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Prediction of the terminal settling velocity of drinking water pellet softening particles

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Abstract: The literature provides a comprehensive collection of equations to estimate the terminal settling velocity of single solid particles in a liquid system. The settling velocity for perfectly round spheres can accurately be calculated. In the contrary for natural imperfect particles the experimentally measured settling velocity deviates considerably compared the calculated value. In drinking water treatment processes natural particles are frequently applied in up flow fluidisation processes and in addition sedimentation processes are applied to clarify water and to concentrate solids.

Keywords: drinking water; terminal settling velocity; calcium carbonate pellets

Introduction

For sustainability goals Waternet is has modified the pellet softening processes in which the garnet sand as a seeding material has been replaced by calcite seeding particles based on the re-used grained, dried and sieved calcium carbonate pellets[7]. Since these calcite particles have an irregular shape the numerical prediction[11][10] is much more complex. 1304 terminal settling experiments[4] have been carried out and compared with the conventional drag force[9] coefficient equations by Brown-Lawler[1] and Fair-Geyer[3]. In addition the measured values are compared[2] with the modified Schiller[8] equation by van Schagen[6] garnet pellets.

Material and Methods

Individual terminal settling experiments for several materials were carried out in the Weesperkarspel drinking water pilot plant of Waternet, located in Amsterdam, the Netherlands. To compare the data from the experiments with the models the normalised mean squared error (NRMSE) is applied. The setup consists of a 4 meter transparent PVC pipe with an inner diameter of 57 mm. Three of the most important parameters were varied: water temperature, water flow and grain size.

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Results and Conclusions

The Brown-Lawler equation and Fair-Geyer equation are suitable to accurately predict the terminal settling velocity of drinking water treatment particles. The van Schagen equation predicts too high values and is not suitable. These models can also be used for the porosity prediction models e.g. Richardson-Zaki. The resulting deviation in estimated drag can be deduced from the natural imperfect particle shape, rough surface and orientation. Therefore, it is not necessary to publish a new empirical model to predict the terminal settling velocity. The Brown equation can be used in drinking water treatment processes. Terminal settling experiments can in addition be used to determine the hydraulic diameter for modelling purposes.

Table 1.1 Normalised mean squared errors for terminal settling velocity.

Material	Experiments	Brown-Lawler	Fair-Geyer	van Schagen
All particles	N=1304	0.093	0.090	0.174
Calcite pellets	N=388	0.030	0.038	0.080
Garnet pellets	N=626	0.050	0.048	0.124
Glass pearls	N=101	0.037	0.033	0.067
Garnet	N=97	0.046	0.044	0.045
Calcite IT	N=45	0.026	0.021	0.029
Calcite UK	N=32	0.031	0.028	0.032
Crystal sand	N=15	0.008	0.005	0.011

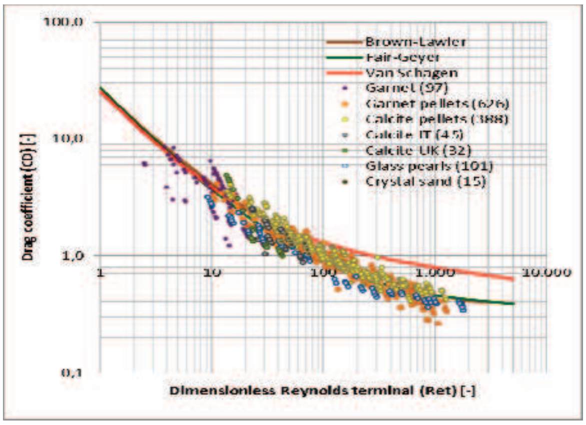

Figure 1.1 Experimental data (N=1304) and predicted terminal settling velocities.

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