Bioaugmentation: an effective commercial technology for the removal of phenols from wastewater




Gregory Poi[A,B], *Esmaeil Shahsavari*[C], *Arturo Aburto-Medina*[C] *and Andrew S Ball*[C,D]

[A]School of Chemical and Life Sciences, Singapore Polytechnic, Singapore 139651

[B]School of Biological Sciences, Flinders University, Bedford Park, SA 5042, Australia

[C]Centre for Environmental Sustainability and Remediation, School of Science, RMIT University, Bundoora, Vic. 3083, Australia

[D]Tel: +61 3 9925 6594, Fax: +61 3 9925 7110, Email: andy.ball@rmit.edu.au

Phenol represents a huge problem in industrial wastewater effluents and needs to be removed due to its toxic and carcinogenic nature. The removal of phenol from the wastewater is often both expensive and time consuming; there is therefore a requirement for a more effective, sustainable solution for the removal of phenol from wastewaters. Bioaugmentation or the addition of phenol degrading microorganisms to contaminated effluents is one such sustainable approach being considered. Here, we describe how bioaugmentation has been applied for the biological treatment of phenol in industrial wastewaters.

Phenol is a key pollutant in contaminated industrial wastewater

Phenol and phenolic derivatives are often found in wastewater discharged from pharmaceutical treatment plants, oil refineries and are toxic and carcinogenic to both humans and animals. It has also been shown to inhibit photosynthesis[1]. Phenol can also be released into the environment due to spillage or leaks from hazardous waste dumps. Phenol is resistant to degradation in the environment and considered a serious pollutant[2] and therefore it is included in the list of priority organic pollutants prepared by the USEPA[3]. Once released into the environment, due to its chemical properties phenol does not adhere to soil, and thus moves through the soil matrix and into groundwater[4].

Bioaugmentation as a cost-effective solution for the removal of phenol from industrial wastewater

Bioaugmentation generally falls in two main strategies: (1) bioaugmentation by enrichment with indigenous microorganisms; and (2) bioaugmentation by enrichment with non-indigenous microorganisms. The reinoculation of an environment with previously adapted indigenous microorganisms directly isolated from the site is often termed indigenous bioaugmentation[5]. However, if the sites do not contain active, pollutant degrading microbes, addition of exogenous microbial strains could be a solution.

In comparison to other technologies used for reducing phenol content in contaminated water such as chemical oxidation, filtration and activated carbon, biological treatment has been shown to be cost effective and versatile resulting in the complete mineralisation of phenol[6,7]. As such, industrial effluents containing phenol have often been treated using low cost biological treatment such as activated sludge systems. However, these systems often failed due to the high concentrations of phenol or fluctuations in phenol wastewater concentration. This has encouraged the development

Figure 1. (*a*) Seed Bioreactor (five drums, 750 L in total), (*b*) Treatment tank (400 m^3) (on the left), (*c*) Bioballs inside each of the drums (placed under the ceramic porous rings), (*d*) Phenol-contaminated wastewater being added to the netted ceramic porous rings. The phenol contaminated water was added to the Seed bioreactor where the consortium was added and later moved to the treatment tank.

of more robust microbial systems able to accommodate large irregular fluctuations to meet compliance in a more consistent manner[8–10].

The addition of single species or microbial consortia for phenol degradation

In nature there are some microbes that can use phenol as source of carbon and energy. The biodegradation of phenol using such phenol degraders has been studied extensively with many cultures including those from commonly occurring Gram negative bacteria e.g. *Pseudomonas* spp.[11,12] and *Alcaligenes* spp.[9], Gram positive bacteria e.g. *Bacillus* spp.[13,14] and *Nocardia* spp.[15], Gram variable bacteria e.g. *Arthrobacteria*[16] and the yeast-like fungi *Aureobasidium pullulans*[17]. Phenol is normally degraded under aerobic condition where enzymes such as phenol monoxygenases (phenol 2-monooxygenase) are involved in its degradation[18].

Reports on phenol degradation using single species of microorganisms are abundantly available[12–14,16], while reports on the application of mixed cultures of microorganisms are less prevalent but interest has increased in recent years[19–21]. The reason for the interest in microbial consortia is the assumption that the application of mixed species consortia in the bioremediation of pollutants has greater stability and tolerance to changing environmental and physiological conditions together with increased metabolic capabilities.

Phenol degradation by a mixed microbial consortia: a case study

Recently Poi *et al.*[22] isolated 22 phenol degraders including *Acinetobacter* sp., *Bacillus* sp. and *Pseudomonas* sp. The screening results showed that all 22 isolates were able to degrade phenol in laboratory based studies. The bioaugmentation of these 22 isolates in a field study using a bioreactor (400 m^3) (Figure 1) resulted in

complete phenol degradation, with a phenol concentration reduced from 407 mg L^{-1} to below detection limit (0.1 mg L^{-1}) over 104 days of incubation. An estimate for the treatment of wastewater from phenol using conventional technologies is around US$100 per tonne. However, through the use of bioremediation techniques such as the system described above, this cost can be reduced to less than US$30 per tonne. As a result, this environmental biotechnology is becoming an increasingly competitive commercial remediation technology.

In conclusion, bioaugmentation represents a promising, sustainable and cost effective approach for the degradation of phenol in industrial wastewaters. This case study provides evidence of the scalability of the process to field studies and promotes its usage in similar contaminated sites.

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Biographies

Gregory Poi completed his Bachelor of Science, Graduate Diploma and Master of Science at UNSW in 1987. He is currently a Senior Lecturer at Singapore Polytechnic since 1989 with a portfolio that includes R&D work, industrial consultancy and collaboration with industrial partners. His primary area of interest is in the bioremediation of phenol and petroleum hydrocarbon contaminated sites, with a focus on translation and scale-up. He holds two patents for the bioremediation of petroleum hydrocarbon contaminated soil and water in Singapore.

Dr Esmaeil Shahsavari is a researcher at the Environmental and Sustainability Research Centre, School of science at RMIT University. He obtained his PhD from RMIT University. He is an expert in the bioremediation of both aquatic and terrestrial environments. His research interests include environmental microbiology, phytoremediation, and next generation sequencing (metagenomics).

Dr Arturo Aburto-Medina is a researcher at the Environmental and Sustainability Research Centre, School of Science at RMIT University. He obtained his PhD from the University of Essex, UK. He has conducted postdoctoral studies in University of California Irvine, Flinders University and has held lecturing positions at UAM and ITESM (Mexico). His research interests include drug discovery, conservation of the environment and the remediation of contaminated sites.

Professor Andy S Ball is a RMIT Distinguished Professor and Director of the Centre for Environmental Sustainability and Remediation at RMIT University. He obtained his PhD in Microbiology from the University of Liverpool, UK. He carried out his Postdoctoral Research at Liverpool University prior to taking up a Lectureship at Essex University, UK before taking up the post of Foundation Chair in Environmental Biotechnology at Flinders University.