Oxygen Dynamics in Algal Based Wastewater Treatment Systems

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Submitted as a PhD thesis at Flinders University of South Australia.
March 2012.

Declaration

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Acknowledgments

I would like to thank all of my colleagues from the former Department of Environmental Health and Biomedical Engineering at Flinders Medical Centre; Given my long tenure in EH during my research it may be best to do this in order of appearance (as best as my memory can now provide); Duncan Craig, Alana Hansen, Peter Hobson, Michelle Critchley, Megge Miller, Briony Vickery, Maria Wilson, Ben Pol, Linda Health, Julanta Ciuk, John Edwards, Richard Bentham, Emily Fearnley, Brian Bridger, Jack Beasly, Darcy Schultz, Robin Woolford, Kateryna Babina, David Sweeney, Eddie Herdianto, Michael Short, Ben Vandenakker, 'the evil third twin', Louis Bradbury, Akio Yamamoto, Kirstin Ross, Sharyn Gaskin, Iryanti Suprihatin, Cheryl Caldwell, Neil Buchanan, Mark Disher, Team Honda, Captain Beefheart, Magnus Fairweather Peabody, Monte Zuma, Peke Deboo, Snoop Dog and of course Mrs Lincoln; to those many I have not mentioned I thank you also. Huge huge thanks go to Monika, Ian and Kateryna, Catherine and David and other colleagues and friends in the Department of Health without whom I would surely have lost my way.

Of course great thanks are offered to my supervisors Nancy Cromar and in particular Howard Fallowfield for his notably notable patience and support, and enthusiasm for science without which I would not have finished.

Lastly and certainly not leastly I offer my deepest thanks to Roma and Dylan for all the encouragement and patience they have shown over the years and of course my wonderful sister Jane, Mum and Mike for all their kind words and support.

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1. INTRODUCTION

Wastewater derived from domestic or industrial sources can contain a diverse range of dissolved and suspended chemical and/or biological contaminants (e.g. nutrients, heavy metals, pharmaceuticals, pathogens) and can present a serious risk to human health or ecosystems if not disposed of appropriately (Metcalf and Eddy 2004).

Such effluent if disposed of without appropriate treatment can cause illness to those who have primary or secondary contact with it. In an effort to protect human health, treated and untreated wastewaters from coastal cities worldwide have traditionally been disposed of via ocean and river outfalls. Unfortunately, an unintended side effect of such disposal methods has been the eutrophication (sometimes termed cultural eutrophication) of these receiving waters and ecosystems (Nixon 1995, 1998) in addition to contamination of recreational and groundwater resources.

In Australia as elsewhere such disposal methods have been shown to contribute to the intensity of some toxic algal blooms in receiving waters (Davis and Koop 2000). Similarly there is strong evidence that disposal of treated wastewater and untreated storm-water from the city of Adelaide to the adjacent coastal environments may have contributed to large declines in sea-grass cover in this area (Fox et al. 2007).

Various methods of wastewater treatment (Chapter 2) are employed to remove nutrients, pathogens, heavy metals, persistent organic pollutants; with the treatment type determined by factors such as effectiveness, cost (land, initial and maintenance) disposal and re-use options and community and government expectation.

An effective and commonly used method for treating organic or domestic wastewaters is to detain the effluent stream in large and shallow lined ponds or impoundments for a period of time. Such ponds are typically termed ‘waste stabilisation ponds’ (WSP) or ‘waste stabilisation lagoons’ or simply ‘ponds’ or ‘lagoons’. Ponds actively mixed using paddlewheels are typically termed ‘high rate algal ponds’ (HRAP) or ‘high rate oxidation ponds’ (HROP). Semantics and basic differences aside, such systems provide a contained environment that allows naturally occurring algae and photosynthetic bacteria to grow profusely in response to light from the sun. The abundant oxygen produced by this photosynthetic activity in a nutrient rich medium provides heterotrophic bacteria with an ideal environment in which to flourish and oxidise organic and inorganic nutrients. Such conditions can also result in dramatic declines in the concentration of viral and bacterial pathogens (Fallowfield et al. 1996, Bolton et al. 2010). Provided that conditions in a pond remain aerobic (an excess of dissolved oxygen in the water) the pond will be largely odour free due to the rapid oxidation of H_2S and other odour forming compounds by dissolved oxygen. The removal of planktonic biomass (algal, bacterial, fungal matter) via settlement, filtration or both can produce an effluent (after chlorination) of sufficient quality for crop irrigation or other non-potable uses (Chapter 2).

Whilst the systems described above are relatively simple from a construction and engineering perspective, the ecology of such systems is not. Design principles have traditionally relied on ‘rules of thumb’ based of hard won experience of what works and doesn’t in the field to determine functional pond depths, waste loading rates and retention times (Chapter 2).

A lesson from history may show how wastewater treatment plants (WWTP) operators and the community might benefit from improvements in the scientific understanding of ecological processes at work in algal based treatment systems. The Bolivar treatment system Adelaide, Australia was constructed during the mid-sixties in response to increased population size and ultimately removed the need for the disposal of screened raw sewage into the Port River and the Gulf St Vincent. The details of the system itself, including primary and secondary bio-filter components are described in Chapter 2.

Treatment failure was experienced at the Bolivar wastewater treatment lagoon during later part of the 1997 (Sheil 2000); organic content of the waste stabilisation pond influent was increased purposefully due to a managed reduction in the capacity of the primary treatment system until the pond 'mode' changed from aerobic to anaerobic, resulting in serious odour problems for the entire city of Adelaide. Prior to this incident the plant had operated to the satisfaction of the community for a period of over thirty years. It can be argued that this episode provides a useful case study where the wastewater treatment system, designed using 'rule of thumb' based approach with a large margin for error, was 'optimised' for the purposes of efficiency (cost saving) without understanding the consequences of these changes on algal productivity and oxygen production. The sulphurous odour that arose from the lagoons was ultimately suppressed when sufficient dissolved oxygen from algal photosynthesis was available in the ponds for oxidation of sulphides.

Photosynthesis drives treatment processes afforded by heterotrophic bacteria and ensures maintenance of aerobic conditions within pond, a great deal of research has therefore been undertaken over the decades to better understand the factors that determine the oxygen dynamics, productivity and ecology of algal/bacterial assemblages present in these systems. Such research has also been undertaken in the area of algal biomass production of *Spirulina sp* for example.

The research presented in this thesis was undertaken with the goal of characterising relations between irradiance, algal oxygen dynamics and productivity. Such factors are basic to the cycling of energy in algal-based wastewater treatment systems as well as natural aquatic ecosystems. It is hoped that the findings of this research may contribute towards a greater understanding of the phytoecology of these systems.