Prediction of the terminal settling velocity of natural particles applied in drinking water treatment processes
Kramer, Onno

Publication date
2017

Document Version
Final published version

Citation (APA)

Important note
To cite this publication, please use the final published version (if applicable).
Please check the document version above.
Prediction of the terminal settling velocity of natural particles applied in drinking water treatment processes

Onno Kramer
Drinking water production processes

- Filtration
- Fluidisation
- Sedimentation

Natural granular particles
Drinking water softening

Chemical CaCO$_3$ crystallisation (caustic soda)
Fluidisation reactors (Liquid-Solid)
Drinking water softening (linear economy)

Seeding material → marble pellets

0.3 mm

1.0 mm
Drinking water softening (linear economy)

Seeding material → marble pellets

500 t/y raw material → 8000 t/y waste material

1g velocity of natural particles applied in drinking water treatment processes
Drinking water softening (Waternet CO₂ neutral in 2020)

Seeding material → marble pellets

500 t/y raw material → 8000 t/y waste material
Drinking water softening (circular economy)

Seeding material → marble pellets → grinding → sieving

Re-using

Valorisation

e.g. glass, paper, carpet etc.
Research aim (after process changes)

Investigating the hydraulic behaviour of imperfectly round spheres in drinking water treatment processes
(1/2) Literature study (drag versus Reynolds)

Literature study (drag versus Reynolds)

- Terminal settling theory
  - Laminar (Stokes)
  - Turbulent (Newton)
- Many prediction models
  - Intermediate regime
- For prefect round spheres
- +/-5% accuracy
(1/2) Literature study (drag versus Reynolds)


20%
N = 480

Empirical models

Stokes (laminar)

Newton (turbulent)

Drag coefficient

Reynolds terminal number

\[ \text{Drag coefficient} = \rho \frac{d^2 v}{\eta} \]

\[ \text{Re} = \frac{\rho d v}{\eta} \]

\[ C_D = \frac{24}{Re} \left(1 + 0.15 Re^{0.61}\right) + \frac{0.407}{1 + \frac{8710}{Re}} \]

\[ \eta \]

\[ \rho \]

\[ d \]

\[ v \]

\[ Re \]

\[ C_D \]

\[ \text{Reynolds Number (R)} \]
Prediction of the terminal settling velocity of natural particles applied in drinking water treatment processes

(2/2) Experimental data

- Stokes
- Brown-Lawler
- Crystal sand (15)
- Garnet pellets (626)
- Calcite IT (45)
- Glass pearls (187)
- IEX balls (6)  
- Newton
- Rapid filter sand (242)
- Garnet (97)
- Calcite pellets (785)
- Calcite IT (32)
- Distortion layer (4) 

Drag coefficient vs. Reynolds terminal number

10%
N = 1046
Prediction of the terminal settling velocity of natural particles applied in drinking water treatment processes

(2/2) Experimental data

Drag coefficient vs Reynolds terminal number

Stokes
Brown-Lawler
Newton
- Rapid filter sand (242)
- Garnet (97)
- Calcite pellets (785)
- Calcite IT (45)
- Glass pearls (187)
- IEX balls (6)
- Garnet pellets (626)
- Crystal sand (15)

N = 2039

0%

Prediction of the terminal settling velocity of natural particles applied in drinking water treatment processes
Explanation of deviation

Deviation caused by variation in:

- Gravitational acceleration +/- 0.1%
- Specific particle density +/- 0.4%
- Fluid viscosity and density (temperature) +/- 1.0%
- Particle size (sieve diameter) +/- 10%
- Particle dimension, (shape, properties and orientation) +/- 15%
Explanation of deviation

Deviation caused by variation in:

- Gravitational acceleration +/- 0.1%
- Specific particle density +/- 0.4%
- Fluid viscosity and density (temperature) +/- 1.0%
- Particle size (sieve diameter) +/- 10%
- Particle dimension, (shape, properties and orientation) +/- 15%
Take home messages (optional)

**Use all your data**
- Be careful with filtering or eliminating less accurate data
- Before fitting your data, try to explain derivative deviation
- From deviation useful information can be retrieved
- Take deviation intro account when predicting or designing processes

**Use proven models:**
- *** Water treatment granular particles
  - Hydraulic behaviour of round spheres can accurately be calculated
  - Natural particles behave differently then perfectly round spheres
  - The measured deviation can decisively be explained
  - In particular particle shape causes distinguished hydraulic behaviour
Thank you for your attention

Onno Kramer$^{1,2,3}$
Eric Baars$^1$
Peter de Moel$^3$
Wim van Vugt$^2$
Leon Kors$^1$
Jan Peter van der Hoek$^{1,3}$

$^1$ Waternet Drinking Water Department
$^2$ HU University of Applied Sciences Utrecht, Institute for
Prediction of the terminal settling velocity of natural particles applied in drinking water treatment processes