ratio was mainly above 0.6 at TSS concentrations lower than 1 g L^{-1}, while it was markedly lower (around 0.5 in average) above

1 g TSS L^{-1}. Figure 4 shows the BOD curves registered for the five-day analysis, and the proportions of BOD_1, BOD_2, BOD_3 and BOD_4 (one-, two-, three- and four-day BOD, respectively) to BOD_5 concentrations were also determined in order to acquire informations about the biodegradation rate of the diverse layers sampled.

Conclusions

Complex investigations were carried out by a special sampling method developed and both hydrodynamic and biochemical primary settling profiles were successfully determined in order to find correlations between hydraulic parameters and biochemical characteristics. Defining the distribution of hydrolysable particulate and colloidal (i.e. slowly biodegradable) COD is key for characterizing preclarified wastewater in order to achieve cost-effective plant operation through advanced primary settling tank design and optimization.

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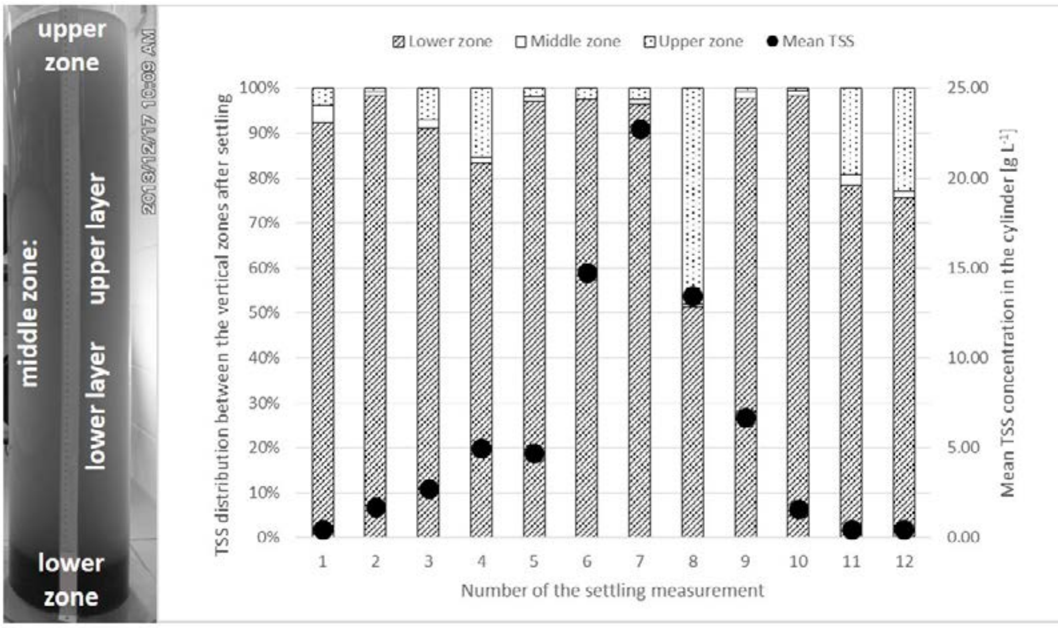

Figure 1 TSS concentration distribution between the three zones in the cylinder after settling (BC WWTP)

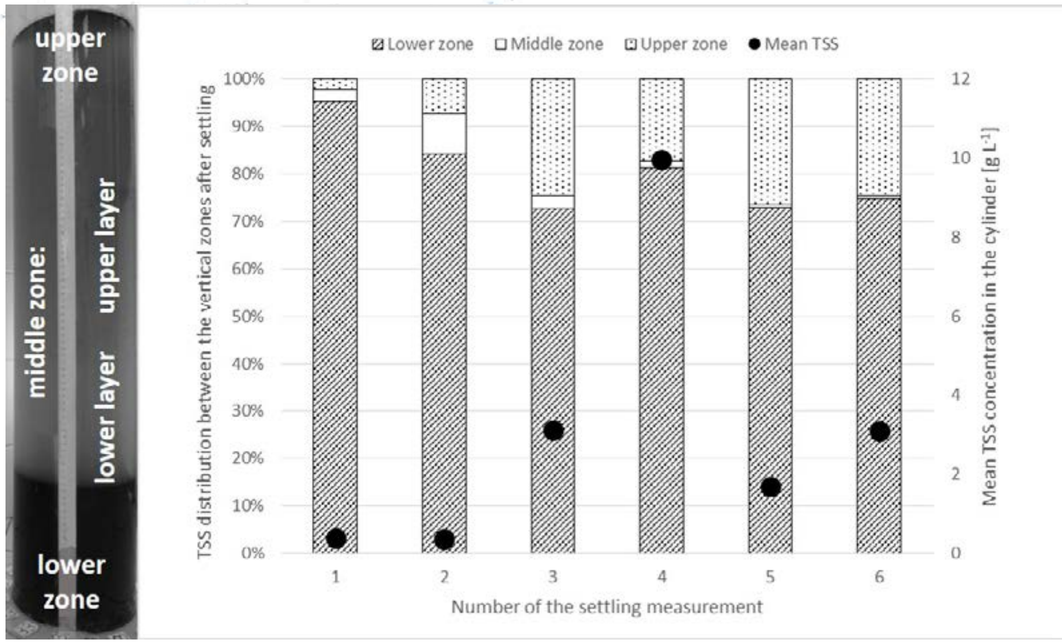

Figure 2 TSS concentration distribution between the three zones in the cylinder after settling (NBP WWTP)

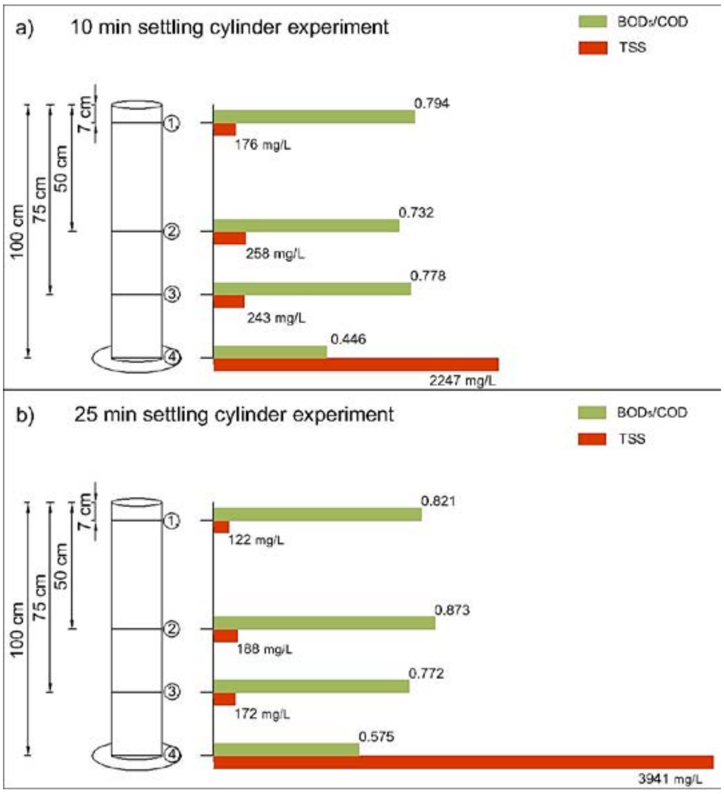

Figure 3 Typical BOD_5/COD ratio and TSS concentration profiles in the settling cylinders after a) 10 minutes and b) 25 minutes of settling of pretreated raw wastewater (i.e. taken after grit and grease removal) at BC WWTP

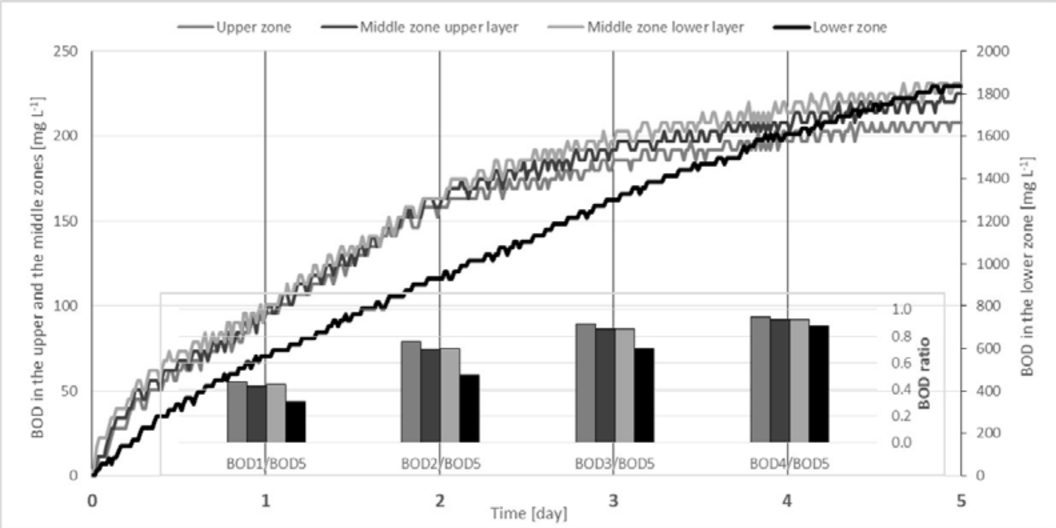

Figure 4 BOD concentration curves (containing BOD_1, BOD_2, BOD_3, and BOD_4 to BOD_5 ratios) of different layers of raw wastewater after settling at BC WWTP