Photoresponsive Polymer Hydrogel Coatings that Change Topography

This chapter provides a brief overview of the principles as well as the potential applications of photoresponsive hydrogel films, which change surface topography. It discusses the operating mechanisms that lead to topographical changes. Changes in topography can affect the wettability of a surface, which is an interesting characteristic for making self-cleaning coatings. The chapter also discusses polymer films that are useful for the development of self-cleaning films. It then discusses responsive materials, for cell culturing and microfluidics applications. The chapter further shows that appealing photoresponsive polymer hydrogel coatings that change topography can be fabricated, which holds great promise in a variety of fields ranging from microfluidic devices to biomedical applications. When the structures of the topography are in the micrometer size regime, they influence the wettability of the surface. Two types of wetting can be defined: Wenzel and Cassie-Baxter.
This letter presents the proof of concept of a novel bio-electroconcentration system (BEC), a hybrid microbial electrolysis/electrodialysis cell specifically designed to recover nitrogen (as ammonia NH$_4$-N), phosphorus (as phosphate PO$_4$-P), and potassium (as K$^+$) from urine. Using a synthetic urine medium, the BECs could reach high current densities of up to 37.6 A m$^{-2}$ at $E_{we}$ values of 0.0 versus the standard hydrogen electrode (SHE) and 50 A m$^{-2}$ at 0.2 V versus SHE, which in turn drove the removal and recovery of N, P, and K at rates of 7.18 kg of NH$_4$-N m$^{-3}$ day$^{-1}$, 0.52 kg of PO$_4$-P m$^{-3}$ day$^{-1}$, and 1.62 kg of K$^+$ m$^{-3}$ day$^{-1}$ into a concentrate stream (containing 1.87 M NH$_4$-N, 0.29 M PO$_4$-P, and 0.18 M K$^+$). Finally, this communication demonstrates the recovery of a nitrogen-rich solid from the synthetic urine (in the form of pure NH$_4$HCO$_3$ crystals with 17% N content) without any chemical additions via the flash-cooling of the produced nutrient-rich concentrate to 4 °C. These two new products may help facilitate the reuse of urine nutrients in the fertilizer or protein production industries of the future.
Microbial community response on wastewater discharge in boreal lake sediments

Despite high performance, municipal wastewater treatment plants (WWTPs) still discharge significant amounts of organic material and nitrogen and even microbes into the receiving water bodies, altering physico-chemical conditions and microbial functions. In this study, we examined how nitrified wastewater affects the microbiology of boreal lake sediments. Microbial community compositions were assessed with next generation sequencing of the 16S rRNA gene, and a more detailed view on nitrogen transformation processes was gained with qPCR targeting on functional genes (nirS, nirK, nosZI, nosZII, amoAarchaea, and amoAbacteria). In both of the two studied lake sites, the microbial community composition differed significantly between control point and wastewater discharge point, and a gradual shift toward natural community composition was seen downstream following the wastewater gradient. SourceTracker analysis predicted that ~2% of sediment microbes were of WWTP-origin on the study site where wastewater was freely mixed with the lake water, while when wastewater was specially discharged to the sediment surface, ~6% of microbes originated from WWTP, but the wastewater-influenced area was more limited. In nitrogen transformation processes, the ratio between nitrifying archaea (AOA) and bacteria (AOB) was affected by wastewater effluent, as the AOA abundance decreased from the control point (AOA:AOB 28:1 in Keuruu, 11:1 in Petäjävesi) to the wastewater-influenced sampling points, where AOB dominated (AOA:AOB 1:2–1:15 in Keuruu, 1:3–1:19 in Petäjävesi). The study showed that wastewater can affect sediment microbial community through importing nutrients and organic material and altering habitat characteristics, but also through bringing wastewater-originated microbes to the sediment, and may thus have significant impact on the freshwater biogeochemistry, especially in the nutrient-poor boreal ecosystems.
Screening biological methods for laboratory scale stabilization of fine fraction from landfill mining

Abstract Increasing interest for the landfill mining and the amount of fine fraction (FF) in landfills (40–70% (w/w) of landfill content) mean that sustainable treatment and utilization methods for FF are needed. For this study FF (<20 mm) was mined from a municipal solid waste (MSW) landfill operated from 1967 to 1989. FF, which resembles soil, was stabilized in laboratory scale reactors in two phases: first, anaerobically for 101 days and second, for 72 days using four different methods: anaerobic with the addition of moisture (water) or inoculum (sewage sludge) and aerobic with continuous water washing, with, or without, bulking material. The aim was to evaluate the effect on the stability of mined FF, which has been rarely reported, and to study the quality and quantity of gas and leachate produced during the stabilization experiment. The study showed that aerobic treatment reduced respiration activity (final values 0.9–1.1 mg O2/g TS) and residual methane potential (1.1 L CH4/kg TS) better than anaerobic methods (1.8–2.3 mg O2/g TS and 1.3–2.4 L CH4/kg TS, respectively). Bulking material mixed in FF in one aerobic reactor had no effect on the stability of FF. The benefit of anaerobic treatment was the production of methane, which could be utilized as energy. Even though the inoculum addition increased methane production from FF about 30%, but the methane production was still relatively low (in total 1.5–1.7 L CH4/kg TS). Continuous water washing was essential to remove leachable organic matter and soluble nutrients from FF, while increasing the volume of leachate collected. In the aerobic treatment, nitrogen was oxidized into nitrite and nitrate and then washed out in the leachate. Both anaerobic and aerobic methods could be used for FF stabilization. The use of FF, in landscaping for example, is possible because its nutrient content (4 g N/kg TS and 1 g P/kg TS) can increase the nutrient content of soil, but this may have limitations due to the possible presence of heavy metal and other contaminants.
Organic compound rich torrefaction condensate, owing to their high water content and acidic nature, have yet to be exploited for practical application. In this study, microbial conversion of torrefaction condensate from pine wood through anaerobic batch digestion (AD) to produce methane was evaluated. Torrefaction condensate exhibited high methane potentials in the range of 430-492 mL/g volatile solids (VS) and 430-460 mL/gVS under mesophilic and thermophilic conditions, respectively. Owing to the changes in the composition, the methane yields differed with the torrefaction condensates produced at different temperatures (225, 275 and 300°C), with a maximum of 492±18 mL/gVS with the condensate produced at 300°C under mesophilic condition. The cyclic batch AD experiments showed that 0.1 VS substrate:VS inoculum is optimum, whereas the higher substrate loading (0.2-0.5) resulted in a reversible inhibition of the methane production. The results suggest that torrefaction condensate could be practically valorized through AD.

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Biological hydrogen production is based on activity of specific enzymes called hydrogenases. Hydrogenases are oxygen sensitive metalloenzymes containing Ni and/or Fe atoms at the active site, catalyzing reversible reduction of protons. Generally, [Fe-Fe] hydrogenases prefer proton reduction to molecular hydrogen, a potential energy carrier molecule that can be produced by bioprocesses in sustainable manner. Thus, monitoring tools have been developed to study the relationship between [Fe-Fe] hydrogenases and biohydrogen production in bioreactors at DNA and RNA levels. In the present study, novel molecular tools are introduced for quantitative monitoring of clostridial [Fe-Fe] hydrogenases at the protein level. Aerobic and anaerobic biopanning (for inactive and active [Fe-Fe] hydrogenase, respectively) of phage displayed single-chain variable fragment (scFv) antibody libraries aided in isolating nine potential scFvs. The enriched antibodies demonstrated high specificity towards Clostridium spp. [Fe-Fe] hydrogenases allowing detection from pure and mixed cultures. Additionally, the antibodies showed different binding characteristics towards hydrogenase catalytic states, providing a possible means for functional detection of clostridial [Fe-Fe] hydrogenases. From hydrogenase-antibody interaction studies we observed that though antibody binding reduced the enzyme catalytic activity, it facilitated to retain hydrogen evolution from oxygen exposed hydrogenases.
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 °C. 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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Structural photoactivation of a full-length bacterial phytochrome
Phytochromes are light sensor proteins found in plants, bacteria, and fungi. They function by converting a photon absorption event into a conformational signal that propagates from the chromophore through the entire protein. However, the structure of the photoactivated state and the conformational changes that lead to it are not known. We report time-resolved x-ray scattering of the full-length phytochrome from Deinococcus radiodurans on micro- and millisecond time scales. We identify a twist of the histidine kinase output domains with respect to the chromophore-binding domains as the dominant change between the photoactivated and resting states. The time-resolved data further show that the structural changes up to the microsecond time scales are small and localized in the chromophore-binding domains. The global structural change occurs within a few milliseconds, coinciding with the formation of the spectroscopic meta-Rc state. Our findings establish key elements of the signaling mechanism of full-length bacterial phytochromes.

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Modeling of the catalytic effects of potassium and calcium on spruce wood gasification in CO₂

Using previously reported thermogravimetric analysis measurements, the effects of calcium and potassium on the char gasification rate of spruce wood were modeled. Spruce wood was leached of inorganic ash elements and doped with measured amounts of potassium and calcium. The wood was gasified in an isothermal thermogravimetric analysis device in CO₂ where the devolatilization of the wood, char formation and char gasification all occurred inside the preheated reactor. A new method for separating the effects of devolatilization and char gasification is presented. Kinetic models were evaluated for their ability to describe the observed catalytic effects of potassium and calcium on the gasification rate. Two modified versions of the random pore model were able to accurately describe the measured conversion rates and the parameters of the kinetic models were found to be dependent on the calcium and potassium concentrations. Empirical correlations were developed to predict the char conversion rate from only the potassium and calcium concentration of the sample.
Microbial electrochemical technologies with the perspective of harnessing bioenergy: Maneuvering towards upscaling

Microbial electrochemical technologies have gained much attention in the recent years during which basic research has been carried out to provide proof of concept by utilizing microorganisms for generating bioenergy in an electro redox active environment. However, these bio-electrocatalyzed systems pose significant challenges towards up-scaling and practical applications. Various parameters viz., electrodes, materials, configuration, biocatalyst, reaction kinetics, fabrication and operational costs, resistance for electron transfer etc. will critically govern the performance of microbial catalyzed electrochemical systems. Majorly, the surface area of electrode materials, biofilm coverage on the electrode surface, enrichment of electrochemically active electrode respiring bacteria and reduction reactions at cathode will aid in increasing the reaction kinetics towards the upscaling of microbial electrochemical technologies. Enrichment of electroactive microbial community on anode electrode can be promoted with electrode pretreatment, controlled anode potential or electrical current, external resistance, optimal operation temperature, chemical additions and bioaugmentation. Inhibition of the growth of methanogens also increases the columbic efficiency, an essential parameter that determines the efficacy of bioelectricity generation. Considering the practical implementation of these microbial electrochemical technologies, the current review addresses the challenges and strategies to improve the performance of bio-electrocatalyzed systems with respect to the operational, physico-chemical and biological factors towards scale up. Besides, the feasibility for long term operation, the scope for future research along with the operational and maintenance costs are discussed to provide a broad spectrum on the role of the system components for the implementation of these bio-electrochemical technologies for practical utility.
Characterization of fine fraction mined from two Finnish landfills

A fine fraction (FF) was mined from two Finnish municipal solid waste (MSW) landfills in Kuopio (1- to 10-year-old, referred as new landfill) and Lohja (24- to 40-year-old, referred as old landfill) in order to characterize FF. In Kuopio the FF (<20mm) was on average 45±7% of the content of landfill and in Lohja 58±11%. Sieving showed that 86.5±5.7% of the FF was smaller than 11.2mm and the fraction resembled soil. The total solids (TS) content was 46-82%, being lower in the bottom layers compared to the middle layers. The organic matter content (measured as volatile solids, VS) and the biochemical methane potential (BMP) of FF were lower in the old landfill (VS/TS 12.8±7.1% and BMP 5.8±3.4m^3 CH_4/t TS) than in the new landfill (VS/TS 21.3±4.3% and BMP 14.4±9.9m^3 CH_4/t TS), and both were lower compared with fresh MSW. In the Kuopio landfill materials were also mechanically sieved in the full scale plant in two size fraction <30mm (VS/TS 31.1% and 32.9m^3 CH_4/t TS) and 30-70mm (VS/TS 50.8% and BMP 78.5m^3 CH_4/t TS). The nitrogen (3.5±2.0g/kg TS), phosphorus (<1.0-1.5g/kg TS) and soluble chemical oxygen demand (COD) (2.77±1.77kg/t TS) contents were low in all samples. Since FF is major fraction of the content of landfill, the characterization of FF is important to find possible methods for using or disposing FF mined from landfills.

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Clashing coalitions: A discourse analysis of an artificial groundwater recharge project in Finland

The purpose of this paper is to increase understanding of the dynamics of knowledge production in the context of large-scale environmental projects causing local conflict. In particular, the paper analyses the discourse coalitions that formed around an artificial groundwater recharge project for the Turku Region in Finland. The material for this study consists of over 400 articles and opinion pieces which were collected from local and regional newspapers between 1999 and 2010. The articles were analysed by using Hajer's [1995. The politics of environmental discourse. Ecological modernisation and the policy process. Oxford, UK: Clarendon] discursive framework, and the analysis was complemented with the concept of knowledge coalition by Van Buuren and Edelenbos [2004. Conflicting knowledge. Why is joint knowledge production such a problem? Science and Public Policy, 31 (4), 289–299]. Results of the study indicate that knowledge coalitions were formed among the researchers, lay residents, and policy-makers, and they all utilised similar expertise-based factual arguments to support their cause. Thus, the paper participates in the academic discussion on the use and interpretation of expert knowledge in environmental policy-making by reshaping the division between experts and lay residents.
High rate autotrophic denitrification in fluidized-bed biofilm reactors

High rate, high efficiency thiosulfate-driven autotrophic denitrification and denitrification with Thiobacillus denitrificans dominated biofilms were achieved in fluidized-bed reactors (FBRs) operated at 20.0 ± 2.0 and 30.0 ± 0.2 °C. Complete nitrate removal was obtained even at nitrate loading rate and hydraulic retention time (HRT) of 600 mg L⁻¹ h⁻¹ and 10 min, respectively. Further decrease of HRT to 5 min resulted in 50% of nitrate removal efficiency. Nitrite did not accumulate when nitrate was used as electron acceptor unless HRT was decreased to 5 min. Effluent pH remained at 5.8 during denitrification. When nitrite was supplemented as the electron acceptor, denitrification effectively proceeded with the highest nitrite loading rate of 228 mg L⁻¹ h⁻¹. Similar denitrification and denitrification performances were obtained at 20.0 ± 2.0 and 30.0 ± 0.2 °C. Batch assays conducted at temperature range from 1 to 46 °C, however, showed a significant impact of temperature on autotrophic denitrification. Ratkowsky model was used to estimate the minimum, optimal and maximum growth temperatures of T. denitrificans dominated culture that were below 1, 26.6 and 50.8 °C, respectively.

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Preferential adsorption of Cu in a multi-metal mixture onto biogenic elemental selenium nanoparticles

Preferential adsorption of Cu contained in wastewaters is desirable as the Cu can then be reprocessed and reused more easily. In this study, biogenic elemental selenium nanoparticles (BioSeNPs) were assessed for their ability to preferentially adsorb Cu from an equimolar mixture containing Cu, Cd and Zn. Variations in metal to BioSeNPs ratios and initial metal solution pH improved the preferential adsorption capacity of BioSeNPs toward Cu, with the ratio of Cu adsorbed to combined Cd and Zn adsorbed varying from 2.3 to 6.6. More than 78% of the added Cu was adsorbed at an initial metal solution pH of 5.2 and metal to BioSeNPs ratio of 0.21mgmg⁻¹ when the ratio of Cu adsorbed to the sum of Cd and Zn adsorbed was 2.3. Infrared spectroscopy revealed that the Cu, Cd and Zn were interacting with the hydroxyl and carboxyl surface functional groups of the BioSeNPs. The modeling of BioSeNPs' acid-base titration revealed the presence of high concentrations of carboxylic groups (C=60.3molkg⁻¹) with a pK_a of 3.9, providing further evidence of their interaction with Cu. The adsorption of Cu resulted in a lower colloidal stability of the BioSeNPs as indicated by more than 99% retention of added BioSeNPs after adsorption of heavy metals and filtration. BioSeNPs showed a good preferential adsorption capacity toward Cu as compared to other adsorbent. This study provides a proof-of-concept for the preferential adsorption of Cu onto BioSeNPs which are present in the effluent of a bioreactor treating selenium oxyanions containing wastewater.

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Scopus rating (2002): SJR 0.692 SNIP 0.983
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Use of diluted urine for cultivation of Chlorella vulgaris

Our aim was to study the biomass growth of microalga Chlorella vulgaris using diluted human urine as a sole nutrient source. Batch cultivations (21 days) were conducted in five different urine dilutions (1:25-1:300), in 1:100-diluted urine as such and with added trace elements, and as a reference, in artificial growth medium. The highest biomass density was obtained in 1:100-diluted urine with and without additional trace elements (0.73 and 0.60 g L(-1), respectively). Similar biomass growth trends and densities were obtained with 1:25- and 1:300-diluted urine (0.52 vs. 0.48 g VSS L(-1)) indicating that urine at dilution 1:25 can be used to cultivate microalgal based biomass. Interestingly, even 1:300-diluted urine contained sufficiently nutrients and trace elements to support biomass growth. Biomass production was similar despite pH-variation from <5 to 9 in different incubations indicating robustness of the biomass growth. Ammonium formation did not inhibit overall biomass growth. At the beginning of cultivation, the majority of the biomass consisted of living algal cells, while towards the end, their share decreased and the estimated share of bacteria and cell debris increased.

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Use of laboratory anaerobic digesters to simulate the increase of treatment rate in full-scale high nitrogen content sewage sludge and co-digestion biogas plants
The aim of this study was to assess the effect of increasing feedstock treatment rate on the performance of full-scale anaerobic digestion using laboratory-scale reactors with digestate and feedstock from full-scale digesters. The studied nitrogen-containing feedstocks were i) a mixture of industrial by-products and pig slurry, and ii) municipal sewage sludge, which digestion was studied at 41 and 52 degrees C, respectively. This study showed the successful reduction of
hydraulic retention times from 25 and 20 days to around 15 days, which increased organic loading rates from 2 to 3.5 kg volatile solids (VS)/m(3) d and 4 to 6 kg VS/m(3) d. As a result, the optimum retention time in terms of methane production and VS removal was 10-15% lower than the initial in the full-scale digesters. Accumulation of acids during start-up of the co-digestion reactor was suggested to be connected to the high ammonium nitrogen concentration and intermediate temperature of 41 degrees C. (C) 2016 Elsevier Ltd. All rights reserved.

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Keywords: Anaerobic digestion, Nitrogen, Co-digestion, Sewage sludge, Hydraulic retention time, MICROBIAL COMMUNITY STRUCTURE, FOOD WASTE, SUBSTRATE RATIO, AMMONIA, INOCULUM, TEMPERATURE, PERFORMANCE, MANURE
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EXT="Tampio, Elina"
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Research output: Scientific - peer-review › Article

Mesophilic anaerobic digestion of pulp and paper industry biosludge-long-term reactor performance and effects of thermal pretreatment
The pulp and paper industry wastewater treatment processes produce large volumes of biosludge. Limited anaerobic degradation of lignocellulose has hindered the utilization of biosludge, but the processing of biosludge using anaerobic digestion has recently regained interest. In this study, biosludge was used as a sole substrate in long-term (400 d) mesophilic laboratory reactor trials. Nine biosludge batches collected evenly over a period of one year from a pulp and paper industry wastewater treatment plant had different solid and nutrient (nitrogen, phosphorus, trace elements) characteristics. Nutrient characteristics may vary by a factor of 2-11, while biomethane potentials (BMPs) ranged from 89 to 102 NL CH<inf>4</inf>/kg<sup>-1</sup> VS between batches. The BMPs were enhanced by 39-88% with thermal
pretreatments at 105-134 °C. Despite varying biosludge properties, stable operation was achieved in reactor trials with a hydraulic retention time (HRT) of 14 d. Hydrolysis was the process limiting step, ceasing gas production when the HRT was shortened to 10 days. However, digestion with an HRT of 10 days was feasible after thermal pretreatment of the biosludge (20 min at 121 °C) due to enhanced hydrolysis. The methane yield was 78 NL CH\text{\textsubscript{4}} kg\textsuperscript{-1} VS for untreated biosludge and was increased by 77% (138 NL CH\text{\textsubscript{4}} kg\textsuperscript{-1} VS) after pretreatment.

General information
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Organisations: Department of Chemistry and Bioengineering, Research group: Industrial Bioengineering and Applied Organic Chemistry, Urban circular bioeconomy (UrCirBio)
Authors: Kinnunen, V., Ylä-Outinen, A., Rintala, J.
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Scopus rating (2015): SJR 2.689 SNIP 2.507 CiteScore 6.63
Scopus rating (2014): SJR 2.957 SNIP 2.727 CiteScore 6.13
Scopus rating (2013): SJR 2.956 SNIP 2.693 CiteScore 6.02
Scopus rating (2012): SJR 2.966 SNIP 2.456 CiteScore 5.15
Scopus rating (2011): SJR 2.867 SNIP 2.374 CiteScore 5.43
Scopus rating (2010): SJR 2.582 SNIP 2.196
Scopus rating (2009): SJR 2.319 SNIP 2.225
Scopus rating (2008): SJR 2.065 SNIP 2.19
Scopus rating (2007): SJR 1.994 SNIP 2.208
Scopus rating (2006): SJR 1.695 SNIP 2.214
Scopus rating (2005): SJR 2.114 SNIP 2.337
Scopus rating (2004): SJR 2.227 SNIP 2.106
Scopus rating (2003): SJR 1.696 SNIP 1.917
Scopus rating (2002): SJR 1.54 SNIP 1.775
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Scopus rating (2000): SJR 1.305 SNIP 1.688
Scopus rating (1999): SJR 1.456 SNIP 1.576
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Synthesis, crystal structure, physico-chemical characterization and dielectric properties of a new hybrid material, 1-Ethylpiperazine-1,4-dium tetrachlorocadmate
Metabolic engineering of Acinetobacter baylyi ADP1 for removal of Clostridium butyricum growth inhibitors produced from lignocellulosic hydrolysates

Background: Pretreatment of lignocellulosic biomass can produce inhibitory compounds that are harmful for microorganisms used in the production of biofuels and other chemicals from lignocellulosic sugars. Selective inhibitor removal can be achieved with biodetoxification where microorganisms catabolize the inhibitors without consuming the sugars. We engineered the strictly aerobic Acinetobacter baylyi ADP1 for detoxification of lignocellulosic hydrolysates by removing the gene for glucose dehydrogenase, gcd, which catalyzes the first step in its glucose catabolism. Results: The engineered A. baylyi ADP1 strain was shown to be incapable of consuming the main sugar components of lignocellulosic hydrolysates, i.e., glucose, xylose, and arabinose, but rapidly utilized acetate and formate. Formate was consumed during growth on acetate and by stationary phase cells, and this was enhanced in the presence of a common aromatic inhibitor of lignocellulosic hydrolysates, 4-hydroxybenzoate. The engineered strain tolerated glucose well up to 70 g/l, and the consumption of glucose, xylose, or arabinose was not observed in prolonged cultivations. The engineered strain was applied in removal of oxygen, a gaseous inhibitor of anaerobic fermentations. Co-cultivation with the A. baylyi ADP1 gcd knockout strain under initially aerobic conditions allowed the strictly anaerobic Clostridium butyricum to grow and produce hydrogen (H₂) from sugars of the enzymatic rice straw hydrolysate. Conclusions: We demonstrated that the model...
Organism of bacterial genetics and metabolism, A. baylyi ADP1, could be engineered to be an efficient biodetoxification strain of lignocellulosic hydrolysates. Only one gene knockout was required to completely eliminate sugar consumption and the strain could be used in production of anaerobic conditions for the strictly anaerobic hydrogen producer, C. butyricum. Because of these encouraging results, we believe that A. baylyi ADP1 is a promising candidate for the detoxification of lignocellulosic hydrolysates for bioprocesses.

**General information**

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Organisations: Department of Chemistry and Bioengineering, Research group: Industrial Bioengineering and Applied Organic Chemistry, Urban circular bioeconomy (UrCirBio), Rhodes University

Authors: Kannisto, M. S., Mangayil, R. K., Shrivastava-Bhattacharya, A., Pletschke, B. I., Karp, M. T., Santala, V. P.

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Scopus rating (2013): SJR 2.17 SNIP 1.815 CiteScore 6.21
Scopus rating (2012): SJR 2.15 SNIP 1.849 CiteScore 5.7
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Scopus rating (2010): SJR 1.774 SNIP 1.745
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Keywords: Acinetobacter baylyi, Biodetoxification, Biohydrogen, Clostridium butyricum, Metabolic engineering, Rice straw hydrolysate

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**Production of Oleaginous Microbial Biomass by Reusing Wastewaters**

Global energy demand continues to increase, which raises the question regarding how to solve the energy crisis caused by diminishing fossil fuels. There is no single alternative energy source that could substitute the fossil fuels, but microbial single cell oils (SCO) could be part of the solution. SCOs can be produced by cultivating microorganisms in wastewater in which nutrients and carbon from the wastewater are used for biomass production. In optimized conditions, microorganisms begin to accumulate lipids, and these lipids can be further refined for the production of biodiesel or renewable diesel. The lipid accumulation of the microorganisms may be enhanced by culturing the microorganisms under stressful conditions. The most commonly used strategy for enhancing lipid accumulation is nitrogen starvation, but it is even more effective when combined with another stress factor, such as moderately increased salinity. In microbial lipid production, the major cost factor is often the substrate needed for the microorganisms. Therefore, utilizing inexpensive substrates and waste materials for the cultivation of oleaginous microorganisms is very desirable. Various wastewaters from municipalities, agriculture, and industrial sources have been studied, and many of these wastewaters have shown the potential for lipid-rich biomass production. Unfortunately, most of the studies have been conducted using sterilized wastewater. In large-scale applications, the sterilization of the wastewater is not cost-effective; therefore, lipid-accumulating microorganisms able to compete with the indigenous microorganisms of the wastewater need to be further studied. The aim of this work was to sustainably produce oleaginous biomass by reusing the carbon and nutrients from wastewaters. This work included an evaluation of the suitability of various wastewaters for lipid-lipid rich biomass production (Paper I), the isolation of yeasts and fungi, which could possibly accumulate lipids by utilizing wastewater as substrate (Paper II), and the determination of the ability of the isolated microorganisms to accumulate lipids by comparing them with known lipid accumulating yeasts (Paper II). Unlike yeasts and fungi, microalgae are able to use an inorganic carbon source for their growth. This feature enables the combination of wastewater and flue gas treatment. Therefore, the growth and lipid accumulation of three microalgal species were compared (Paper III), and the suitability of the most potential microalgal species for accumulating lipids in sterilized and non-sterilized wastewater was studied (Paper III & IV). Based on the
results of this study, palm oil mill effluent (POME) has more potential for lipid production than chemithermomechanical pulp mill effluent (CTMP) or municipal wastewater (MWW) (Paper I). The residual lipids and solids of POME obstructed the analyses of the microbial SCOs. Eukaryotes isolated from POME with agar plates were genetically identified as Candida silvae NRRL Y-6725 (with 100% similarity), Galactomyces geotrichum LMA-20 (with 99.8% similarity), Lecythophora hoffmannii CBS245.38T (with 96.7% similarity), and Graphium penicillioides JCM9300 (with 99.3% similarity) (Paper II). The fungus Graphium penicillioides had a great potential for lipid accumulation based on the comparison study with well-known oleaginous yeast strains (Yarrowia lipolytica DSMZ8212, Cryptococcus curvatus DSMZ70022, & Cryptococcus albidus DSMZ701097) in a synthetic medium (Paper II). The lipid content per dry weight was higher with G. penicillioides compared to C. curvatus after 15 days of incubation (29.1±3.0 wt% vs 20.2±2.9 wt%, Paper II). Unfortunately, the overall lipid concentration was lower due to a lower biomass concentration. G. penicillioides contained more than 20% lipids, so it can be called oleaginous. From the three microalgae isolated from a Taiwanese freshwater area (Chlorella sorokiniana CY1, Chlorella vulgaris CY5, & Chlamydomonas sp. JSC-04), C. vulgaris accumulated more lipids when various media, nitrogen sources, and nitrogen concentrations were studied (Paper III). The C. vulgaris in the BG-11 medium, initially containing 0.38 g NaNO3/L, produced 3.8 g/L biomass and 57.5 wt% lipids after 12 days of incubation. The most suitable wastewater dilution for the lipid accumulation of C. vulgaris on sterilized anaerobically treated piggery wastewater was 5x dilution, which resulted in initial chemical oxygen demand and total Kjeldahl nitrogen of 75.4 mg/L and 57.4 mg/L, respectively. C. vulgaris was suitable for accumulating lipids on both sterilized and non-sterilized anaerobically treated piggery wastewater (PW) (Paper IV). The highest lipid content and productivity with the non-sterilized wastewater were rather promising (32.5±3.2 wt%, 71.2±2.2 g/L/d). However, under the conditions of these experiments, C. vulgaris excreted dissolved organic carbon (Paper III & IV), and the aim in wastewater treatment is the removal of organic carbon. In summary, this work demonstrates the potential of indigenous eukaryotic microorganisms for lipid-rich biomass production. G. penicillioides isolated from POME has the potential for lipid-rich biomass production in a synthetic medium, which has not been previously reported. Similarly, C. vulgaris has the potential for lipid-rich biomass production in non-sterilized piggery wastewater, while most of the studies in the literature on C. vulgaris and wastewater have been conducted using sterilized wastewater. To enable simultaneous accumulation of lipids and efficient treatment of wastewater, special attention should be focused on the growth conditions.
Two of the perylene monoimide derivatives were found to be a perfect basement for construction of multilayered films. Using a metal-ligand interaction it was possible to prepare stable double layers, as well ten molecules thick stable deeply colored multilayer films. The developed approach is versatile and will allow in future to expand the capabilities of molecular film architecture.

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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<sub>s</sub>) 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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Organisations: Department of Chemistry and Bioengineering, Research group: Industrial Bioengineering and Applied Organic Chemistry, Urban circular bioeconomy (UrCirBio), Center of Bioscience and Biotechnology, Research Center for Energy Technology and Strategy, National Cheng Kung University, Department of Environmental Engineering, Department of Chemical Engineering
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Early online date: 23 Jul 2015

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Journal: Biochemical Engineering Journal
Volume: 103
Searching for a robust strategy for minimizing alkali chlorides in fluidized bed boilers during burning of high SRF-energy-share fuel

To meet the increasing volume of waste to be treated via energy recovery, high SRF-energy-share fuel is being fired in conventional waste-to-energy facilities. In this work, corrosion related risk during firing of 70 e-% share (target fuel) is studied and compared against the base case fuel containing 50 e-% share. Cl and S concentration is highest in the target fuel as a direct result of increasing the proportion of SRF in the fuel mixture. Br, Zn and Pb showed the same trend. Meanwhile, the concentration of Na, K, Al and Si are highly dependent on the type of the SRF fired. The corrosion risk of the base and target fuels are analyzed using the composition of the fine aerosol fraction and deposit samples measured near the vicinity of the superheater. Surprisingly aerosols for the target fuel are less risky - having less Cl and more S, than that of the base fuel. The effects of sulfur based additives - elemental sulfur and sulfate injection, and fuel substitution on the risk of superheater corrosion are likewise analyzed. All these strategies can reduce the concentration of Cl in the aerosols, however it is concluded that sulfate injection is considered as a robust strategy for mitigating alkali chloride formation. Sulfate injection is able to reduce Cl in the aerosols and deposits regardless of the quality of the fuel mixture. Robust strategies are important in ensuring the boiler performance during high SRF-energy share firing. An attempt of linking the quality of the deposits and the properties of the flue gas and aerosols around the superheater using partial least squares regression is also presented.

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Organisations: Department of Chemistry and Bioengineering, Urban circular bioeconomy (UrCirBio), University of Jyväskylä, Valmet Technologies Oy, VTT Technical Research Centre of Finland, Department of Chemistry, Renewable Natural Resources and Chemistry of Living Environment, Stora Enso
Authors: Bajamundi, C. J. E., Vainikka, P., Hedman, M., Silvennoinen, J., Heinanen, T., Taipale, R., Konttinen, J.
Number of pages: 12
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Publication date: 1 Sep 2015
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Selecting an indigenous microalgal strain for lipid production in anaerobically treated piggery wastewater

The aim of this study was to select a potential microalgal strain for lipid production and to examine the suitability of anaerobically treated piggery wastewater as a nutrient source for production of lipid-rich biomass with the selected microalga. Biomass and lipid productivity of three microalgal strains (Chlorella sorokiniana CY1, Chlorella vulgaris CY5 and Chlamydomonas sp. JSC-04) were compared by using different media, nitrogen sources, and nitrogen concentrations. The highest lipid content and productivity (62.5 wt%, 162 mg/L/d) were obtained with C. vulgaris with BG-11 with 62 mg N/L. Secondly, C. vulgaris was cultivated in sterilized, diluted (1–20×), anaerobically treated piggery wastewater. Biomass production decreased and lipid content increased, when wastewater was more diluted. The highest lipid content of 54.7 wt% was obtained with 20× dilution, while the highest lipid productivity of 100.7 mg/L/d with 5× dilution. Piggery wastewater is a promising resource for mass production of oleaginous microalgal biomass.

General information
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Organisations: Department of Chemistry and Bioengineering, Research group: Industrial Bioengineering and Applied Organic Chemistry, Urban circular bioeconomy (UrCirBio)
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Supported Fe2O3-TiO2 nanocomposites are fabricated by an original vapor phase synthetic strategy, consisting of the initial growth of Fe2O3 nanosystems on fluorine-doped tin oxide substrates by plasma enhanced-chemical vapor deposition, followed by atomic layer deposition of TiO2 overlayers with variable thickness, and final thermal treatment in air. A thorough characterization of the target systems is carried out by X-ray diffraction, atomic force microscopy, field emission-scanning electron microscopy, energy dispersive X-ray spectroscopy, transmission electron microscopy, and X-ray photoelectron spectroscopy. High purity nanomaterials characterized by the co-presence of Fe2O3 (hematite) and TiO2 (anatase), with an intimate Fe2O3-TiO2 contact, are successfully obtained. In addition, photocatalytic tests demonstrate that, whereas both single-phase oxides do not show appreciable activity, the composite systems are able to degrade methyl orange aqueous solutions under simulated solar light, and even visible light, with an efficiency directly dependent on TiO2 overlayer thickness. This finding opens attractive perspectives for eventual applications in wastewater treatment.
Electricity production by a microbial fuel cell fueled by brewery wastewater and the factors in its membrane deterioration

Electricity production from brewery wastewater using dual-chamber microbial fuel cells (MFCs) with a tin-coated copper mesh in the anode was investigated by changing the hydraulic retention time (HRT). The MFCs were fed with wastewater samples from the inlet (inflow, MFC-1) and outlet (outflow, MFC-2) of an anaerobic digester of a brewery wastewater treatment plant. Both chemical oxygen demand removal and current density were improved by decreasing HRT. The best MFC performance was with an HRT of 0.5 d. The maximum power densities of 8.001 and 1.843 µW/cm² were obtained from reactors MFC-1 and MFC-2, respectively. Microbial diversity at different conditions was studied using PCR-DGGE profiling of 16S rRNA fragments of the microorganisms from the biofilm on the anode electrode. The MFC reactor had mainly Geobacter, Shewanella, and Clostridium species, and some bacteria were easily washed out at lower HRTs. The fouling characteristics of the MFC Nafion membrane and the resulting degradation of MFC performance were examined. The ion exchange capacity, conductivity, and diffusivity of the membrane decreased significantly after fouling. The morphology of the Nafion membrane and MFC degradation were studied using scanning electron microscopy and attenuated total reflection-Fourier transform infrared spectroscopy.

General information

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Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Chemistry and Bioengineering, Portland State University, Department of Civil and Environmental Engineering, Yildiz Technical University
Authors: Çetinkaya, A. Y., Köroğlu, E. O., Demir, N. M., Baysoy, D. Y., Özkaya, B., Çakmakçi, M.
Number of pages: 9
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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.
Catalytic effect of Ca and K on CO2 gasification of spruce wood char

Gasification is one route to produce chemicals and liquid fuels from biomass. The gasification of the char is catalyzed by alkali and alkaline earth metals in the biomass. In this work the catalytic effect of calcium (Ca) and potassium (K) on CO2 gasification of spruce wood was studied using a thermo gravimetric analyzer (TGA). The ash-forming elements were first removed from the wood using an acid leaching method. Then, various concentrations of K and Ca were absorbed to the wood by ion-exchange to carboxylic and phenolic groups, impregnation of K2CO3 or physically mixing of CaC2O4. The prepared spruce samples were placed in a mesh holder and gasified in the TGA at 850°C in 100% CO2. The results demonstrate that the gasification rate of the char increased linearly with an increase in the concentration of Ca or K. Crystalline CaC2O4 distributed only at the surface of the wood particles resulted in low catalytic activity. The catalytic activity of Ca was higher than K in the beginning of char gasification but the catalytic effect of Ca decreased earlier than the catalytic effect of potassium. Further, the char structure was investigated by SEM-EDX. The SEM analysis from interrupted gasification experiments showed the formation of CaCO3 and K2CO3 layer on the char surface. By adding corresponding levels of Ca and K as the original spruce to the acid washed sample, a similar gasification reactivity was obtained at 850°C.
Selenium biomineralization for biotechnological applications

Selenium (Se) is not only a strategic element in high-tech electronics and an essential trace element in living organisms, but also a potential toxin with low threshold concentrations. Environmental biotechnological applications using bacterial biomineralization have the potential not only to remove selenium from contaminated waters, but also to sequester it in a reusable form. Selenium biomineralization has been observed in phylogenetically diverse microorganisms isolated from pristine and contaminated environments, yet it is one of the most poorly understood biogeochemical processes. Microbial respiration of selenium is unique because the microbial cells are presented with both soluble (SeO₄²⁻ and SeO₃²⁻ and insoluble (Se) forms of selenium as terminal electron acceptor. Here, we highlight selenium biomineralization and the potential biotechnological uses for it in bioremediation and wastewater treatment.

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Authors: Nancharaiah, Y. V., Lens, P. N. L.
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Scopus rating (2014): SJR 4.344 SNIP 3.35 CiteScore 10.31
Biomimetic collagen I and IV double layer Langmuir-Schaefer films as microenvironment for human pluripotent stem cell derived retinal pigment epithelial cells

The environmental cues received by the cells from synthetic substrates in vitro are very different from those they receive in vivo. In this study, we applied the Langmuir-Schaefer (LS) deposition, a variant of Langmuir-Blodgett technique, to fabricate a biomimetic microenvironment mimicking the structure and organization of native Bruch's membrane for the production of the functional human embryonic stem cell derived retinal pigment epithelial (hESC-RPE) cells. Surface pressure-area isotherms were measured simultaneously with Brewster angle microscopy to investigate the self-assembly of human collagens type I and IV on air-subphase interface. Furthermore, the structure of the prepared collagen LS films was characterized with scanning electron microscopy, atomic force microscopy, surface plasmon resonance measurements and immunofluorescent staining. The integrity of hESC-RPE on double layer LS films was investigated by measuring transepithelial resistance and permeability of small molecular weight substance. Maturation and functionality of hESC-RPE cells on double layer collagen LS films was further assessed by RPE-specific gene and protein expression, growth factor secretion, and phagocytic activity. Here, we demonstrated that the prepared collagen LS films have layered structure with oriented fibers corresponding to architecture of the uppermost layers of Bruch's membrane and result in increased barrier properties and functionality of hESC-RPE cells as compared to the commonly used dip-coated controls.

General information

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Organisations: Department of Chemistry and Bioengineering, Research group: Supramolecular photochemistry, Tampere University of Technology, BioMediTech, Frontier Photonics, Integrated Technologies for Tissue Engineering Research (ITTE), Aalto University, BioMediTech, Univ Tampere, University of Tampere, BioMediTech, BMT FM5, Centre for Drug Research, Faculty of Pharmacy, Helsinki University, Department of Forest Products Technology, School of Chemical Technology, Division of Biopharmaceutical Sciences
Number of pages: 13
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Publication information
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Volume: 51
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Characteristics and agronomic usability of digestates from laboratory digesters treating food waste and autoclaved food waste

Digestate characteristics such as organic and nutrient content, hygienic quality and stability are valuable measures when evaluating the use of food waste (FW) digestate as organic fertiliser. This study compared the characteristics of FW and autoclaved (160 °C, 6.2 bar) FW and their digestates from laboratory-scale reactors. Decreased ammonification and low ammonium nitrogen content were observed in the digestate from an autoclaved FW reactor due to autoclave treatment of FW, which affected the nitrogen-containing molecules by formation of Maillard compounds. The methane potential of autoclaved FW and its digestate was decreased by 40% due to reduced microbial activity as microbes were not able to adapt to the conditions within a reactor fed with autoclaved FW. Both studied materials were suitable for agricultural use in terms of their nutrient content, hygienic quality and stability, and thus the decrease in ammonium nitrogen in digestate from an autoclaved FW reactor supported the use of digestate as soil amendment rather than fertiliser.

General information
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Organisations: Department of Chemistry and Bioengineering, Research group: Industrial Bioengineering and Applied Organic Chemistry, Urban circular bioeconomy (UrCirBio), Natural Resources Institute Finland (Luke)
Authors: Tampio, E., Ervasti, S., Rintala, J.
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Scopus rating (2015): SJR 1.609 SNIP 2.383 CiteScore 5.57
Viable but non-culturable (VBNC) state is referred to as a dormant state of non-sporulating bacteria enhancing the survival in adverse environments. To our knowledge, only few studies have been conducted on whole genomic expression of Vibrio parahaemolyticus VBNC state. Since a degradation of nucleic acids in V. vulnificus non-culturable state has been detected, we hypothesize that gene regulation of VBNC cells is highly reduced, downregulation of gene expression is dominant and only metabolic functions crucial for survival are kept on a sustained basis. Hence, we performed the whole transcriptomic profiles of V. parahaemolyticus in three phases (exponential, early stationary phase and VBNC state). Compared with exponential and early stationary phase, in V. parahaemolyticus VBNC cells we found 509 induced genes and 309 repressed by more than 4-fold among 4820 investigated genes. Upregulation was dominant in most of non-metabolism functional categories, while five metabolism-related functional categories revealed downregulation in VBNC state. To our knowledge, this is the first study of comprehensive transcriptomic analyses of three phases of V. parahaemolyticus RIMD2210633. Although the mechanism of VBNC state is not yet clear, massive regulation of gene expression occurs in VBNC state compared with expression in other two phases, indicating VBNC cells are active.

**Gene expression profiles of Vibrio parahaemolyticus in viable but non-culturable state**

Viable but non-culturable (VBNC) state is referred to as a dormant state of non-sporulating bacteria enhancing the survival in adverse environments. To our knowledge, only few studies have been conducted on whole genomic expression of Vibrio parahaemolyticus VBNC state. Since a degradation of nucleic acids in V. vulnificus non-culturable state has been detected, we hypothesize that gene regulation of VBNC cells is highly reduced, downregulation of gene expression is dominant and only metabolic functions crucial for survival are kept on a sustained basis. Hence, we performed the whole transcriptomic profiles of V. parahaemolyticus in three phases (exponential, early stationary phase and VBNC state). Compared with exponential and early stationary phase, in V. parahaemolyticus VBNC cells we found 509 induced genes and 309 repressed by more than 4-fold among 4820 investigated genes. Upregulation was dominant in most of non-metabolism functional categories, while five metabolism-related functional categories revealed downregulation in VBNC state. To our knowledge, this is the first study of comprehensive transcriptomic analyses of three phases of V. parahaemolyticus RIMD2210633. Although the mechanism of VBNC state is not yet clear, massive regulation of gene expression occurs in VBNC state compared with expression in other two phases, indicating VBNC cells are active.
One of the aims of synthetic biology is the sustainable production of high-value compounds and bioenergy molecules. Synthetic biologists exploit fundamental engineering principles, such as DNA component standardization, modular genetic circuits, and de novo design, to create novel production pathways and products. A well-characterized host cell serves as the chassis for the system construction; generally, the model bacterium Escherichia coli is applied. However, the metabolism and characteristics of E. coli are not ideal for all applications. Furthermore, many E. coli based systems are patent protected which restricts the use in forthcoming applications. Acinetobacter baylyi ADP1 is a potential alternative host for synthetic biology. The metabolism and genetics of the strain are well-understood, and the engineering of its genome is technically straightforward. The versatile and unusual metabolic pathways, including those producing long chain hydrocarbons, can be rerouted, modified, and integrated into novel ones. I exploited A. baylyi ADP1 as a model host for the production of high-value hydrocarbons, triacylglycerols and wax esters. I employed metabolic engineering, novel molecular monitoring tools, and synthetic pathway design to improve the production, and to demonstrate the utility of ADP1 as a synthetic biology host. In particular, the production of triacylglycerols was improved over 5-folds by targeted gene deletions which resulted in redirected carbon flux towards the product and elimination of competitive pathways. The long-chain hydrocarbon metabolism, including alcohol and wax ester biosynthesis, is not yet fully understood. These pathways are regulated through several mechanisms sensitive to specific environmental conditions and the cellular states. However, the lack of robust and straight-forward analysis tools has restricted the studies of lipid metabolism and production kinetics. I developed a simple in vivo tool for the investigation of the long chain hydrocarbon metabolism in real-time. The tool is based on a light-producing reporter enzyme, bacterial luciferase. The enzyme utilizes a specific intermediate of the hydrocarbon synthesis pathway as a substrate for bioluminescence production. Initially, the tool was applied for monitoring the wax ester metabolism of A. baylyi ADP1. Subsequently, I modified the monitoring tool for studying the degradation of alkanes. The studies suggest that the tool can be applied for production optimization in different hosts and for a variety of products. I also reconstructed the wax ester synthesis pathway of A. baylyi ADP1 by replacing a natural key enzyme with an alternative well-characterized component, enabling a regulated production of unnatural wax esters. Bioprocess control and scale-up of production systems are challenging. Multispecies cultures are suggested to improve the robustness and performance of bacterial production processes. I exploited the metabolic versatility of A. baylyi ADP1 to construct a rationally engineered synthetic coculture with E. coli. The designed coculture exhibited improved biomass and recombinant protein production compared to the pure culture of E. coli. To conclude, I have shown that the strain ADP1 is a suitable host for synthetic biology applications, especially for long-chain hydrocarbon production, the development of novel tools for metabolic studies, and for exploiting the existing unusual metabolic networks of the cell. Thus, further studies of the remaining challenges related to ADP1 bioprocess and as-of-yet uncharacterized cell mechanisms, are warranted.
Light induced cytosolic drug delivery from liposomes with gold nanoparticles

Externally triggered drug release at defined targets allows site- and time-controlled drug treatment regimens. We have developed liposomal drug carriers with encapsulated gold nanoparticles for triggered drug release. Light energy is converted to heat in the gold nanoparticles and released to the lipid bilayers. Localized temperature increase renders liposomal bilayers to be leaky and triggers drug release. The aim of this study was to develop a drug releasing system capable of releasing its cargo to cell cytosol upon triggering with visible and near infrared light signals. The liposomes were formulated using either heat-sensitive or heat- and pH-sensitive lipid compositions with star or rod shaped gold nanoparticles. Encapsulated fluorescent probe, calcein, was released from the liposomes after exposure to the light. In addition, the pH-sensitive formulations showed a faster drug release in acidic conditions than in neutral conditions. The liposomes were internalized into human retinal pigment epithelial cells (ARPE-19) and human umbilical vein endothelial cells (HUVECs) and did not show any cellular toxicity. The light induced cytosolic delivery of calcein from the gold nanoparticle containing liposomes was shown, whereas no cytotoxic release was seen without light induction or without gold nanoparticles in the liposomes. The light activated liposome formulations showed a controlled content release to the cellular cytosol at a specific location and time. Triggering with visual and near infrared light allows good tissue penetration and safety, and the pH-sensitive liposomes may enable selective drug release in the intracellular acidic compartments (endosomes, lysosomes). Thus, light activated liposomes with gold nanoparticles are an attractive option for time- and site-specific drug delivery into the target cells. (C) 2015 Elsevier B.V. All rights reserved.
Biohydrogen Production: A Protein to Community Level Perspective Study

Excessive usage of traditional energy reserves leading to increased environmental pollution and global warming have strongly urged for alternative sustainable energy sources. Due to non-polluting nature and high energy yields, hydrogen (H₂) gas is considered as an ideal candidate for alternative fuel. Biohydrogen (bioH₂) production from organic wastes is a sustainable approach, addressing energy production through organic waste disposal. Organic wastes such as lignocellulosic biomass and industrial glycerol, a by-product of biodiesel manufacturing process, have been recently investigated for their bioconversion potential. However, bioconversion of such organic wastes is a challenge due to the presence of impurities, toxic degradation products and complex nature. In comparison to pure bacterial strains, natural microflora could be an ideal inoculum choice offering better adaptability, substrate utilization efficiency and bioconversion rates. Another challenge to ensure efficient fermentation is to optimize various physico-chemical factors such as pH, temperature, substrate selection and concentration, medium compounds, and H₂ removal and collection due to individual and interactive effects on microbial growth, metabolism and hydrogenase enzyme. Hydrogenases are metalloenzymes that reversibly catalyzes proton reduction to H₂, and are divided into three classes based on the metal cofactor at the active site, [Fe-Fe], [Ni-Fe] and [Fe] hydrogenase. Among the hydrogenase classes, [Fe-Fe] hydrogenases exhibit highest catalytic activity involving mostly in H₂ production. Apart from their pivotal role in fermentative H₂ production, [Fe-Fe] hydrogenases are extremely prone to catalytic inactivation upon oxygen exposure. This is the major challenge, at the protein level, that hinders a cost-effective approach for biotechnological applications and suggests the requirement of targeted tools to investigate the inactivation process at the molecular level. The purpose of the present study was to investigate bioH₂ production in protein to community level perspective. More specifically the aims were to (1) establish an anaerobic biopanning procedure to enrich antibody binders specific against clostridial [Fe-Fe] hydrogenase protein, (2) develop and standardize a novel enrichment system, (3) implement the enrichment technique to enrich functional inoculum capable of degrading complex substrates, (4) enrich crude glycerol fermenting microbial community
and finally, (5) optimize the physico-chemical factors influencing fermentative H₂ production for efficient bioprocess. In the present study, biopanning with synthetic 'mixed' single chain variable fragment (scFv) libraries against active and inactive clostridial [Fe-Fe] hydrogenases aided the enrichment of anti-hydrogenase antibodies. Out of ninety four (from inactive hydrogenase) and ninety two (from active hydrogenase) random clones screened, nine potential antibody clones with recognition specificity towards Clostridium acetobutylicum [Fe-Fe] hydrogenase were selected. The enriched binders also recognized [Fe-Fe] hydrogenase from C. butyricum. Based on the results from this study, it could be reasoned that the binders with generic specificity against closely related clostridial [Fe-Fe] hydrogenases can be used as novel molecular tools for quantitative monitoring [Fe-Fe] hydrogenases at the protein level. Another of-note observation was the specificity of the antibody binders towards active and inactive hydrogenases. Preliminary experiments indicated 7Ac binder (enriched against active hydrogenase) specificity towards the catalytically active [Fe-Fe] hydrogenase rather to the inactive state and 48In (enriched against inactive hydrogenase) recognized both catalytic states. These findings indicate the possibility to apply the isolated antibody clones for functional detection of clostridial [Fe-Fe] hydrogenases. The study progresses in investigating bioH₂ production in perspective of microbial community. The novel microbial enrichment system was developed and the proof-of-principle experiments conducted using artificial mixed microbial community and varied selection criteria allowed the enrichment of the best H₂ producer. The system was implemented in enriching cellobiose degrading H₂ producer from an environmental sample. The bacterial strain isolated by spread plate technique on agar plates containing CMC was affiliated with Citrobacter sp. and named as Citrobacter sp. CMC-1. Citrobacter sp. CMC-1 utilized glucose, cellobiose and CMC and followed mixed-acid fermentation profile producing H₂ and carbon dioxide (CO₂) as gaseous metabolites and acetate, formate, lactate and ethanol as liquid metabolites. At optimized values of cultivation conditions (pH 6.0 and 34 °C) the H₂ yield was 1.82 mol-H₂/mol-glucose. The isolate efficiently fermented monomeric hemi-cellulose sugars to H₂ (mol-H₂/mol-substrate): Galactose, 1.18; Mannose, 1.23; Xylose, 1.22; Arabinose, 0.94 and Rhamnose, 1.01. Except for arabinose, an increase in cultivation period improved the biomass and H₂ yield (mol-H₂/mol-substrate): Galactose, 1.68; Mannose, 1.93 and Xylose, 1.63) followed with observations of reduced formate accumulation in the medium, indicating that Citrobacter sp. CMC-1 produced H₂ from formate breakdown via the FHL complex. Microbial community pre-dominated with Clostridium spp. enriched from activated sludge fermented crude glycerol mainly to H₂, CO₂, acetate, butyrate and ethanol. Optimal bioprocess conditions for the enriched inoculum were experimentally observed to be pH 6.5, 40 °C and 1g/L crude glycerol. The H₂ yield from raw glycerol at optimal cultivation conditions was 1.1 mol-H₂/mol-glycerol consumed. At elevated crude glycerol concentrations, substrate utilization and H₂ production were limited due to the presence of impurities in the crude glycerol fraction. The bioconversion of crude glycerol to H₂ was further improved by statistical optimization of the growth medium composition. Initial screening with Plackett – Burman design identified NH₄Cl, K₂HPO₄ and KH₂PO₄ with individual and interactive effects on H₂ yield. Among the three identified media components, NH₄Cl and KH₂PO₄ imparted the maximal significance and were optimized in scrutiny. A series of statistical models identified the optimal media composition for improved H₂ production from crude glycerol fermentations and were successful in improving the H₂ yield by 29% (1.42 mol-H₂/mol-glycerol consumed ) in comparison to previously reported value (1.1 mol-H₂/mol-glycerol consumed ).
Ecological Sanitation - A Logical Choice? The Development of the Sanitation Institution in a World Society

Sustainability, encompassing ecological, economic as well as sociocultural aspects, has become a driving force for many political and administrational decisions. It is no longer enough to follow old practices or rely on profit margins – it is necessary to consider the needs of society and nature in a more holistic way as a larger whole. Sustainability is the key word also in terms of sanitation; ecological sanitation, or ecosan for short, has come to mark the sustainable approach to handling human excreta.

In 2014, there are still approximately 2.5 billion people in the world without access to adequate sanitation; 1.1 billion practice open defecation. Lack of sanitation is often – but not necessarily – linked to lack of clean drinking water and poor hygiene. However, poor wastewater treatment also occurs in more developed countries as well as in times of crisis. In the case of natural disasters, even waterborne sanitation, which is often considered the norm, does not prevent the risk of contamination from pathogens. Ecological sanitation aims at a closed cycle of nutrients and absence of water; dry toilets, composting and urine diversion help to return nutrients back into the soil.

Based on these challenges, it is necessary to examine alternatives to the current toilet institution that considers waterborne sanitation as the norm. This dissertation explores the feasibility of ecological sanitation as a potential alternative to the mainstream option and the aim is to discover which issues affect the development and change of the current waterborne toilet institution. From a multi- and interdisciplinary point of view, the dissertation determines the various aspects affected by ecosan, such as water and environment, health, culture, education, agriculture, business and technology, and from these points of view develops futures scenarios for sustainable sanitation practices. Technology is here defined beyond artefacts and processes encompassing also knowhow as well as the sociotechnical systems of use, including legislation, culture and practices.

The data collected for this research includes expert interviews (n=11), case studies from Ethiopia, Finland, New Zealand and Zambia, and literature review including various policy documents and legislation of the aforementioned case countries to shed light to the current state of ecological sanitation and how it is taken into account from a legal perspective. In addition, a two-round consensus-Delphi survey (n1=44, n2=22) together with theme seminars was conducted among Finnish experts to determine the future potential of ecological sanitation.

Through qualitative data analyses, the potential futures and desirable outcomes are mapped with the help of futures research and environmental scanning. The overall challenge of potentially changing the waterborne toilet institution is discussed in the light of the World Polity Theory – with the understanding that global norms are valid everywhere and that change eventually must start from intergovernmental actors rather than political decision makers.

This research brings more insight to the relatively unknown and overlooked subject of ecological sanitation. The integrated approach offers new insight into sustainable sanitation practices and closed loop approach from view points of the various sectors of society, including social, economic and ecological aspects. The undisputed challenges of inadequate sanitation facilities faced by 2.5 billion people worldwide are generally not recognized in scientific literature, although several invaluable studies have contributed to the field. Still, concrete results for improvement are still required.

The results of this study find that ecological sanitation must be approached from a multidisciplinary point of view in order to understand the variety of sectors impacted by these sustainable practices. As a conclusion it can be stated that the traditional norms in waterborne sanitation are difficult to change but the pressure of limited phosphorus resources and deteriorating or non-existing infrastructure require alternative solutions to the norm. As yet, legislation has generally not allowed or considered the use of human excreta as fertiliser, but practices are slowly changing along with attitudes. Institutions do not change easily but can do so while attitudes, policies and practices all start adopting new ways of operating.

It is possible that in the future ecological sanitation will indeed be accepted as a feasible option along with other sanitation methods. This is supported also by the increasing need for sustainable practices in societies. However, in more daunting futures the lack of closed cycles will lead to shortages in resources as well as the lack of wellbeing in communities without access to sanitation. Thus, the research of sustainable sanitation solution is significant and necessary – also in the future.

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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 recovery 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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Improved bioconversion of crude glycerol to hydrogen by statistical optimization of media components

Bioconversion of crude glycerol to hydrogen has gained importance as it addresses both sustainable energy production and waste disposal issues. Until recently, statistical optimizations of crude glycerol bioconversion to hydrogen have been greatly focused on pure strains. In this study, biohydrogen production from crude glycerol by an enriched microbial culture (predominated with Clostridium species) was improved by statistical optimization of media components. Plackett-Burman design identified MgCl_2·6H_2O and KCl with negative effect on hydrogen production and selected NH_4Cl, K_2HPO_4 and KH_2PO_4 as significant variables. Box-Behnken design indicated the optimal region beyond design area and studies were continued by ridge analysis. Central composite face centered design envisaged a maximal hydrogen yield of 1.41 mol-H_2/mol-glycerol consumed at concentrations 4.40 g/L and 2.27 g/L for NH_4Cl and KH_2PO_4 respectively. Confirmation experiment with the optimized media (NH_4Cl, 4.40 g/L; K_2HPO_4, 1.6 g/L; KH_2PO_4, 2.27 g/L; MgCl_2·6H_2O, 1.0 g/L; KCl, 1.0 g/L; Na-acetate·3H_2O, 1.0 g/L and tryptone, 2.0 g/L) revealed an excellent correlation between predicted and experimental hydrogen yield. Optimization of media components by design of experiments enhanced hydrogen yield by 29%.

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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 landfiling 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 and penetrated deeper in the filter bed indicating improved gas diffusion. However, the CH4 removal efficiency did not increase from 25–30 %. The reason for this remained unknown, but the results indicated that soil as filter material was able to maintain its elimination capacity despite the formation of EPS. Mixing was shown to be an effective and necessary method for improving the gas diffusion properties of the filter bed.

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Metals removal and recovery in bioelectrochemical systems: A review

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Methane oxidation potential of boreal landfill cover materials: The governing factors and enhancement by nutrient manipulation

Methanotrophs inhabiting landfill covers are in a crucial role in mitigating CH₄ emissions, but the characteristics of the cover material or ambient temperature do not always enable the maximal CH₄ oxidation potential (MOP). This study aimed at identifying the factors governing MOPs of different materials used for constructing biocovers and other cover structures. We also tested whether the activity of methanotrophs could be enhanced at cold temperature (4 and 12 °C) by improving the nutrient content (NO₃⁻, PO₄³⁻, trace elements) of the cover material. Compost samples from biocovers designed to support CH₄ oxidation were exhibiting the highest MOPs (4.16 µmol CH₄ g⁻¹ dw h⁻¹), but also the soil samples collected from other cover structures were oxidising CH₄ (0.41 µmol CH₄ g⁻¹ dw h⁻¹). The best predictors for the MOPs were the NO₃⁻ content and activity of heterotrophic bacteria at 72.8 %, which were higher in the compost samples than in the soil samples. The depletion of NO₃⁻ from the landfill cover material limiting the activity of methanotrophs could not be confirmed by the nutrient manipulation assay at 4 °C as the addition of nitrogen decreased the MOPs from 0.090 µmol CH₄ g⁻¹ dw h⁻¹ to < 0.085 µmol CH₄ g⁻¹ dw h⁻¹. At 12 °C, all nutrient additions reduced the MOPs. The inhibition was believed to result from high ionic concentration caused by nutrient addition. At 4 °C, the addition of trace elements increased the MOPs (> 0.096 µmol CH₄ g⁻¹ dw h⁻¹) suggesting that this was attributable to stimulation of the enzymatic activity of the psychrotolerant methanotrophs.
Method with high-throughput screening potential for antioxidative substances using Escherichia coli biosensor katG'::lux

A new method is described for the rapid real-time screening of antioxidative properties using a recombinant Escherichia coli DPD2511 biosensor. This microplate technique, without time-consuming pre-incubations and handling, has potential for a high-throughput search of bioactive compounds. Special emphasis was given to obtaining highly reliable and repeatable results.
Stabilization of fine fraction from landfill mining in anaerobic and aerobic laboratory leach bed reactors

Fine fraction (FF, <20mm) from mined landfill was stabilized in four laboratory-scale leach bed reactors (LBR) over 180 days. The aim was to study feasibility of biotechnological methods to treat FF and if further stabilization of FF is possible. Four different stabilization methods were compared and their effects upon quality of FF were evaluated. Also during the stabilization experiment, leachate quality as well as gas composition and quantity were analyzed. The methods studied included three anaerobic LBRs (one without water addition, one with water addition, and one with leachate recirculation) and one aerobic LBR (with water addition). During the experiment, the most methane was produced in anaerobic LBR without water addition (18.0 LCH$_4$/kgVS), while water addition and leachate recirculation depressed methane production slightly, to 16.1 and 16.4 LCH$_4$/kgVS, respectively. Organic matter was also removed via the leachate and was measured as chemical oxygen demand (COD). Calculated removal of organic matter in gas and leachate was highest in LBR with water addition (59 gCOD/kgVS), compared with LBR without water addition or with leachate recirculation (51 gCOD/kgVS). Concentrations of COD, ammonium nitrogen and anions in leachate decreased during the experiment, indicating washout mechanism caused by water additions. Aeration increased sulfate and nitrate concentrations in leachate due to oxidized sulfide and ammonium. Molecular weight distributions of leachates showed that all the size categories decreased, especially low molecular weight compounds, which were reduced the most. Aerobic stabilization resulted in the lowest final VS/TS (13.1%), lowest respiration activity (0.9-1.2 mgO$_2$/gTS), and lowest methane production after treatment (0.0-0.8 LCH$_4$/kgVS), with 29% of VS being removed from FF. Anaerobic stabilization methods also reduced organic matter by 9-20% compared with the initial amount. Stabilization reduced the quantity of soluble nitrogen in FF and did not alter concentration of soluble and insoluble phosphorus, and insoluble nitrogen. All four stabilization methods decreased organic matter and thus are possible stabilization methods for FF, but aerobic treatment was the most efficient in this study.
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\(^{2+}\), K\(^{+}\)), 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\(^{2+}\)/Mg\(^{2+}\) 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\(_4^+\), alkalinity, solids and organic content, and interfering ions such as Ca\(^{2+}\) and K\(^+\).

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Enabling and Integrative Infrastructure Policy: The Role of Inverse Infrastructures in Local Infrastructure Provision with Special Reference to Finnish Water Cooperatives

Infrastructures are necessary to support the functionality of urban communities. Globalization, increased polycentricity, new trends in governance and tightening public budgets have increased interest in alternative ways of providing such infrastructures. One product of this trend is the 'inverse infrastructure,' which refers to a modularized, semi-autonomous and user-driven infrastructure that is a result of the self-organization of local actors. In this study, we discuss the nature of such infrastructures and the challenges they pose to local infrastructure policy with special reference to the case of water cooperatives in Finland. Our conclusion is that inverse infrastructures have a potential to contribute to local infrastructure services either as cost-effective alternative or as supplement to large technical systems. Their full utilization requires, however, enabling and integrative infrastructure policy.
Inhibitory effects of substrate and soluble end products on biohydrogen production of the alkalithermophile Caloramator celer: Kinetic, metabolic and transcription analyses

In this study the tolerance of the alkalithermophile Caloramator celer towards substrate (glucose) and soluble end product (acetate, formate and ethanol) inhibition was assessed employing nonlinear inhibition models. In addition, the effects of subinhibitory concentrations of end products on fermentative metabolism and regulation of 12 key genes involved in pyruvate catabolism were studied. Optimal growth and H₂ production were found at 50 mM of glucose and the critical substrate concentration was observed at 290-360 mM. Two inhibition models revealed that ethanol had a higher inhibitory effect on growth rate, whereas H₂ production kinetics was more sensitive towards increasing concentrations of acetate and formate. Acetate, the main soluble metabolite of the fermentation, inhibited the H₂ production by increasing the ionic strength in the medium. Subinhibitory concentrations of soluble end products induced changes in the metabolite profile of C. celer, specifically exogenous acetate (80 mM) and ethanol (40 mM) slightly increased the H₂ yield by 4 and 7%, respectively. However, despite the observed metabolic shifts, gene regulation was minimal and not always in agreement with the measured product yields. Overall, the results suggest that further optimization of the H₂ production process from C. celer should focus on methods to evolve adapted osmotolerant strains and/or remove soluble metabolites, especially acetate, from the culture. Copyright © 2014, Hydrogen Energy Publications, LLC. Published by Elsevier Ltd. All rights reserved.
Assessment of metabolic flux distribution in the thermophilic hydrogen producer Caloramator celer as affected by external pH and hydrogen partial pressure

Background: Caloramator celer is a strict anaerobic, alkali-tolerant, thermophilic bacterium capable of converting glucose to hydrogen (H₂), carbon dioxide, acetate, ethanol and formate by a mixed acid fermentation. Depending on the growth conditions C. celer can produce H₂ at high yields. For a biotechnological exploitation of this bacterium for H₂ production it is crucial to understand the factors that regulate carbon and electron fluxes and therefore the final distribution of metabolites to channel the metabolic flux towards the desired product. Results: Combining experimental results from batch fermentations with genome analysis, reconstruction of central carbon metabolism and metabolic flux analysis (MFA), this study shed light on glucose catabolism of the thermophilic alkali-tolerant bacterium C. celer. Two innate factors pertaining to culture conditions have been identified to significantly affect the metabolic flux distribution: culture pH and partial pressures of H₂ (P_H₂). Overall, at alkaline to neutral pH the rate of biomass synthesis was maximized, whereas at acidic pH the lower growth rate and the less efficient biomass formation are accompanied with more efficient energy recovery from the substrate indicating high cell maintenance possibly to sustain intracellular pH homeostasis. Higher H₂ yields were associated with fermentation at acidic pH as a consequence of the lower synthesis of other reduced by-products such as formate and ethanol. In contrast, P_H₂ did not affect the growth of C. celer on glucose. At high P_H₂ the cellular redox state was balanced by rerouting the flow of carbon and electrons to ethanol and formate production allowing unaltered glycolytic flux and growth rate, but resulting in a decreased H₂ synthesis. Conclusion: C. celer possesses a flexible fermentative metabolism that allows redistribution of fluxes at key metabolic nodes to simultaneously control redox state and efficiently harvest energy from substrate even under unfavorable conditions (i.e. low pH and high P_H₂). With the H₂ production in mind, acidic pH and low P_H₂ should be preferred for a high yield-oriented process, while a high productivity-oriented process can be achieved at alkaline pH and high P_H₂. © 2014 Ciranna et al.; licensee BioMed Central Ltd.

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Chemistry and Bioengineering, Research group: Industrial Bioengineering and Applied Organic Chemistry, Tampere University of Technology, Urban circular bioeconomy (UrCirBio), Lunds Universitet / Lunds Tekniska Högskola, Lund Univ, Lund University, Department of Applied Microbiology
Authors: Ciranna, A., Pawar, S. S., Santala, V., Karp, M., van Niel, E. W. J.
Publication date: 28 Mar 2014
Peer-reviewed: Yes

Publication information
Journal: Microbial Cell Factories
Volume: 13
Issue number: 1
Article number: 48
ISSN (Print): 1475-2859
Ratings:
Scopus rating (2016): SJR 1.446 SNIP 1.228 CiteScore 3.92
Rewiring the wax ester production pathway of acinetobacter baylyi ADP1

Wax esters are industrially relevant high-value molecules. For sustainable production of wax esters, bacterial cell factories are suggested to replace the chemical processes exploiting expensive starting materials. However, it is well recognized that new sophisticated solutions employing synthetic biology toolbox are required to improve and tune the cellular production platform to meet the product requirements. For example, saturated wax esters with alkanol chain lengths C12 or C14 that are convenient for industrial uses are rare among bacteria. Acinetobacter baylyi ADP1, a natural producer of wax esters, is a convenient model organism for studying the potentiality and modifiability of wax esters in a natural host by means of synthetic biology. In order to establish a controllable production platform exploiting well-characterized biocomponents, and to modify the wax ester synthesis pathway of A. baylyi ADP1 in terms product quality, a fatty acid reductase complex LuxCDE with an inducible arabinose promoter was employed to replace the natural fatty acyl-CoA reductase acr1 in ADP1. The engineered strain was able to produce wax esters by the introduced synthetic pathway. Moreover, the fatty alkanol chain length profile of wax esters was found to shift toward shorter and more saturated carbon chains, C16:0 accounting for most of the alkanols. The study demonstrates the potentiality of recircuiting a biosynthesis pathway in a natural producer, enabling a regulated production of a customized bioproduct. Furthermore, the LuxCDE complex can be potentially used as a well-characterized biopart in a variety of synthetic biology applications involving the production of long-chain hydrocarbons. © 2014 American Chemical Society.
Metabolic engineering of Acinetobacter baylyi ADP1 for improved growth on gluconate and glucose

A high growth rate in bacterial cultures is usually achieved by optimizing growth conditions, but metabolism of the bacterium limits the maximal growth rate attainable on the carbon source used. This limitation can be circumvented by engineering the metabolism of the bacterium. Acinetobacter baylyi has become a model organism for studies of bacterial metabolism and metabolic engineering due to its wide substrate spectrum and easy-to-engineer genome. It produces naturally storage lipids, such as wax esters, and has a unique gluconate catabolism as it lacks a gene for pyruvate kinase. We engineered the central metabolism of A. baylyi ADP1 more favorable for gluconate catabolism by expressing the pyruvate kinase gene (pykF) of Escherichia coli. This modification increased growth rate when cultivated on gluconate or glucose as a sole carbon source in a batch cultivation. The engineered cells reached stationary phase on these carbon sources approximately twice as fast as control cells carrying an empty plasmid and produced similar amount of biomass. Furthermore, when grown on either gluconate or glucose, pykF expression did not lead to significant accumulation of overflow metabolites and consumption of the substrate remained unaltered. Increased growth rate on glucose was not accompanied with decreased wax ester production, and the pykF-expressing cells accumulated significantly more of these storage lipids with respect to cultivation time.

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Chemistry and Bioengineering, Research group: Industrial Bioengineering and Applied Organic Chemistry, Tampere University of Technology, Urban circular bioeconomy (UrCirBio)
Authors: Kannisto, M., Aho, T., Karp, M., Santala, V.
Number of pages: 7
Pages: 7021-7027
Publication date: 2014
Peer-reviewed: Yes

Publication information
Journal: Applied and Environmental Microbiology
Volume: 80
Issue number: 22
ISSN (Print): 0099-2240
Ratings:
Scopus rating (2016): SJR 1.691 SNIP 1.243 CiteScore 4.08
Scopus rating (2015): SJR 1.896 SNIP 1.351 CiteScore 4.14
Scopus rating (2014): SJR 1.862 SNIP 1.402 CiteScore 4.02
Scopus rating (2013): SJR 1.999 SNIP 1.41 CiteScore 4.25
Scopus rating (2012): SJR 1.967 SNIP 1.427 CiteScore 4.29
Scopus rating (2011): SJR 1.91 SNIP 1.453 CiteScore 4.12
Scopus rating (2010): SJR 1.885 SNIP 1.431
Scopus rating (2009): SJR 1.975 SNIP 1.529
Scopus rating (2008): SJR 2.168 SNIP 1.574
Scopus rating (2007): SJR 2.045 SNIP 1.652
Water supply and sanitation services in Finland before World War II is reviewed. In Finland, fire insurance companies played a significant role in the initial development of water services. Water was needed for putting out fires as well as for domestic and other community purposes. At first, Finnish houses were insured, if at all, with the General Fire Insurance Fund in Stockholm. Important social and political reforms such as municipal self-government and universal suffrage also influenced positively the development of the sector. After Finnish cities opted for municipal ownership and responsibility, three other technical options were adopted: metering-based billing, a ban on lead pipes, and the acceptance of flush toilets. Several plans for sewer systems were made and some were also constructed in the late 1800s. Although the wettest areas of the towns were drained and hygiene improved, lakes were still being polluted due to untreated wastewater discharges. The bucket was replaced by a drainpipe, and the problems were flushed out of sight, untreated, to the nearest water systems as is typical of protosystems.

General information
State: Published
Ministry of Education publication type: A2 Review article in a scientific journal
Organisations: Department of Chemistry and Bioengineering, Tampere University of Technology, Life Cycle Effectiveness of the Built Environment (LCE@BE), Former organisation of the author
Authors: Juuti, P., Katko, T.
Number of pages: 8
Pages: 80-87
Publication date: 2014
Peer-reviewed: Yes

Publication information
Journal: Flux
Volume: 97-98
Issue number: 4
ISSN (Print): 1154-2721
Ratings:
Scopus rating (2016): SJR 0.118 SNIP 0.489 CiteScore 0.13
Scopus rating (2015): SJR 0.132 SNIP 0.124 CiteScore 0.16
Scopus rating (2014): SJR 0.138 SNIP 0.594 CiteScore 0.11
Scopus rating (2013): SJR 0.195 SNIP 0.304 CiteScore 0.11
Scopus rating (2012): SJR 0.201 SNIP 0.282 CiteScore 0.07
Scopus rating (2011): SJR 0.185 SNIP 0.308 CiteScore 0.11
Scopus rating (2010): SJR 0.124 SNIP 0.255
Scopus rating (2009): SJR 0.113 SNIP 0.322
Scopus rating (2008): SJR 0.102 SNIP 0.206
Culturable psychrotolerant methanotrophic bacteria in landfill cover soil

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Chemistry and Bioengineering
Authors: Kallistova, A. Y., Montonen, L., Jurgens, G., Münster, U., Kevbrina, M. V., Nozhevnikova, A. N.
Number of pages: 8
Pages: 847-855
Publication date: 2013
Peer-reviewed: Yes

Publication information
Journal: Microbiology
Volume: 82
Issue number: 6
ISSN (Print): 0026-2617
Ratings:
Scopus rating (2016): SJR 0.302 SNIP 0.559 CiteScore 0.82
Scopus rating (2015): SJR 0.349 SNIP 0.558 CiteScore 0.79
Scopus rating (2014): SJR 0.272 SNIP 0.386 CiteScore 0.6
Scopus rating (2013): SJR 0.32 SNIP 0.592 CiteScore 0.72
Scopus rating (2012): SJR 0.345 SNIP 0.48 CiteScore 0.63
Scopus rating (2011): SJR 0.282 SNIP 0.476 CiteScore 0.58
Scopus rating (2010): SJR 0.294 SNIP 0.428
Scopus rating (2009): SJR 0.308 SNIP 0.569
Scopus rating (2008): SJR 0.271 SNIP 0.496
Scopus rating (2007): SJR 0.225 SNIP 0.306
Scopus rating (2006): SJR 0.183 SNIP 0.342
Scopus rating (2005): SJR 0.155 SNIP 0.174
Scopus rating (2004): SJR 0.136 SNIP 0.079
Scopus rating (2003): SJR 0.165 SNIP 0.189
Scopus rating (2002): SJR 0.198 SNIP 0.205
Scopus rating (2001): SJR 0.211 SNIP 0.259
Scopus rating (2000): SJR 0.244 SNIP 0.365
Original language: English
DOI: 10.1134/S0026261714010044

Bibliographical note
Impact of heavy metals on denitrification of simulated mining wastewaters

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Chemistry and Bioengineering, Urban circular bioeconomy (UrCirBio)
Authors: Zou, G., Ylinen, A., Di Capua, F., Papirio, S., Lakaniemi, A., Puhakka, J.
Number of pages: 4
Pages: 500-503
Publication date: 2013
Peer-reviewed: Yes

Publication information
Journal: Advanced Materials Research
Volume: 825
ISSN (Print): 1022-6680
Ratings:
Scopus rating (2016): SJR 0.12 SNIP 0.154
Scopus rating (2015): SJR 0.115 SNIP 0.106 CiteScore 0.08
Scopus rating (2014): SJR 0.141 SNIP 0.171 CiteScore 0.09
Scopus rating (2013): SJR 0.143 SNIP 0.203 CiteScore 0.11
Scopus rating (2012): SJR 0.136 SNIP 0.265 CiteScore 0.12
Scopus rating (2011): SJR 0.15 SNIP 0.385 CiteScore 0.19
Scopus rating (2010): SJR 0.155 SNIP 0.232
Scopus rating (2009): SJR 0.168 SNIP 0.254
Scopus rating (2008): SJR 0.169 SNIP 0.238
Scopus rating (2007): SJR 0.186 SNIP 0.657
Scopus rating (2006): SJR 0.251 SNIP 0.598
Original language: English
DOIs:
10.4028/www.scientific.net/AMR.825.500

Bibliographical note
Contribution: organisation=keb,FACT1=1<br/>Portfolio EDEND: 2013-11-29<br/>Publisher name: Trans Tech Publications Ltd.
Source: researchoutputwizard
Source-ID: 3792
Research output: Scientific - peer-review › Article

Energy Demands of Nitrogen Supply in Mass Cultivation of Two Commercially Important Microalgal Species, Chlorella vulgaris and Dunaliella tertiolecta

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Chemistry and Bioengineering, Urban circular bioeconomy (UrCirBio)
Authors: Hulatt, C. J., Lakaniemi, A., Puhakka, J. A., Thomas, D. N.
Pages: 669-684
Publication date: 2012
Peer-reviewed: Yes

Publication information
Journal: BioEnergy Research
Volume: 5
Issue number: 3
ISSN (Print): 1939-1234
Ratings:
Scopus rating (2016): SJR 0.943 SNIP 0.932 CiteScore 2.64
Growth of Chlorella vulgaris and associated bacteria in photobioreactors

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Chemistry and Bioengineering, Urban circular bioeconomy (UrCirBio)
Authors: Lakaniemi, A., Intihar, V. M., Tuovinen, O. H., Puhakka, J. A.
Pages: 69-78
Publication date: 2012
Peer-reviewed: Yes

Publication information
Journal: Microbial Biotechnology
Volume: 5
Issue number: 1
ISSN (Print): 0964-7562
Ratings:
Scopus rating (2016): SJR 1.207 SNIP 0.992 CiteScore 3.56
Scopus rating (2015): SJR 1.382 SNIP 1.124 CiteScore 3.59
Scopus rating (2014): SJR 1.37 SNIP 1.18 CiteScore 3.19
Scopus rating (2013): SJR 1.19 SNIP 0.985 CiteScore 3
Scopus rating (2012): SJR 1.152 SNIP 0.978 CiteScore 2.7
Scopus rating (2011): SJR 0.919 SNIP 0.761 CiteScore 1.92
Scopus rating (2010): SJR 0.856 SNIP 0.76
Scopus rating (2009): SJR 0.768 SNIP 0.661
Original language: English
DOIs:
10.1007/s12155-011-9175-x

Bibliographical note
Contribution: organisation=keb bio,FACT1=1<br/>Publisher name: Springer-Verlag
Source-ID: 4239
Research output: Scientific - peer-review › Article

Growth of Dunaliella tertiolecta and associated bacteria in photobioreactors

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Chemistry and Bioengineering, Urban circular bioeconomy (UrCirBio)
Authors: Lakaniemi, A., Intihar, V. M., Tuovinen, O. H., Puhakka, J. A.
Pages: 1357-1365
Publication date: 2012
Peer-reviewed: Yes

Publication information
Journal: Microbial Biotechnology
Volume: 5
Issue number: 1
ISSN (Print): 0964-7562
Ratings:
Scopus rating (2016): SJR 1.207 SNIP 0.992 CiteScore 3.56
Scopus rating (2015): SJR 1.382 SNIP 1.124 CiteScore 3.59
Scopus rating (2014): SJR 1.37 SNIP 1.18 CiteScore 3.19
Scopus rating (2013): SJR 1.19 SNIP 0.985 CiteScore 3
Scopus rating (2012): SJR 1.152 SNIP 0.978 CiteScore 2.7
Scopus rating (2011): SJR 0.919 SNIP 0.761 CiteScore 1.92
Scopus rating (2010): SJR 0.856 SNIP 0.76
Scopus rating (2009): SJR 0.768 SNIP 0.661
Original language: English
DOIs:
10.1111/j.1751-7915.2011.00298.x

Bibliographical note
Contribution: organisation=keb bio,FACT1=1<br/>Publisher name: Wiley-Blackwell Publishing Ltd
Source-ID: 4643
Research output: Scientific - peer-review › Article
Production of Electricity and Butanol from Microalgal Biomass in Microbial Fuel Cells

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Chemistry and Bioengineering, Urban circular bioeconomy (UrCirBio)
Authors: Lakaniemi, A., Tuovinen, O. H., Puhakka, J. A.
Pages: 481-491
Publication date: 2012
Peer-reviewed: Yes

Publication information
Journal: BioEnergy Research
Volume: 5
Issue number: 2
ISSN (Print): 1939-1234
Ratings:
Scopus rating (2016): SJR 0.943 SNIP 0.932 CiteScore 2.64
Scopus rating (2015): SJR 1.317 SNIP 1.285 CiteScore 3.35
Scopus rating (2014): SJR 1.453 SNIP 1.344 CiteScore 3.64
Scopus rating (2013): SJR 1.162 SNIP 1.384 CiteScore 3.66
Scopus rating (2012): SJR 1.362 SNIP 1.645 CiteScore 4.23
Scopus rating (2011): SJR 1 SNIP 1.435 CiteScore 3.16
Scopus rating (2010): SJR 0.458 SNIP 0.671
Original language: English
Biogenic hydrogen and methane production from Chlorella vulgaris and Dunaliella tertiolecta biomass

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Chemistry and Bioengineering, Urban circular bioeconomy (UrCirBio)
Authors: Lakaniemi, A., Hulatt, C. J., Thomas, D. N., Tuovinen, O. H., Puhakka, J. A.
Number of pages: 12
Pages: 1-12
Publication date: 2011
Peer-reviewed: Yes

Publication information
Journal: Biotechnology for Biofuels
Volume: 4
Issue number: 1
Article number: 34
ISSN (Print): 1754-6834
Ratings:
Scopus rating (2016): SJR 1.969 SNIP 1.65 CiteScore 5.89
Scopus rating (2015): SJR 2.409 SNIP 1.89 CiteScore 6.79
Scopus rating (2014): SJR 2.414 SNIP 1.722 CiteScore 5.86
Scopus rating (2013): SJR 2.17 SNIP 1.815 CiteScore 6.21
Scopus rating (2012): SJR 2.15 SNIP 1.849 CiteScore 5.7
Scopus rating (2011): SJR 2.249 SNIP 2.168 CiteScore 6.1
Scopus rating (2010): SJR 1.774 SNIP 1.745
Scopus rating (2009): SJR 1.317 SNIP 1.74
Original language: English
DOIs:
10.1186/1754-6834-4-34

Biogenic hydrogen and methane production from reed canary grass

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Chemistry and Bioengineering, Urban circular bioeconomy (UrCirBio)
Authors: Lakaniemi, A., Koskinen, P. E., Nevatalo, L. M., Kaksonen, A. H., Puhakka, J. A.
Pages: 773-780
Publication date: 2011
Peer-reviewed: Yes

Publication information
Journal: Biomass & Bioenergy
Volume: 35
Issue number: 2
ISSN (Print): 0961-9534
Ratings:
Mine wastewater treatment using Phalaris arundinacea plant material hydrolyzate as substrate for sulfate-reducing bioreactor

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Chemistry and Bioengineering
Authors: Lakaniemi, A., Nevatalo, L. M., Kaksonen, A. H., Puhakka, J. A.
Pages: 3931-3939
Publication date: 2010
Peer-reviewed: Yes

Publication information
Journal: Bioresource Technology
Volume: 101
Issue number: 11
ISSN (Print): 0960-8524
Ratings:
Scopus rating (2016): CiteScore 5.94 SJR 2.191 SNIP 1.91
Scopus rating (2015): SJR 2.255 SNIP 1.908 CiteScore 5.47
Scopus rating (2014): SJR 2.41 SNIP 2.104 CiteScore 5.3
Scopus rating (2013): SJR 2.412 SNIP 2.503 CiteScore 5.97
Scopus rating (2012): SJR 2.389 SNIP 2.465 CiteScore 5.25
Scopus rating (2011): SJR 2.314 SNIP 2.508 CiteScore 5.56
Scopus rating (2010): SJR 2.086 SNIP 2.355
Scopus rating (2009): SJR 1.912 SNIP 2.231
Scopus rating (2008): SJR 1.734 SNIP 2.732
Scopus rating (2007): SJR 1.529 SNIP 2.423
Scopus rating (2006): SJR 1.315 SNIP 1.98
Scopus rating (2005): SJR 1.269 SNIP 2.006
Hydrolysed cellulose material as sulfate reduction electron donor to treat metal- and sulfate containing waste water

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Former organisation of the author
Authors: Lakaniemi, A., Nevatalo, L., Kaksonen, A., Puhakka, J.
Pages: 326-326
Publication date: 2007
Peer-reviewed: Yes

Publication information
Journal: Advanced Materials Research
Volume: 20-21
ISSN (Print): 1022-6680
Ratings:
Scopus rating (2016): SJR 0.12 SNIP 0.154
Scopus rating (2015): SJR 0.115 SNIP 0.106 CiteScore 0.08
Scopus rating (2014): SJR 0.141 SNIP 0.171 CiteScore 0.09
Scopus rating (2013): SJR 0.143 SNIP 0.203 CiteScore 0.11
Scopus rating (2012): SJR 0.136 SNIP 0.265 CiteScore 0.12
Scopus rating (2011): SJR 0.15 SNIP 0.385 CiteScore 0.19
Scopus rating (2010): SJR 0.155 SNIP 0.232
Scopus rating (2009): SJR 0.168 SNIP 0.254
Scopus rating (2008): SJR 0.169 SNIP 0.238
Scopus rating (2007): SJR 0.186 SNIP 0.657
Scopus rating (2006): SJR 0.251 SNIP 0.598
Original language: English
DOI:
10.4028/www.scientific.net/AMR.20-21.326

Bibliographical note
Contribution: organisation=bio,FACT1=1
Source: researchoutputwizard
Source-ID: 14835
Research output: Scientific - peer-review › Article

Comparison of the total mercury content in sediment samples with a mercury sensor bacteria test and Vibrio fischeri toxicity test

The suitability of a luminescent bacterial sensor strain Escherichia coli MC1061(pTOO11) [Virta, M.; Lampinen, J.; Karp, M. Anal Chem 1995, 67, 667-669] for the measuring of mercury from sediment samples was evaluated. The sensor strain is based on the control of expression of a reporter gene, firefly luciferase, by a mercury sensitive regulation unit. The sensor responds to mercury by increased luminescence as a consequence of increased production of the reporter protein luciferase. The method is simple to perform since the luminescence is recorded with a portable luminometer and the sensor bacteria are freeze-dried. The results obtained from river sediment samples were compared with the total mercury
Detecting bioavailable toxic metals and metalloids from natural water samples using luminescent sensor bacteria

We have generated microbial sensors for analyzing the presence of various metals or metalloids by recombinant DNA technology. The strains are based on strictly regulated promoters controlling the expression of the firefly luciferase gene in microbial cells. The regulator-reporter constructs are located in shuttle plasmids capable of replicating in gram-negative or -positive microbial organisms. The sensors developed are real-time indicators of metal responsive gene expression giving results in approximately 30 min, with optimal induction times ranging from 60 to 240 min. We describe here the performance of these metal sensing bacteria for the assessment of different water samples spiked with lead, arsenic, mercury or cadmium. We show that these bacteria are sensitive detectors of metal bioavailability, which is difficult or even impossible to measure by traditional analytical chemistry methods. All measurements were done using freeze-dried bacteria, which makes these sensors reagent-like and also easy to use in field conditions. (C) 2000 Elsevier Science Ltd. All rights reserved.
A recombinant *Escherichia coli* sensor strain for the detection of tetracyclines

A bioluminescent *Escherichia coli* K-12 strain for the specific detection of the tetracycline group of antibiotics is described. A sensor plasmid, containing five genes from bacterial luciferase operon of *Photorhabdus luminescens* inserted under the control of tetracycline-responsive elements of the transposon Tn10, was constructed. Usage of the full-length luciferase operon in the sensor resulted in tetracycline-dependent light production without additions, i.e., self-luminescent phenotype, since all the substrates were intrinsically produced by the recombinant organism. The time needed for optimal induction of light emission was 90 min. Maximal induction of similar to 100-fold over uninduced levels by using 20 ng of tetracycline, and picomole sensitivities for the seven different tetracyclines tested, were obtained without added Mg2+ ions. The higher the pH and the magnesium ion concentration in the assay medium the higher was the amount of membrane-impermeable tetracycline-Mg2+ chelate complex. In consequence, by adjusting the pH and the Mg2+ ion concentration, the sensitivity of the assay can be modified for different analytical purposes. Different non-tetracycline antibiotics did not cause induction of light emission.