Softening of drinking water by the pellet reactor - Effects of influent water composition on calcium carbonate pellet characteristics

Pellet softening of drinking water can provide aesthetic, socioeconomic and environmental benefits in areas with hard water. Calcium carbonate pellets are the main by-product from pellet softening and their characteristics determine their reuse potentials. We characterized pellets from a pilot-scale pellet reactor treating 16 water types at 8 Danish drinking water treatment plants to investigate the variations in pellet characteristics and how they depend on the influent water composition. The pellets consisted of up to 100% calcium as calcium carbonate, but contained often also impurities such as strontium, magnesium, iron and sodium each contributing with up to 1.3% of the pellet mass. Other elements, including heavy metals, accounted for <0.04% of the pellet mass. The quartz sand seeding material contributed with up to 15% of the pellet mass and can be a barrier for pellet reuse. Therefore, replacing this with calcium carbonate (limestone) seeding material increases the pellet purity. Modelling the chemical speciation indicated that elements not forming carbonates (e.g. potassium and magnesium), are only incorporated into pellets to a limited extent. The concentrations of strontium, magnesium, manganese, iron and nickel in the pellets had a strong positive correlation with the influent water concentration. Consequently, the pellet purity increases if the concentration of these elements is reduced in the water before softening by other treatment technologies. Potassium, arsenic and zinc showed no or only a weak correlation. The pellets precipitated as calcite, and had a reactivity of ≤25.7% and a specific surface area of ≤0.32m²/g, which limits the potential reuse in agriculture. The pellet mineralogy was independent of the investigated range of influent water quality and seeding materials. Including pellet quality when designing the softening process can improve pellet reuse, ultimately leading to a more environmentally sustainable drinking water supply.
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Water Softeners add Comfort and Cost Water

Water softeners provide various benefits and have water loss as a downside. The amount of water consumed by a water softening system will vary depending amongst others on the softening technology and size of the system. Water softening systems can be implemented at a water treatment plant by the water utility, the so-called centralised drinking water softening (relatively large size), or as a home water treatment system by the consumer (predominantly small size).

Hard drinking water can be undesirable from a human health, environmental, socioeconomic and aesthetic point of view. Hard water increases the use of soap and detergents and has an increased tendency of calcium carbonate scaling (lime scaling) on surfaces in contact with the water. Lime scaling can decrease the service life of household appliances and installations, and increase both the energy consumption by household installations (e.g. kettles and heating elements) and the use of descaling agents. Avoiding these effects can lead to both socioeconomic and environmental benefits. Hard water in most cases has a relatively low pH value and might contain high hydrogen carbonate and sulphate concentrations, and in this case consequently has an increased solubility of copper and lead. This may cause leaching from copper and lead containing pipe materials and exceedance of guideline concentrations. Centralised drinking water softening therefore is an effective and efficient lead and copper control strategy. However, reducing the water hardness too much may lead to drinking water that is corrosive towards steel and cast iron piping material.

Several softening technologies exist with different mechanisms for hardness removal including precipitation, ion exchange and membrane separation. In addition, each softening technology has multiple design options depending on e.g. the choice of softening chemical and membrane type. All softening technologies reduce water hardness but the benefits and downsides vary depending on the removal mechanism and process design. Selection of the most appropriate softening technology for both large and small size implementation therefore requires comparison and evaluation in a holistic framework including economic, societal, technical and environmental aspects.

A holistic comparison of water softening technologies is since early 2017 under development at the Department of Environmental Engineering of the Technical University of Denmark, using the long-term experiences with different softening technologies applied in full-scale in the Netherlands, Flanders and Denmark.

Our presentation will showcase the available softening technologies and their most recent developments, and will highlight the strengths and weaknesses of the different technologies thereby specifically addressing the environmental benefits and downsides, i.e. the water consumption of a water softening system. A procedure for comparing and evaluating different softening technologies will also be offered, thereby facilitating a more optimal technology selection and decision making.
Blødgøring: hvor meget kalk fjernes fra vandet

General information
State: Published
Organisations: Department of Environmental Engineering, Urban Water Systems
Contributors: Tang, C., Albrechtsen, H.
Number of pages: 2
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Publication date: 2018
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Holistic design of centralised drinking water softening

General information
State: Published
Contributors: Tang, C., Rosshaug, P. S., Kristensen, J. B., Albrechtsen, H.
Number of pages: 2
Publication date: 2018
Peer-reviewed: Yes
Electronic versions:
Holistic_design_of_centralised_drinking_water_softening_ID_46_.pdf
Source: PublicationPreSubmission
Source-ID: 149219468
Research output: Research - peer-review › Conference abstract for conference – Annual report year: 2018
Optimizing the benefits from drinking water softening by better calculating the calcium carbonate precipitation potential - CCPP

General information
State: Published
Organisations: Department of Environmental Engineering, Urban Water Systems, HOFOR A/S, NIRAS A/S
Contributors: Tang, C., Rosshaug, P. S., Kristensen, J. B., Rygaard, M., Albrechtsen, H.
Number of pages: 1
Publication date: 2017
Peer-reviewed: Yes
Electronic versions:
**Fremtidens vandteknologi er blå - ikke grønne**

**General information**
State: Published
Organisations: Department of Environmental Engineering, Urban Water Systems
Contributors: Tang, C.
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**Publication information**
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Issue number: 6
ISSN (Print): 1602-3609
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ISI indexed (2013): ISI indexed no
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Original language: Danish
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**Bibliographical note**
Tidsskriftartikel (ikke peer review)
Source: PublicationPreSubmission
Source-ID: 140387016
Research output: Communication › Journal article – Annual report year: 2017

**Pellets fra central blødgøring - fra affald til ressource**

**General information**
State: Published
Organisations: Department of Environmental Engineering, Urban Water Systems, HOFOR A/S
Contributors: Tang, C., Albrechtsen, H., Lopato, L., Nyberg Kornholt, S.
Pages: 54-55
Publication date: 2017
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Journal: DanskVand
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ISSN (Print): 1602-3609
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Original language: Danish
Electronic versions:
DanskVand_2017.pdf
Source: PublicationPreSubmission
Source-ID: 128828780
Research output: Research › Journal article – Annual report year: 2017

**Possibilities for reuse of calcium carbonate pellets from drinking water softening**

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State: Published
Organisations: Department of Environmental Engineering, Urban Water Systems, HOFOR A/S
Contributors: Tang, C., Lopato, L., Nyberg Kornholt, S., Albrechtsen, H.
Host publication information
Title of host publication: Abstract proceedings - 11th annual meeting Danish water forum
Place of publication: Frederiksberg
Publisher: University of Copenhagen
Editors: Flindt Jørgensen, L., Mosolff Larsen, T., Jensen, B. K.
Electronic versions:
Abstract proceedings book
Source: PublicationPreSubmission
Source-ID: 128828913
Research output: Research - peer-review » Conference abstract in proceedings – Annual report year: 2017

Optimized Softening - Note 1: Reuse of Pellets from Central Drinking Water Softening

General information
State: Published
Organisations: Department of Environmental Engineering, Urban Water Systems
Contributors: Tang, C., Albrechtsen, H.
Number of pages: 12
Publication date: 2016

Publication information
Place of publication: Kgs. Lyngby
Publisher: Technical University of Denmark, DTU Environment
Original language: English
Research output: Commissioned » Report – Annual report year: 2017

Optimized Softening - Note 2: Pellet Characteristics

General information
State: Published
Organisations: Department of Environmental Engineering, Urban Water Systems
Contributors: Tang, C., Albrechtsen, H.
Number of pages: 30
Publication date: 2016

Publication information
Place of publication: Kgs. Lyngby
Publisher: Technical University of Denmark, DTU Environment
Original language: English
Research output: Commissioned » Report – Annual report year: 2017

Optimized Softening - Note 3: Optimization of Pellets from Drinking Water Softening

General information
State: Published
Organisations: Department of Environmental Engineering, Urban Water Systems
Contributors: Tang, C., Albrechtsen, H.
Number of pages: 8
Publication date: 2016

Publication information
Place of publication: Kgs. Lyngby
Publisher: Technical University of Denmark, DTU Environment
Original language: English
Research output: Commissioned » Report – Annual report year: 2017

Samarbejde mellem forskning og forsyning giver bonus

General information
State: Published
Vandkvalitetskrav for anvendelser af opsamlet regnvand i tøjvask, toaletskyl og brandslukning: Centralt sekundavandsanlæg i bydelen Nye, Aarhus (baggrundsnotat)

General information
State: Published
Organisations: Department of Environmental Engineering, Urban Water Systems
Contributors: Tang, C., Albrechtsen, H.
Number of pages: 19
Publication date: 2016

Wastewater Treatment Potentials in Kangerlussuaq: Characterization of Flow and Chemical Loadings

General information
State: Published
Organisations: Department of Environmental Engineering, Urban Water Systems, Technical University of Denmark
Contributors: Konring, A., Tang, C.
Number of pages: 2
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Book of Abstracts Artek Event 2016.pdf

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Byg Report R-340
Source: PublicationPreSubmission
Source-ID: 123425720
Research output: Research › Conference abstract in proceedings – Annual report year: 2016
Biocides in urban wastewater treatment plant influent at dry and wet weather: concentrations, mass flows and possible sources

In recent years, exterior thermal insulation systems became more and more important leading to an increasing amount of houses equipped with biocide-containing organic façade coatings or fungicide treated wood. It is known that these biocides, e.g. terbutryn, carbendazim, and diuron, as well as wood preservatives as propiconazole, leach out of the material through contact with wind driven rain. Hence, they are present in combined sewage during rain events in concentrations up to several hundred ng L(-1). The present study focused on the occurrence of these biocides in five wastewater treatment plants in Denmark and Sweden during dry and wet weather. It was discovered, that biocides are detectable not only during wet weather but also during dry weather when leaching from façade coatings can be excluded as source. In most cases, the concentrations during dry weather were in the same range as during wet weather (up to 100 ng L(-1)); however, for propiconazole noteworthy high concentrations were detected in one catchment (4.5 μg L(-1)). Time resolved sampling (12 × 2 h) enabled assessments about possible sources. The highest mass loads during wet weather were detected when the rain was heaviest (e.g. up to 116 mg h(-1) carbendazim or 73 mg h(-1) mecoprop) supporting the hypothesis that the biocides were washed off by wind driven rain. Contrary, the biocide emissions during dry weather were rather related to household activities than with emissions from buildings, i.e., emissions were highest during morning and evening hours (up to 50 mg h(-1)). Emissions during night were significantly lower than during daytime. Only for propiconazole a different emission behaviour during dry weather was observed: the mass load peaked in the late afternoon (3 g h(-1)) and declined slowly afterwards. Most likely this emission was caused by a point source, possibly from inappropriate cleaning of spray equipment for agriculture or gardening.
Scopus rating (2012): CiteScore 5.15 SJR 2.914 SNIP 2.442
Web of Science (2012): Impact factor 4.655
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 5.43 SJR 2.862 SNIP 2.355
Web of Science (2011): Impact factor 4.865
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.592 SNIP 2.192
Web of Science (2010): Impact factor 4.546
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 2.319 SNIP 2.224
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 2.073 SNIP 2.178
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.94 SNIP 2.184
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.902 SNIP 2.233
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Scopus rating (2003): SJR 1.702 SNIP 1.908
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Scopus rating (2002): SJR 1.568 SNIP 1.757
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 1.319 SNIP 1.69
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 1.399 SNIP 1.662
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 1.432 SNIP 1.55

Original language: English
DOI:
10.1016/j.watres.2014.04.014
Source: PublicationPreSubmission
Source-ID: 91720768
Research output: Research - peer-review › Journal article – Annual report year: 2014

Projects:

**Optimal and holistic implementation of central drinking water softening**
Tang, C., PhD Student, Department of Environmental Engineering
Albrechtsen, H., Main Supervisor
Rygaard, M., Supervisor
Wormslev, E. C., Supervisor
Samfinansierede - Virksomhed
01/12/2016 → 28/01/2020
Award relations: Optimal and holistic implementation of central drinking water softening
Project: PhD
Activities:

11th annual Danish Water Forum (DWF) 2017
Period: 30 Jan 2017
Camilla Tang (Speaker)
Department of Environmental Engineering
Urban Water Systems

Related event

11th annual Danish Water Forum (DWF) 2017
30/01/2017 → 30/01/2017
Frederiksberg, Denmark
Activity: Talks and presentations › Conference presentations

Prizes:

3rd prize "Best Student Presentation" at ARTEK Event 2016, International Conference - Sanitation in Cold Climate Regions
Camilla Tang (Recipient)
Department of Environmental Engineering, Urban Water Systems

Details
Awarded date: 14 Apr 2016
Prize: Prizes, scholarships, distinctions

Best Student Project winner at the VandTek fair 2016
Camilla Tang (Recipient)
Department of Environmental Engineering, Urban Water Systems

Details
Awarded date: 22 Sep 2016
Prize: Prizes, scholarships, distinctions

Press clippings:

Blødt vand i hovedstaden skal spare husstande for millioner
Camilla Tang
14/02/2017
Department of Environmental Engineering, Urban Water Systems

Media contribution (1)

Blødt vand i hovedstaden skal spare husstande for millioner
14/02/2017
Politiken (National), Denmark, Web
Anna Belling-Ladegaard
http://politiken.dk/indland/art5833405/Bi%C3%B8dt-vand-i-hovedstaden-skal-spare-husstande-for-millioner
Camilla Tang
Press/Media: Press / Media