Modelling and characterization of primary settlers in view of whole plant and resource recovery modelling

Giulia Bachis, Thibaud Maruéjouls, Sovanna Tik, Youri Amerlinck, Henryk Melcer, Ingmar Nopens, Paul Lessard and Peter A. Vanrolleghem

ABSTRACT

Characterization and modelling of primary settlers have been neglected pretty much to date. However, whole plant and resource recovery modelling requires primary settler model development, as current models lack detail in describing the dynamics and the diversity of the removal process for different particulate fractions. This paper focuses on the improved modelling and experimental characterization of primary settlers. First, a new modelling concept based on particle settling velocity distribution is proposed which is then applied for the development of an improved primary settler model as well as for its characterization under addition of chemicals (chemically enhanced primary treatment, CEPT). This model is compared to two existing simple primary settler models (Otterpohl and Freund; Lessard and Beck), showing to be better than the first one and statistically comparable to the second one, but with easier calibration thanks to the ease with which wastewater characteristics can be translated into model parameters. Second, the changes in the activated sludge model (ASM)-based chemical oxygen demand fractionation between inlet and outlet induced by primary settling is investigated, showing that typical wastewater fractions are modified by primary treatment. As they clearly impact the downstream processes, both model improvements demonstrate the need for more detailed primary settler models in view of whole plant modelling.

Key words | ASM fractionation, CEPT, particle settling velocity distribution, primary clarification model

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INTRODUCTION

The role of primary settling in wastewater treatment has often been neglected and very few efforts have been made for its optimization and modelling (Lessard & Beck 1988; Gernaey *et al.* 2001; Ribes *et al.* 2002). It has been neglected either because primary settling is not considered very influential for modelling purposes, or because the simple models proposed earlier were considered sufficiently robust to describe the primary settling tank (PST) behaviour (Otterpohl & Freund 1992). In many modelling case studies, the boundaries of the wastewater treatment plant (WWTP) are defined from the primary effluent onwards, i.e. using the primary effluent as model input, thereby keeping the primary settler out of the modelling scope. However, a better understanding and modelling of the processes taking place in the PST result in a more accurate description of the primary effluent characterization and sludge wastage. As such, it results in improved operation of the subsequent treatment phases, i.e. water and sludge treatment.

Improved primary settler models are also essential ingredients of whole WWTP descriptions since their impact on wastewater fractionation may be significant. In this respect, Choubert *et al.* (2013) stated that, based on combined expertise of modellers (Phillips *et al.* 2009) and sensitivity analysis (Petersen *et al.* 2002), profound effects of wastewater characterization on modelling outputs (Henze *et al.* 2000) have been shown:

- sludge production is influenced by the estimated inert particulate chemical oxygen demand (COD);
- oxygen demand is influenced by the estimated total biodegradable COD;
- anoxic denitrification rate and anaerobic phosphorus release are influenced by the estimated readily biodegradable COD;

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- effluent COD is influenced by the estimated inert soluble COD.

The importance of providing reliable wastewater characterization, enabling the link with the industry-standard activated sludge models (ASMs) (Henze *et al.* 2000), was also highlighted. Hence, the function of PSTs under the ASM framework should be reconsidered.

In this context, the simulation study of Flores-Alsina *et al.* (2014) illustrated the considerable advantages given by the enhancement of the total suspended solids (TSS) removal in a PST on final effluent quality and operational costs. This enhancement can be obtained by addition of chemicals (combined or not with lamellar settling) in the primary treatment, which may increase TSS removal efficiency up to 90% (Tchobanoglous *et al.* 2003).

Chemically enhanced primary treatment (CEPT) by addition of coagulants/flocculants, which is often operated under wet weather conditions, may also be pursued for maximizing the organic material directed to biogas production and other resource recovery options. As such it is a crucial factor in the evaluation and design of energy self-sufficient WWTPs. CEPT can be applied to achieve many different objectives in wastewater treatment facilities: (i) to increase the TSS removal performance of the PST in plants only based on primary treatment; (ii) to reduce organic loading rates thereby reducing oxygen demand on aerobic biological treatment facilities; (iii) to achieve high levels of phosphorus removal through precipitation; and lastly (iv) to permit increased hydraulic loading rates to an existing PST, thus enhancing plants that receive high wet weather flows.

The first most significant application of CEPT was in the 1960s by Canadian and US engineers to address eutrophication of the Great Lakes through chemical precipitation of phosphorus. Galil & Rebhun (1990) showed that the reduction in organic load using CEPT significantly reduced aeration tank volume in the downstream activated sludge process. More recently, in the USA, with increased emphasis on combined sewer overflow (CSO) and sanitary sewer overflow controls, agencies are seeking inexpensive and compact solutions to manage wet weather flows, other than just increasing secondary treatment hydraulics and process capacity. CEPT has been extensively evaluated because of the minimal investment in new infrastructure. Indeed, hydraulic capacities of existing primary settlers can be increased by a factor of up to three, which is often sufficient to manage peak wet weather flows. Bench-scale (Melcer *et al.* 2005, 2010) and pilot-scale (Melcer *et al.* 2012; Newman *et al.* 2013) demonstrations of wet weather treatment using CEPT have been conducted. These have led to the application of CEPT at full scale.

Existing settling models based on particle settling velocity make use of a unique settling velocity for all the particles, even though the particles are heterogeneous and the assumption of a single settling velocity is a too simplistic approach. Since particles in sewage are characterized by a wide range of settling velocities, the characterization of the particles according to the distribution of their settling velocities is a useful way to take this variety into account. Therefore, by introducing the concept of a particle settling velocity distribution (PSVD) in the model a better picture of primary settling can be achieved. Moreover, even though little literature exists on the topic, a few studies have highlighted that a link exists between particle physical properties and particle biodegradation properties (Chebbo & Bachoc 1992; Hvitved-Jacobsen *et al.* 1998; Morgenroth *et al.* 2002), emphasizing the need to focus more on how primary settler models and subsequent biological reaction models have to be complementary. Hence, models of an adequate complexity need to be developed for a more accurate description of the PST behaviour and the chemical/biological phenomena that may affect particles, their settling velocity and, as a consequence, their removal. Indeed, the efficiency of the PST directly influences the performance of the subsequent treatment units in WWTPs, since during settling organic matter and suspended solids of the influent, as well as pollutants associated with them, are removed. Not only does this determine the load to the downstream treatment steps, it is also critical in the evaluation of the benefits that the sludge treatment train will be able to accomplish (energy and nutrient recovery).

This work presents different ongoing developments related to the improved modelling and experimental characterization of primary settlers. The paper is organized in three sections: (1) a new primary settling model based on PSVD is first proposed; (2) it is briefly illustrated how PSVD can also be used to characterize and model a CEPT process; and (3) ASM fractionation around primary settlers is discussed.

PSVD FOR PRIMARY SETTLER MODEL DEVELOPMENT

A new dynamic primary settler model, based on the PSVD approach and inspired by the work of Maruéjouls *et al.* (2012) on retention tanks, was initially presented by Bachis *et al.* (2012). This model allows improved predictions in terms of effluent TSS compared to previous primary settling models. It was shown that by creating a number of particle classes that cover the settling velocity distribution, a vertical gradient of the concentration of each of the particle classes and the pollutants associated to them can be calculated.

The ViCAs (Vitesses de Chute en Assainissement) batch settling protocol developed by Chebbo & Gromaire (2009) is an excellent method to feed this type of PSVD-model, as it allows the experimental determination of the fraction of the different settling velocity classes, each characterized by a distinct settling velocity V_s. A ViCAs experiment consists of filling a settling column (H = 60 cm, Ø = 7 cm) with a homogenized suspension. Solids settled during predefined time intervals are recovered at the bottom of the column and analysed for TSS. From the time evolution of the cumulated mass of particles settled since the beginning of the experiment one can calculate the distribution of settling velocities.

The PSVD settler model was implemented in the modelling and simulation environment WEST (www.mikebydhi.com). To describe the vertical gradient of particle class concentrations the settler is divided into a number of layers and a mass balance is calculated around each layer for each of the classes. The number of particle classes has been chosen in order to have sufficient flexibility of the model and at the same time not to excessively increase the number of parameters to calibrate and equations to solve. Five particle classes with different (constant) settling velocities make up the core of the model. An earlier version of this model based on three particle classes was tested as well, but this was less accurate in the simulation of the data.

Influent TSS fractionation into particle classes

Each particle class is assigned a fraction of the influent TSS. Given the dynamics of the wastewater composition, this assignment is, however, not constant. To assign the fraction of influent TSS to the classes, advantage is taken of the observation from multiple ViCAs experiments that the ViCAs curves are located higher for low TSS concentration and lower for high TSS. This means that high TSS samples contain a larger fraction of rapidly settling particles. Therefore, the assignment is made by interpolating the PSVD curve between two boundary curves (continuous lines on Figure 1). These are the boundaries delimiting the zone where most of the observed influent PSVD curves for the particular plant under study were located (results not shown). The upper limit of this zone is the ViCAs representing low influent TSS concentrations (down to 70 mg/L), while the lower limit is given for high influent TSS concentrations (up to 300 mg/L). The assignment for a sample with a certain TSS concentration is performed as follows: for a certain settling velocity (on the x-axis), the two corresponding limiting TSS fractions are determined (y-axis) and a linear interpolation is made between them from the influent TSS value. Thus, the observed relation between PSVD and TSS concentration is used to define the fraction of each class of the influent TSS. The settling velocities characterizing each class were calculated as the geometrical mean of the settling velocity boundaries of the class, according to the following equation:

$$V_s = \sqrt{v_i \times v_{ii}}$$

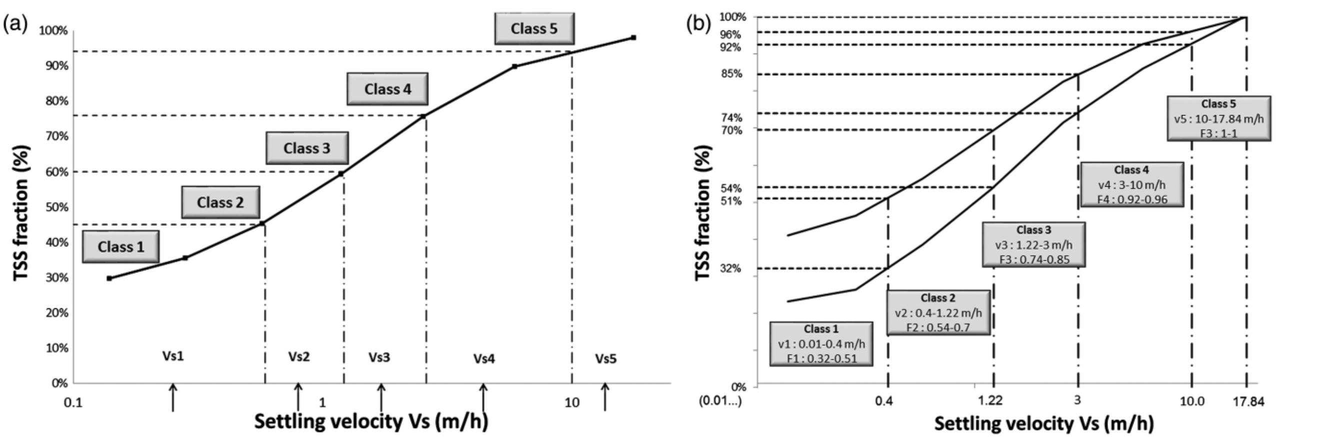

Figure 1 | Example of fractionation of a single ViCAs curve into five classes with associated settling velocities (a). The dots on the ViCAs curve are the experimental points. (b) Fractionation of the ViCAs zone into five classes with the corresponding TSS (70 and 300 mg/L, see text) and velocity boundaries. Settling velocities characterizing each class are calculated as the geometrical mean of the settling velocity boundaries of the class.

where v_i is the settling velocity defining the lower limit of the class on the y axis and v_{ii} is the settling velocity defining the upper limit of the class on the y axis.

Primary settler data

The performance of the five-classes PSVD model was evaluated through the simulation of the data from the Eastern wastewater treatment plant of Québec City (Canada). Two series of data were available: one was the TSS 24 h evolution of the influent and effluent collected at the full-scale primary settlers during a sampling campaign conducted in 2010 (2 days under dry weather flow conditions and 1 day under wet weather flow conditions); the other data set contained online TSS values measured by turbidity sensors on a pilot-scale primary settler (2013) (1 day under dry weather flow conditions).

The PSTs of the Eastern WWTP of Québec City are lamellar settlers, with a total surface of 27,000 m^2, treating a mean flow rate of 236,600 m^3/d during dry weather conditions. The 5 m^3 (2 m^2 surface) pilot-scale PST was installed in the same WWTP and it received the influent from the full-scale PSTs, treating a mean flow rate of 192 m^3/d.

Evaluation of the model performance

Model parameters were estimated by fitting the model to the data sets. The goodness-of-fit of the model was statistically evaluated through the calculation of the chi-squared criterion (weighted least squares). The assumption of independent and normally distributed measurement errors is made.

$$\chi^2(\theta) = \sum_{i=1}^{n} \left(\frac{1}{\sigma_i} (y_i - \hat{y}_i(\theta)) \right)^2$$

where y_i is the observed value; $\hat{y}_i(\theta)$ is the simulated value for the parameter set θ; σ_i is the standard measurement error of the observation y_i and n represents the number of data points to which the model was fitted. The computed χ^2 is then compared to tabulated values of the chi-squared distribution for $n-1-n_\theta$ degrees of freedom (n_θ stands for the number of estimated parameters), to decide whether the model is justified by the data or not (Gujer 2008).

Calibration results

The parameters estimated during the calibration consisted on the location of the five settling velocity class boundaries (see Figure 1, lower limit not visible). During the calibration of the model different settling velocities and, consequently, different sets of fractions were tested until a good model fit to the measured effluent TSS time series was achieved. Two of the four full-day data sets were used for the calibration, visibly resulting in a good fit for the effluent TSS concentrations (Figure 2). The calculated χ^2 for the two events is respectively 11 (Figure 2(a)) and 34 (Figure 2(b)). For 18 degrees of freedom ($n = 24$ and $n_\theta = 5$) the observed χ^2 is in 99% of the cases smaller than the critical value 34.8. This means that the model is justified by the data, especially for the first simulation. The PSVD model's V_s values and limit TSS fractions resulting from the calibration are given in Table 1.

Validation results

The remaining two full-day data sets were used to validate the model. One of the data sets was collected at the full-scale PST, the other was the data set with on-line turbidity data collected at the pilot primary settler treating the same wastewater.

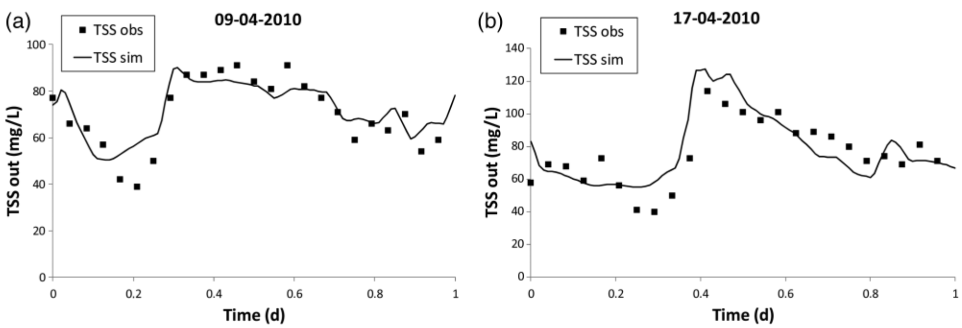

Figure 2 | Model fit for effluent TSS concentrations during the calibration phase.

Table 1 | Settling velocity (V_s) and boundary TSS fractions (F) associated with each of the five classes in the PSVD model and settling velocities used in the primary settling model from Lessard & Beck (1988)

	Class 1	Class 2	Class 3	Class 4	Class 5
Class-characterizing V_s (m/h)	0.06	0.70	1.91	5.48	13.36
F (high TSS) (%)	32	22	20	18	8
F (low TSS) (%)	51	19	15	11	4
	Dry weather		Wet weather		Return liquors
V_s Lessard & Beck (1988) (m/h)	1		2		10

Full-scale PST validation

The TSS concentrations were simulated quite well (Figure 3(a)). The χ^2-test resulted in an acceptable value (23) since in 90% of the cases the sum of squares is smaller than 26.

Pilot-scale PST validation

The pilot-scale PST was modelled in the same way as the full-scale PST, only adjusting the dimensions. The PSVD model was fed with influent TSS data obtained through a linear correlation from NTU data provided by the turbidity sensor located at the inlet of the pilot-scale PST. The PSVD model parameters estimated above were applied as such. Figure 3(b) confronts the simulated effluent TSS concentrations with the observations from the turbidity sensor located at the effluent of the pilot-scale PST. Even if it failed the χ^2-test, it can be stated that, given the difference in the configuration of the settler, a remarkably good fit is obtained.

An additional evaluation of the PSVD model was done by comparing it with earlier, simpler models and simulating the same data series. The model proposed by Otterpohl & Freund (1992) and that of Lessard & Beck (1988) were chosen for the comparison, since their equations were already implemented in WEST. Two of the four events were used: the data of April 9 for the calibration of the models and those of March 13 (turbidity measurements) for their validation. The calibration for the Otterpohl and Freund model consisted of adjusting the parameter for the correction of the removal efficiency (f_corr), while in the case of Lessard and Beck the settling velocity was the only parameter calibrated (4 m/h). It was assumed that 35% of the TSS were non-settleable.

A χ^2 value of 10 was obtained for the Otterpohl and Freund model and 11 for the Lessard and Beck model on the calibration data set (Figure 4(a)). These models thus both performed statistically comparable to the PSVD model. In the validation phase, however, the model of Otterpohl and Freund was not fitting the data at all, with too low TSS concentrations at the outlet (Figure 4(b)). The model of Lessard and Beck, on the other hand, performed still quite well, being able to reproduce the data in a way somewhat better than the PSVD model (χ^2-values of 40 compared to 64).

To make a final evaluation of the two best models, a further test was conducted by applying both models to simulate a detailed set of TSS concentrations obtained from the 10-day sampling campaign that Lessard and Beck ran at the Norwich (UK) treatment plant in 1988. Supernatant liquors from the sludge treatment were returned to the primary inlet two or three times a day. Return of supernatant sludge liquors and storm sewage to the influent stream affected the wastewater composition, producing peaks of TSS concentrations that were reproduced in the effluent as well. Therefore, Lessard and Beck distinguished in their model three different streams: (i) crude sewage, (ii) storm sewage, and (iii) crude sewage with return liquors. They

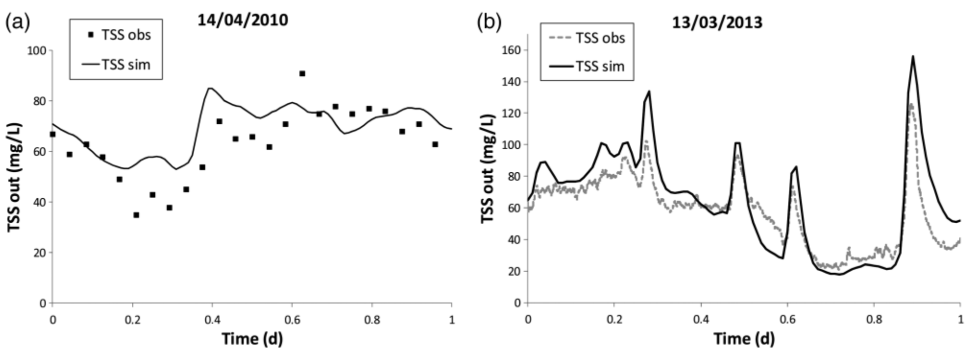

Figure 3 | Model fit for effluent TSS concentrations during the validation phase of the full-scale PST (a) and the pilot-scale PST (b) simulated with the same PSVD model and model parameters.

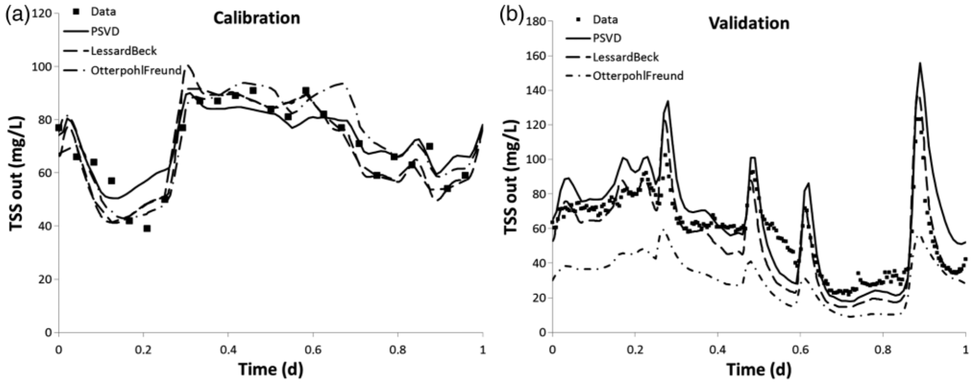

Figure 4 | PSVD, Lessard & Beck (1988), and Otterpohl & Freund (1992) model fit comparison in (a) the calibration phase and (b) the validation phase. Data of April 9 and March 13 (turbidity measurements) were used for calibration and validation respectively.

attributed different settling velocities to each of them (1, 2 and 10 m/h respectively) (Table 1). Hence, in their work the unique value of the settling velocity parameter had to be changed each time one of the three mentioned events occurred (Figure 5(a)). When applying the dynamic PSVD model (Figure 5(b)) no such time-varying parameter is needed as it just needs the observed influent TSS concentrations. Moreover, and somewhat surprisingly, the Norwich data can be simulated by using the same fractionation, hence the same characteristic settling velocities and fraction limits used for the Québec City data. The only parameter that had to be adapted was the upper TSS concentration delimiting the ViCAs zone (700 mg/L instead of 300 mg/L). This is necessary to simulate the higher TSS concentration peaks measured at the inlet of the Norwich treatment plant.

In conclusion, a new dynamic primary settler model based on particle classes has been developed, showing to be effective in predicting effluent TSS concentration and being very accurate in simulating the TSS dynamics at the outlet of a primary settler. The comparison with existing dynamic settling models showed that the PSVD model is better than the model proposed by Otterpohl & Freund (1992) and statistically comparable to the model proposed by Lessard & Beck (1988). The PSVD model, however, calibrated on the full-scale data set provides very good prediction power for different sewages and weather conditions, as it allows use of the same calibration results.

PSVD FOR CEPT MODELLING

The effect of CEPT on the PSVD can also be characterized by means of ViCAs tests. To illustrate this, samples taken at the inlet of the pilot-scale PST after addition of coagulants/flocculants were subjected to the ViCAs test. Figure 6(a) illustrates that the inlet PSVD after chemical addition is shifted towards higher settling velocities and outside the typical reference zone of the primary settler influent without CEPT (Maruéjouls *et al.* 2011). The effect is more pronounced for slow settling particles, which is the logical consequence of the aggregation of the particles produced

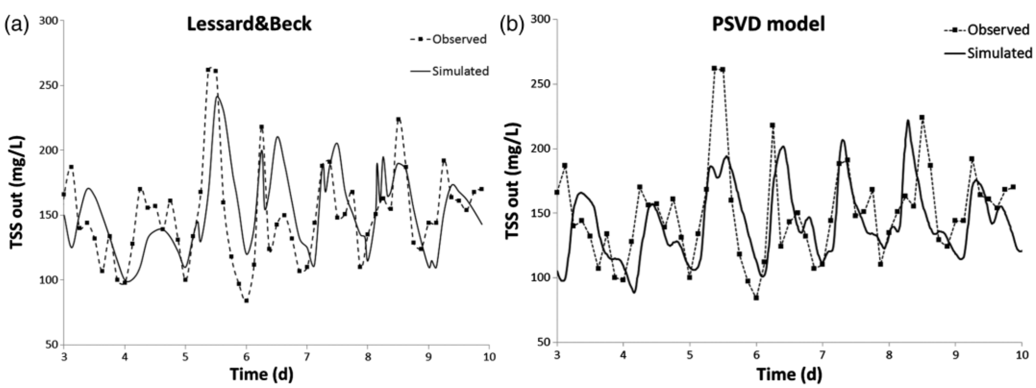

Figure 5 | Model fit for effluent TSS concentrations in (a) the Lessard and Beck model and (b) the PSVD model.

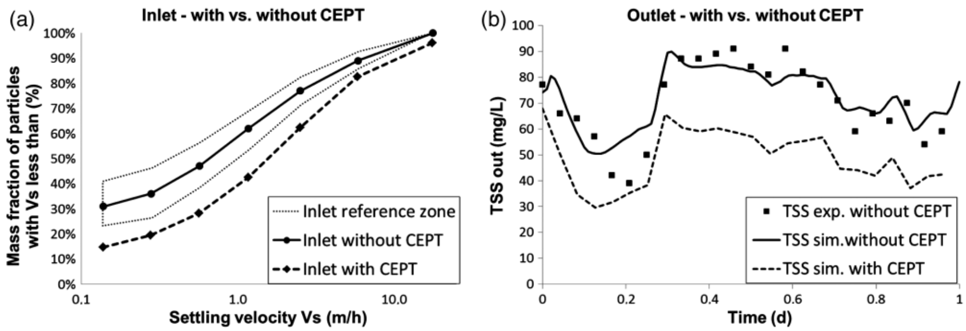

Figure 6 | (a) Comparison of PSVD observed at the PST inlet during operation without CEPT and with CEPT. The reference zone illustrates typical PSVD observed at the PST inlet in Québec City, Canada, without CEPT (Maruéjouls *et al.* 2011). (b) PSVD model fit for effluent TSS concentrations without CEPT and simulation with CEPT.

by the addition of chemicals, making them grow in size and increase in settling velocity.

This experimental approach may thus be very well suited to model the effect of the addition of coagulation/flocculation chemicals on primary settling. Indeed, the curve with the appropriate PSVD (with or without chemical addition) may be used directly as input to the model, fractionating the TSS in the appropriate better settling fractions. Applying the model using the PSVD with chemical addition results in a significantly better TSS removal, as illustrated with the simulation of CEPT applied to the same influent situation (Figure 6(b)). Further confirmations are under study.

ASM FRACTIONATION IN PRIMARY TREATMENT

Primary treatment removes particles from the wastewater and as such changes its composition. These changes can be expressed in terms of several calculated ratios of traditional pollutant characteristics (Table 2). Fractionation of wastewater is thus affected by primary settling, thus impacting the subsequent treatment processes (Kristensen *et al.* 1992, Pasztor *et al.* 2009).

For the correct model-based evaluation of a WWTP in which ASMs are used to describe the subsequent bioreactor models, a proper prediction of the primary effluent into the ASM input fractions is required. However, the effect of the PST on these fractions is frequently overlooked or oversimplified (the fractions in the PST are assumed to remain constant under all conditions).

The ratios calculated for the Québec City samples and shown in Table 2 are quite comparable to the ratios given as reference (Rieger *et al.* 2012). Even the trends of the changes between influent and effluent are comparable, i.e. where the ratio increases for the effluent for the reference data, it also increases for the Québec City data and vice versa.

Table 2 | Differences in typical ratios of traditional wastewater characteristics of raw influent and primary effluent of municipal wastewater treatment (redrafted after Rieger *et al.* 2012) and comparison with Québec City ratios

		Ratio	Unit	*n*[a]	mean	Std%[b]		*n*	Mean	Std%
Reference	Raw influent	Ntot/CODtot	g N/g COD	12	**0.095**	17%	Québec City	8	**0.089**	1%
		N-NHx/TKN[c]	g N/g N	13	**0.684**	8%		8	**0.482**	13%
		CODtot/BOD5	g COD/g BOD	12	**2.060**	11%		8	**2.062**	32%
		TSS/CODtot	g TSS/g COD	12	**0.503**	18%		11	**0.573**	14%
		VSS/TSS	g SS/g SS	12	**0.740**	20%		6	**0.846**	5%
		BOD5/BOD∞	g BOD/g BOD	7	**0.655**	7%		8	**0.859**	6%
	Primary effluent	Ntot/CODtot	g N/g COD	9	**0.134**	35%		8	**0.123**	2%
		N-NHx/TKN	g N/g N	11	**0.755**	4%		8	**0.509**	9%
		CODtot/BOD5	g COD/g BOD	9	**1.874**	31%		8	**1.931**	20%
		TSS/CODtot	g TSS/g COD	9	**0.380**	21%		11	**0.426**	9%
		VSS/TSS	g SS/g SS	9	**0.794**	7%		6	**0.872**	2%
		BOD5/BOD∞	g BOD/gBOD	6	**0.644**	10%		8	**0.894**	4%

[a]Number of answers.
[b]Standard deviation in %.
[c]TKN: total Kjeldahl nitrogen.

It can be observed that the ratio of volatile suspended solids (VSS) to TSS is quite stable between inlet and outlet, meaning that there is no predominant settling of the organic or inorganic fraction. Since, by definition, TSS is the sum of the volatile and inert suspended solids (VSS + iSS), the stability of the VSS/TSS ratio assures the stability of the inert suspended solids fraction between inlet and outlet at the Québec City WWTP. Therefore the PSVD model does not need to include the iSS fraction explicitly to predict the dynamics of the particulates in the primary settler. An extension of the model with such fraction would be straightforward though.

Note that the models described above only focus on TSS removal prediction and do not consider variations in other fractions in the primary settler. Therefore, to better describe the subsequent biological treatment by providing a good fractionation, primary settling was also studied from an ASM point of view, taking inlet and outlet samples from primary settlers at three different WWTPs (Eindhoven, Roeselare and Québec City). Samples coming from Eindhoven and Roeselare WWTPs, on the one hand, and those coming from the Québec City plant, on the other hand, were collected and analysed by different research groups. The samples were analysed in terms of COD fractions into four components: the readily biodegradable COD, S_B; the slowly biodegradable COD, XC_B; the inert soluble COD, S_U; the inert particulate COD, $X_{U,Inf}$ (notation from Corominas *et al.* 2010). For the Québec City samples, these fractions were determined by combining a respirometric protocol together with total (COD) and soluble (sCOD) COD analysis and ultimate biochemical oxygen demand (UBOD) measurements (Petersen *et al.* 2003). S_B directly resulted from the respirometric test on the wastewater sample, while XC_B, S_U and $X_{U,Inf}$ were calculated as follows: $XC_B = UBOD - S_B$; $S_U = sCOD - S_B$; $X_{U,Inf} = COD - sCOD - XC_B$. For the WWTPs of Eindhoven and Roeselare both a respirometric evaluation (Petersen *et al.* 2003) and the STOWA method (Roeleveld & van Loosdrecht 2002) were applied.

The two protocols resulted in different COD fractions for the same wastewater sample, as already pointed out in previous studies (Gillot & Choubert (2010), Fall *et al.* (2011)). Nevertheless, and more importantly, both fractionation approaches showed that primary treatment has a significant impact on the ASM1 fractions observed at inlet and outlet of the primary settler. Primary treatment yielded a significant variation of the particulates ratio ($XC_B/X_{U,Inf}$) (decreasing on average from 1.9 to 1.2 for the Eindhoven, from 1.1 to 0.5 for the Roeselare and from 1.6 to 1.9 for the Québec City experiments), while the solubles ratio (S_U/S_B) was not affected by the primary settler for the Eindhoven and Roeselare samples, but it seemed to increase (from 0.9 to 1.5) for the Québec City samples (Figure 7). These results require further work to better understand what happens to the fractions inside the PST. Chemical and biochemical reactions (e.g. hydrolysis) may partially explain these changes in the ratios, but some hydrodynamic issues (e.g. dead zones) are also supposed to occur, possibly inducing unexpected variations.

For the Québec City WWTP a more detailed analysis was conducted (Table 3). The wastewater samples could be classified into two types: a low loaded one (sampled at nighttime) and a highly loaded one (sampled at daytime). According to this classification, by comparing inlet

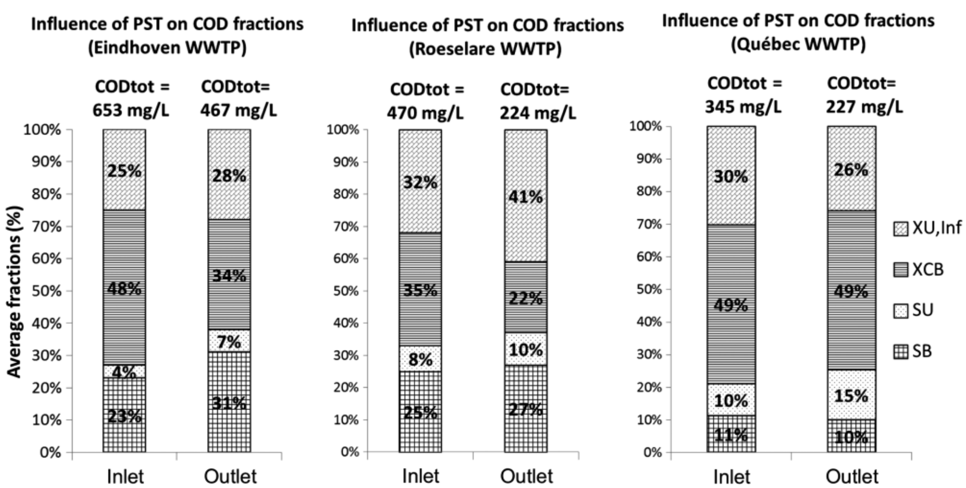

Figure 7 | Evolution of COD fractions before and after a PST at three WWTPs: Eindhoven (The Netherlands), Roeselare (Belgium) (both by the STOWA protocol) and Québec City (respirometric protocol).

Table 3 | Particulate and soluble ratios compared for different samples: samples collected during daytime without addition of chemicals (Ø daytime); samples collected at nighttime without addition of chemicals (Ø nighttime); and samples collected both at day time and nighttime under the addition of chemicals (CEPT)

	Date	$XC_B/X_{U,Inf}$ IN	$XC_B/X_{U,Inf}$ OUT	S_U/S_B IN	S_U/S_B OUT
Ø daytime	14 May	0.96	0.86	0.03	0.10
	12 Nov	1.39	1.19	0.88	0.69
	03 Dec	7.16	1.96	2.43	2.37
	10 Dec	1.73	2.86	1.41	5.72
Ø nighttime	16 Apr	1.55	34.80	3.89	1.87
	07 May	1.01	2.79	1.36	6.00
	13 Aug	0.72	2.55	0.02	1.41
CEPT	21 May	6.27	0.85	2.92	1.06
	16 Jul	2.60	7.87	0.27	1.77
	23 Jul	1.12	1.99	1.05	3.44
	30 Jul	1.47	1.22	0.46	0.85
	06 Aug	1.26	1.14	0.79	1.69
	10 Sep	1.45	1.97	0.51	1.67
	17 Dec	1.54	2.49	0.15	4.41

and outlet samples different trends in the aforementioned ratios were noticed: the particulate ratio ($XC_B/X_{U,Inf}$) systematically decreases for daytime samples, but increases for wastewaters collected at nighttime. Moreover, some work was also conducted on samples collected after addition of chemicals. It was found that both the particulate and the soluble ratios tend to increase, i.e. the primary effluent contains relatively more biodegradable material than the influent.

These first results, although requiring further investigation, show that primary treatment has a significant impact on the ASM1 fractions. Therefore, the influence of the PST on the wastewater characterization cannot be neglected and a proper COD fractionation into model variables can significantly improve simulation results of systems including PSTs. For instance, by applying the PSVD model concept to the mass balances of the ASM fractions in the primary settler model, i.e. having five classes for each of the ASM fractions, it will be possible to make them settle at different velocities, allowing the observed increase in ratios to be predicted properly. This will result in an appropriate fractionation at the primary settler effluent.

CONCLUSIONS

All studies presented in this contribution focus on primary settlers. The authors believe that PSTs need to be properly modelled and characterized in view of reliable whole plant and resource recovery modelling. A new modelling approach, based on particle settling velocity distributions (PSVD), is proposed, and was shown to successfully predict TSS effluent concentrations on the basis of influent TSS time series and a number of ViCAs characterization experiments. Simulation results under calibration and validation of the model were presented. It is illustrated that this approach can also be used to characterize primary influent under addition of chemicals, representing a potentially useful tool for the modelling of PSTs under CEPT. Finally, wastewater fractionation results obtained for the influent and the effluent of PSTs have shown, for the first time, that the primary settler produces a significant change in the wastewater composition ratios and, as a consequence, in the ASM fractionation of the wastewater. Hence, it can be anticipated that a more detailed primary settler model with explicit consideration of ASM fractions may be needed to properly feed the subsequent bioreactor models of a whole plant and resource recovery model.

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