Delft University of Technology

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

Kramer, Onno; de Moel, Peter; Baars, E.T.; van Vugt, W.H.; van der Hoek, Jan Peter

Publication date
2017

Document Version
Final published version

Published in
Poster abstract overview

Citation (APA)
Kramer, O., de Moel, P., Baars, E. T., van Vugt, W. H., & van der Hoek, J. P. (2017). Prediction of the terminal settling velocity of drinking water pellet softening particles. In *Poster abstract overview: 5th IWA Young Water Professionals BeNeLux conference* (pp. 81-82)

Important note
To cite this publication, please use the final published version (if applicable).
Please check the document version above.

Copyright
Other than for strictly personal use, it is not permitted to download, forward or distribute the text or part of it, without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license such as Creative Commons.

Takedown policy
Please contact us and provide details if you believe this document breaches copyrights.
We will remove access to the work immediately and investigate your claim.

This work is downloaded from Delft University of Technology.
For technical reasons the number of authors shown on this cover page is limited to a maximum of 10.

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

O.J.I. Kramer[1*], P.J. de Moel[2,4], E.T. Baars[2], W.H. van Vugt[3], J.P. van der Hoek[1,2]

[1] Delft University of Technology, Faculty of Civil Engineering and Geosciences, Department of Water Management, PO Box 5048, 2600 GA, Delft, the Netherlands, (E-mail: o.j.i.kramer@tudelft.nl), Tel: +31 6-42147123
[2] Waternet, PO Box 94370, 1090 GJ, Amsterdam, the Netherlands, (E-mail: onno.kramer@waternet.nl), Tel: +31 6-52480035
[3] HU University of Applied Sciences Utrecht, Institute for Life Science and Chemistry, PO Box 12011, 3501 AA Utrecht, The Netherlands
[4] Omnisys, Eiberlaan 23, 3871 TG Hoevelaken, The Netherlands

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.

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.

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

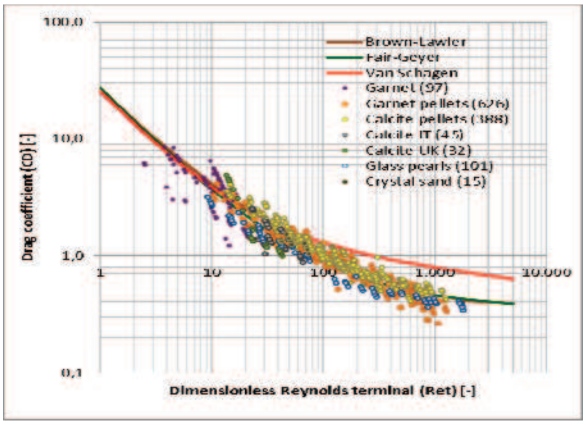

Figure 1.1 Experimental data (N=1304) and predicted terminal settling velocities.

References

[1] Brown, P. P. and Lawler, (2003), D.F., Sphere drag and settling velocity revisited, *Journal of Environmental Engineering ASCE*, **124**(3), pp. 222-231

[2] Camp, T. R., (1946), Sedimentation and the design of settling tanks, *Trans. of the American Society of Civil Eng*, **111**, pp. 895-899

[3] Fair, G.M., Geyer, J.C. and Okun, D.A., (1954), *Water supply and waste water disposal*, 1st ed., Wiley, New York, ISBN: 9780471251316

[4] Kramer, O.J.I., Jobse, M.A., Baars, E.T., Helm, A.W.C., van der, Colin, M.G., Kors, L.J., and Vugt, W.H., van, (2015), Model-based prediction of fluid bed state in full-scale drinking water pellet softening reactors, *IWA congress, New Developments in IT and Water Conference*, Conference paper, pp. 1-26

[5] Kramer, O.J.I., (2014), Circular economy in drinking water treatment: re-use of grinded pellets as seeding material in the pellet softening process, *Conference poster presentation at the IWA World Water Congress and Exhibition*, Lisbon

[6] Schagen, van, K.M., Rietveld, L.C. Babuška, R. Kramer, O.J.I., (2008), Model-based operational constraints for fluidised bed crystallisation, *Water Research* **42**, pp. 327–337

[7] Schetters, M.J.A., Hoek, van der, J.P., Kramer, O.J.I., Kors, L.J., Palmen, L.J., Hofs, B. and Koppers, H., (2015), Circular economy in drinking water treatment: reuse of grinded pellets as seeding material in the pellet softening process, Water Science and Technology, **71**(4), pp. 479-486

[8] Schiller, L., Naumann, A., (1933). Über die grundlegenden Berechnungen bei der Schwerkraftaufbereitung *Ver. Deut. Ing.*, 77, pp. 318–320

[9] Stokes, G., (1850), On the effect of the internal friction of fluids on the motion of pendulums, *Trans. Cambridge Philos. Soc.*, **IX**, pp. 8

[10] Turton, R. and Levenspiel, O., (1986), A short note on the drag correlation for spheres, *Powder Technology*, **47**, pp. 83-86

[11] Yang, W., (2003), Handbook of Fluidization and Fluid-Particle Systems, pp 49-54, pp. 138-142