Influence of sample pretreatment and weather conditions on grit characteristics

Q. Plana[1,2,*], J. Carpentier[1], F. Tardif[1], A. Pauléat[3], A. Gadbois[3], P. Lessard[2,4], P.A. Vanrolleghem[1,2]

[1] model*EAU*, Université Laval, 1065, Avenue de la Médecine, Québec (QC), G1V 0A6, Canada

[2] CentrEau, Centre de recherche sur l'eau, Université Laval, 1065 avenue de la Médecine, Québec (QC), G1V 0A6, Canada

[3] Veolia Water Technologies, 4105, Sartelon, Saint-Laurent, Québec (QC), H4S 2B3, Canada

[4] Département de génie civil et de génie des eaux, Université Laval, 1065, Avenue de la Médecine, Québec (QC), G1V 0A6, Canada

* Corresponding author: queralt.plana.1@ulaval.ca

ABSTRACT

Grit causes problems in water resource recovery facilities (WRRFs), clogging pipes, damaging pumps, and reducing the active volume of aeration tanks and anaerobic digesters. Grit chambers are built to remove these particulates. However, despite the large observed variability in grit composition, no standardized methodology exists to characterize grit particles for grit chamber design and operation. Thus, this paper presents a comparison of the existing sieving methods to characterize grit particles in view of proper grit chamber design to ultimately optimize the efficiency of this important WRRF unit process. In addition, the influence of the weather conditions on grit characteristics is also presented.

KEYWORDS: particle size distribution, grit composition, sieving tests

INTRODUCTION

Grit chambers can be found at the headworks of most water resource recovery facilities (WRRFs) to remove grit during dry and peak wet weather flows obtaining then a final product suitable for landfill disposal (Wilson et al., 2007). Their use is meant to protect the equipment and processes downstream and maintain the performance of primary and secondary treatment (Wilson et al., 2007; Tchobanoglous et al., 2014).

Despite their important role, characterization studies of these units are scarce (McNamara et al., 2014) and the interest to study them has been lower than for any other treatment unit (WEF, 2016). As a result, the characteristics of particulate pollutants at the inlet, outlet and underflow streams of grit chambers are rarely documented and their removal efficiency is often questioned as grit can still be found in downstream processes (Reddy and Pagilla, 2009). This lack of knowledge leads, among others, to a grit definition that is not agreed upon, and a non-existing standard protocol for grit sampling and characterization, leading to a wide diversity of methods (Rife and Botero, 2012).

The separation mechanism that is exploited in grit chambers is discrete particle settling and, thus, the grit particles' settling velocity is the key parameter for grit chamber design. To design these units, grit has traditionally been defined as sand, gravel, cinders or other heavy materials with a diameter larger than 210 µm (65 mesh) and a specific gravity above 2.65 g/cm^3 (Tchobanoglous et al., 2014). According to this definition, the grit particles settling velocity can be estimated through Stokes' Law:

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

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)).

Recent studies have questioned whether the assumption of particles bigger than 210 µm and a specific gravity above 2.65 g/cm^3 is adequate to design grit chambers since the mentioned specific gravity holds for clean silica sand. However, grit particles are not clean sand as they can contain a considerable organic fraction (Barter and Sherony, 2011). Hence, the settleability of the grit particles is varying as the density varies with particle's composition. In addition, a large heterogeneity of the particles and a vertical stratification in the flows are observed (WEF, 2016).

As a result of the different concepts, i.e. particle size, specific gravity and settling velocity, included in the grit definitions and the heterogeneity of the particles, several parameters are currently being used to characterize them such as particle size, density or settling velocity. This variety of parameters leads to a wide variety of characterization methods (WEF, 2016). For example, to characterize the particles size, two sieving analysis are commonly used: dry and wet sieving. For dry sieving tests, the samples are previously dried at 105 °C. In case of wet sieving, only fresh samples are used. These methods are commonly used, but there is no standard protocol existing for them. Hence, different sieving methodologies, e.g. stacked sieves and individual sieves, together with different sample pretreatments, e.g. removing the water excess of the sample, washing the sample to remove small particles and burning the sample to remove the organic fraction, are being used (WEF, 2016). Importantly, a sieving test should be safe, repeatable, and allow to store a sample for some time to facilitate analysis of many samples.

Furthermore, given the particles' heterogeneity and its stratification in the flow, a representative sample is difficult to obtain (WEF, 2016). A sampling method has to be selected according to the sampling point and the hydraulics of the system studied. Generally, the studied points are the inlet, outlet, underflow and the removed grit (grit bin) (WEF, 2016; Reddy and Pagilla, 2009).

Due to the challenges related to the heterogeneity in the wastewater, the large variations, and the low priority given to better understanding grit removal, erratic grit characteristics and uncertain grit loads are often obtained (WEF, 2016; Pretorius, 2012). Thus, the sampling and characterization methods should be improved to deal with this.

OBJECTIVES

Given the wide diversity of methods used to characterize the grit particles, the parameters used to characterize them, and the complexity to sample representatively, the objective of this study was to evaluate the performance of the different sieving methods and the sample pretreatment approaches in use today to characterize the particles that settle in a grit chamber.

The influence of dry and wet weather conditions, as well as the influence of snow melt on the obtained grit characteristics have been looked at.

METHODOLOGY

The fresh grit particles removed by a vortex grit chamber at the WRRF of Saint-Nicolas (Qc, Canada) treating combined sewage have been characterized. The grit particles characterized have been collected directly after the washing and dewatering (so-called classification) at the moment of the grit removal from the grit chamber and before the grit particles fell into the grit bin. This sampling strategy allowed to sample representatively under known conditions.

Three parameters have been studied to characterize the collected grit particles: the particle size distribution (PSD), the composition and the density. The PSD has been determined by dry and wet sieving following the indications proposed by WEF (2016). In both sieving tests, 15 stacked sieves ranging from 75 µm to 13.5 mm have been used. The collected grit was placed on the top of the sieve series with the sample passing through all sieves. For dry sieving, the sieves have been shaken using an automated shaker manufactured by for 15 minutes to favor size separation. In case of wet sieving, the force applied for particle classification has been sprinkling of water at low pressure, making the particles rolling on each sieve. After particle classification, the mass collected at each sieve has been collected and weighted.

The composition of the grit particles is quantified as the inorganic (inorganic solids, IS) and organic (volatile solids, VS) fractions, both determined following Standard Methods (APHA et al., 2012). Finally, the density of the grit particles has been estimated considering that grit density is between 1.1 and 2.65 g/cm^3, depending on its composition (WEF, 2016). Assuming that the inorganic fraction has a density of 2.65 g/cm^3 and the organic fraction, 1.1 g/cm^3, the equation proposed to estimate the density of the grit particles is:

$$\rho_{estimated} = F_{inorganic} \times 2.65 + \left(1 - F_{inorganic}\right) \times 1.1 \qquad (2)$$

To evaluate how these parameters can be influenced by sample conditioning, several pretreatments have been tested on different samples. The strategy applied is based on a combination of washing the sample to remove the particles smaller than 75 µm or not, and on drying the sample at 105°C, burning at 550°C to remove the organic fraction or doing nothing with the sample before the sieving test (See the experimental plan on figure 1). Afterwards, each particle size class was characterized by its IS fraction and density. This experimental plan has been repeated with 7 different grit samples. In two occasions, triplicates have been made for each different sieving test to evaluate the variability of the test.

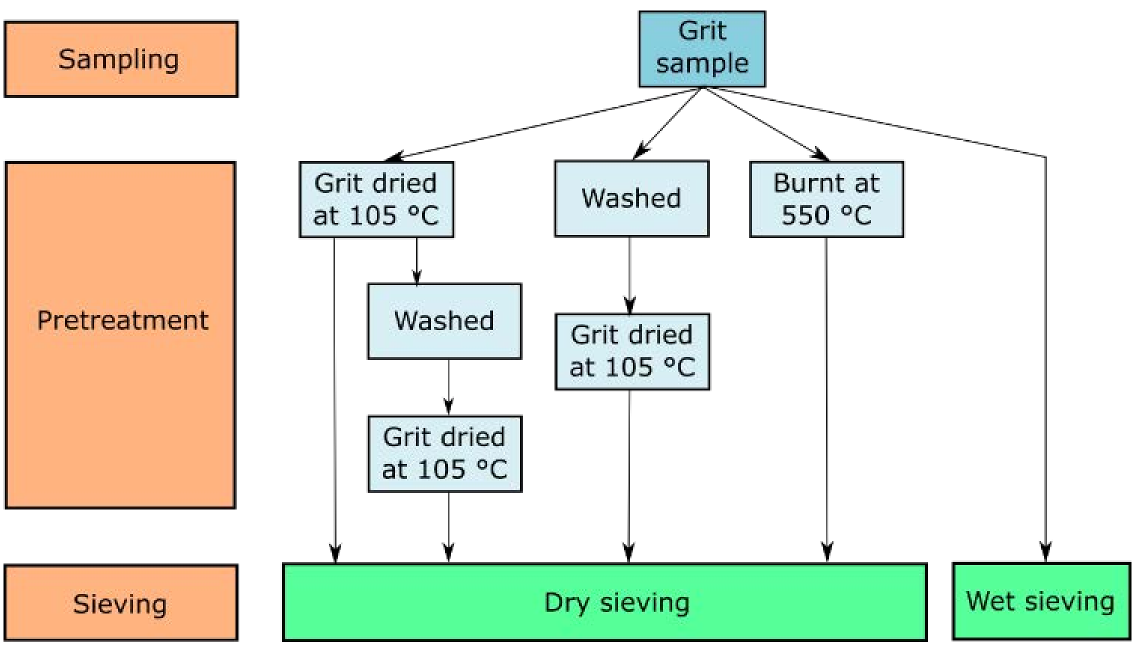

Figure 1. Experimental plan to determine the influence of the sample conditioning to characterize the particle size distribution of the final grit product by sieving.

The influence of rain and snow melt events on the studied parameters has also been studied. Several samples were taken under dry weather conditions (7 samples), under wet weather (3 samples) and, also, a snow melting period (1 sample). Only the following sieving methodology was applied: fresh grit was washed and dried at 105 °C before the dry sieving test. Again, for each particle class obtained from the sieving test, the IS fraction and the density have been studied.

RESULTS AND DISCUSSION

Particle Size Distribution (PSD)

An example of the different PSD curves obtained with the different sample pretreatment protocols for a sample collected under dry weather conditions are shown on figure 2. Significant differences were observed for the different pretreatments. Particles were clearly smaller when the sample was previously burnt ("ashed grit") because all organic fraction was removed, leading to disaggregation of agglomerates into the primary particles. When the sample was not washed and when the sample was washed after it was dried, bigger particles were observed because some particles had aggregated. Finally, with dry sieving of washed wet grit and wet sieving, the results obtained were similar and are located between the PSD curves obtained for ashed grit and dried grit without pretreatment.

The differences observed between curves are about a factor 5 (note the logarithmic scale). Then, if the determined PSD is used to estimate the settling velocity of the grit particles for the design of a grit camber using Stokes' Law (Equation 1), a difference up to a factor of 25 can follow, depending on the pretreatment method used. Indeed, the diameter of the particle appears at the power of 2 in Equation 1.

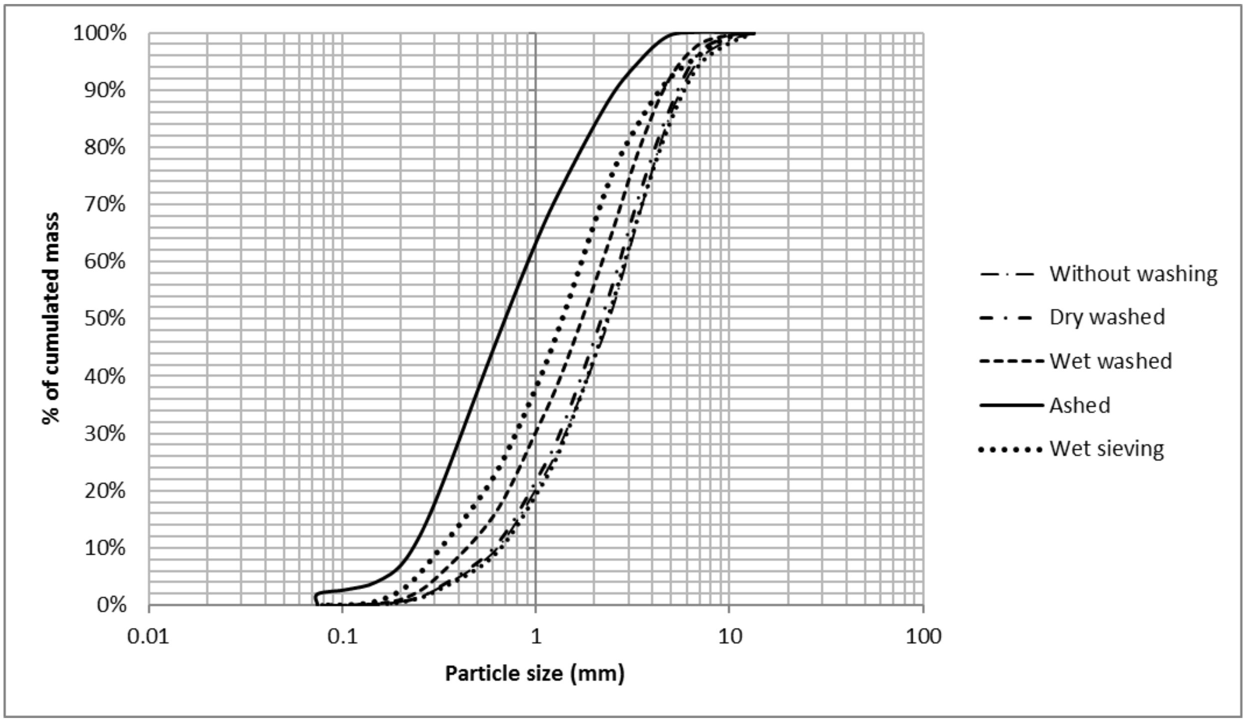

Figure 2. Granulometric curves for different sample pretreatments of St-Nicolas WRRF under dry weather

Composition

Regarding the inorganic and organic fraction of each particle size, it was observed that small particles were more inorganic than large particles, i.e., the inorganic fraction for small particles represents 80-90%, whereas for large particles, it was only 10-20%. Similar results of the composition for the different particle classes have been observed for the different sieving tests independently of the pretreatment (except for the ashed grit, of course).

Given density estimations with equation 2, it follows that smaller, mostly inorganic particles can be expected to have a high-density close to 2.65 g/cm^3. Conversely, the larger, mostly organic particles had a low density, close to 1.1 g/cm^3. Thus, it can be concluded that both small particles with high density and large particles with low density can be retained in a grit chamber since both size and density affect the settleability of particles.

Impact of weather conditions

The average PSD curves obtained under different weather conditions (dry weather, rain events, snow melt) at the grit chamber are presented in figure 3. Under dry weather conditions, the grit particles retained in the vortex grit chambers were larger than those retained after rain events or a snow melt period. The smallest particles were observed during the snow melting period. This can be caused by the runoff of sand that is used for the roads' de-icing. Also, it was observed that during rain events and snow melting periods, the grit retained in the grit chamber contains a higher inorganic fraction than the grit collected under dry weather conditions (See figure 4).

The combination of small size and high-density particles thus confirm the earlier observation on the relation between these grit characteristics and their retention in grit chambers. Ultimately, it is the settling velocity that determines whether a particle is retained or not.

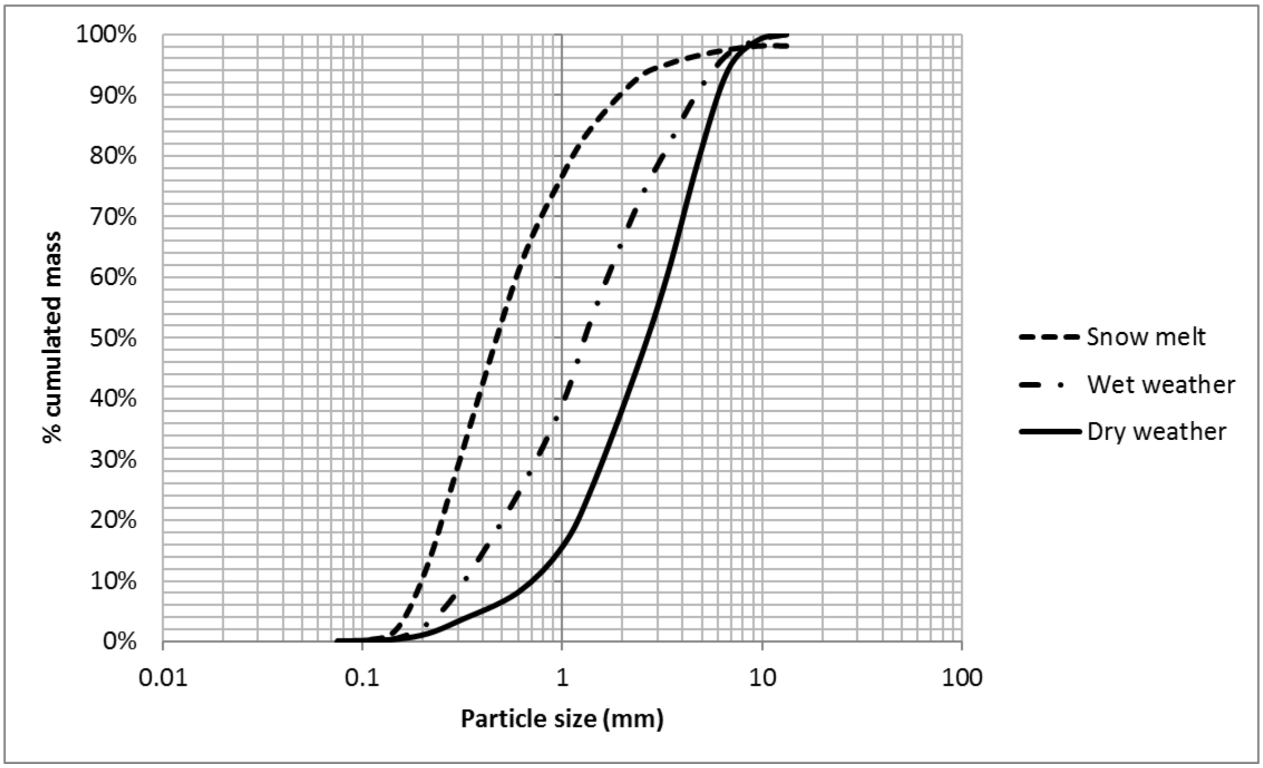

Figure 3. Average of the PSD curves under different weather conditions of St-Nicolas WRRF

CONCLUSIONS

The characteristics of the grit particles retained in grit chambers can be influenced by the type of sieving, the sample pretreatment before the sieving test, and the influent (dry weather, rain events, snow melt). The sample pretreatment can induce considerable differences on the obtained PSD and lead to a biased estimation of the settling velocity of the grit particles (key variable for the process). When grit is not previously washed, the particles can appear larger because of possible aggregation, and when the grit sample is burnt, more particles can be retained on the finer sieves due to the removal of the organic fraction and subsequent disaggregation.

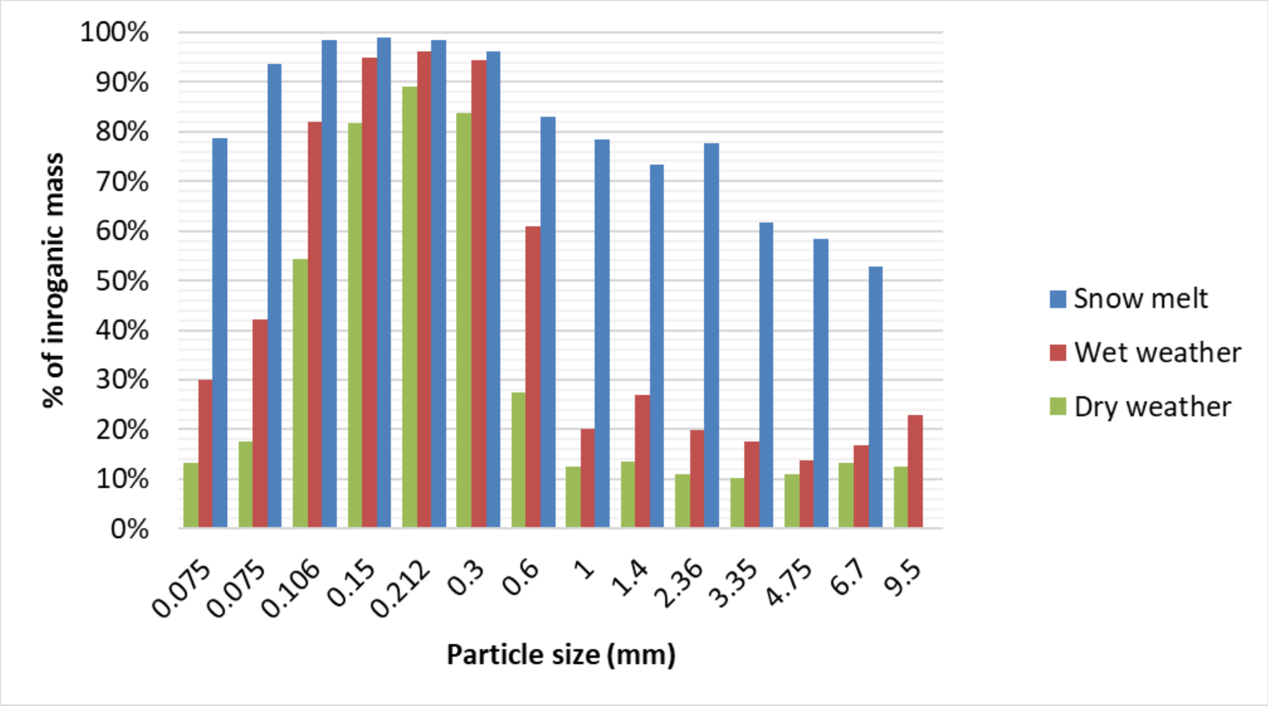

Figure 4. Average of the inorganic fraction under the different weather conditions in St-Nicolas WRRF

Wet sieving can be considered as reference method since the particles are not modified during neither sample conditioning nor during the test. Unfortunately, the wet sieving test cannot meet the requirements mentioned in the introduction as grit is considered a biorisk waste. And, the sample must be fresh at the moment of the test since the characteristics of the particles may change after 24 h. Also, this test requires more time than others (about 3 times more than a dry sieving) and two people are involved on the manipulation.

Comparing the different sample pretreatment methods and considering wet sieving as the reference method, a dry sieving test after having previously washed the wet grit can be recommended because it is a safe (pathogens are killed during drying) and repeatable test, and it also allows to store the sample some time to facilitate analysis.

Grit characteristics can also depend on the influent type, e.g. dry weather, rain events and snow melt periods. During wet weather and snow melt periods, smaller and more inorganic grit particles were found to be retained in the grit chamber.

ACKNOWLEDGEMENT

The authors wish to acknowledge the financial support by a Collaborative Research and Development grant of the Natural Sciences and Engineering Research Council (NSERC). Peter Vanrolleghem holds the Canada Research Chair in Water Quality Modelling.

REFERENCES

APHA, AWWA and WEF (2012). *Standard Methods for the Examination of Water and Wastewater* (22nd ed.). Washington, DC, USA: American Public Health Association (APHA), the American Water Works Association (AWWA), and the Water Environment Federation (WEF).

Barter, P. and M. Sherony (2011). Grit – you don't know what you're missing! In *5th European Water & Wastewater Management Conference, 26-27 September 2011, London, United Kingdom*.

McNamara, B., M. Sherony, and P. Herrick (2014). Relative performance of grit removal systems. In *87th Water Environment Federation Technical Exhibition and Conference (WEFTEC2014), New Orleans, Louisiana, USA.*

Pretorius, C. F. (2012). A review of vortex grit basin design. In *85th Water Environment Federation Technical Exhibition and Conference (WEFTEC2012), New Orleans, Louisiana, USA*.

Reddy, M. P. and K. Pagilla (2009). Integrated methods for wastewater treatment plant upgrading and optimization. Technical report, Water Environment Research Foundation, Alexandria, VA, USA, and IWA Publishing, London, UK.

Rife, J. C. and L. Botero (2012). Last of the neglected treatment processes: Rewriting the Manual of Practice no. 8 section on grit removal. In *85th Water Environment Federation Technical Exhibition and Conference (WEFTEC2012), New Orleans, Louisiana, USA.*

Tchobanoglous, G., H. D. Stensel, R. Tsuchihashi, F. L. Burton, M. Abu-Orf, G. Bowden, and W. Pfrang (2014). *Wastewater Engineering: Treatment and Resource Recovery*. *Metcalf and Eddy* (5th ed.). New York, NY, USA: McGraw-Hill Education.

WEF (2016). *Guidelines of Grit Sampling and Characterisation*. Alexandria, VA, USA: Water Environment Federation.

Wilson, G., G. Tchobanoglous, and J. Griffiths (2007). *The Grit Book*. Hydro International. Hillsboro, OR, USA.