Sustainable Drinking Water

Several of the mysteries surrounding drinking water will be considered
\[ \varepsilon = f\left(v_s, v(T), d_p, \rho_p\right) \]

✓ Modelling optimal process states
Circular Water Process Modelling
Researching sustainable drinking water

1.2 million clients
the water utility of Amsterdam and surroundings
Waternet: a public water cycle utility

Core values Waternet
✓ Economic effectivity
✓ Customer orientation
✓ Sustainability
Aquatic Chemistry
The Periodic Table of the Elements

- **alkali metals**
- **alkaline metals**
- **metalloids**
- **nonmetals**
- **transition metals**
- **noble gases**
- **lanthanoids**
- **actinoids**
- **unknown elements**
- **radioactive elements have masses in parentheses**

**Notes**:
- As of yet, elements 113-118 have no official name designated by the IUPAC.
- 1 kJ/mol = 0.239 kcal/mol
- All elements are implied to have an oxidation state of zero.

[Link to Wikipedia article on Periodic Table](https://en.wikipedia.org/wiki/Periodic_table)
The Periodic Table of the Elements

Notes:
- As of yet, elements 113-118 have no official names designated by the IUPAC.
- 1 kJ/mol = 96.485 eV.
- All elements are implied to have an oxidation state of zero.

Source: https://en.wikipedia.org/wiki/Periodic_table
The Periodic Table of the Elements

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<th>Group</th>
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**Notes:**
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[https://en.wikipedia.org/wiki/Periodic_table](https://en.wikipedia.org/wiki/Periodic_table)
Water in our solar system

Earth
- 1386 million km$^3$

Europa
- Smallest moon Jupiter
- 2855 million km$^3$

Pluto
- 4316 million km$^3$

Ganymedes
- Largest moon Jupiter
- 54362 million km$^3$

Our blue planet earth

1386 million km³ water
Covered area 70%
Volume water 0.1%

- 69.6% ice/snow
- 30.1% fresh ground water
  - 0.3% fresh surface water

97.5% salt 2.5% fresh

Total: 0.01% suitable for drinking water
Due to great drought, people are crowding around the well: Natwarghad, Gujarat, India. 
Photo: Amit Dave, National Geographic Magazine 2010.
In the village of Basudevpur (India) a woman walks on cork-dry soil.
Photo: Biswaranjan Rout, National Geographic Magazine 2010.
Gabra women in northern Kenya walk 5 hours a day for a few liters of polluted water. Photo: Lynn Johnson, National Geographic Magazine 2010.
According to the WHO in 2018:

Two billion people do not have access to clean drinking water.

Four billion people cannot use safe sanitation.

Three million people die each year from contaminated water-related diseases.

Women scrape water from the Arayo River in Ethiopia. 
Photo: Lynn Johnson, National Geographic Magazine 2010.
Broad Street cholera outbreak in 1854
https://en.wikipedia.org/wiki/1854_Broad_Street_cholera_outbreak
The “Goudsbloem“ canal was closed in 1854 for hygienic reasons.
Drawing: Willem Hekking, Amsterdam City Archives.
Collection of feces by employees with the "eau de cologne" car, 1920 in the center of Amsterdam “Jordaan“. Amsterdam City Archives.
Welcome to Tower Hamlets

Burdett-Coutts Fountain

The Burdett-Coutts Memorial Drinking Fountain was designed by Henry Astley Darbishire in 1862 for the philanthropist Angela Burdett Coutts (1814 – 1906) and is believed to have cost £6,000 (easily more than half a million pounds today.) Water would pour from the four cherub’s vases and silver plated cups on chains allowed the poor East Londoners sanitary drinking water. This was a first for many East Londoners, who had often drunk from the filthy bathing lakes nearby.

It is constructed of pink marble and granite with stone drinking fountains and it boasts a distinctive cupola with an ornamental date and four clock-faces. The Cupidae orcher, sculptured cherubs and inscriptions have been repaved and restored, and a recreated gold mermaid acts as a weathervane sitting on top of the cupola. The fountain when first built was originally called The Victoria Fountain, and the name is still visible engraved in the granite. A small engraving above the date stems from Psalm 24 and reads “The earth is the Lord’s and all that therein is.”

Angela Burdett-Coutts, the youngest of the six children of Sir Francis Burdett, the Radical MP, was born on the 23rd April, 1814. Angela’s mother, Sophia Coutts, was the daughter of Thomas Coutts the wealthy banker. On the death of her Grandfather’s second wife, Harriet, Angela, at 23 years of age inherited almost the entire estate in a will. Harriet wished the fortune to remain in the Coutts family and she will contain certain covenants, notably that she was to take the Coutts name and that she must never marry a foreign national.

Consequently, in 1837, Angela Burdett, at 23 the youngest of Thomas’ grandchildren changed her name to Burdett-Coutts inheriting the interest in a Trust including a half-share in the Bank. She became one of the wealthiest women in Britain and was renowned for her philanthropic vigour.

Due to her great wealth she was relentlessly pursued by a stream of suitors, but Angela Burdett-Coutts had no intention of getting married. She decided to give a large percentage of the money to good causes, especially the relief of poverty. She was great friends with other Victorian notables including Charles Dickens, William Gladstone, Benjamin Disraeli and the Duke of Wellington.

The first people to benefit from Angela’s money were London’s fallen women. She campaigned to get much needed and valuable life-skills such as needlework and cooking taught to special schools so that women had a respectable means to earn a living. One such school opened in Spitalfields, an area of London where there were high levels of poverty and unemployment.

Her father also encouraged her to be interested in science and she provided funds for research projects, geology, archaeology and the natural sciences. As a result she met men like Charles Babbage, and in 1839 she provided financial backing for Babbage’s “Calculating Engine”, the forerunner of the modern computer.

Housing for the poor in the East End of London was another area that Angela was keen to address and cancer research also owes much to her early financial support of London’s Royal Marsden Hospital, then the Brompton Cancer Hospital.

In 1871, Burdett-Coutts became “the first woman to have been made a peer in recognition of her accomplishments.” Baroness Burdett-Coutts shocked polite society when she finally got married in 1861 at the age of 67. Her husband William Ashmead-Bartlett, who took her surname, was less than half her age as he had been her godfather and secretary, and would later become the MP for Westminster. William was American by birth, which meant that under the conditions of her legacy Burdett-Coutts forfeited much of her inheritance. They remained happily married until Angela’s death.

Baroness Angela Burdett-Coutts died on 30th December 1906 of acute bronchitis. She laid in state for two days and 30,000 people came to pay their respects to a woman who had become known as the ‘Queen of the Poor’. She was buried a week later in Westminster Abbey.

By the time she died Angela had donated over £3m to charitable causes. She brought about positive changes for animals, women, the poor, children, the church, working conditions, education as well as causes abroad.

Little wonder that she was described by King Edward VII as "after my mother, the most remarkable woman to the kingdom. The nearby Burdett Road commemorates her memory to this day and Angela also appeared in the Trollope novel ‘Phiz’s Daughter’. For more information scan the QR code or visit: www.towerhamlets.gov.uk/victoriapark
Water was transported from the river “Vecht” to Amsterdam by boat. Photo: Amsterdam City Archives.
Amsterdam Water Supply Dunes in the vicinity of the city “Haarlem”.
Construction of the infiltration and extraction canals in the drinking water dunes 1850-1870.
Netherlands first water supply company “Leiduin” in the village “Vogelenzang“.
In 1881 Amsterdam received water from a second treatment facility and pumping station “Weesperkarşpel”
Photo: Amsterdam City Archives.
How do you like your tap water?
Safe drinking water may not need to contain a residual disinfectant

By Fernando Rosario-Ortiz,1,2 Joan Rose,3 Vanessa Speight,4 Urs von Gunten,2,5 Jerald Schnoor2,6

The expectation that tap water is safe has been sorely tested by the recent events in Flint, Michigan, where lead contamination has caused a public health emergency (1). Apart from contamination with heavy metals and other harmful substances, a key concern is the control of microbial contamination. To prevent microbial growth and protect consumers from pathogens from other sources, some countries, such as the United States, require the presence of residual disinfectant in drinking water. However, the presence of a disinfectant can lead to the formation of potentially carcinogenic disinfection by-products (DPBs), issues with corrosion, and complaints based on the fact that people dislike the taste of disinfectants in their water (2). The experience of several European countries shows that such residual disinfectants are not necessary as long as other appropriate safeguards are in place.

From the early 1900s, the control of microbial waterborne pathogens, including Salmonella typhi and Vibrio cholera, led to a major reduction of waterborne diseases in the industrialized world. Filtration and chlorine disinfection reduced mortality in the United States substantially. But in 1974, chloroform, a probable human carcinogen formed by the reaction of chlorine with naturally occurring organic matter, was discovered in chlorinated drinking water. This discovery led to a debate about microbiological safety versus exposure to harm-
Drinking water challenges

- Pathogens and pesticides in water
- Climate change
- Energy issues and sustainability
- Terrorism
- Cost price
- Laws and regulations
- Stories on social media
- Demanding customers
- ...
Water pollutants

Aim:

✓ Producing reliable drinking water with a complex treatment “train”

Characterisation:

✓ Suspended substances and solids
✓ Dissolved substances and gases
✓ Organisms
Water pollutants

Characterisation:

✓ Suspended substances and solids
✓ Dissolved substances and gases
  - Mineral ingredients such as cations and anions
    e.g. arsenic
  - Organic ingredients i.e. nutrients, toxic substances
    e.g. pesticides, medicines, hormones, X-ray contrast liquids, drugs
  - Dissolved gases
    e.g. like methane, ammonia, hydrogen disulphide
  - Radioactive substances
✓ Micro-biological organisms
  e.g. viruses, bacteria, algae, higher organisms
Purification techniques (chemical-physical-biological)

Precipitation
  Coagulation, Sedimentation, Filtration, Ion Exchange, Micro sieves

Oxidation
  Chlorine, Ozone, UV, Hydrogen Peroxide, Photochemical

Adsorption
  Granular Activated Carbon

Conditioning
  Softening, pH Correction

Membranes
  Micro, Ultra, Nano, RO (also ... pure H₂O then add Ca²⁺ and Mg²⁺)
Pre-treatment: Loenderveen

Source: Rhine
Pre-treatment: Nieuwegein

Main treatment: Weesperkarspel

Source: Bethune polder

Main treatment: Leiduin
Treatment philosophy for high drinking water quality

Source protection
Multiple barriers for pathogens
Multiple barriers for organic micropollutants
Central softening
No chlorine
Biologically stable

High quality distribution network
Monitoring and action
Improve sustainability (energy, chemicals, reduction of soap at households): CO₂ footprint
Try out new innovations in pilot plants
Treatment plant from raw water to drinking water

Pre-treatment

Main-treatment
Pre-treatment

Source Filtration Coagulation Sedimentation Infiltration Reservoir Transport

Source protection river “Rhine”
Area 250,000 km²
Length 1,230 km
Flow rate 2000 m³/s
50 million inhabitants
9 countries
Much - industry
   - Agriculture
   - transport
Alarm early warning system
Pre-treatment

Dosage: FeCl₃
Formation of flocks

Removal of:
- Suspended solids
- Phosphate to prevent Algae growth
- Heavy metals
- Bacteria, protozoa and viruses

Coagulation sludge is processed into bricks
Pre-treatment

Dune and lake water infiltration
60-90 days residence time
Reduction of organic micro compounds
Reduction of peak concentrations
Removal of ammonia
Strategic storage
Pre-treatment

Removal:
- Suspended solids
- Bacteria
- Ammonium
- Iron
- Manganese

Nitrification: $2NH_4^+ + 5O_2 \rightarrow 2NO_3^- + 2H_2O + 4H^+$

Back washing every week
Pre-treatment

Source Coagulation Sedimentation Infiltration Filtration Reservoir Transport

Storage intermediate product “Nieuwegein”
100-160 million m³ / year
Delivery to Tata Steel, among others
Transport ”Leiduin”

Storage intermediate product “Loenderveen”
30 million m³ / year
Transport ”Weesperkarspel”
Dosing ozone gas causing oxidation
Water disinfection
Improving taste, odour and colour
Removal:

- Bacteria, viruses and spores (pathogens)
- Organic micro-pollutants, e.g. pesticides
- Medicines (metabolites may be formed)
- Organic compounds (natural organic matter)
- Increased biodegradability
- Formation of bromate (suspected carcinogenic)
Main-treatment

Ozone Softening BACF SSF Reservoir Network

Pellet softening:

Hard to soft water
Removal of CaCO₃
Total hardness: 1.4 mmol/L
I-s fluidised bed reactors
Fluid velocity 80 m/h
400 million m³/y in NL
Cost 4 € cent per m³
Main-treatment

- GAC = Granular Activated Carbon
- BACF = Biological Activated Carbon Filtration
- Adsorption process in micro pores
- Superficial fluid velocity $\approx 10 \text{ m/h}$
- $1\text{ g GAC} \approx 1\text{ m}^2$ of 1 football field
- Removal organic micro pollutants
  e.g. pesticides, medicines, polycyclic aromated hydrocarbons, and chlorinated organic compounds
- Bio degradation natural organic matter (NOM)
- Re-activation 1#/year

Back wash procedure
Approximately once a week
Main-treatment

Ozone  Softening  BACF  SSF  Reservoir  Network

- Slow sand filtration
- Superficial velocity $\approx 1 \text{ m/h}$
- Surface area 1 filter 1000 m$^2$
- Improvement of biological stability
- Water disinfection
- Removal:
  - Bacteria
  - Protozoa
  - Viruses
Main-treatment

Ozone  Softening  BACF  SSF  Reservoir  Network

Storage of drinking water
Production:
10 thousand m$^3$/h
→ 2/3 Leiduin
→ 1/3 Weeserkarspel
> 1 million customers
3000 km of tubes in distribution network
Time scales of unit operations

Pre-treatment

- Physical [sec]
- Chemical [min]
- Biological [day]

Variation in the different hydraulic Residence times due to different Flow rates and degree of mixing and Process area.

Main treatment
Drinking water treatment processes: multiphase flows

Geldart’s fluidisation classification
Drinking water treatment processes: multiphase flows

Source  Coagulation  Sedimentation  Infiltration  Filtration  Ozone  Softening  BACF  SSF  Reservoir  Network

Back wash procedure every week
Drinking water treatment processes: multiphase flows

Ozone gas dosage and distribution in water

Gas dispersion system

Computational Fluid Dynamic modelling
Waternet sustainability goals transition to a zero carbon utility

✓ Objectives:
  • **Strategic goals**
    • CO$_2$ neutral policy in a circular economy
  • **Tactic goals**
    • Optimal water quality and cost reduction
  • **Operational goals**
    • Reduction chemicals
    • Re-use waste materials
Waternet sustainability goals transition to a zero carbon utility

- Reuse calcite in drinking water softening
- Thermal energy from the water cycle
e.g. Sanquin (blood bank)
- Struvite from waste water and urine
  \[ \text{Mg}^{2+} + \text{PO}_4^{3-} + \text{NH}_4^+ + 6\text{H}_2\text{O} \rightarrow \text{Mg(NH}_4\text{)PO}_4\cdot6(\text{H}_2\text{O}) \]
- Cellulose, protein from waste water
- Bio-plastics from sludge
- Bio-composite of plants
- Groen gas from biogas
Applied sustainability in drinking water softening

- **Public health**
  - e.g. reduces solubility of lead and copper

- **Environmental benefits**
  - e.g. less washing powder and less sludge in waste water treatment

- **Economic benefits**
  - e.g. life time hot water equipment

- **Client comfort**
  - e.g. cleaner laundry, tasteful tea
Softening: liquid-solid fluidisation processes

- Fluidisation process
- liquid-solid = water-calcite pellets
- Large specific surface area
- Crystallisation limestone

\[
\text{OH}^- + \text{HCO}_3^- \leftrightarrow \text{CO}_3^{2-} + \text{H}_2\text{O}
\]

\[
\text{CO}_3^{2-} + \text{Ca}^{2+} \rightarrow \text{CaCO}_3\downarrow
\]
From mined garnet to crushed calcite grains

Seeding-material (garnet sand) → Calcite pellets

500 ton/y raw material Australia → 8000 ton/y waste
From mined garnet to crushed calcite grains

Waternet CO₂ neutral in 2020

Seeding-material (garnet sand) $\rightarrow$ Calcite pellets

500 ton/y raw material Australia $\rightarrow$ 8000 ton/y waste
From mined garnet to crushed calcite grains
Linear economy

Garnet sand

Calcite pellet
From mined garnet to crushed calcite grains

Linear economy
From mined garnet to crushed calcite grains
Circular economy

- Hygienising
- Re-using
- Valorisation

Calcite pellet

Calcite

Sieving

Grinding
Products from calcite
The process itself

- Stratified reactor bed
- Crystallisation
- Profile
- Prediction state
- Optimisation

\[ A_s = 6 \frac{(1 - \varepsilon)}{d_p} \]

\[ \text{CO}_3^{2-} + \text{Ca}^{2+} \rightarrow \text{CaCO}_3 \downarrow \]
Knowledge gap / challenge

✓ Hydrodynamic behaviour of natural irregularly shaped particles in drinking water treatment processes
Hydraulic modelling of liquid-solid fluidization in drinking water treatment processes

- Examined particles
- Particle size characterisation
- Pilot set-up
- Fluidisation experiments
- Modelling

- Glass pearls
- Monodispersed

- CaCO₃ pellets
- Crushed calcite
Hydraulic modelling of liquid-solid fluidization in drinking water treatment processes

- Examined particles
- Particle size characterisation
- Pilot set-up
- Fluidisation experiments
- Modelling

Sieve analysis

Particle size distribution

Scanner + Image analyses

Particle morphological analysis
Examined particles
Particle size characterisation
Pilot set-up
Fluidisation experiments
Modelling
Problem-Based-Learning with the fluidisation expansion column 2019
Liquid-solid fluidisation experiments

- Examined particles
- Particle size characterisation
- Pilot set-up
- Fluidisation experiments
- Modelling

- 6 fractions
  (0.7 < \(d_p\) < 3.5 mm)
- 6 temperatures
  (5, 10, 15, 20, 25, 35 °C)
- 25 ascending water flows
  (0-400 m/h)
Liquid-solid fluidisation experiments

- Examined particles
- Particle size characterisation
- Pilot set-up
- Fluidisation experiments
- Modelling

- 10 sieved fractions 
  
  \(0.4 < d_s < 2.0\) mm

- 4 temperatures
  
  (5, 15, 25, 35 °C)

- 25 ascending water flows
  
  (0-180 m/h)
Liquid-solid fluidisation experiments

Particle and fluid properties
✓ Fluid velocity
✓ Bed height and particle mass
✓ Particle size (and shape)
✓ Temperature

Fluidisation characteristics
✓ Bed expansion (porosity)
✓ Pressure difference
✓ Flow regime
✓ Hydrodynamic state

Graphs:
- Glass beads (1,0 mm)
  - Porosity vs Superficial velocity
  - Pressure difference vs Superficial velocity

Legend:
- T=33°C
- T=28°C
- T=21°C
- T=16°C
- T=11°C
- T=7°C
Accurate prediction fluidised bed porosity in drinking water treatment processes

- Kozeny (1927)
- Carman-Kozeny (1937)
- Ergun (1954)
- Richardson-Zaki (1954)
- Empirical data model (2019)

\[
\frac{\Delta P}{\Delta L} = 180 \frac{v_s \eta (1 - \varepsilon)^2}{d_p^2 \varepsilon^3}
\]

\[
\frac{\Delta P}{\Delta L} = (\rho_p - \rho_f) g (1 - \varepsilon_{mf})
\]

\[
\frac{\Delta P}{\Delta L} = 180 \frac{v_m f \eta (1 - \varepsilon_{mf})^2}{d_p^2 \varepsilon_{mf}^3} + 2.87 \frac{\rho_f v_m f^{1.9} \eta^{0.1} (1 - \varepsilon_{mf})^{1.1}}{d_p^{1.1} \varepsilon_{mf}^3}
\]

\[
\varepsilon^n = \frac{v_s}{v_t}
\]

\[
\varepsilon = f(v_s, v(T), \rho_p, d_p)
\]

\[
\varepsilon = f(v_s, v(T), \rho_p, \text{morphs})
\]
Accurate prediction fluidised bed porosity in drinking water treatment processes

Modelling results:

- Kozeny (1927)
- Carman-Kozeny (1937)
- Ergun (1954)
- Richardson-Zaki (1954)
- Empirical data model (2019)
Accurate prediction fluidised bed porosity in drinking water treatment processes

\[ \varepsilon = f(v_s, v(T), d_p, \rho_p) \]
Accurate prediction fluidised bed porosity in drinking water treatment processes

\[ \varepsilon = f(Ar, Re_p) \]

\[ Re_p = \frac{\rho_f \nu_s d_p}{\eta} \]

\[ Ar = \frac{gd_p^3 \rho_f (\rho_p - \rho_f)}{\eta^2} \]
Accurate prediction fluidised bed porosity in drinking water treatment processes

\[ \varepsilon = f(v_s, v(T), d_{10}, d_{50}, d_{90}, \rho_p) \]
Accurate prediction fluidised bed porosity in drinking water treatment processes

\[ \varepsilon = f(v_s, v(T), d_{10}, \rho_p) \]

**Model:**

\[
e = a + 37436 \cdot \mu + b \cdot v_s + c \cdot v_s^3 + \frac{-d}{(cdd10 \cdot v_s)} + \frac{(f + g \cdot \mu)}{cdd10} - h \cdot cdd10 - i \cdot v_s^2
\]

**Text:**

\[
e = 0.240312652200618 + 37436 \cdot \mu + 9.03728868647141 \cdot v_s + 139.87068129242 \cdot v_s^3 + \frac{-0.00058041929184557}{(cdd10 \cdot v_s)} + \frac{(0.151270645618926 + 50987.4826317065 \cdot \mu)}{cdd10} - 0.0664432672354808 \cdot cdd10 - 52.5647299773652 \cdot v_s^2
\]
QMUL GAC Summer Project 2019 with:
Arza, Sofian, Jamila, Phoebe, Nabila, Faris, Yousof, Safia, Fouzia and Hassan

Experimental determination of buoyant particle density of granular activated carbon grains applied in drinking water treatment plants

\[ \rho_p = \frac{\rho_f}{1 - \frac{A\Delta P}{mg}} \]

Abstract
Granular activated carbon (GAC) filters have been used for decades to remove various kinds of organic micro-pollutants, disinfection by-products and taste and odour compounds from drinking water by adsorption. By the end of one filter run, the water inlet is closed, and the water direction is reversed upwards to flush the media and flush out all the impurities, which were trapped during the filtration stage. The backwash fluid velocity needs to be high enough to flush out all the captured impurities. However, too high fluid velocities must be avoided to prevent media washout.

Driven by sustainability goals, fossil-based GAC is replaced by bio-based GAC with a lower particle density and therefore a different fluidisation behaviour. Hydraulic prediction models are needed for optimal backwash procedural purposes. Accurate models should be able to predict the expansion rate based on fluid and particle properties such as the GAC buoyant density (GBD).

To determine the GBD, a liquid-solid fluidisation set-up was used to conduct experiments with 9 types of GAC which are frequently applied in drinking water treatment. A differential pressure device is used as a soft sensor to calculate the GBD. This method is accurate (1-3%) for rigid particles to determine the GBD. However, it is more complex for porous particles like GAC due to air trapped inside the pores. We carried out fluidisation experiments for GAC samples with increasing wetted fraction, obtained by sampling the samples for increasing lengths of time in a water bath.

The experimental GBD results are used to develop optimal prediction models.
Thank you for your attention
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Publications: TUDelft PureCycle, ResearchGate,

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Faculty of Mechanical, Maritime and Materials Engineering, Department Process and Energy, Section Intensified Reaction and Separation Systems
Hydraulic modelling of liquid-solid fluidisation in drinking water treatment processes

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Topics that will NOT be discussed include:

Water in space, Relation periodic system and aquatic chemistry (PHREEQC),
A dry planet, Water stress, History of water treatment in London and Amsterdam,
Water treatment processes train, Disinfection, decimal elimination capacity, Applied sustainability through softening
Use and re-use of calcite, from waste to raw materials, Resource recovery
Unit operations: multiphase flow, Irregular shaped particles (ImageJ),
Softening reactor challenge (particle profile),
Experimental research: Expansion column,
Modelling challenges: Data driven modelling (Eureqa),
Education: Working together for sustainable drinking water

GAC project
Internship industrial placement
Drinkwater ontharding (multidisciplinaire aanpak, multi-domeinen)

**Techniek**
- Regeltechniek
- Werktuigbouwkunde
- Elektrotechniek
- Onderhoud
- Ontwerp
- Gebouwbeheer

**Informatietechnologie**
- Procesautomatisering
- Alarmbeheer
- Sensor techniek
- Database beheer
- ICT, cyber-veiligheid
- Kantoor automatisering

**Mens en organisatie**
- Personele zaken
- Boekhouding, inkoop
- Kantooromgeving
- Klimaatbeheersing
- Financering
- Management
- ARBO, veiligheid
- Bewaking
- Juridische zaken, octrooi
- Opleiding, educatie
- Helpdesk

**Technologie**
- Procestechnologie
- Microbiologie
- Waterkwaliteit
- Laboratorium analyses
- Duurzaamheid
- Optimalisatie
Climate change ultimately affects us all.
Photo: Carol Byers, The Patriot Institute, 2017.
Plastic soup. 150 million tons/y of disposable plastic, of which 10 million tons of plastic ends up in the sea. Photo: Daily mail, 2018.
## Conditionering van de zuiveringsprocessen

<table>
<thead>
<tr>
<th>Keuze</th>
<th>CO₂ of HCl</th>
<th>CO₂ of HCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>H⁺/OH⁻</td>
<td>Nitrificatie</td>
<td>Oxidatie</td>
</tr>
<tr>
<td>Hardheid</td>
<td>Dosering</td>
<td></td>
</tr>
</tbody>
</table>

### Diagram

- Influent
- Snelfilter
- Ozonisatie
- Ontharding
- Koolfilter
- Nafilter
- Reservoir
- Netwerk

### PHREEQC

pH-REdox-EQuilibrium
AOC verwijdering in zuiveringsprocessen

![Diagram van zuiveringsproces]

**Assimileraar organisch koolstof (AOC) [μg/L]**

0 20 40 60 80 100 120 140 160 180 200

**AOC verwijdering**
Eureqa®: The A.I.-Powered Modeling Engine

Eureqa automates the process of model building and interpretation, enabling you to extract answers from your data 90% faster.
Waternet: some key figures

- Customers: 1.2 million
- Municipalities: 20
- Employees: 1,770
- Annual budget: € 383 million
- Drinking water: 90 million m³/y
- Drinking water connections: 100%
- Drinking water treatment plants: 2
- Drinking water pipelines: 3,100 km
- Leakage: 2-3%
- Non-revenue water: 0%
- Wastewater: 125 million m³/y
- Sewage connection: 100%
- Wastewater treatment plants: 12
- Sewerage system: 4,200 km
- Dikes: 800 km
- Nature (resources): 4,200 hectares