## Determination of chlorinated 5-methyl-5-hydroxyfuranones in drinking water, in chlorinated humic water, and in pulp bleaching liquor

Hydroxyfuranones with monochloro-, dichloro-, and trichloromethyl groups at C-5 (5-MHFs) were qualitatively and quantitatively determined in extracts of chlorination stage bleaching liquors (CBL) from a pulp mill, of chlorinated natural humic water (HW), and of three samples of drinking water (DW1-3) treated with various disinfectants. In addition, the mutagenic potency of the compounds in Ames tester strain TA100 was observed, and their stability in water at pH 2 and pH 8 was determined. In CBL, eight of the nine hydroxyfuranones studied were observed, and some of the compounds were found in concentrations higher than 0.5 mg/L. Thus, these compounds must be considered as major chlorinated byproducts of chlorine bleaching. In the drinking water extracts, the 5-dichloromethyl compounds and one 5-monochloromethyl compound were detected. The concentration of the compounds ranged from <1 to 45 ng/L. The compounds were found to be mutagenic in the Ames assay; the most potent mutagen generated about 1.5 revertants/nmol, while the weakest mutagen generated about 0.3 revertants/nmol. The total mutagenicity contribution of these hydroxyfuranones was approximately 2% in the sample of CBL and much less than 1% in the samples of drinking water. The stability of the compounds was higher at pH 2 than at pH 8, and in general, a higher degree of chlorine substitution increased the compound stability.

### General information

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Organisations: Department of Organic Chemistry, Abo Akademi University, Åbo Akademi University
Contributors: Franzén, R., Kronberg, L.
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### Bibliographical note

EXT=”Franzen, Robert"
Source: Scopus
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Research output: Contribution to journal › Article › Scientific › peer-review

## Occurrence of some chlorinated enol lactones and cyclopentene-1,3-diones in chlorine-treated waters

Enol lactones (5-dichloromethylene-2-furanones) and 2,2- dichlorocyclopentene-1,3-diones, a total of six compounds, were synthesized and subsequently qualitatively and quantitatively determined in a sample of chlorination stage liquor from the bleaching of softwood kraft pulp (CBL), in chlorine-treated natural humic water (HW), and in three samples of drinking water treated with various disinfectants (DW1-3). All the compounds could be observed in the samples, in concentrations ranging from 2 to 170 µg/L in CBL, from 7 to 65 ng/L in HW, and at most a few nanograms per liter in DW1-3. The compounds were found to be weakly mutagenic in the Ames assay (strain TA100 without metabolic activation). The contribution of the compounds to the total mutagenicity in the studied samples was negligible. The compounds were unstable in aqueous solutions at pH 7.0, and under these conditions they were in part converted to 5-(dichloromethyl)-5-hydroxy-2-furanones. In acidified methanol, the enol lactones were partially converted to 5-(dichloromethyl)- 5-methoxy-2-furanones.

### General information

Publication status: Published
MoE publication type: A1 Journal article-refereed
Organisations: Abo Akad Univ, Abo Akademi University, Dept Phys, Abo Akademi University, Åbo Akademi, Department of Organic Chemistry
Contributors: Smeds, A., Franzen, R., Kronberg, L.
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Source: Scopus
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Research output: Contribution to journal › Article › Scientific › peer-review

**Anaerobic solubilisation of nitrogen from municipal solid waste (MSW)**
This paper reviews anaerobic solubilisation of nitrogen municipal solid waste (MSW) and the effect of current waste management practises on nitrogen release. The production and use of synthetically fixed nitrogen fertiliser in food production has more than doubled the flow of excessive nitrogenous material into the community and hence into the waste disposal system. This imbalance in the global nitrogen cycle has led to uncontrolled nitrogen emissions into the atmosphere and water systems. The nitrogen content of MSW is up to 4.0% of total solids (TS) and the proteins in MSW have a lower rate of degradation than cellulose. The proteins are hydrolysed through multiple stages into amino acids that are further fermented into volatile fatty acids, carbon dioxides, hydrogen gas, ammonium and reduced sulphur. Anaerobic digestion of MSW putrescibles could solubilise around 50% of the nitrogen. Thus, the anaerobic digestion of putrescibles may become an important method of increasing the rate of nitrogen recycling back to the ecosystem. A large proportion of the nitrogen in MSW continues to end up in landfills; for example, in the EU countries around 2 million tonnes of nitrogen is disposed of annually this way. Nitrogen concentration in the leachates of existing landfills are likely to remain at a high level for decades to come. Under present waste management practices with a relatively low level of efficiency in the source segregation or mechanical sorting of putrescibles from grey waste and with a low level of control over landfill operating procedures, nitrogen solubilisation from landfilled waste will take at least a century.

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MoE publication type: A1 Journal article-refereed
Organisations: University of Jyväskylä, Jyväskylän yliopisto, Metener Ltd
Contributors: Jokela, J. P. Y., Rintala, J. A.
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ASJC Scopus subject areas: Environmental Engineering, Applied Microbiology and Biotechnology, Waste Management and Disposal, Pollution
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DOIs:

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Source: Scopus
Source ID: 36248984678
Research output: Contribution to journal › Article › Scientific › peer-review

**Thermophilic aerobic wastewater treatment, process performance, biomass characteristics, and effluent quality**
Thermophilic aerobic wastewater treatment is reviewed. Thermophilic processes have been studied in laboratory and pilot-scale while full-scale applications are rare. The paper focuses on the microbiology of aerobic thermophiles, performance of the aerobic wastewater treatments, sludge yield, and alternatives to enhance performance of the thermophilic process.

Thermophilic processes have been shown to operate under markedly high loading rates (30-180 kg COD $m^{-3}d^{-1}$). Reported sludge production values under thermophilic conditions vary between 0.05 and 0.3 kg SS kg $COD_{removed}$, which are about the same or lower than generally obtained in mesophilic processes. Compared to analogous mesophilic treatment, thermophilic treatment commonly suffers from poorer effluent quality, measured by lower total COD and filtrated (GF-A) COD removals. However, in the removal of soluble (bacterial membrane filtered) COD both mesophilic and thermophilic treatments have produced similar results. Sludge settleability in thermophilic processes have been reported to be better or poorer than in analogous mesophilic processes, although cases with better settling properties are rare. Combining thermophilic with mesophilic treatment or ultrafiltration may in some cases markedly improve effluent quality.

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**Biogas from energy crops - Optimal pre-treatments and storage, co-digestion and energy balance in boreal conditions**
The objective of this research was to evaluate the biogas production from crops in boreal conditions, focusing on the optimal pre-treatment and storage methods, co-digestion and energy balance of farm-scale crop based biogas plants. Alkaline treatments offered some potential for improving the methane yield from grass and sugar beet tops. The results show that the $CH_4$ yield of energy crops can be maintained by appropriate ensiling conditions for even after 11 months in ambient conditions. The $CH_4$ yield was best preserved with wet grass mixture without additives. Co-digestion of manure and crops was shown to be feasible with feedstock volatile solids (VS) containing up to 40% of crops. The highest specific methane yields of 268, 229 and 213ICH $_4kg^{-1}$ $VS_{added}$ in co-digestion of cow manure with grass, sugar beet tops and straw, respectively, were obtained during feeding with 30% of crop in the feedstock, corresponding to 85-105% of the total methane potential in the substrates as determined by batch assays. The energy output:input ratio of farm-scale grass silage based biogas plant varied significantly (3.5-8.2) with different assumptions and system boundaries being lowest when using only inorganic fertilizers and highest when half of the heat demand of the system could be covered by metabolic heat.

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Organisations: Jyväskylän yliopisto, MTT Agrifood Research Finland, Jyväskylä Innovation Ltd., University of Jyväskylä
Contributors: Seppälä, M., Paavola, T., Lehtomäki, A., Pakarinen, O., Rintala, J.
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Keywords: Co-digestion, Energy balance, Energy crops, Methane production, Pre-treatment, Storage
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10.2166/wst.2008.503
Source: Scopus
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Research output: Contribution to journal › Article › Scientific › peer-review

**Effects of solid-liquid separation on recovering residual methane and nitrogen from digested dairy cow manure**

The feasibility of optimizing methane and nitrogen recovery of samples obtained from farm biogas digester (35 °C) and post-storage tank (where digested material is stored for 9-12 months) was studied by separating the materials into different fractions using 2, 1, 0.5 and 0.25 mm sieves. Mass-balances revealed that digested material mainly consists of <0.25 mm (60-69%) and >2 mm (18-27%) fractions, while fractions between 2 and 0.25 mm made the rest. Incubation of solid fractions >0.25 mm of digester material at 35 °C resulted in specific methane yields of 0.060-0.085 $m^3$ $kg^{-1}$ volatile solids (VS) during initial 30-50 d and 0.16-0.18 $m^3$ $kg^{-1}$ VS at the end of 340 d incubation. Similarly, fractions >0.25 mm of post-storage tank material produced 0.055-0.092 $m^3$ $kg^{-1}$ VS and 0.13-0.16 $m^3$ $kg^{-1}$ VS of methane after 30-50 d and after 250 d, respectively. Methane yields for fractions ≤0.25 mm of post-storage tank was 0.03 $m^3$ $kg^{-1}$ VS after 30-50 d and 0.05 $m^3$ $kg^{-1}$ VS after 250 d compared to 0.20 $m^3$ $kg^{-1}$ VS and 0.41 $m^3$ $kg^{-1}$ VS, respectively for the same fraction of digester material. Separation of digested cow manure into solids and liquid fractions to recover methane may be feasible only for post-storage tank material and not for digester material. Nitrogen management would not be feasible with neither material as total nitrogen and ammonium-nitrogen concentrations were equally distributed among the segregated fractions.

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Contributors: Kaparaju, P. L. N., Rintala, J. A.
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Keywords: Anaerobic digestion, Digested material, Farm-scale digester, Fractionation, Methane, Post-storage tank
DOIs:

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Source: Scopus
Source ID: 34848884581
Research output: Contribution to journal › Article › Scientific › peer-review

**Effects of storage on characteristics and hygienic quality of digestates from four co-digestion concepts of manure and biowaste**

This study evaluated the effects of storage in northern winter conditions (5 °C) on the characteristics and nutrients separation of digestates from co-digestion of manure and biowaste as well as the hygienic quality of the digestates after digestion and storage. During 3-11 months' storage average nitrogen losses and reductions of total solids (TS) and volatile solids (VS) were 0-15%. With some exceptions, soluble chemical oxygen demand (SCOD) had increased slightly (from ~6.5 to ~7.5 g/l) after 3 months' storage, while after 9-11 months' it had decreased from 8.3-11 to 5.6-8.4 g/l. The concentrations of $P_{tot}$ and PO4-P in the separated liquid fractions decreased 40-57% after 3 months' storage and 71-91% after 9 months' storage compared to the initial concentrations. The methane potential losses during 9-11 months' storage corresponded 0-10% of the total methane potential without storage. The hygienic quality of the digestates from the 55 °C reactor and during storage fulfilled the Animal By-Products Regulation (ABPR) demands while the 35 °C digestate contained 0-105 cfu/g of indicator bacteria (faecal coliforms, enterobacteria, enterococcus) and >10 cfu/g of spiked

salmonella, which amounts decreased slowly during storage. Sulphite reducing clostridia was not affected by either digestion or storage.

### General information

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Organisations: Jyväskylän yliopisto, University of Jyväskylä
Contributors: Paavola, T., Rintala, J.
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Original language: English
ASJC Scopus subject areas: Agronomy and Crop Science, Food Science, Process Chemistry and Technology, Applied Microbiology and Biotechnology, Bioengineering, Environmental Engineering, Waste Management and Disposal
Keywords: Biowaste, Digestate, Hygienic quality, Manure, Solid/liquid separation
DOIs:

10.1016/j.biortech.2008.01.005
Source: Scopus
Source ID: 44449089925
Research output: Contribution to journal › Article › Scientific › peer-review

## Storing energy crops for methane production: Effects of solids content and biological additive

The effect of storage on chemical characteristics and $CH_4$ yield (taking into account loss of VS during storage) of a mixture of grasses and ryegrass, ensiled as such (low solids content) and after drying (medium and high solids) with and without biological additive, were studied in field and laboratory trials. Up to 87% and 98% of $CH_4$ yield was preserved with low solids grass (initial TS 15.6%) and high solids ryegrass (initial TS 30.4%), respectively, after storage for 6 months, while under suboptimal conditions at most 37% and 52% of $CH_4$ yield were lost. Loss in $CH_4$ yield was mainly due to VS loss, presumably caused by secondary fermentation as also suggested by increasing pH during storage. Biological additive did not assist in preserving the $CH_4$ yield.

### General information

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MoE publication type: A1 Journal article-refereed
Organisations: Jyväskylän yliopisto, University of Jyväskylä
Contributors: Pakarinen, O., Lehtomäki, A., Rissanen, S., Rintala, J.
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Original language: English
ASJC Scopus subject areas: Agronomy and Crop Science, Food Science, Process Chemistry and Technology, Applied Microbiology and Biotechnology, Bioengineering, Environmental Engineering, Waste Management and Disposal
Keywords: Anaerobic digestion, Biogas, Energy crop, Grass, Storage
DOIs:

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Source: Scopus
Source ID: 44449146372
Research output: Contribution to journal › Article › Scientific › peer-review

### Methane oxidation in a boreal climate in an experimental landfill cover composed from mechanically-biologically treated waste

The present study evaluated microbial methane ($CH_4$) oxidation in a boreally located outdoor landfill lysimeter (volume 112 $m^3$, height 3.9 m) filled with mechanically-biologically treated waste (MBT residual) and containing a cover layer made from the same MBT residual. The calculations based on gas emission and pore gas measurements showed that, between April and October 2005, a significant proportion (> 96%) of the methane produced (< 23 l $CH_4$ $m^{-2}$ $d^{-1}$) in the lysimeter was oxidized. Methane was oxidized mainly at the depths of 35-75 cm, as indicated by the upward decrease both in the methane concentration and in the methane-to-carbon dioxide ratio in the pore gas. Lower methane oxidation (< 0.8 $CH_4$ $m^{-2}$ $d^{-1}$; this was < 22% of the methane produced) was observed only during the coldest time of the year (January 2006), apparently due to the fall in temperature at the depths of 25-70 cm (from 9-25 °C during April to October to 2-9 °C in January). Unexpectedly, the highest methane oxidation potential (MOP) was observed in samples from the top layer where exposure to methane was low. Overall, the results show that MBT residual is a suitable support medium for methane oxidation in landfill covers in field conditions in a boreal climate.

#### General information

Publication status: Published
MoE publication type: A1 Journal article-refereed
Organisations: Jyväskylän yliopisto, University of Jyväskylä
Contributors: Einola, J. M., Sormunen, K. M., Rintala, J. A.
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#### Publication information

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ISSN (Print): 0048-9697
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Original language: English
ASJC Scopus subject areas: Environmental Chemistry, Pollution, Waste Management and Disposal, Environmental Engineering
Keywords: Greenhouse gases, Landfill gas, Low temperature, Mechanical-biological treatment, Methane oxidation, Municipal solid waste
DOIs:

10.1016/j.scitotenv.2008.08.016
Source: Scopus
Source ID: 56249090340
Research output: Contribution to journal › Article › Scientific › peer-review

### Internal leachate quality in a municipal solid waste landfill: Vertical, horizontal and temporal variation and impacts of leachate recirculation

The aim of this study was to monitor and characterise internal leachate quality at a Finnish municipal solid waste landfill (Lahti, Kujala, in operation for approximately 50 years) to provide information about its horizontal and vertical variation as well as effects of leachate recirculation on leachate quality. The study area (approximately 4 h) of the landfill had 14 monitoring wells for leachate quality monitoring over a 2-year period. The leachate was monitored for COD, BOD, TKN, $NH_4$-N, Cl, pH and electric conductivity. The results showed high horizontal and vertical variability in leachate quality between monitoring wells, indicating that age and properties of waste, local conditions (e.g., water table) and degradation and dilution processes have a marked effect on local leachate quality. The mean COD values (642-8037 mg/l) and mean BOD/COD ratios (0.08-0.17) from the different monitoring wells were typical of landfills in the methanogenic phase of degradation. The leachate in the monitoring wells was notably more concentrated than the leachate effluent used for leachate recirculation. In the landfill as a whole the effects of the leachate recirculation on leachate quality, although difficult to distinguish from those caused by other factors, appeared to be minor during the study period.

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Contributors: Sormunen, K., Ettala, M., Rintala, J.
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Original language: English
ASJC Scopus subject areas: Health, Toxicology and Mutagenesis, Pollution, Waste Management and Disposal, Environmental Chemistry, Environmental Engineering
Keywords: Landfill, Leachate, Nitrogen, Organic matter, Sampling
DOIs:

10.1016/j.jhazmat.2008.03.081
Source: Scopus
Source ID: 54549090158
Research output: Contribution to journal › Article › Scientific › peer-review

**Impact of crop species on bacterial community structure during anaerobic co-digestion of crops and cow manure**
The bacterial communities in three continuously stirred tank reactors co-digesting cow manure with grass silage, oat straw, and sugar beet tops, respectively, were investigated by 16S rRNA gene-based fingerprints and clone libraries. The analyses revealed both clearly distinct and similar phylotypes in the bacterial communities between the reactors. The major groups represented in the three reactors were Clostridia, unclassified Bacteria, and Bacteroidetes. Phylotypes affiliated with Bacilli or Deltaproteobacteria were unique to the sugar beet and straw reactor, respectively. Unclassified Bacteria dominated in sugar beet reactor while in the straw and grass reactor Clostridia was the dominant group. An increase in organic loading rate from 2 to 3 kg volatile solids $m^{-3}$ $d^{-1}$ resulted in larger changes in the bacterial community in the straw compared to grass reactor. The study shed more light on the evolution of bacterial community during anaerobic co-digestion of different crops and manure to methane. 

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Organisations: Tampere University of Technology, Jyväskylän yliopisto, Jyväskylä Innovation Ltd., University of Jyväskylä
Contributors: Wang, H., Lehtomäki, A., Tolvanen, K., Puhakka, J., Rintala, J.
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ISSN (Print): 0960-8524
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Scopus rating (2009): SJR 1.915 SNIP 2.234
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ASJC Scopus subject areas: Bioengineering, Environmental Engineering, Waste Management and Disposal
Keywords: Anaerobic digestion, Bacterial community structure, Continuously stirred tank reactor, Denature gradient gel electrophoresis, Terminal restriction fragment length polymorphism
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10.1016/j.biortech.2008.10.040
URLs:

http://www.scopus.com/inward/record.url?scp=58149189873&partnerID=8YFLogxK (Link to publication in Scopus)

**Bibliographical note**
poistettu tupla r=235<br/>Contribution: organisation=keb bio,FACT1=1
Source: researchoutputwizard
Source ID: 11706
Research output: Contribution to journal › Article › Scientific › peer-review

### Biogas production from boreal herbaceous grasses - Specific methane yield and methane yield per hectare

The objective of this study was to determine the specific methane yields of four grass species (cocksfoot, tall fescue, reed canary grass and timothy) cultivated under boreal conditions as well as how harvesting time and year of cultivation affects the specific methane yields per ha. The specific methane yields of all grasses and all harvests varied from 253 to 394 Nl $CH_4$/kg volatile solids (VS) added. The average specific methane yield of the 1st harvest of all grasses was higher than the 2nd harvests. In this study the methane and energy yields from different harvest years were ranged from 1200 to 3600 $Nm^3$ $CH_4$/ha/a, corresponding from 12 to 36 $MWh_{CH4}$/ha/a. The methane yield per hectare of the 1st harvest was always higher than that of the 2nd harvest per hectare because of the higher dry matter yield and specific methane yield. High biomass yield per hectare, good digestibility and regrowth ability after harvesting are important factors when choosing grass species for biogas production. If 30% of fallow and the second harvest of grassland were cultivated grasses and harvested for biogas production in Finland, the energy produced could be 4.9 $TWh_{CH4}$.

#### General information

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MoE publication type: A1 Journal article-refereed
Organisations: Jyväskylän yliopisto, University of Jyväskylä
Contributors: Seppälä, M., Paavola, T., Lehtomäki, A., Rintala, J.
Number of pages: 7
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Peer-reviewed: Yes

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Volume: 100
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ISSN (Print): 0960-8524
Ratings:

Scopus rating (2009): SJR 1.915 SNIP 2.234
Original language: English
ASJC Scopus subject areas: Bioengineering, Environmental Engineering, Waste Management and Disposal
Keywords: Biogas production, Grass, Harvest time, Specific methane yield
DOIs:

10.1016/j.biortech.2009.01.044
Source: Scopus
Source ID: 62649158890
Research output: Contribution to journal › Article › Scientific › peer-review

### Weathering of gasification and grate bottom ash in anaerobic conditions

The effect of anaerobic conditions on weathering of gasification and grate bottom ash were studied in laboratory lysimeters. The two parallel lysimeters containing the same ash were run in anaerobic conditions for 322 days, after which one was aerated for 132 days. The lysimeters were watered throughout the study and the quality of leachates and changes in the binding of elements into ash were observed. The results show that organic carbon content and initial moisture of ashes are the key parameters affecting the weathering of ashes. In the grate ash the biodegradation of organic carbon produced enough $CO_2$ to regulate pH. In contrast the dry gasification ash, containing little organic carbon, was not carbonated under anaerobic conditions and the pH decreased only after aeration was started. During the aeration the $CO_2$ absorption capacity was not reached, indicating that intense aeration would be needed to fully carbonate gasification ash. The results indicate that in common weathering practice the main emissions-reducing processes are leaching and carbonation due to $CO_2$ from biodegradation. The results of the aeration study suggest that the role of atmospheric $CO_2$ in the weathering process was insignificant.

#### General information

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Organisations: Jyväskylän yliopisto, University of Jyväskylä
Contributors: Sivula, L., Ilander, A., Väisänen, A., Rintala, J.
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ISSN (Print): 0304-3894
Ratings:
Scopus rating (2010): SJR 1.677 SNIP 1.706
Original language: English
ASJC Scopus subject areas: Health, Toxicology and Mutagenesis, Pollution, Waste Management and Disposal, Environmental Chemistry, Environmental Engineering
Keywords: Aeration, Anaerobic, Carbonation, Gasification ash, Weathering
DOIs:
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Research output: Contribution to journal › Article › Scientific › peer-review

### Effect of micro-aeration and leachate replacement on COD solubilization and VFA production during mono-digestion of grass-silage in one-stage leach-bed reactors

The effect of micro-aeration and leachate replacement with fresh water on chemical oxygen demand (COD) solubilization and volatile fatty acid (VFA) production during the mono-digestion of grass-silage in one-stage leach-bed reactors (LBRs) was investigated in four LBRs, L0 (control), L1, L2 and L3 in batch mode at 35 ± 1 °C for 57 days. Results showed that leachate replacement without pH adjustment (L3) resulted in 2.7 and 1.3 times more SCOD in the leachate compared to control (L0) or leachate replacement with initial pH adjustment (L1), respectively. Micro-aeration at flow rate of 1 L $min^{-1}$ (2.5 L of air) in L2 resulted in 4-fold increase in VFA production (from 2.2 to 9 g $L^{-1}$) without any significant increase in cumulative SCOD in the leachate. Increasing the air flow rate to 4 L $min^{-1}$ (24 L of air) in L2 resulted in a decrease in SCOD extraction. Leachate replacement without pH adjustment (L3) resulted in higher (mean) specific SCOD production (0.51 g SCOD $g^{-1}$ $VS_{added}$) than control (L0, 0.34 g SCOD $g^{-1}$ $VS_{added}$), leachate replacement with initial pH adjustment (L1, 0.33 g SCOD $g^{-1}$ $VS_{added}$) or micro-aeration (L2, 0.32 g SCOD $g^{-1}$ $VS_{added}$). These results suggest that the challenge of hydrolysis during anaerobic digestion of particulate substrates like grass-silage can be improved by micro-aeration and leachate replacement methods with or without pH adjustment.

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Contributors: Jagadabhi, P. S., Kaparaju, P., Rintala, J.
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DOIs:
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Source ID: 73749087133
Research output: Contribution to journal › Article › Scientific › peer-review

### Two-stage anaerobic digestion of tomato, cucumber, common reed and grass silage in leach-bed reactors and upflow anaerobic sludge blanket reactors

Anaerobic digestion of tomato, cucumber, common reed and grass silage was studied in four separate two-stage reactor configuration consisting of leach bed reactor (LBR) and upflow anaerobic sludge blanket reactor (UASB). LBR studies showed that COD solubilization for cucumber and grass silage was higher (50%) than tomato (35%) and common reed (15%). Results also showed that 31-39% of initial TKN present in tomato and cucumber was solubilized in the leachates and 47-54% of the solubilized TKN was converted to $NH_4$-N. The corresponding values for common reed and grass silage were 38-50% and 18-36%, respectively. Biomethanation of the leachates in UASB reactors resulted in methane yields of 0.03-0.14$m^3$ $CH_4$ $kg^{-1}$$VS_{fed}$ for the studied crop materials. Thus, high COD solubilization, high nitrogen mineralization and solubilization rates were feasible during anaerobic digestion of lignocellulosic materials in a two-stage LBR-UASB reactor system.

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Organisations: Urban circular bioeconomy (UrCirBio), Jyväskylän yliopisto, University of Jyväskylä
Contributors: Jagadabhi, P. S., Kaparaju, P., Rintala, J.
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ASJC Scopus subject areas: Bioengineering, Environmental Engineering, Waste Management and Disposal
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Source ID: 79951945757
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**The effect of organic loading rate and retention time on hydrogen production from a methanogenic CSTR**
The possibility of shifting a methanogenic process for hydrogen production by changing the process parameters viz., organic loading rate (OLR) and hydraulic retention time (HRT) was evaluated. At first, two parallel semi-continuously fed continuously stirred tank reactors (CSTR) were operated as methanogenic reactors (M1 and M2) for 78days. Results showed that a methane yield of 198-218L/kg volatile solids fed ($VS_{fed}$) was obtained when fed with grass silage at an OLR of 2kgVS/$m^3$/d and HRT of 30days. After 78days of operation, hydrogen production was induced in M2 by increasing the OLR from 2 to 10kgVS/$m^3$/d and shortening the HRT from 30 to 6days. The highest $H_2$ yield of 42L/kgVS$_{fed}$ was obtained with a maximum $H_2$ content of 24%. The present results thus demonstrate that methanogenic process can be shifted towards hydrogen production by increasing the OLR and decreasing HRT.

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Organisations: Urban circular bioeconomy (UrCirBio), Jyväskylän yliopisto, University of Jyväskylä
Contributors: Pakarinen, O., Kaparaju, P., Rintala, J.
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ASJC Scopus subject areas: Bioengineering, Environmental Engineering, Waste Management and Disposal
Keywords: Grass silage, Hydrogen, Methane, Shifting, VFA
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Source ID: 80052377734
Research output: Contribution to journal › Article › Scientific › peer-review

**Magnetophoretic harvesting of oleaginous Chlorella sp. by using biocompatible chitosan/magnetic nanoparticle composites**

The consumption of energy and resources such as water in the cultivation and harvesting steps should be minimized to reduce the overall cost of biodiesel production from microalgae. Here we present a biocompatible and rapid magnetophoretic harvesting process of oleaginous microalgae by using chitosan-$Fe_3O_4$ nanoparticle composites. Over 99% of microalgae was harvested by using the composites and the external magnetic field without changing the pH of culture medium so that it may be reused for microalgal culture without adverse effect on the cell growth. Depending on the working volume (20-500mL) and the strength of surface magnetic-field (3400-9200G), the process of harvesting microalgae took only 2-5min. The method presented here not only utilizes permanent magnets without additional energy for fast harvesting but also recycles the medium effectively for further cultivation of microalgae, looking ahead to a large scale economic microalgae-based biorefinement.

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Organisations: Urban circular bioeconomy (UrCirBio), Korea Institute of Energy Research, Chungnam National University, Korea District Heating Corp.
Contributors: Lee, K., Lee, S. Y., Na, J. G., Jeon, S. G., Praveenkumar, R., Kim, D. M., Chang, W. S., Oh, Y. K.
Number of pages: 4
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Original language: English
ASJC Scopus subject areas: Bioengineering, Environmental Engineering, Waste Management and Disposal
Keywords: Chitosan, Harvesting, Magnetic nanoparticle, Medium recycling, Microalgae
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Source: Scopus
Source ID: 84886601332
Research output: Contribution to journal › Article › Scientific › peer-review

**Repeated use of stable magnetic flocculant for efficient harvest of oleaginous Chlorella sp.**
In the present study, a simple magnetic-particle recycling strategy was developed for harvest of the oleaginous microalga Chlorella sp. KR-1. The method entails the flocculation of microalgal cells and bare-$Fe_3O_4$ magnetic particles (bMP) by electrostatic attraction and the subsequent recovery of the bMP from the harvested flocs by electrostatic repulsion below and above the isoelectric points (IEP), respectively. For 10 recycles, the bMP showed 94-99% and 90-97% harvest and recovery efficiencies, respectively. Furthermore, neither the use of bMP nor pH adjustment showed any adverse effect on the microalgal cell growth or the co-existing bacterial species, as confirmed from the subsequent medium-recycling test and denaturing gradient gel electrophoresis (DGGE) analysis.

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MoE publication type: A1 Journal article-refereed
Organisations: Urban circular bioeconomy (UrCirBio), Korea Institute of Energy Research, Chungnam National University, KAIST
Contributors: Lee, K., Lee, S. Y., Praveenkumar, R., Kim, B., Seo, J. Y., Jeon, S. G., Na, J. G., Park, J. Y., Kim, D. M., Oh, Y. K.
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Keywords: Electrostatic interaction, Harvest, Magnetic particles, Medium recycling, Microalgae
DOIs:

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Source: Scopus
Source ID: 84903726411
Research output: Contribution to journal › Article › Scientific › peer-review

### Software design for simulating microbial bioprocesses in bioreactor

UML based software design use is presented to implement a simulation environment. Simulation environment will be a software application which will provide a playground for researchers to simulate bioreactor experiments involving microbial species and predict the products of the experiment. Four subsystems namely: Feed system, Bioreactor system, Microbial system and Products system were identified and are presented as four major classes. The implementation of the system is left open at this stage and simulation environment can be implemented using object oriented programming languages like C++, JAVA and platforms like MATLAB (Simulink).

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Organisations: Department of Chemistry and Bioengineering, President, Research group: Industrial Bioengineering and Applied Organic Chemistry, Department of Signal Processing, Research area: Information Technology for Biology and Health, Research area: Intelligence in Machines, Research group: MMDM, Research area: Signal and Information Processing, Prostate cancer research center (PCRC), Urban circular bioeconomy (UrCirBio), Tampere University of Technology, Institute of Signal Processing
Contributors: Nikhil, Puhakka, J. A., Visa, A., Yli-Harja, O.
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ASJC Scopus subject areas: Environmental Engineering, Renewable Energy, Sustainability and the Environment, Management, Monitoring, Policy and Law, Water Science and Technology
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Research output: Chapter in Book/Report/Conference proceeding › Conference contribution › Scientific › peer-review

### Improved biomass and lipid production in a mixotrophic culture of Chlorella sp. KR-1 with addition of coal-fired flue-gas

Industrial $CO_2$-rich flue-gases, owing to their eco-toxicity, have yet to be practically exploited for microalgal biomass and lipid production. In this study, various autotrophic and mixotrophic culture modes for an oleaginous microalga, Chlorella sp. KR-1 were compared for the use in actual coal-fired flue-gas. Among the mixotrophic conditions tested, the fed-batch feedings of glucose and the supply of air in dark cycles showed the highest biomass (561mg/Ld) and fatty-acid methyl-ester (168mg/Ld) productivities. This growth condition also resulted in the maximal population of microalgae and the minimal population and types of KR-1-associated-bacterial species as confirmed by particle-volume-distribution and denaturing-gradient-gel-electrophoresis (DGGE) analyses. Furthermore, microalgal lipid produced was assessed, based on its fatty acid profile, to meet key biodiesel standards such as saponification, iodine, and cetane numbers.

### General information

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Organisations: Urban circular bioeconomy (UrCirBio), Korea Institute of Energy Research, Gachon University
Contributors: Praveenkumar, R., Kim, B., Choi, E., Lee, K., Park, J. Y., Lee, J. S., Lee, Y. C., Oh, Y. K.
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Original language: English
ASJC Scopus subject areas: Bioengineering, Environmental Engineering, Waste Management and Disposal, Medicine(all)
Keywords: Chlorella sp., Coal-fired flue-gas, Fed-batch, Lipid, Mixotrophic culture
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### Combination of a novel electrode material and artificial mediators to enhance power generation in an MFC

This study focuses on two main aspects: developing a novel cost-effective electrode material and power production from domestic wastewater using three different mediators. Methylene blue (MB), neutral red (NR) and 2-hydroxy-1,4-naphthoquinone (HNQ) were selected as electrode mediators with different concentrations. A tin-coated copper mesh electrode was tested as anode electrode. Maximum power density of the microbial fuel cell (MFC) with 300 μM MB was 636 $mW/m^2$. Optimal mediator concentrations with respect to the achieved maximum power output for MB, NR and HNQ were 300 μM, 200 μM and 50 μM, respectively. The results demonstrate that tin-coated copper mesh showed a higher biocompatibility and electrical conductivity.

### General information

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Organisations: Department of Chemistry and Bioengineering, Firat University
Contributors: Taskan, E., Özkaya, B., Hasar, H.
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ASJC Scopus subject areas: Environmental Engineering, Water Science and Technology
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Research output: Contribution to journal › Article › Scientific › peer-review

### Fungal treatment of landfill mining fine fraction to increase its stability and end-use potential

Landfill mining, i.e. extraction, processing, treatment and recovery of landfilled materials, is conducted to prevent pollution and to recover materials and energy from waste (Krook et al., 2012). On average, half of landfilled waste is material resembling soil, i.e. its fine fraction (FF, < 20 mm) (Kaartinen et al., 2013). The end-use potential of the FF is limited due to its organic matter content, a possible presence of harmful contaminants as well as its stability. The aim of this study was to evaluate if fungal treatment stabilises FF and removes organic contaminants thus allowing an end-use of FF as soil-like material. Basidiomycetous fungi were obtained and maintained according to Valentin et al. (2008) prior to experiments and were screened for their potential to grow in FF originally landfilled between 1967 – 1989. Screening experiments and previous experiences with contaminated soil (Valentin et al. 2008) led to the selection of Phanerochaete velutina for fungal treatment experiments, which were carried out at room temperature for 58 days. Two acryl columns (height 600 mm, radius 75 mm) were filled with 1 – 2 cm layer of gravel at the bottom and 5.8 kg of FF on the top as well as 500 mL of tap

water. The fungal column was amended with fungal bark inoculum to the middle of the column. Two ports at the bottom of the columns were used to collect leachate and aerate columns with humidified air at 0.1 L/min, respectively. Carbon dioxide (CO2) production was followed during the experiment with gas chromatography. The columns were covered with aluminium foil to stop germination of seeds present in FF. Total solids and volatile solids (VS) were analysed from FF according to standard SFS 3008. Organic contaminants mentioned in criteria for landfilling were analysed from FF in an accredited laboratory. Aerobic stability of FF was determined by the Oxitop method and anaerobic stability of FF was determined as biochemical methane potential. In less than one month, fungal mycelium was observed throughout the FF in the column inoculated with Phanerochaete velutina while no mycelium was observed in the control column. At this stage the experiment was continued in order to allow fungal mycelium to degrade and produce CO2. Concentrations of mineral oils (C10-C40) and organic matter, measured as VS, were higher in FF than in waste that can be placed to landfills. Mineral oil concentrations exceeded Finnish criteria set for contaminated soil. The aerobic stability of FF was high even initially and it did not increase in control or fungal treatments. Fungal treatment reduced organic matter content of FF and reduced mineral oil concentrations, although the criteria set in legislation could not be met in these experiments.

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Organisations: Research group: Industrial Bioengineering and Applied Organic Chemistry, Department of Chemistry and Bioengineering, University of Helsinki, Department of Food and Environmental Sciences
Contributors: Palmroth, M. R. T., Mönkäre, T. J., Steffen, K. T.
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ASJC Scopus subject areas: Bioengineering, Geotechnical Engineering and Engineering Geology, Environmental Engineering
Keywords: bioremediation

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xabstract
Research output: Chapter in Book/Report/Conference proceeding › Conference contribution › Scientific › peer-review

## Metals removal and recovery in bioelectrochemical systems: A review
Metal laden wastes and contamination pose a threat to ecosystem well being and human health. Metal containing waste streams are also a valuable resource for recovery of precious and scarce elements. Although biological methods are inexpensive and effective for treating metal wastewaters and in situ bioremediation of metal(loid) contamination, little progress has been made towards metal(loid) recovery. Bioelectrochemical systems are emerging as a new technology platform for removal and recovery of metal ions from metallurgical wastes, process streams and wastewaters. Biodegradation of organic matter by electroactive biofilms at the anode has been successfully coupled to cathodic reduction of metal ions. Until now, leaching of Co(II) from LiCoO<inf>2</inf> particles, and removal of metal ions i.e. Co(III/II), Cr(VI), Cu(II), Hg(II), Ag(I), Se(IV), and Cd(II) from aqueous solutions has been demonstrated. This article reviews the state of art research of bioelectrochemical systems for removal and recovery of metal(loid) ions and pertaining removal mechanisms.

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Organisations: Department of Chemistry and Bioengineering, Research group: Industrial Bioengineering and Applied Organic Chemistry, Urban circular bioeconomy (UrCirBio), CSIR-Indian Institute of Chemical Technology, Bhabha Atomic Research Centre
Contributors: Nancharaiah, Y. V., Venkata Mohan, S., Lens, P.
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Source: Scopus
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### Struvite precipitation in raw and co-digested swine slurries for nutrients recovery in batch reactors

The release of nitrogen (N) and phosphorus (P) from agro-industrial sources is a major environmental concern. Furthermore, the scarcity of mineable P and the growing demand for food worldwide necessitate that we find an alternative P source. This study applied struvite precipitation for N-P recovery to slurries with high levels of organics and ammonia to achieve environmental protection from excessive nutrients diffusion and to generate a sustainable P source. Batch tests were carried out on raw and co-digested swine slurries to study the feasibility of struvite precipitation and the effect of several parameters, including pH, reaction time, competing ions (Ca<sup>2+</sup>, K<sup>+</sup>), total solids (TS), and alkalinity. The batch assays with raw swine slurries showed high N-P removals (up to 80%), while the anaerobic liquor returned lower recovery efficiency due to the high solids and alkali content. Struvite crystallization was detected at pH values as low as 6, and the characteristics of the recovered struvite matched those of the theoretical. Slight co-precipitation of calcium-phosphates occurred and was dependent on the Ca<sup>2+</sup>/Mg<sup>2+</sup> ratio rather than on varying pH values. Struvite precipitation was shown to be feasible in complex matrices as agro-industrial effluents, characterized by high NH<inf>4</inf><sup>+</sup>, alkalinity, solids and organic content, and interfering ions such as Ca<sup>2+</sup> and K<sup>+</sup>.

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Organisations: Department of Chemistry and Bioengineering
Contributors: Taddeo, R., Lepistö, R.
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ASJC Scopus subject areas: Environmental Engineering, Water Science and Technology
Keywords: Eutrophication, Manure treatment, Nutrients removal and recovery, Struvite
DOIs:

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Source: Scopus
Source ID: 84929000113
Research output: Contribution to journal › Article › Scientific › peer-review

### Fluidized-bed denitrification of mining water tolerates high nickel concentrations

This study revealed that fluidized-bed denitrifying cultures tolerated soluble Ni concentrations up to 500mg/L at 7-8 and 22°C. From 10 to 40mg/L of feed Ni, denitrification resulted in complete nitrate and nitrite removal. The concomitant reduction of 30mg/L of sulfate produced 10mg/L of sulfide that precipitated nickel, resulting in soluble effluent Ni below 22mg/L. At this stage, Dechloromonas species were the dominant denitrifying bacteria. From 60 to 500mg/L of feed Ni, nickel remained in solution due to the inhibition of sulfate reduction. At soluble 60mg/L of Ni, denitrification was partially inhibited prior to recover after 34days of enrichment by other Ni-tolerant species (including Delftia, Zoogloea and Azospira) that supported Dechloromonas. Subsequently, the FBR cultures completely removed nitrate even at 500mg/L of Ni. Visual Minteq speciation model predicted the formation of NiS, $NiCO_3$ and $Ni_3(PO_4)_2$, whilst only $Ni_3(PO_4)_2$ was detected by

XRD.

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MoE publication type: A1 Journal article-refereed
Organisations: Department of Chemistry and Bioengineering, Research group: Industrial Bioengineering and Applied Organic Chemistry, Urban circular bioeconomy (UrCirBio), Université Paris-Est, Laboratoire Géomatériaux et Environnement (EA 4508), UPEM
Contributors: Zou, G., Papirio, S., van Hullebusch, E. D., Puhakka, J. A.
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Keywords: Denitrification, Denitrifying communities, Fluidized-bed reactor, Nickel, X-ray diffraction
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Source: Scopus
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Research output: Contribution to journal › Article › Scientific › peer-review

## Lipid production by eukaryotic microorganisms isolated from palm oil mill effluent
Microbial oil production combined with wastewater management is one option for a more sustainable future. Micrographs of microbial cultures enriched from palm oil mill effluent (POME) showed lipid inclusion in the eukaryotic cells, indicating the cells can accumulate lipids. However, enriching the culture did not increase the total lipids. Therefore, eukaryotic microorganisms were isolated from POME to investigate whether these microorganisms are potential lipid producers. Four strains were isolated, and their lipid synthesis capabilities were compared with known oleaginous yeasts in a synthetic oil-free medium. Two strains (identified as Galactomyces geotrichum and Graphium penicillioides) had the potential to accumulate lipid accumulation based on the increase in triacylglycerol content. G. penicillioides was the most promising strain for lipid production as this strain accumulated more lipids than the well-known oleaginous yeast Cryptococcus curvatus (29.1 ± 3.0. wt% vs. 20.2 ± 2.9. wt%). To our knowledge, oil synthesis and accumulation by G. penicillioides have not previously been reported.

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Organisations: Department of Chemistry and Bioengineering, Research group: Industrial Bioengineering and Applied Organic Chemistry, Urban circular bioeconomy (UrCirBio), National Cheng Kung University, Center of Bioscience and Biotechnology, Research Center for Energy Technology and Strategy, Neste Oil Oyj
Contributors: Marjakangas, J. M., Lakaniemi, A. M., Koskinen, P. E. P., Chang, J. S., Puhakka, J. A.
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Research output: Contribution to journal › Article › Scientific › peer-review

**Effects of anode potentials on bioelectrogenic conversion of xylose and microbial community compositions**
The results on the effects of different anode potentials on current densities, coulombic efficiencies and microbial communities are contradictory and have not been studied with xylose, an important constituent of lignocellulosic materials. In this study, the effects of different anode potentials (+0.2, 0 and -0.2V vs. Ag/AgCl) on current generation, xylose degradation and microbial communities were examined with an exoelectrogenic enrichment culture originating from anaerobic sludge. Anode potential of +0.2V (vs. Ag/AgCl) resulted in the highest current density and coulombic efficiency of 1.5±0.2A/m<sup>2</sup> and 62±11%, respectively, and there was no accumulation of soluble metabolites. With anode potentials of 0 and -0.2V the current densities remained low and acetate, butyrate and propionate were detected in the end of batch runs. Different anode potentials resulted in substantial differences in the anodic bacterial species. At more positive anode potentials, Ochrobactrum intermedium reported to be capable of direct electron transfer dominated. At more negative anode potentials, a known mediator-producer, Alcaligenes faecalis, and Desulfitobacterium hafnience, that has been reported to use mediated electron transfer, were detected. This study shows that the anode potential has a substantial effect on microbial communities and on xylose metabolism.

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Contributors: Kokko, M. E., Mäkinen, A. E., Sulonen, M. L. K., Puhakka, J. A.
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**Cultivation of Nannochloropsis for eicosapentaenoic acid production in wastewaters of pulp and paper industry**
The eicosapentaenoic acid (EPA) containing marine microalga Nannochloropsis oculata was grown in an effluent from anaerobic digestion of excess activated sludge from a wastewater treatment plant serving a combination of a pulp and a paper mill and a municipality (digester effluent, DE), mixed with the effluent of the same wastewater treatment plant. The maximum specific growth rate and photosynthesis of N. oculata were similar in the DE medium and in artificial sea water medium (ASW) but after 7. days, algae grown in the DE medium contained seven times more triacylglycerols (TAGs) per cell than cells grown in ASW, indicating mild stress in the DE medium. However, the volumetric rate of EPA production was similar in the ASW and DE media. The results suggest that N. oculata could be used to produce EPA, utilizing the nutrients available after anaerobic digestion of excess activated sludge of a pulp and paper mill.

**General information**

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Contributors: Polishchuk, A., Valev, D., Tarvainen, M., Mishra, S., Kinnunen, V., Antal, T., Yang, B., Rintala, J., Tyystjärvi, E.
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Research output: Contribution to journal › Article › Scientific › peer-review

## Airtightness of residential buildings in Finland

Single-family buildings and apartments in multi-family apartment buildings have been studied in Finland in two large-scale studies between the years 2002 and 2009. This paper is based on the measurements of airtightness of 170 single-family detached houses and 56 apartments by fan pressurisation method at 50 Pa.The mean air change rate of 10 autoclaved aerated concrete block, 10 shuttering concrete block, 10 concrete element, 10 brick masonry, 10 lightweight aggregate concrete block, 100 timber-framed, and 20 log single-family houses was 1.5 h<sup>-1</sup>, 1.6 h<sup>-1</sup>, 2.6 h<sup>-1</sup>, 2.8 h<sup>-1</sup>, 3.2 h<sup>-1</sup>, 3.9 h<sup>-1</sup> and 6.0 h<sup>-1</sup>, respectively. In concrete-built multi-storey houses, in which the intermediate floor was cast on site, the mean n<inf>50</inf>-value of 23 apartments was 0.7 h<sup>-1</sup>. The mean n<inf>50</inf>-value of 20 apartments in multi-storey houses built from concrete elements was 1.6 h<sup>-1</sup>. 16 apartments in timber-framed multi-storey houses had a mean n<inf>50</inf>-value 2.9 h<sup>-1</sup>.Factors like construction method and insulation material (polyurethane insulation) in timber-framed houses, seam insulation material in log houses and ceiling structure in heavyweight buildings among others were found to have an effect on the average values of air change rates. The mean values of airtightness do not satisfy the recommended level of airtightness in Finland. Most important result, however, is that good airtightness of individual houses was reached within all house groups regardless of the choice of structure, storeys, ventilation system or technology of construction.

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Contributors: Vinha, J., Manelius, E., Korpi, M., Salminen, K., Kurnitski, J., Kiviste, M., Laukkarinen, A.
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**Simultaneous nutrient removal and lipid production with Chlorella vulgaris on sterilized and non-sterilized anaerobically pretreated piggery wastewater**

Piggery wastewater is a potent nutrient source for microalgal lipid production. Wastewater has been usually sterilized when used for microalgal cultivation. This is uneconomical in large-scale applications. Therefore, lipid productivity of Chlorella vulgaris CY5 using sterilized and non-sterilized diluted anaerobically pretreated piggery wastewater was studied in batch reactors. The maximum average lipid productivity was obtained after 12 days of incubation and it was higher with the sterilized wastewater than with the non-sterilized one (117g/L/d vs. 91.3g/L/d), due to the higher biomass concentration. Because of the unexpected increase of dissolved organic carbon (DOC) in the cultures, second experiment was conducted to characterize the composition of produced DOC in non-sterilized wastewater. Carbohydrate content increased in the liquid phase but decreased in the biomass after nitrogen had been exhausted. After 12 days of incubation, soluble chemical oxygen demand (COD<inf>s</inf>) was 414±56mg/L, biomass production was 2.8±0.15g/L, and lipid content was 30.3±1.2wt%. Average lipid productivity from day zero to day 12 was 70.5±1.1g/L/d. C. vulgaris removed nutrients from the non-sterilized wastewater and produced oleaginous biomass, although the lipid productivity was higher with sterilized wastewater.

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Contributors: Marjakangas, J. M., Chen, C. Y., Lakaniemi, A. M., Puhakka, J. A., Whang, L. M., Chang, J. S.
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Research output: Contribution to journal › Article › Scientific › peer-review

**Cell-wall disruption and lipid/astaxanthin extraction from microalgae: Chlorella and Haematococcus**

Recently, biofuels and nutraceuticals produced from microalgae have emerged as major interests, resulting in intensive research of the microalgal biorefinery process. In this paper, recent developments in cell-wall disruption and extraction methods are reviewed, focusing on lipid and astaxanthin production from the biotechnologically important microalgae Chlorella and Haematococcus, respectively. As a common, critical bottleneck for recovery of intracellular components such as lipid and astaxanthin from these microalgae, the composition and structure of rigid, thick cell-walls were analyzed. Various chemical, physical, physico-chemical, and biological methods applied for cell-wall breakage and lipid/astaxanthin

extraction from Chlorella and Haematococcus are discussed in detail and compared based on efficiency, energy consumption, type and dosage of solvent, biomass concentration and status (wet/dried), toxicity, scalability, and synergistic combinations. This report could serve as a useful guide to the implementation of practical downstream processes for recovery of valuable products from microalgae including Chlorella and Haematococcus.

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**Composites of high-temperature thermomechanical pulps and polylactic acid**
High-temperature thermomechanical pulps (HT-TMP, defibrated at 150 to 170 °C) were compared to a reference TMP (defibrated at 130 °C) as a reinforcement for polylactic acid (PLA). Composites were prepared by melt compounding, followed by injection molding, gradually increasing the used fiber content from 0 to 20 wt.%. The injection-molded specimens were characterized by tensile and impact strength tests, scanning electron microscopy, water absorption tests, and differential scanning calorimetry. The TMP fiber damage was also characterized before and after melt compounding by optical analysis. At 20% fiber content, the Young's modulus increased significantly, while the tensile strength remained unchanged and the impact strength decreased slightly. All fibers suffered damage during melt compounding, but the tensile strength remained about the same as in pure PLA. All types of TMP were able to increase the PLA rate of crystallization. The HT-TMP fibers were dispersed more evenly in PLA than the 130 °C TMP. The 170 °C TMP produced composites of lower water absorption than the other two TMP types, probably because of its lower hemicellulose content and its higher surface coverage by lignin.

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Organisations: Department of Materials Science, Research group: Plastics and Elastomer Technology, Aalto University
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Research output: Contribution to journal › Article › Scientific › peer-review

### High efficiency dilute nitride solar cells: Simulations meet experiments

Parameter extraction procedure and simulation of dilute nitride solar cells are reported. Using PC1D simulation and fitting to experimental current-voltage and external quantum efficiency data, we retrieve the phenomenological material parameters for GaInNAs solar cells. Based on these, we have constructed a model that can explain the changes in short circuit current and open circuit voltage of n-i-p solar cells subjected to rapid thermal annealing. The model reveals that non-annealed MBE-grown GaInNAs material has an n-type doping that evolves to p-type upon rapid thermal annealing. The change of doping type and the shift of the physical location of the pn-junction were confirmed by Kelvin-probe force microscopy. The PC1D modelling was found to work well also for GaInNAs p-i-n solar cells with opposite polarity. It was also found that the GaInNAs lower doping levels in p-i-n solar cells grown at lowered As/III flux ratios were associated with increased carrier lifetimes.

#### General information

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### Agronomic characteristics of five different urban waste digestates

The use of digestate in agriculture is an efficient way to recycle materials and to decrease the use of mineral fertilizers. The agronomic characteristics of the digestates can promote plant growth and soil properties after digestate fertilization but also harmful effects can arise due to digestate quality, e.g. pH, organic matter and heavy metal content. The objective of this study was to evaluate the differences and similarities in agronomic characteristics and the value of five urban waste digestates from different biogas plants treating either food waste, organic fraction of organic solid waste or a mixture of waste-activated sludge and vegetable waste. The digestate agronomic characteristics were studied with chemical analyses and the availability of nutrients was also assessed with growth experiments and soil mineralization tests. All studied urban digestates produced 5-30% higher ryegrass yields compared to a control mineral fertilizer with a similar inorganic nitrogen concentration, while the feedstock source affected the agronomic value. Food waste and organic fraction of municipal solid waste digestates were characterized by high agronomic value due to the availability of nutrients and low heavy metal load. Waste-activated sludge as part of the feedstock mixture, however, increased the heavy metal content and reduced nitrogen availability to the plant, thus reducing the fertilizer value of the digestate.

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Contributors: Tampio, E., Salo, T., Rintala, J.
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## Release and characteristics of fungal fragments in various conditions
Intact spores and submicrometer size fragments are released from moldy building materials during growth and sporulation. It is unclear whether all fragments originate from fungal growth or if small pieces of building materials are also aerosolized as a result of microbial decomposition. In addition, particles may be formed through nucleation from secondary metabolites of fungi, such as microbial volatile organic compounds (MVOCs). In this study, we used the elemental composition of particles to characterize the origin of submicrometer fragments released from materials contaminated by fungi.Particles from three fungal species (Aspergillus versicolor, Cladosporium cladosporioides and Penicillium brevicompactum), grown on agar, wood and gypsum board were aerosolized using the Fungal Spore Source Strength Tester (FSSST) at three air velocities (5, 16 and 27m/s). Released spores (optical size, $d_p$≥0.8μm) and fragments ($d_p$≤0.8μm) were counted using direct-reading optical aerosol instruments. Particles were also collected on filters, and their morphology and elemental composition analyzed using scanning electron microscopes (SEMs) coupled with an Energy-Dispersive X-ray spectroscopy (EDX).Among the studied factors, air velocity resulted in the most consistent trends in the release of fungal particles. Total concentrations of both fragments and spores increased with an increase in air velocity for all species whereas fragment-spore (F/S) ratios decreased. EDX analysis showed common elements, such as C, O, Mg and Ca, for blank material samples and fungal growth. However, N and P were exclusive to the fungal growth, and therefore were used to differentiate biological fragments from non-biological ones. Our results indicated that majority of fragments contained N and P.Because we observed increased release of fragments with increased air velocities, nucleation of MVOCs was likely not a relevant process in the formation of fungal fragments. Based on elemental composition, most fragments originated from fungi, but also fragments from growth material were detected.

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Contributors: Mensah-Attipoe, J., Saari, S., Veijalainen, A. M., Pasanen, P., Keskinen, J., Leskinen, J. T. T., Reponen, T.
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### Effect of heavy metal co-contaminants on selenite bioreduction by anaerobic granular sludge

This study investigated bioreduction of selenite by anaerobic granular sludge in the presence of heavy metals and analyzed the fate of the bioreduced selenium and the heavy metals. Selenite bioreduction was not significantly inhibited in the presence of Pb(II) and Zn(II). More than 92% of 79 mg/L selenite was removed by bioreduction even in the presence of 150 mg/L of Pb(II) or 400 mg/L of Zn(II). In contrast, only 65-48% selenite was bioreduced in the presence of 150-400 mg/L Cd(II). Formation of elemental selenium or selenide varied with heavy metal type and concentration. Notably, the majority of the bioreduced selenium (70-90% in the presence of Pb and Zn, 50-70% in the presence of Cd) and heavy metals (80-90% of Pb and Zn, 60-80% of Cd) were associated with the granular sludge. The results have implications in the treatment of selenium wastewaters and biogenesis of metal selenides.

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Contributors: Mal, J., Nancharaiah, Y. V., van Hullebusch, E. D., Lens, P. N. L.
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### Possible impacts of increasing maximum truck weight: Finland case study

#### General information

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Organisations: Department of Information Management and Logistics
Contributors: Nykänen, L., Liimatainen, H.
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### Hydrothermal carbonization of pulp mill streams

The progress of the conversion, the yield, the structure and the morphology of the produced carbonaceous materials as a function of time were systematically studied with pyrolysis-GC/FID and FESEM microscope. The conversion of galactoglucomannan, bleached kraft pulp and TEMPO oxidized cellulose nanofibrils followed the reaction route of glucose being slower though with fibrous material, higher molar mass and viscosity. The conversion of kraft lignin was minor following completely different reaction route. Carbonaceous particles of different shape and size were produced with yields between 23% and 73% after 4 h with being higher for lignin than carbohydrates. According to the results, potential pulp mill streams represent lignocellulosic resources for generation of carbonaceous materials.

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Contributors: Wikberg, H., Ohra-aho, T., Honkanen, M., Kanerva, H., Harlin, A., Vippola, M., Laine, C.
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### Methodological approaches for fractionation and speciation to estimate trace element bioavailability in engineered anaerobic digestion ecosystems: An overview

Optimal supply of trace elements (TE) is a prerequisite for microbial growth and activity in anaerobic digestion (AD) bioprocesses. However, the required concentrations and ratios of essential TE for AD biotechnologies strongly depend on prevailing operating conditions as well as feedstock composition. Furthermore, TE in AD bioreactors undergo complex physicochemical reactions and may be present as free ions, complex bound or as precipitates depending on pH, or on the presence of sulfur compounds or organic macromolecules. To overcome TE deficiency, various commercial mineral products are typically applied to AD processes. The addition of heavy metals poses the risk of overdosing operating systems, which may be toxic to microbial consortia and ultimately the environment. Adequate supplementation, therefore, requires appropriate knowledge not only about the composition, but also on the speciation and bioavailability of TE. However, very little is yet fully understood on this specific issue. Evaluations of TE typically only include the measurement of total TE concentrations but do not consider the chemical forms in which TE exist. Thus detailed information on bioavailability and potential toxicity cannot be provided. This review provides an overview of the state of the art in approaches to determine bioavailable TE in anaerobic bioprocesses, including sequential fractionation and speciation techniques. Critical aspects and considerations, including with respect to sampling and analytical procedures, as well as mathematical modeling, are examined. The approaches discussed in this review are based on our experiences and on previously published studies in the context of the “COST Action 1302: European Network on Ecological Roles of Trace Metals in Anaerobic Biotechnologies.”

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of Birmingham, Université Reims Champagne Ardenne, Swedish University of Agricultural Sciences, Univ Porto, Universidade do Porto, Fac Med, Dept Med Imaging, Centro Ricerche Produzioni Animali (CRPA), ENEA/CREATE/Università Degli Studi Napoli Federico II, University of Cassino and Southern Lazio, BIOENERGY 2020 GmbH, Natl. University of Ireland, Galway
Contributors: van Hullebusch, E. D., Guibaud, G., Simon, S., Lenz, M., Yekta, S. S., Fermoso, F. G., Jain, R., Duester, L., Roussel, J., Guillon, E., Skyllberg, U., Almeida, C. M. R., Pechaud, Y., Garuti, M., Frunzo, L., Esposito, G., Carliell-Marquet, C., Ortner, M., Collins, G.
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Research output: Contribution to journal › Article › Scientific › peer-review

**Recent advances in nutrient removal and recovery in biological and bioelectrochemical systems**
Nitrogen and phosphorous are key pollutants in wastewater to be removed and recovered for sustainable development. Traditionally, nitrogen removal is practiced through energy intensive biological nitrification and denitrification entailing a major cost in wastewater treatment. Recent innovations in nitrogen removal aim at reducing energy requirements and recovering ammonium nitrogen. Bioelectrochemical systems (BES) are promising for recovering ammonium nitrogen from nitrogen rich waste streams (urine, digester liquor, swine liquor, and landfill leachate) profitably. Phosphorus is removed from the wastewater in the form of polyphosphate granules by polyphosphate accumulating organisms. Alternatively, phosphorous is removed/recovered as Fe-P or struvite through chemical precipitation (iron or magnesium dosing). In this article, recent advances in nutrients removal from wastewater coupled to recovery are presented by applying a waste biorefinery concept. Potential capabilities of BES in recovering nitrogen and phosphorous are reviewed to spur future investigations towards development of nutrient recovery biotechnologies.

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Organisations: Department of Chemistry and Bioengineering
Contributors: Nancharaiah, Y. V., Venkata Mohan, S., Lens, P. N. L.
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## Long-term stability of bioelectricity generation coupled with tetrathionate disproportionation

To prevent uncontrolled acidification of the environment, reduced inorganic sulfur compounds (RISCs) can be bioelectrochemically removed from water streams. The long-term stability of bioelectricity production from tetrathionate ($S_4O_6^{2-}$) was studied in highly acidic conditions (pH <2.5) in two-chamber fed-batch microbial fuel cells (MFCs). The maximum current density was improved from previously reported 80 mA $m^{-2}$ to 225 mA $m^{-2}$ by optimizing the external resistance. The observed reaction products of tetrathionate disproportionation were sulfate and elemental sulfur. In long-term run, stable electricity production was obtained for over 700 days with the average current density of 150 mA $m^{-2}$. The internal resistance of the MFC decreased over time and no biofouling was observed. This study shows that tetrathionate is an efficient substrate also for long-term bioelectricity production.

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Source ID: 84974777755
Research output: Contribution to journal › Article › Scientific › peer-review

## Mitigation of propylene glycol emissions to groundwater and soil

Background
Propylene glycol based deicing agents are used at airports to remove ice and prevent ice accumulation into airplanes. Propylene glycol is readily biodegradable both aerobically and anaerobically but it has been noticed to migrate into groundwater (Greco et al., 2012). Currently propylene glycol emissions are collected and treated at municipal treatment plants. More information is needed about mitigation measures to prevent propylene glycol emissions into ground water and soil.
Aim
The objective of current study was to study whether low cost materials can improve propylene glycol degradation in soil and decrease its migration into groundwater and soil at low temperatures. The low cost materials were chosen based on literature survey and small scale laboratory experiments as well as technical parameters and current use at Finnish airport structures. Experiments were carried out in two pilot-scale temperature controlled lysimeters (height 3 m, radius 50 cm) operated at -5 to 20°C, i.e. simulating winter, spring and summer conditions to compare control lysimeter and amended lysimeter. Deicing agent was mixed with flake ice in order to simulate snow and added on top of the soil and/or amendments. The purpose was to find out whether addition of peat and blast furnace sand can mitigate propylene glycol emissions.
Conclusion
Lysimeter leachate formation and migration of propylene glycol into lysimeter leachate were minimal when the soil was frozen. Biodegradation of propylene glycol was detected as formation of its degradation products in both lysimeters after the soil temperature had increased above 0 ºC. However, comparison of results from control lysimeter and lysimeter amended with peat and blast furnace sand revealed that the amendments did not improve biodegradation of propylene glycol nor decrease its migration into lysimeter leachate.

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Organisations: Department of Chemistry and Bioengineering, Research group: Industrial Bioengineering and Applied Organic Chemistry, Tampere University of Technology, Finavia Oy

Contributors: Palmroth, M. R. T., Pispa, L., Kettunen, R. H., Hänninen, T., Rintala, J. A.
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ASJC Scopus subject areas: Environmental Engineering
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Research output: Other conference contribution › Paper, poster or abstract › Scientific

### Sustainable nutrients recovery and recycling by optimizing the chemical addition sequence for struvite precipitation from raw swine slurries

Livestock farming contributes heavily to nitrogen (N) and phosphorus (P) flows into the environment, a major cause of eutrophication of coastal and freshwater systems. Furthermore, the growing demand for N-P fertilizers is increasing the emission of anthropogenic reactive N into the atmosphere and the depletion of the current P reserves. Therefore, it is essential to minimize the anthropogenic impact on the environment and recycle the wasted N-P for agricultural reuse. This study focused on enhancing struvite ($MgNH_4PO_4*6H_2O$) precipitation from raw swine slurries in batch and laboratory-scale reactors. Different chemical addition sequences were evaluated, and the best removal efficiency (E%) was obtained when the chemicals were mixed before the precipitation process. Struvite was detected at a pH as low as 6 (E%N-P~50%), and high E%N-P was found at pH 7–9.5 (80–95%). Furthermore, air stripping was used in place of NaOH to adjust pH, returning the same efficiency as if only alkali had been used. XRD and FE-SEM analysis of the precipitate showed that the recovered struvite was of high purity with orthorhombic crystalline structure and only trace amounts of impurities from matrix organics, co-precipitation products (CaO and amorphous calcium-phosphates), and residuals of added chemicals (MgO).

#### General information

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Contributors: Taddeo, R., Kolppo, K., Lepistö, R.
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Keywords: Air stripping, Chemical addition, Crystallization, Manure management, Nutrients recycling, Struvite
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### Performance of a sonic jet-type charger in high dust load

Sonic jet chargers have originally been used in aerosol measurement devices for particle charging and neutralization. Here, our goal was to study if this charger type could be used in particle control devices in which particle concentrations and gas volumes are much higher. The study includes charging efficiency tests in a laboratory and with a commercial 20 kW wood pellet burner. Actual particle removal efficiency was tested with a laboratory scale parallel plate electrostatic collector. The results show that sonic jet-type chargers also have potential in filtering applications.

#### General information

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Contributors: Laitinen, A., Keskinen, J.

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Source ID: 84979021416
Research output: Contribution to journal › Article › Scientific › peer-review

**Magnesium aminoclay enhances lipid production of mixotrophic Chlorella sp. KR-1 while reducing bacterial populations**
Improving lipid productivity and preventing overgrowth of contaminating bacteria are critical issues relevant to the commercialization of the mixotrophic microalgae cultivation process. In this paper, we report the use of magnesium aminoclay (MgAC) nanoparticles for enhanced lipid production from oleaginous Chlorella sp. KR-1 with simultaneous control of KR-1-associated bacterial growth in mixotrophic cultures with glucose as the model substrate. Addition of 0.01–0.1 g/L MgAC promoted microalgal biomass production better than the MgAC-less control, via differential biocidal effects on microalgal and bacterial cells (the latter being more sensitive to MgAC's bio-toxicity than the former). The inhibition effect of MgAC on co-existing bacteria was, as based on density-gradient-gel-electrophoresis (DGGE) analysis, largely dosage-dependent and species-specific. MgAC also, by inducing an oxidative stress environment, increased both the cell size and lipid content of KR-1, resulting in a considerable, ~25% improvement of mixotrophic algal lipid productivity (to ~410 mg FAME/L/d) compared with the untreated control.

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Organisations: Department of Chemistry and Bioengineering, Research group: Industrial Bioengineering and Applied Organic Chemistry, Chungnam National University, Korea Institute of Energy Research, Gachon University
Contributors: Kim, B., Praveenkumar, R., Lee, J., Nam, B., Kim, D. M., Lee, K., Lee, Y. C., Oh, Y. K.
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Source ID: 84982219447
Research output: Contribution to journal › Article › Scientific › peer-review

### Mild pressure induces rapid accumulation of neutral lipid (triacylglycerol) in Chlorella spp.

Effective enhancement of neutral lipid (especially triacylglycerol, TAG) content in microalgae is an important issue for commercialization of microalgal biorefineries. Pressure is a key physical factor affecting the morphological, physiological, and biochemical behaviors of organisms. In this paper, we report a new stress-based method for induction of TAG accumulation in microalgae (specifically, Chlorella sp. KR-1 and Ch. sp. AG20150) by very-short-duration application of mild pressure. Pressure treatments of 10–15 bar for 2 h resulted in a considerable, ~55% improvement of the 10–100 g/L cells' TAG contents compared with the untreated control. The post-pressure-treatment increase of cytoplasmic TAG granules was further confirmed by transmission electron microscopy (TEM). Notwithstanding the increased TAG content, the total lipid content was not changed by pressurization, implying that pressure stress possibly induces rapid remodeling/transformation of algal lipids rather than de novo biosynthesis of TAG.

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Contributors: Ramasamy, P., Kim, B., Lee, J., Vijayan, D., Lee, K., Nam, B., Jeon, S. G., Kim, D. M., Oh, Y. K.
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DOIs:

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Source ID: 84989931657
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### The effect of low-temperature pretreatment on the solubilization and biomethane potential of microalgae biomass grown in synthetic and wastewater media

Microalgae have been suggested as a sustainable raw material for biofuel production in the form of methane via anaerobic digestion. Here, pretreatments at 60–80 °C were investigated, aiming to study the impact of algae culture media on biomethane potential and pretreatment efficiency. Chlorella vulgaris and mixed culture of native algae species (dominating by Scenedesmus sp.) were grown in synthetic medium, wastewater (sterilized and non-sterilized) and digestate from anaerobic digestion of pulp and paper biosludge (sterilized and non-sterilized). The biomethane potential for native microalgal biomass varied between 154 and 252 L $CH_4$ $kg^{-1}$ VS depending on culture media. The efficiency of the low-temperature pretreatment (80 °C, 3 h) for solubilization (9–12%) of C. vulgaris and native algae biomass was similar for algae grown in sterilized and non-sterilized wastewater media. The pretreatment increased the biomethane potential of native algae biomass by 11–24%.

#### General information

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**Biological removal of selenate and ammonium by activated sludge in a sequencing batch reactor**
Wastewaters contaminated by both selenium and ammonium need to be treated prior to discharge into natural water bodies, but there are no studies on the simultaneous removal of selenium and ammonium. A sequencing batch reactor (SBR) was inoculated with activated sludge and operated for 90 days. The highest ammonium removal efficiency achieved was 98%, while the total nitrogen removal was 75%. Nearly a complete chemical oxygen demand removal efficiency was attained after 16 days of operation, whereas complete selenate removal was achieved only after 66 days. The highest total Se removal efficiency was 97%. Batch experiments showed that the total Se in the aqueous phase decreased by 21% with increasing initial ammonium concentration from 50 to 100 mg $L^{-1}$. This study showed that SBR can remove both selenate and ammonium via, respectively, bioreduction and partial nitrification-denitrification and thus offer possibilities for treating selenium and ammonium contaminated effluents.

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Organisations: Chemistry and Bioengineering, Research group: Industrial Bioengineering and Applied Organic Chemistry, UPEM, Homi Bhabha National Institute, Mumbai, Hydraulic and Environmental Engineering (IHE) Inst. for Water Education
Contributors: Mal, J., Nancharaiah, Y. V., van Hullebusch, E. D., Lens, P. N.
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Research output: Contribution to journal › Article › Scientific › peer-review

**Cultivation of Scenedesmus acuminatus in different liquid digestates from anaerobic digestion of pulp and paper industry biosludge**
Different undiluted liquid digestates from mesophilic and thermophilic anaerobic digesters of pulp and paper industry biosludge with and without thermal pretreatment were characterized and utilized for cultivating Scenedesmus acuminatus. Higher S. acuminatus biomass yields were obtained in thermophilic digestates (without and with pretreatment prior to anaerobic digestion (AD): 10.2 ± 2.2 and 10.8 ± 1.2 g $L^{-1}$, respectively) than in pretreated mesophilic digestates (7.8 ± 0.3 g $L^{-1}$), likely due to differences in concentration of sulfate, iron, and/or other minor nutrients. S. acuminatus removed over 97.4% of ammonium and 99.9% of phosphate and sulfate from the digestates. Color (74–80%) and soluble COD (29–39%) of the digestates were partially removed. Different AD processes resulted in different methane yields (18–126 L $CH_4$ $kg^{-1}$ VS), digestate compositions, and microalgal yields. These findings emphasize the importance of optimizing each processing step in wood-based biorefineries and provide information for pulp and paper industry development for enhancing value generation.

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Contributors: Tao, R., Lakaniemi, A., Rintala, J. A.
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Keywords: Digestate characteristics, Microalgal growth, Nutrient recovery, Pulp and paper industry, Wastewater treatment
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## Fate of metallic engineered nanomaterials in constructed wetlands: prospection and future research perspectives

Metallic engineered nanomaterials (ENMs) undergo various transformations in the environment which affect their fate, toxicity and bioavailability. Although constructed wetlands (CWs) are applied as treatment systems for waste streams potentially containing metallic ENMs, little is known about the fate and effects of ENMs in CWs. Hence, literature data from related fields such as activated sludge wastewater treatment and natural wetlands is used to predict the fate and effects of ENMs in CWs and to analyze the risk of nanomaterials being released from CWs into surface waters. The ENMs are likely to reach the CW (partly) transformed and the transformations will continue in the CW. The main transformation processes depend on the type of ENM and the ambient environmental conditions in the CW. In general, ENMs are expected to undergo sorption onto (suspended) organic matter and plant roots. Although the risk of ENMs being released at high concentrations from CWs is estimated low, caution is warranted because of the estimated rise in the production of these materials. As discharge of (transformed) ENMs from CWs during normal operation is predicted to be low, future research should rather focus on the effects of system malfunctions (e.g. short-circuiting). Efficient retention in the CW and increasing production volumes in the future entail increasing concentrations within the CW substrate and further research needs to address possible adverse effects caused.

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Organisations: Chemistry and Bioengineering, Laboratory of Industrial Water and Ecotechnology, Universiteit Gent, Laboratory of Analytical Chemistry and Applied Ecochemistry, Laboratory of Chemistry and Bioengineering, Royal Military College of Canada
Contributors: Auvinen, H., Gagnon, V., Rousseau, D. P. L., du Laing, G.
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Keywords: Discharge, Effluent, Nanoparticle, Transformation, TSS, Wastewater
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Source: Scopus
Source ID: 85021244022
Research output: Contribution to journal › Article › Scientific › peer-review

### Effects of different nickel species on autotrophic denitrification driven by thiosulfate in batch tests and a fluidized-bed reactor

Nickel is a common heavy metal and often occurs with nitrate ($NO_3^-$) in effluents from mining and metal-finishing industry. The present study investigates the effects of increasing concentrations (5–200 mg Ni/L) of $NiEDTA^{2-}$ and $NiCl_2$ on autotrophic denitrification with thiosulfate ($S_2O_3^{2-}$) in batch tests and a fluidized-bed reactor (FBR). In batch bioassays, 50 and 100 mg Ni/L of $NiEDTA^{2-}$ only increased the transient accumulation of $NO_2^-$, whereas 25–100 mg Ni/L of $NiCl_2$ inhibited denitrification by 9–19%. $NO_3^-$ and $NO_2^-$ were completely removed in the FBR at feed $NiEDTA^{2-}$ and $NiCl_2$ concentrations as high as 100 and 200 mg Ni/L, respectively. PCR-DGGE revealed the dominance of Thiobacillus denitrificans and the presence of the sulfate-reducing bacterium Desulfovibrio putealis in the FBR microbial community at all feed nickel concentrations investigated. Nickel mass balance, thermodynamic modeling and solid phase characterization indicated that nickel sulfide, phosphate and oxide precipitated in the FBR during $NiCl_2$ injection.

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Organisations: Chemistry and Bioengineering, Research group: Industrial Bioengineering and Applied Organic Chemistry, Research group: Bio- and Circular Economy, University of Cassino and Southern Lazio, UPEM, Hydraulic and Environmental Engineering (IHE) Inst. for Water Education
Contributors: Di Capua, F., Milone, I., Lakaniemi, A., Hullebusch, E. D., Lens, P. N., Esposito, G.
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Research output: Contribution to journal › Article › Scientific › peer-review

### Indoor thermal environment, air exchange rates, and carbon dioxide concentrations before and after energy retro fits in Finnish and Lithuanian multi-family buildings

Impacts of energy retrofits on indoor thermal environment, i.e. temperature (T) and relative humidity (RH), as well as ventilation rates and carbon dioxide ($CO_2$) concentrations, were assessed in 46 Finnish and 20 Lithuanian multi-family buildings, including 39 retrofitted case buildings in Finland and 15 in Lithuania (the remaining buildings were control buildings with no retrofits). In the Finnish buildings, high indoor T along with low RH levels was commonly observed both before and after the retrofits. Ventilation rates (l/s per person) were higher after the retrofits in buildings with mechanical exhaust ventilation than the corresponding values before the retrofits. Measured $CO_2$ levels were low in vast majority of buildings. In Lithuania, average indoor T levels were low before the retrofits and there was a significant increase in the

average T after the retrofits. In addition, average ventilation rate was lower and $CO_2$ levels were higher after the retrofits in the case buildings (N = 15), both in apartments with natural and mixed ventilation. Based on the results, assessment of thermal conditions and ventilation rates after energy retrofits is crucial for optimal indoor environmental quality and energy use.

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Contributors: Leivo, V., Prasauskas, T., Du, L., Turunen, M., Kiviste, M., Aaltonen, A., Martuzevicius, D., Haverinen-Shaughnessy, U.
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ASJC Scopus subject areas: Environmental Engineering, Environmental Chemistry, Waste Management and Disposal, Pollution
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**Nutrient management via struvite precipitation and recovery from various agroindustrial wastewaters: Process feasibility and struvite quality**
Improving environmental protection and finding sustainable and renewable resources of nutrients are core issues in circular bioeconomy. Thus, this study evaluated the efficiency of recovering struvite, $MgNH_4PO_4 \cdot 6H_2O$, from different agro-industrial wastewaters (four highly loaded reject waters of anaerobically co-digested agro-industrial waste and a raw swine slurry) and assessed the quality of recovered struvite crystals and their reusability as fertilizer. The efficiency of crystallization ($E_c$ 40–80%) and amount of struvite in the precipitate ($P_p$ 55–94%) highly varied due to the characteristics of influent wastewaters, particularly to the content of competing elements, such as alkaline and heavy metals and total solids (TS). In particular, $E_c$ (94, 75, 61%) and $P_p$ (76, 66, 48%) decreased at increasing TS (0.57, 0.73, 0.99%), demonstrating the hindering effect of solid content on struvite recovery and quality. According to X-ray diffraction analysis, the structure of all isolated samples corresponded to crystalline, orthorhombic struvite, which exhibited high purity (32–48 $g/kg_d$ N, 114–132 $g/kg_d$ P, and 99–116 $g/kg_d$ Mg) containing only a few foreign elements, whose amount depended on the characteristics of the influent wastewater. All struvite contained other plant macronutrients (K, Ca) and many micronutrients (Fe, Na, Cu, Mn, Co, Zn) that further enhance its agronomic value. Therefore, this study showed that struvite can be successfully recovered from a wide range of highly loaded agroindustrial wastewaters, and that the quality of the recovered struvite could be suitable for reuse in agriculture.

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Keywords: Crystalline purity, Heavy metals, Nutrient recycling, Solid content, Sustainable fertilizer
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Research output: Contribution to journal › Article › Scientific › peer-review

**Effects of wastewater constituents and operational conditions on the composition and dynamics of anodic microbial communities in bioelectrochemical systems**
Over the last decade, there has been an ever-growing interest in bioelectrochemical systems (BES) as a sustainable technology enabling simultaneous wastewater treatment and biological production of, e.g. electricity, hydrogen, and further commodities. A key component of any BES degrading organic matter is the anode where electric current is biologically generated from the oxidation of organic compounds. The performance of BES depends on the interactions of the anodic microbial communities. To optimize the operational parameters and process design of BES a better comprehension of the microbial community dynamics and interactions at the anode is required. This paper reviews the abundance of different microorganisms in anodic biofilms and discusses their roles and possible side reactions with respect to their implications on the performance of BES utilizing wastewaters. The most important operational parameters affecting anodic microbial communities grown with wastewaters are highlighted and guidelines for controlling the composition of microbial communities are given.

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MoE publication type: A2 Review article in a scientific journal
Organisations: Chemistry and Bioengineering, Laboratory for MEMS Applications, Universitat Freiburg im Breisgau, Karlsruhe Institute of Technology, Insitute for Technical Physics, Germany, University of Bremen
Contributors: Kokko, M., Epple, S., Gescher, J., Kerzenmacher, S.
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Peer-reviewed: Yes

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ASJC Scopus subject areas: Bioengineering, Environmental Engineering, Renewable Energy, Sustainability and the Environment, Waste Management and Disposal
Keywords: Bioelectrochemical system, Exoelectrogen, Microbial community, Wastewater
DOIs:

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Source: Scopus
Source ID: 85043472557
Research output: Contribution to journal › Review Article › Scientific › peer-review

**Radon, fungal spores and MVOCs reduction in crawl space house: A case study and crawl space development by hygrothermal modelling**
In this case study was to investigate how ventilation of the crawl space will influence on concentrations of radon, fungal spores and MVOCs in the crawl space and indoors of detached house. The crawl space pressurisation by exhaust air from indoors was successful to prevent the convective flow of radon from the soil, but it increased microbial growth in the crawl space. After installation of the supply and exhaust ventilation in the crawl-space and in the living space, the concentrations of fungal spores in the crawl space and also entry of radon and MVOCs into a house decreased. A microbiologically safe crawl space was determined with hygrothermal simulation utilizing the Finnish Mould Growth Model and a two year examination period. The optional structures of the crawl space being depressurised with exhaust ventilation included an open base uncovered ground and various air-sealed closed structures. When mould growth of building materials was at medium resistant sensitivity class, mould was not observed during different air change rates in any of the examined

structures. Open base uncovered gravel ground is a functional solution of a crawl space, only when there are no organic materials. The air-sealed ground structure is recommended build with concrete + insulation and when air exchange rate (ach) varied from 0.2 to 1 $h^{-1}$. A concrete ground in the crawl space having ach from 0.2 to 0.6 $h^{-1}$ is also very effective. XPS insulation and plastic sheet covered ground are not recommendable due to their high mould index.

**General information**
Publication status: Published
MoE publication type: A1 Journal article-refereed
Organisations: Civil Engineering, Ramboll Finland Ltd., Ita-Suomen yliopisto
Contributors: Keskikuru, T., Salo, J., Huttunen, P., Kokotti, H., Hyttinen, M., Halonen, R., Vinha, J.
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Original language: English
ASJC Scopus subject areas: Environmental Engineering, Civil and Structural Engineering, Geography, Planning and Development, Building and Construction
Keywords: Air change, Crawl space, Ground covers, Modelling, Mould growth, Radon
DOIs:

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**Bibliographical note**
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Source: Scopus
Source ID: 85046008041
Research output: Contribution to journal › Article › Scientific › peer-review

**Performance of a biotrickling filter for the anaerobic utilization of gas-phase methanol coupled to thiosulphate reduction and resource recovery through volatile fatty acids production**
The anaerobic removal of continuously fed gas-phase methanol (2.5–30 $g/m^3$.h) and the reduction of step-fed thiosulphate (1000 mg/L) was investigated in a biotrickling filter (BTF) operated for 123 d at an empty bed residence time (EBRT) of 4.6 and 2.3 min. The BTF performance during steady step-feed and special operational phases like intermittent liquid trickling in 6 and 24 h cycles and operation without pH regulation were evaluated. Performance of the BTF was not affected and nearly 100% removal of gas-phase methanol was achieved with an $EC_{max}$ of 21 $g/m^3$.h. Besides, >99% thiosulphate reduction was achieved, in all the phases of operation. The production of sulphate, $H_2S$ and volatile fatty acids (VFA) was monitored and a maximum of 2500 mg/L of acetate, 200 mg/L of propionate, 150 mg/L of isovalerate and 100 mg/L isobutyrate was produced.

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Publication status: Published
MoE publication type: A1 Journal article-refereed
Organisations: Chemistry and Bioengineering, Hydraulic and Environmental Engineering (IHE) Inst. for Water Education, Institute for Water Education
Contributors: Eregowda, T., Matanhike, L., Rene, E. R., Lens, P. N.
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Original language: English
ASJC Scopus subject areas: Bioengineering, Environmental Engineering, Renewable Energy, Sustainability and the Environment, Waste Management and Disposal

Keywords: Anaerobic, Biotrickling filter (BTF), Gas-phase methanol, Steady and intermittent BTF operation, Thiosulphate reduction, Volatile fatty acid
DOIs:

10.1016/j.biortech.2018.04.095
Source: Scopus
Source ID: 85047081553
Research output: Contribution to journal › Article › Scientific › peer-review

**Temperature control as key factor for optimal biohydrogen production from thermomechanical pulping wastewater**
This study evaluates the use of non-pretreated thermo-mechanical pulping (TMP) wastewater as a potential substrate for hydrogen production by dark fermentation. Batch incubations were conducted in a temperature gradient incubator at temperatures ranging from 37 to 80 °C, using an inoculum from a thermophilic, xylose-fed, hydrogen-producing fluidised bed reactor. The aim was to assess the short-term response of the microbial communities to the different temperatures with respect to both hydrogen yield and composition of the active microbial community. High throughput sequencing (MiSeq) of the reversely transcribed 16S rRNA showed that Thermoanaerobacterium sp. dominated the active microbial community at 70 °C, resulting in the highest hydrogen yield of 3.6 (±0.1) mmol $H_2$ $g^{-1}$ $COD_{tot}$ supplied. Lower hydrogen yields were obtained at the temperature range from 37 to 65 °C, likely due to consumption of the produced hydrogen by homoacetogenesis. No hydrogen production was detected at temperatures above 70 °C. Thermomechanical pulping wastewaters are released at high temperatures (50–80 °C), and thus dark fermentation at 70 °C could be sustained using the heat produced by the pulp and paper plant itself without any requirement for external heating.

**General information**
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MoE publication type: A1 Journal article-refereed
Organisations: Chemistry and Bioengineering, Research group: Bio- and Circular Economy, Research group: Industrial Bioengineering and Applied Organic Chemistry, Natl. University of Ireland, Galway, Institute for Water Education, UNESCO–IHE
Contributors: Dessì, P., Porca, E., Lakaniemi, A., Collins, G., Lens, P. N.
Number of pages: 8
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ISSN (Print): 1369-703X
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Original language: English
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Keywords: Dark fermentation, MiSeq, Pulp and paper mill wastewater, Thermoanaerobacterium, Thermomechanical pulping, Thermophilic
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Temperature control as key factor
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Source: Scopus
Source ID: 85048157059
Research output: Contribution to journal › Article › Scientific › peer-review

**Biological treatment of selenium-laden wastewater containing nitrate and sulfate in an upflow anaerobic sludge bed reactor at pH 5.0**
This study investigated the removal of selenate ($SeO_4^{2-}$), sulfate ($SO_4^{2-}$) and nitrate ($NO_3^-$) at different influent pH values ranging from 7.0 to 5.0 and 20 °C in an upflow anaerobic sludge blanket (UASB) reactor using lactate as an electron donor. At pH 5.0, the UASB reactor showed a 20–30% decrease in reactor performance compared to operation at pH 5.5 to 7.0, reaching removal efficiencies of 79%, 15%, 43% and 61% for $NO_3^-$, $SO_4^{2-}$, $Se_{total}$ and $Se_{diss}$, respectively. However, the reactor stability was an issue upon lowering the pH to 5.0 and further experiments are recommended. The sludge formed during low pH operation had a fluffy, floc-like appearance with filamentous structure, possibly due to the low polysaccharide (PS) to protein (PN) ratio (0.01 PS/PN) in the soluble extracellular polymeric substances (EPS) matrix of the biomass. Scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDX) analysis of the sludge confirmed Se oxyanion reduction and deposition of $Se^0$ particles inside the biomass. Microbial community analysis using Illumina MiSeq sequencing revealed that the families of Campylobacteraceae and

Desulfomicrobiaceae were the dominant phylotypes throughout the reactor operation at approximately 23% and 10% relative abundance, respectively. Furthermore, approximately 10% relative abundance of both Geobacteraceae and Spirochaetaceae was observed in the granular sludge during the pH 5.0 operation. Overall, this study demonstrated the feasibility of UASB operation at pH values ranging from 7.0 to 5.0 for removing Se and other oxyanions from wastewaters.

**General information**
Publication status: Published
MoE publication type: A1 Journal article-refereed
Organisations: Chemistry and Bioengineering, Bhabha Atomic Research Centre, Montana State University (MSU), Hydraulic and Environmental Engineering (IHE) Inst. for Water Education
Contributors: Tan, L. C., Nancharaiah, Y. V., Lu, S., van Hullebusch, E. D., Gerlach, R., Lens, P. N.
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Publication date: 1 Nov 2018
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**Publication information**
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Original language: English
ASJC Scopus subject areas: Environmental Engineering, Environmental Chemistry, Chemistry(all), Pollution, Health, Toxicology and Mutagenesis
Keywords: Acid mine drainage, Anaerobic granular sludge, Microbial diversity, Selenate bioreduction, UASB reactor
DOIs:

10.1016/j.chemosphere.2018.07.079
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Source ID: 85053212365
Research output: Contribution to journal › Article › Scientific › peer-review

**Editorial**

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Publication status: Published
MoE publication type: B1 Article in a scientific magazine
Organisations: Civil Engineering
Contributors: Länsivaara, T.
Number of pages: 1
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**Publication information**
Journal: Environmental Geotechnics
Volume: 5
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Original language: English
ASJC Scopus subject areas: Environmental Engineering, Environmental Chemistry, Water Science and Technology, Geotechnical Engineering and Engineering Geology, Waste Management and Disposal, Geochemistry and Petrology, Nature and Landscape Conservation, Management, Monitoring, Policy and Law
DOIs:

10.1680/jenge.2018.5.6.309
Source: Scopus
Source ID: 85059019429
Research output: Contribution to journal › Editorial › Scientific

**Bio-hydrogen Production from Sewage Sludge: Screening for Pretreatments and Semi-continuous Reactor Operation**
Abstract: The high volumes of sewage sludge produced have raised interests for simultaneous treatment and clean energy production, e.g. in the form of hydrogen. Pretreatment of sewage sludge is required to enhance microbial degradation and in turn hydrogen yield from sewage sludge. The potential of five substrate pretreatments, individually and in combinations, to increase biohydrogen production from mixed primary and secondary sewage sludge at four incubation

pH (5, 7, 9, and 11) was studied in batch assays. Alkali + ultrasonication pretreatment increased the hydrogen production almost seven times (0.35 mmol $H_2$/g VS) compared to untreated sewage sludge at initial pH 11. In general, higher hydrogen yields and lower acetate concentrations were obtained under alkaline conditions (pH 9 and 11), being more favorable for protein degradation and not favorable for hydrogen consumption via homoacetogenesis. Subsequently, fermentation of alkali + ultrasonication pretreated sewage sludge in a semi-continuous stirred tank reactor (CSTR) produced a maximum hydrogen yield of 0.1 mmol $H_2$/g VS, three times higher than the yield obtained from alkali pretreated sludge. The gas produced in the CSTRs contained a low concentration of $CO_2$ (< 5%), and is thus easily upgradable to biohydrogen. Graphic Abstract: [Figure not available: see fulltext.].

**General information**
Publication status: Published
MoE publication type: A1 Journal article-refereed
Organisations: Materials Science and Environmental Engineering, Water Pollution Research Department, National Research Centre, Indian Institute of Technology Hyderabad, Natl. University of Ireland, Galway, Ain Shams University
Contributors: El-Qelish, M., Chatterjee, P., Dessì, P., Kokko, M., El-Gohary, F., Abo-Aly, M., Rintala, J.
Publication date: 2019
Peer-reviewed: Yes

**Publication information**
Journal: Waste and Biomass Valorization
ISSN (Print): 1877-2641
Original language: English
ASJC Scopus subject areas: Environmental Engineering, Renewable Energy, Sustainability and the Environment, Waste Management and Disposal
Keywords: Alkali treatment, Continuously stirred tank reactor (CSTR), Dark fermentation, Pretreatment, Sewage sludge, Ultrasonication
DOIs:
10.1007/s12649-019-00743-5
Source: Scopus
Source ID: 85069208392
Research output: Contribution to journal › Article › Scientific › peer-review

## High-solids anaerobic digestion requires a trade-off between total solids, inoculum-to-substrate ratio and ammonia inhibition

Increasing total solids in anaerobic digestion can reduce the methane yield by highly complex bio-physical–chemical mechanisms. Therefore, understanding those mechanisms and their main drivers becomes crucial to optimize this waste treatment biotechnology. In this study, seven batch experiments were conducted to investigate the effects of increasing the initial total solids in high-solids anaerobic digestion of the organic fraction of municipal solid waste. With inoculum-to-substrate ratio = 1.5 g VS/g VS and maximum total solids ≤ 19.6%, mono-digestion of the organic fraction of municipal solid waste showed a methane yield = 174–236 NmL $CH_4$/g VS. With inoculum-to-substrate ratio ≤ 1.0 g VS/g VS and maximum total solids ≥ 24.0%, mono-digestion experiments acidified. Co-digestion of the organic fraction of municipal solid waste and beech sawdust permitted to reduce the inoculum-to-substrate ratio to 0.16 g VS/g VS while increasing total solids up to 30.2%, though achieving a lower methane yield (117–156 NmL $CH_4$/g VS). At each inoculum-to-substrate ratio, higher total solids corresponded to higher ammonia and volatile fatty acid accumulation. Thus, a 40% lower methane yield for mono-digestion was observed at a $NH_3$ concentration ≥ 2.3 g N–$NH_3$/kg reactor content and total solids = 15.0%. Meanwhile, co-digestion lowered the nitrogen content, being the risk of acidification exacerbated only at total solids ≥ 20.0%. Therefore, the biodegradability of the substrate, as well as the operational total solids and inoculum-to-substrate ratio, are closely interrelated parameters determining the success of methanogenesis, but also the risk of ammonia inhibition in high-solids anaerobic digestion.

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MoE publication type: A1 Journal article-refereed
Organisations: Materials Science and Environmental Engineering, Department of Civil and Mechanical Engineering, University of Cassino and Southern Lazio, LBE, INRA, ENEA/CREATE/Università Degli Studi Napoli Federico II
Contributors: Pastor-Poquet, V., Papirio, S., Trably, E., Rintala, J., Escudié, R., Esposito, G.
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**Publication information**
Journal: INTERNATIONAL JOURNAL OF ENVIRONMENTAL SCIENCE AND TECHNOLOGY
ISSN (Print): 1735-1472
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ASJC Scopus subject areas: Environmental Engineering, Environmental Chemistry, Agricultural and Biological Sciences(all)
Keywords: Batch experiments, Co-digestion, High-solids anaerobic digestion, Methane yield, Organic fraction of municipal solid waste, Thermophilic, Volatile fatty acids

DOIs:
10.1007/s13762-019-02264-z
Source: Scopus
Source ID: 85061488051
Research output: Contribution to journal › Article › Scientific › peer-review

**Why social sustainability counts: The impact of corporate social sustainability culture on financial success**

Awareness is growing in European companies of the importance of managing all aspects of sustainability. However, the elusive social aspect of sustainability and its influence on successful business has been under-investigated in corporate culture literature so far. The aim of this paper is to examine whether a correlation can be found between corporate social sustainability culture (expressed as explicit “items” of corporate values and practices emphasizing employee and societal well-being) and the financial success of a company. This is examined through a multiple regression analysis of two contrasting European polls, examining items indicating corporate social sustainability culture, and financial outcomes. The empirical results show that four specific success-related social sustainability dimensions of corporate culture are predictors of a company being classified as financially successful. These are: Sustainability strategy and leadership; Mission, communication and learning; Social care and work life; and Loyalty and identification. The paper contributes to the understanding of how to manage corporate social sustainability culture whilst supporting companies’ financial performance, and provides evidence-grounded recommendations to business managers and stakeholders aiming to manage social sustainability proactively by undertaking cultural change and development initiatives.

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MoE publication type: A1 Journal article-refereed
Organisations: Mechanical Engineering and Industrial Systems, Deep White GmbH, Chalmers University of Technology, Politecnico di Milano, Festo AG & Co. KG, Panepistimion Patron
Contributors: Schönborn, G., Berlin, C., Pinzone, M., Hanisch, C., Georgoulias, K., Lanz, M.
Number of pages: 10
Pages: 1-10
Publication date: 1 Jan 2019
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Volume: 17
ISSN (Print): 2352-5509
Original language: English
ASJC Scopus subject areas: Environmental Engineering, Environmental Chemistry, Renewable Energy, Sustainability and the Environment, Industrial and Manufacturing Engineering
Keywords: Corporate culture, Corporate sustainability, Financial performance, Social sustainability, Success factors, Sustainability
DOIs:
10.1016/j.spc.2018.08.008
Source: Scopus
Source ID: 85053411172
Research output: Contribution to journal › Article › Scientific › peer-review

**Semi-continuous mono-digestion of OFMSW and Co-digestion of OFMSW with beech sawdust: Assessment of the maximum operational total solid content**

In this study, mono-digestion of the organic fraction of municipal solid waste (OFMSW) and co-digestion of OFMSW with beech sawdust, simulating green waste, were used to investigate the maximum operational total solid (TS) content in semi-continuous high-solids anaerobic digestion (HS-AD). To alleviate substrate overloading in HS-AD, the effluent mass was relatively reduced compared to the influent mass, extending the mass retention time. To this aim, the reactor mass was daily evaluated, permitting to assess the reactor content removal by biogas production. During mono-digestion of OFMSW, the $NH_3$ inhibition and the rapid TS removal prevented to maintain HS-AD conditions (i.e. TS ≥ 10%), without exacerbating the risk of reactor acidification. In contrast, the inclusion of sawdust in OFMSW permitted to operate HS-AD up to 30% TS, before acidification occurred. Therefore, including a lignocellulosic substrate in OFMSW can prevent acidification and stabilize HS-AD at very high TS contents (i.e. 20–30%).

**General information**
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MoE publication type: A1 Journal article-refereed
Organisations: Chemistry and Bioengineering, Research group: Bio- and Circular Economy, University of Cassino and Southern Lazio, ENEA/CREATE/Università Degli Studi Napoli Federico II, University of Montpellier, University of Montpellier

Contributors: Pastor-Poquet, V., Papirio, S., Trably, E., Rintala, J., Escudié, R., Esposito, G.
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Early online date: 2018

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Journal: Journal of Environmental Management
Volume: 231
ISSN (Print): 0301-4797
Original language: English
ASJC Scopus subject areas: Environmental Engineering, Waste Management and Disposal, Management, Monitoring, Policy and Law
Keywords: Acidification, Ammonia inhibition, High-solids anaerobic digestion, Influent/effluent uncoupling, Substrate overloading
DOIs:

10.1016/j.jenvman.2018.10.002

**Bibliographical note**
EXT="Papirio, Stefano"
Source: Scopus
Source ID: 85054370336
Research output: Contribution to journal › Article › Scientific › peer-review

**Effects of energy retrofits on Indoor Air Quality in multifamily buildings**
We assessed 45 multifamily buildings (240 apartments) from Finland and 20 (96 apartments) from Lithuania, out of which 37 buildings in Finland and 15 buildings in Lithuania underwent energy retrofits. Building characteristics, retrofit activities, and energy consumption data were collected, and Indoor Air Quality (IAQ) parameters, including carbon monoxide (CO), nitrogen dioxide ($NO_2$), formaldehyde ($CH_2O$), selected volatile organic compounds (benzene, toluene, ethylbenzene, and xylenes (BTEX), radon, and microbial content in settled dust were measured before and after the retrofits. After the retrofits, heating energy consumption decreased by an average of 24% and 49% in Finnish and Lithuanian buildings, respectively. After the retrofits of Finnish buildings, there was a significant increase in BTEX concentrations (estimated mean increase of 2.5 μg/$m^3$), whereas significant reductions were seen in fungal (0.6-log reduction in cells/$m^2$/d) and bacterial (0.6-log reduction in gram-positive and 0.9-log reduction in gram-negative bacterial cells/$m^2$/d) concentrations. In Lithuanian buildings, radon concentrations were significantly increased (estimated mean increase of 13.8 Bq/$m^3$) after the retrofits. Mechanical ventilation was associated with significantly lower $CH_2O$ concentrations in Finnish buildings. The results and recommendations presented in this paper can inform building retrofit studies and other programs and policies aimed to improve indoor environment and health.

**General information**
Publication status: Published
MoE publication type: A1 Journal article-refereed
Organisations: Civil Engineering, Research group: Concrete and Bridge Structures, National Public Health Institute, Lappeenranta University of Technology, Kaunas University of Technology
Contributors: Du, L., Leivo, V., Prasauskas, T., Täubel, M., Martuzevicius, D., Haverinen-Shaughnessy, U.
Publication date: 28 Mar 2019
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ISSN (Print): 0905-6947
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ASJC Scopus subject areas: Environmental Engineering, Building and Construction, Public Health, Environmental and Occupational Health
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**Bibliographical note**
INT=CENG,"Haverinen-Shaughnessy, Ulla"
Source: Scopus
Source ID: 85064549626

### Effects of elevated pressures on the activity of acidophilic bioleaching microorganisms

This study reports effects of elevated pressures on the oxidation of a soluble ferrous iron and low-grade sulphidic ore as little is known about biological iron and sulphur oxidation under these conditions. Pressure effects were studied in a pressurised batch-operated stirred tank reactor using acidophilic enrichment cultures. The oxidation of soluble $Fe^{2+}$ by enrichment culture dominated by Leptospirillum ferriphilum, Sulfobacillus sp. and Ferrimicrobium acidiphilum increased with increasing pressure induced by technical air to up to +3 bar (0.63 bar $P_{O2}$) and was inhibited at +7 bar (1.47 bar $P_{O2}$). Elevated pressures induced by nitrogen (low oxygen partial pressure) were tolerated up to +40 bar. Another enrichment culture dominated by Acidithiobacillus ferrivorans, Sulfobacillus sp. and F. acidiphilum partially oxidised the ore at pressures up to +20 bar induced with air (4.2 bar $P_{O2}$). This is the first study reporting activity of acidophiles under pressurised conditions in a stirred tank reactor.

#### General information

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Organisations: Materials Science and Environmental Engineering
Contributors: Hajdu-Rahkama, R., Ahoranta, S., Lakaniemi, A., Puhakka, J. A.
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ASJC Scopus subject areas: Biotechnology, Bioengineering, Environmental Engineering, Biomedical Engineering
Keywords: Acidophiles, Biooxidation, Iron oxidation, Pressure tolerance, Pressurised stirred tank reactor
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10.1016/j.bej.2019.107286
Source: Scopus
Source ID: 85070494949
Research output: Contribution to journal › Article › Scientific › peer-review

### Anaerobic treatment of LCFA-containing synthetic dairy wastewater at 20°C: Process performance and microbial community dynamics

Facilitating anaerobic degradation of long-chain fatty acids (LCFA) is key for tapping the high methane production potential of the fats, oil and grease (FOG) content of dairy wastewaters. In this study, the feasibility of using high-rate granular sludge reactors for the treatment of mixed LCFA-containing synthetic dairy wastewater (SDW) was assessed at 20 °C. The effects of the LCFA concentration (33–45% of COD) and organic loading rates (2–3 gCOD/L·d) were determined using three parallel expanded granular sludge bed reactors. For the first time, long term anaerobic treatment of LCFA-containing feed at 20 °C was shown to be feasible and was linked to the microbial community dynamics in high-rate reactors. During a two-month operation, a soluble COD removal of 84–91% and COD to methane conversion of 44–51% was obtained. However, granular sludge flotation and washout occurred after two months in all reactors without volatile fatty acids (VFA) accumulation, emphasizing the need for sludge retention for long-term granular sludge reactor operation with LCFA-containing feed at low ambient temperatures. The temporal shifts in microbial community structure were studied in the high-rate treatment of SDW, and the process disturbances (elevated LCFA loading, LCFA accumulation, and batch operation) were found to decrease the microbial community diversity. The relative abundance of Methanosaeta increased with higher LCFA accumulation in the settled and flotation layer granules in the three reactors, therefore, acetoclastic methanogenesis was found to be crucial for the high-rate treatment of SDW at 20 °C. This study provides an initial understanding of the continuous anaerobic treatment of LCFA-containing industrial wastewaters at low ambient temperatures.

#### General information

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MoE publication type: A1 Journal article-refereed
Organisations: Materials Science and Environmental Engineering, Tampere Water, Hydraulic and Environmental Engineering (IHE) Inst. for Water Education, Natl. University of Ireland, Galway
Contributors: Singh, S., Rinta-Kanto, J. M., Kettunen, R., Tolvanen, H., Lens, P., Collins, G., Kokko, M., Rintala, J.
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Publication date: 15 Nov 2019
Peer-reviewed: Yes

**Publication information**
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ASJC Scopus subject areas: Environmental Engineering, Environmental Chemistry, Waste Management and Disposal, Pollution
Keywords: Dairy wastewater, Expanded granular sludge bed (EGSB), Granule disintegration, Long chain fatty acids (LCFA), Methanogenesis pathway, Microbial community dynamics
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10.1016/j.scitotenv.2019.07.136
Source: Scopus
Source ID: 85069487981
Research output: Contribution to journal › Article › Scientific › peer-review

## Power production and microbial community composition in thermophilic acetate-fed up-flow and flow-through microbial fuel cells

The microbial communities developed from a mixed-species culture in up-flow and flow-through configurations of thermophilic (55 °C) microbial fuel cells (MFCs), and their power production from acetate, were investigated. The up-flow MFC was operated for 202 days, obtaining an average power density of 0.13 W/m$^3$, and Tepidiphilus was the dominant transcriptionally-active microorganisms. The planktonic community developed in the up-flow MFC was used to inoculate a flow-through MFC resulting in the proliferation of Ureibacillus, whose relative abundance increased from 1 to 61% after 45 days. Despite the differences between the up-flow and flow-through MFCs, including the anode electrode, hydrodynamic conditions, and the predominant microorganism, similar ($p = 0.05$) volumetric power (0.11–0.13 W/m$^3$), coulombic efficiency (16–18%) and acetate consumption rates (55–69 mg/L/d) were obtained from both. This suggests that though MFC design can shape the active component of the thermophilic microbial community, the consortia are resilient and can maintain similar performance in different MFC configurations.

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MoE publication type: A1 Journal article-refereed
Organisations: Materials Science and Environmental Engineering, Research group: Bio- and Circular Economy, Natl. University of Ireland, Galway, Indian Institute of Technology Hyderabad
Contributors: Dessì, P., Chatterjee, P., Mills, S., Kokko, M., Lakaniemi, A., Collins, G., Lens, P. N.
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