Grit particle characterization: Study of the settleability

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ABSTRACT

Grit chambers are installed at the headworks of a water resource recovery facility (WRRF) to reduce the impact of grit particles to the equipment and processes downstream. This settling process should thus be designed and operated in an efficient way. Despite the importance of knowing settling characteristics for design and operation of grit chambers, previous grit definitions have been based only on particle size characteristics, and not on settling velocities. Thus, this study presents an evaluation of the performance of two promising settling velocity characterization methods, ViCAs and elutriation, to characterize wastewater particles in view of the design and the optimization of the efficiency of the grit removal unit.

KEYWORDS

Characterization methods, elutriation, particle settling velocity distribution, settling tests, ViCAs

INTRODUCTION

Grit accumulation and grit-induced damage can be reduced not only by installing a grit chamber at the headworks of water resource recovery facilities (WRRFs) but also by designing and operating this settling process in a highly efficient way (WEF, 2010). Thus, grit particles should be well-characterized and representatively sampled, but, surprisingly, no standard peer-reviewed characterization and sample protocols exist yet (Reddy and Pagilla, 2009; WEF, 2016).

Despite the importance of the settling characteristics for sedimentation based on gravitational forces (Camp, 1936) and with a settling velocity of removal of 70 m/h for typical grit chambers design (Tchobanoglous, et al. 2014), previous grit definitions have focused on particle size characteristics considering only the inorganic fraction and assuming that particles are homogeneous spheres with a specific gravity of 2.65 (U.S. EPA, 2004). Then, according to this definition, the settling velocity of the grit particles is generally estimated through Stokes' Law:

$$v_s = \frac{g \times (\rho_p - \rho_w) \times d_p^2}{18 \times \mu} \tag{1}$$

where, v_s is the settling velocity (m/s), g the acceleration due to gravity (m/s^2), ρ_p the particles specific gravity (kg/m^3), ρ_w the specific gravity of water (kg/m^3), d_p the diameter of the particles (m), and μ the water viscosity (kg/(m·s)).

However, in reality, grit particles are heterogeneous particles that do not have a single representative value of specific gravity and should not be considered inorganic homogeneous spheres (Herrick et al., 2015; Plana et al., 2017).

An increasing number of studies question whether the conventional definition of grit is a proper approximation (Barter and Sherony, 2011). Thus, the Water Environment Federation's Grit Task Force has suggested a definition that considers the settling velocity of the girt particle as it exists in the raw wastewater (WEF, 2016). In addition, it is now recognized that the organic fraction of the grit particles is significant, and the specific gravity is variable and lies between 1.1 and 2.65 (WEF, 2016; Plana et al., 2017).

OBJECTIVE

Given the importance of the settling velocity for grit particle characterization and for grit chamber design, and the lack of standard and accepted methods for this characterization, the objective of this study is to evaluate the performance of different settling velocity characterization methods in use today to characterize wastewater particles.

METHODOLOGY

The inlet of a grit chamber was sampled and characterized on several occasions. For sampling, a multipoint sampler was used. Considered as a representative method to sample the inlet channel (WEF, 2016), four sampling points were installed and homogenized covering the cross section of the channel and with the opening placed against the flow as presented in Figure 1.

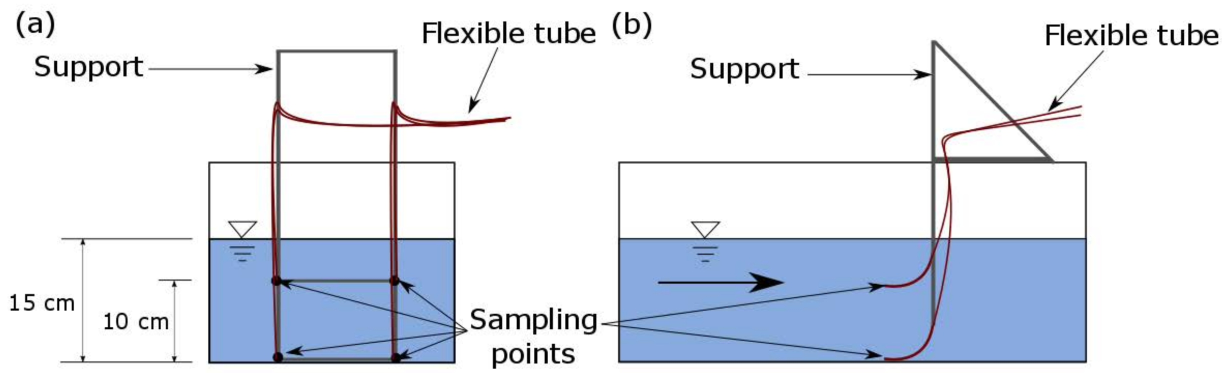

Figure 1. Schema of the multipoint sampler used. (a) Cross section of the channel; (b) Profile of the channel.

From the five samples collected at the inlet at different solids concentrations, the particle settling velocity distribution (PSVD) was assessed with two methods currently in use for raw wastewater samples (e.g. at the inlet of WRRFs and in sewer systems): the experimental protocol ViCAs (a French acronym for settling velocity in wastewater) developed by Chebbo and Gromaire (2009) and the elutriation method (Krishnappan et al., 2004). Both methods allow to experimentally fractionate the total suspended solids (TSS) in different settling velocity classes, where each fraction is characterized by a settling velocity v_s.

The ViCAs batch settling protocol consists in filling a settling column (H = 70 cm, Ø = 7 cm) with a homogenized sample (Figure 2.a). Settling solids are recovered at the bottom of the column at different time intervals (t = 1, 3, 5, 10, 20, 35 and 60 min) and analysed for TSS. Then, with the cumulated mass of settled particles over the experiment time, it is possible to estimate the distribution of the settling velocities. In this study, according to the time intervals, this distribution corresponds to velocities of 35, 12, 7, 3.5, 2, 1, and 0.5 m/h respectively.

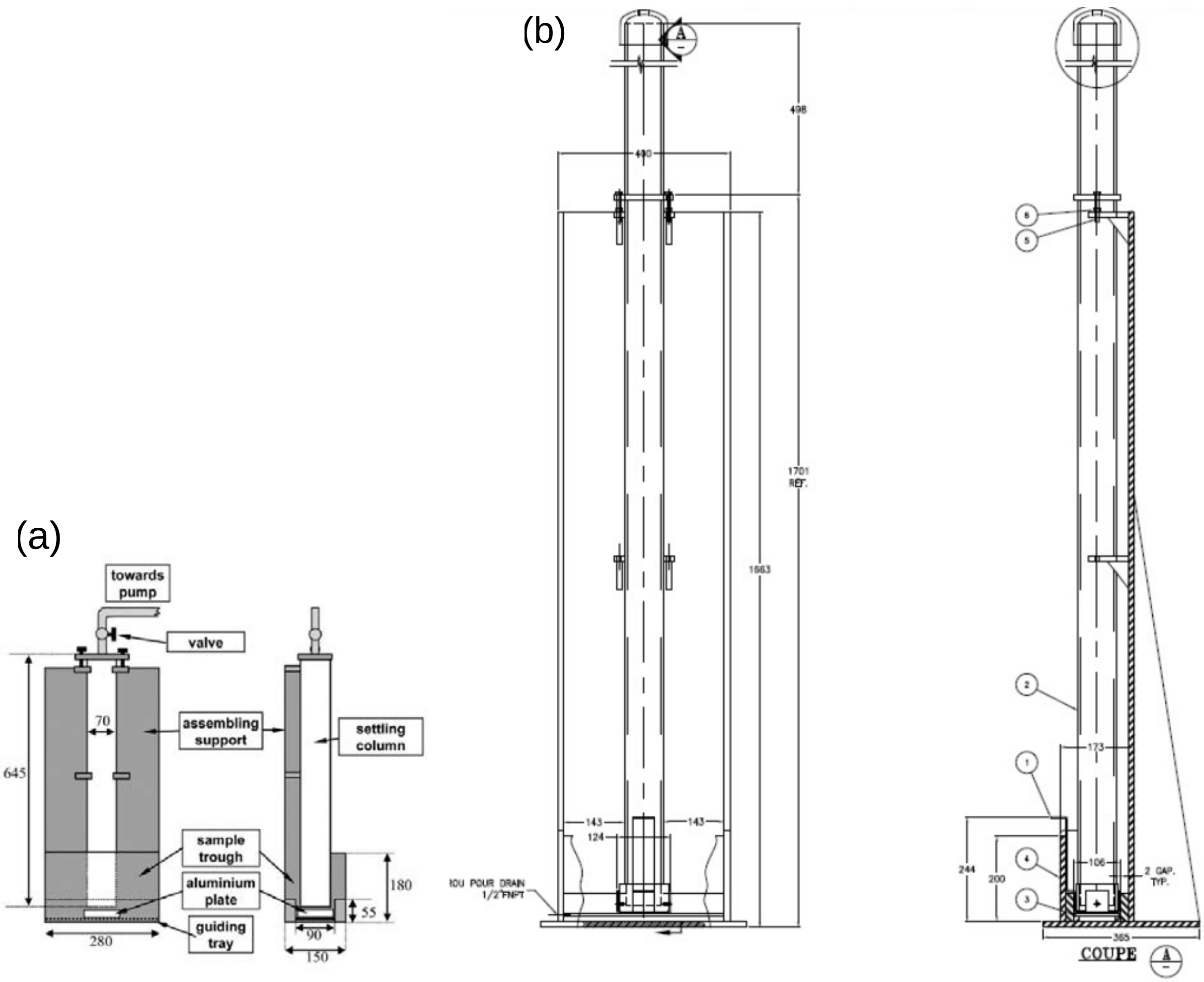

Figure 2. Schema of the ViCAs experimental setup. (a) original 70 cm ViCAs column (Chebbo and Grommaire, 2009) (b) Adapted 2m-ViCAs column.

The elutriation system is built as a series of columns with increasing diameters (Ø = 3.4, 4.3, 7, 10.5, 14.3 and 19.7 cm) (Figure 3). The sample enters close to the bottom of each column going upward, and leaves the column close to the top (Krishnappan et al., 2004). Thus, the upflow velocity decreases as the water moves downstream along the set of the columns, allowing the particles with a settling velocity higher than the upflow velocity to remain at the bottom of the column. Then, the particles settled in each column are collected separately and quantified as

TSS. In this study, the elutriation method was operated at 1.6 L/min with six columns with upflow velocities of 104, 65, 24, 11, 6, and 3 m/h.

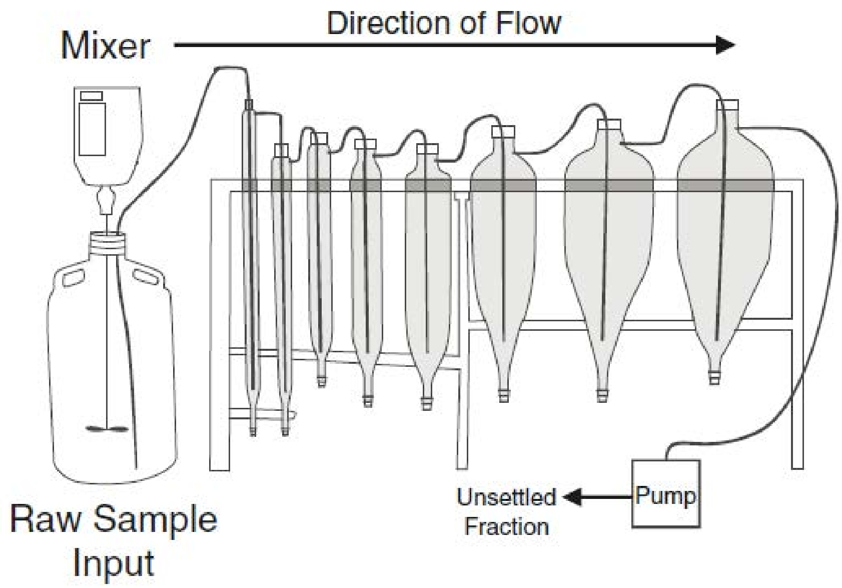

Figure 3. Schema of the elutriation system built (Krishnappan et al., 2012).

RESULTS

Both ViCAs and elutriation methods allow evaluating the PSVD for wastewater samples. However, while the ViCAs settling column has been applied to study the PSVD of wastewater particles in sewer systems and in WRRFs, the 70cm-ViCAs column does not allow to study settling velocities above 40 m/h. Thus, the standard design was modified and upgraded to a 2m-column with a Ø = 8 cm to better study fast settling particles such as grit particles (Figure 2.b). The time intervals used to collect the settled solids were kept the same as for the 70cm-column test leading to the corresponding distribution of settling velocities of 120, 40, 24, 12, 6, 3.5, and 2 m/h, respectively.

Among the five different tests, with samples with TSS concentrations between 60 and 350 mg/L, Figure 4 shows an example of the results of the sample with a concentration of 250 mg/L from both the 70cm and 2m ViCAs columns; and together with the elutriation results. Logically, differences were observed between both ViCAs columns: the range of settling velocities studied is different and the PSVDs do not coincide. In this study, the 70cm-ViCAs column only allows to study settling velocities up to 40 m/h, whereas the 2m-ViCAs column goes up to 120 m/h. Thus, the 2m-ViCAs column allows to study the settling velocities of interest for grit particles (considering the typical design overflow rate of 70 m/h as depicted in red on Figure 4).

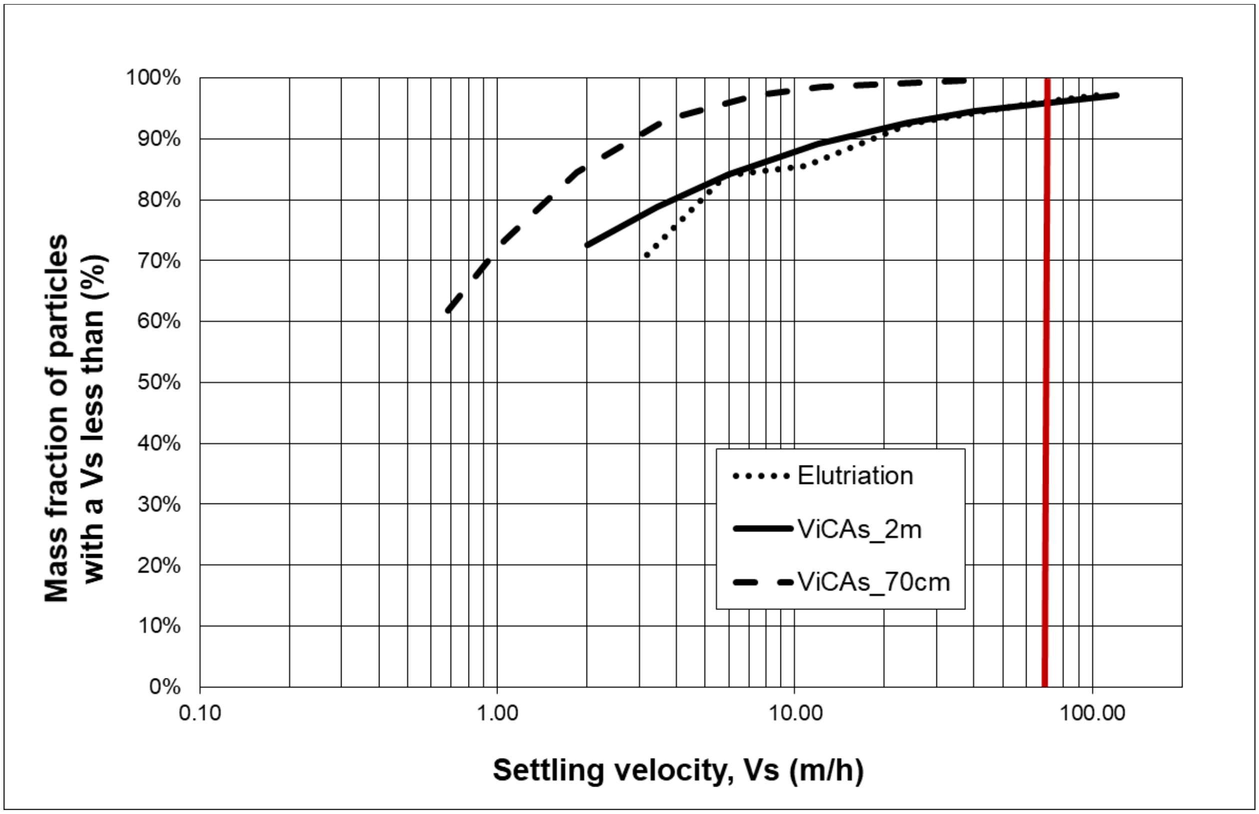

Figure 4. PSVD curves obtained with the two ViCAs columns and the elutriation system with a sample at the inlet of the grit chamber with a TSS concentration of 250 mg/L. The red line represents the design overflow rate of 70 m/h.

For the 2m-ViCAs column and the elutriation method similar results were observed. The PSVD studied ranges between 2 and 120 m/h. The small differences can be explained by the fact that for the ViCAs protocol, the PSVD curve is obtained after numerical adjustment of a smooth continuous function whereas for the elutriation method, the curve is not smoothed.

CONCLUSIONS

In conclusion, since grit is highly heterogeneous, the study of the PSVD provides key information on the settleability of the particles as they exist in the raw wastewater, and thus, provides a better knowledge of the particle characteristics. However, existing PSVD methods, such as the ViCAs, have to be adapted for fast settling particles, such as grit particles.

More importantly, since the organic fraction of removed grit is significant and variable (Plana et al., 2017), and since the density of the particles is variable, direct measurement of the governing characteristic, particle settling velocity, should be pursued, rather than using particle sizing that cannot easily be translated into settling characteristics. Hence, the study of the PSVD allows a better estimation of the grit chamber performance, and, consequently, has the potential of promoting a better design.

Finally, 2m-ViCAs columns and the elutriation test allow to study the same PSVD. Further studies should be performed to determine which is preferred.

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