Skip to main content

- Environmental biotechnology
- Published: 13 August 2015

Photosynthetic aeration in biological wastewater treatment using immobilized microalgae-bacteria symbiosis

- Prashant Praveen[1] &
- Kai-Chee Loh[1]

Applied Microbiology and Biotechnology **volume 99**, pages 10345–10354 (2015)Cite this article

Abstract

by more than 30 %. These results indicate that immobilized microalgae in symbiosis with heterotrophic bacteria are promising in wastewater aeration.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Ecol Eng 64:213–221

Article Google Scholar

3. Buhr HO, Miller SB (1983) A dynamic-model of the high-rate algal baceterial wastewater treatment pond. Water Res 17:29–37

CAS Article Google Scholar

4. Covarrubias SA, de-Bashan LE, Moreno M, Bashan Y (2012) Alginate beads provide a beneficial physical barrier against native microorganisms in wastewater treated with immobilized bacteria and microalgae. Appl Microbiol Biotechnol 93:2669–2680

CAS Article PubMed Google Scholar

5. Cruz I, Bashan Y, Hernandez-Carmona G, de-Bashan LE (2013) Biological deterioration of alginate beads containing immobilized microalgae and bacteria during tertiary wastewater treatment. Appl Microbiol Biotechnol 97:9847–9858

6. Dilly O (2003) Regulation of the respiratory quotient of soil microbiota by availability of nutrients. FEMS Microbiol Ecol 43:375–381

CAS Article PubMed Google Scholar

7. Essam T, ElRakaiby M, Hashem A (2013) Photosynthetic based algal-bacterial combined treatment of mixtures of organic pollutants and CO2 mitigation in a continuous photobioreactor. World J Microbiol Biotechnol 29:969–974

CAS Article PubMed Google Scholar

8. Garcia-Ochoa F, Gomez E, Santos VE, Merchuk JC (2010) Oxygen uptake rate in microbial processes: an overview. Biochem Eng J 49:289–307

CAS Article Google Scholar

9. Gonzalez C, Marciniak J, Villaverde S, Leon C, Garcia PA, Munoz R (2008) Efficient nutrient removal from swine manure in a tubular biofilm photo-bioreactor using algae-bacteria consortia. Water Sci Technol 58:95–102

CAS Article PubMed Google Scholar

10. Gonzalez LE, Bashan Y (2000) Increased growth of the microalga *Chlorella vulgaris* when coimmobilized and cocultured in alginate beads with the plant-growth-promoting bacterium *Azospirillum brasilense*. Appl Environ Microbiol 66:1527–1531

PubMed Central CAS Article PubMed Google Scholar

14. Lee Y-K, Shen H (2007) Basic culturing techniques. Handbook of Microalgal Culture. Blackwell Publishing Ltd, In, pp. 40–56

Google Scholar

15. McLean BM, Baskaran K, Connor MA (2000) The use of algal-bacterial biofilms to enhance nitrification rates in lagoons: experience under laboratory and pilot-scale conditions. Water Sci Technol 42:187–194

CAS Google Scholar

16. Medina M, Neis U (2007) Symbiotic algal bacterial wastewater treatment: effect of food to microorganism ratio and hydraulic retention time on the process performance. Water Sci Technol 55:165–171

CAS Article PubMed Google Scholar

17. Moreno-Garrido I (2008) Microalgae immobilization: current techniques and uses. Biores Technol 99:3949–3964

CAS Article Google Scholar

18. Mouget JL, Dakhama A, Lavoie MC, Delanoue J (1995) Algal growth enhancement by bacteria—is consumption of photosynthetic oxygen involved. FEMS Microbiol Ecol 18:35–43

CAS Article Google Scholar

19. Munoz R, Guieysse B (2006) Algal-bacterial processes for the treatment of hazardous contaminants: a review. Water Res 40:2799–2815

CAS Article PubMed Google Scholar

20. Munoz R, Kollner C, Guieysse B, Mattiasson B (2004) Photosynthetically oxygenated salicylate biodegradation in a continuous stirred tank photobioreactor. Biotechnol Bioeng 87:797–803

CAS Article PubMed Google Scholar

21. Munoz R, Rolvering C, Guieysse B, Mattiasson B (2005) Photosynthetically oxygenated acetonitrile biodegradation by an algal-bacterial microcosm: a pilot-scale study. Water Sci Technol 51:261–265

CAS PubMed Google Scholar

22. Noel JD, Koros WJ, McCool BA, Chance RR (2012) Membrane-mediated delivery of carbon dioxide for consumption by photoautotrophs: eliminating thermal regeneration in carbon capture. Ind Eng Chem Res 51:4673–4681

CAS Article Google Scholar

26. Rooke JC, Leonard A, Sarmento H, Meunier CF, Descy JP, Su BL (2011) Novel photosynthetic CO(2) bioconvertor based on green algae entrapped in low-sodium silica gels. J Mater Chem 21:951–959

CAS Article Google Scholar

27. Ruiz-Marin A, Mendoza-Espinosa LG, Stephenson T (2010) Growth and nutrient removal in free and immobilized green algae in batch and semi-continuous cultures treating real wastewater. Biores Technol 101:58–64

CAS Article Google Scholar

28. Semmens MJ (2008) Alternative MBR configurations: using membranes for gas transfer. Desalination 231:236–242

CAS Article Google Scholar

29. Shi J, Podola B, Melkonian M (2014) Application of a prototype-scale twin-layer photobioreactor for effective N and P removal from different process stages of municipal wastewater by immobilized microalgae. Biores Technol 154:260–266

CAS Article Google Scholar

30. Su YY, Mennerich A, Urban B (2012) Synergistic cooperation between wastewater-born algae and activated sludge for wastewater treatment: influence of algae and sludge inoculation ratios. Biores Technol 105:67–73

CAS Article Google Scholar

31. Sutherland IW (2001) The biofilm matrix - an immobilized but dynamic microbial environment. Trends Microbiol 9:222–227

CAS Article PubMed Google Scholar

32. Tang HY, Chen M, Ng KYS, Salley SO (2012) Continuous microalgae cultivation in a photobioreactor. Biotechnol Bioeng 109:2468–2474

CAS Article PubMed Google Scholar

33. Van Den Hende S, Vervaeren H, Saveyn H, Maes G, Boon N (2011) Microalgal bacterial floc properties are improved by a balanced inorganic/organic carbon ratio. Biotechnol Bioeng 108:549–558

Article Google Scholar

34. Vu TKL (2014) Symbiotic hollow fiber membrane photobioreactor for microalgal growth and activated sludge waste water treatment. PhD Thesis. National University of Singapore

35. Zeng X, Danquah MK, Zheng C, Potumarthi R, Chen XD, Lu Y (2012) NaCS–PDMDAAC immobilized

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Author information

Affiliations

1. Department of Chemical and Biomolecular Engineering, 4 Engineering Drive 4, Singapore, 117585, Singapore

   Prashant Praveen & Kai-Chee Loh

Authors

1. Prashant Praveen
   View author publications

   You can also search for this author in PubMed Google Scholar

2. Kai-Chee Loh
   View author publications

   You can also search for this author in PubMed Google Scholar

Corresponding author

Correspondence to Kai-Chee Loh.

Rights and permissions

About this article

- Published: 13 August 2015
- Issue Date: December 2015
- DOI: https://doi.org/10.1007/s00253-015-6896-3

Keywords

- Aeration
- Biodegradation
- Cell immobilization
- Microalgae
- Symbiosis

extended data figure 4

- **Fig. 5**
  extended data figure 5
- **Fig. 6**
  extended data figure 6
- **Fig. 7**
  extended data figure 7

1. Arbib Z, Ruiz J, Álvarez-Díaz P, Garrido-Pérez C, Perales JA (2014) Capability of different microalgae species for phytoremediation processes: wastewater tertiary treatment, CO2 bio-fixation and low cost biofuels production. Water Res 49:465–474

   CAS Article PubMed Google Scholar

2. Boelee NC, Temmink H, Janssen M, Buisman CJN, Wijffels RH (2014) Balancing the organic load and light supply in symbiotic microalgal–bacterial biofilm reactors treating synthetic municipal wastewater. Ecol Eng 64:213–221

   Article Google Scholar

3. Buhr HO, Miller SB (1983) A dynamic-model of the high-rate algal baceterial wastewater treatment pond. Water Res 17:29–37

   CAS Article Google Scholar

4. Covarrubias SA, de-Bashan LE, Moreno M, Bashan Y (2012) Alginate beads provide a beneficial physical barrier against native microorganisms in wastewater treated with immobilized bacteria and microalgae. Appl Microbiol Biotechnol 93:2669–2680

   CAS Article PubMed Google Scholar

5. Cruz I, Bashan Y, Hernandez-Carmona G, de-Bashan LE (2013) Biological deterioration of alginate beads containing immobilized microalgae and bacteria during tertiary wastewater treatment. Appl Microbiol Biotechnol 97:9847–9858

8. Garcia-Ochoa F, Gomez E, Santos VE, Merchuk JC (2010) Oxygen uptake rate in microbial processes: an overview. Biochem Eng J 49:289–307

CAS Article Google Scholar

9. Gonzalez C, Marciniak J, Villaverde S, Leon C, Garcia PA, Munoz R (2008) Efficient nutrient removal from swine manure in a tubular biofilm photo-bioreactor using algae-bacteria consortia. Water Sci Technol 58:95–102

CAS Article PubMed Google Scholar

10. Gonzalez LE, Bashan Y (2000) Increased growth of the microalga *Chlorella vulgaris* when coimmobilized and cocultured in alginate beads with the plant-growth-promoting bacterium *Azospirillum brasilense*. Appl Environ Microbiol 66:1527–1531

PubMed Central CAS Article PubMed Google Scholar

11. Guo Z, Tong YW (2014) The interactions between *Chlorella vulgaris* and algal symbiotic bacteria under photoautotrophic and photoheterotrophic conditions. J Appl Phycol 26:1483–1492

CAS Article Google Scholar

12. Karya NGAI, van der Steen NP, Lens PNL (2013) Photo-oxygenation to support nitrification in an algal–bacterial consortium treating artificial wastewater. Biores Technol 134:244–250

CAS Article Google Scholar

13. Lam MK, Lee KT (2012) Immobilization as a feasible method to simplify the separation of microalgae from water for biodiesel production. Chem Eng J 191:263–268

CAS Article Google Scholar

14. Lee Y-K, Shen H (2007) Basic culturing techniques. Handbook of Microalgal Culture. Blackwell

CAS Article PubMed Google Scholar

17. Moreno-Garrido I (2008) Microalgae immobilization: current techniques and uses. Biores Technol 99:3949–3964

CAS Article Google Scholar

18. Mouget JL, Dakhama A, Lavoie MC, Delanoue J (1995) Algal growth enhancement by bacteria—is consumption of photosynthetic oxygen involved. FEMS Microbiol Ecol 18:35–43

CAS Article Google Scholar

19. Munoz R, Guieysse B (2006) Algal-bacterial processes for the treatment of hazardous contaminants: a review. Water Res 40:2799–2815

CAS Article PubMed Google Scholar

20. Munoz R, Kollner C, Guieysse B, Mattiasson B (2004) Photosynthetically oxygenated salicylate biodegradation in a continuous stirred tank photobioreactor. Biotechnol Bioeng 87:797–803

CAS Article PubMed Google Scholar

21. Munoz R, Rolvering C, Guieysse B, Mattiasson B (2005) Photosynthetically oxygenated acetonitrile biodegradation by an algal-bacterial microcosm: a pilot-scale study. Water Sci Technol 51:261–265

CAS PubMed Google Scholar

22. Noel JD, Koros WJ, McCool BA, Chance RR (2012) Membrane-mediated delivery of carbon dioxide for consumption by photoautotrophs: eliminating thermal regeneration in carbon capture. Ind Eng Chem Res 51:4673–4681

CAS Article Google Scholar

23. Pires JCM, Alvim-Ferraz MCM, Martins FG, Simoes M (2012) Carbon dioxide capture from flue gases using microalgae: engineering aspects and biorefinery

CAS Article Google Scholar

26. Rooke JC, Leonard A, Sarmento H, Meunier CF, Descy JP, Su BL (2011) Novel photosynthetic CO(2) bioconvertor based on green algae entrapped in low-sodium silica gels. J Mater Chem 21:951–959

CAS Article Google Scholar

27. Ruiz-Marin A, Mendoza-Espinosa LG, Stephenson T (2010) Growth and nutrient removal in free and immobilized green algae in batch and semi-continuous cultures treating real wastewater. Biores Technol 101:58–64

CAS Article Google Scholar

28. Semmens MJ (2008) Alternative MBR configurations: using membranes for gas transfer. Desalination 231:236–242

CAS Article Google Scholar

29. Shi J, Podola B, Melkonian M (2014) Application of a prototype-scale twin-layer photobioreactor for effective N and P removal from different process stages of municipal wastewater by immobilized microalgae. Biores Technol 154:260–266

CAS Article Google Scholar

30. Su YY, Mennerich A, Urban B (2012) Synergistic cooperation between wastewater-born algae and activated sludge for wastewater treatment: influence of algae and sludge inoculation ratios. Biores Technol 105:67–73

CAS Article Google Scholar

31. Sutherland IW (2001) The biofilm matrix - an immobilized but dynamic microbial environment. Trends Microbiol 9:222–227

CAS Article PubMed Google Scholar

32. Tang HY, Chen M, Ng KYS, Salley SO (2012)

sludge waste water treatment. PhD Thesis. National University of Singapore

35. Zeng X, Danquah MK, Zheng C, Potumarthi R, Chen XD, Lu Y (2012) NaCS–PDMDAAC immobilized autotrophic cultivation of *Chlorella* sp. for wastewater nitrogen and phosphate removal. Chem Eng J 187:185–192

    CAS Article Google Scholar

36. Zhang YD, Ng CK, Cohen Y, Cao B (2014) Cell growth and protein expression of *Shewanella oneidensis* in biofilms and hydrogel-entrapped cultures. Mol Biosys 10:1035–1042

    Article Google Scholar