Biotechnology Advances 35 (2017) 490–504

Contents lists available at ScienceDirect

Biotechnology Advances

journal homepage: www.elsevier.com/locate/biotechadv

Transport of bacteria in porous media and its enhancement by surfactants for bioaugmentation: A review

Hua Zhong [a,b,c,*], Guansheng Liu [a,b,*], Yongbing Jiang [d], Jinzhong Yang [a,b], Yang Liu [c], Xin Yang [c], Zhifeng Liu [c], Guangming Zeng [c]

[a] State Key Laboratory of Water Resources and Hydropower Engineering Science, Wuhan University, Wuhan, Hubei 430072, China
[b] School of Water Resources and Hydropower Engineering, Wuhan University, Wuhan, Hubei 430072, China
[c] College of Environmental Science and Engineering, Hunan University, Changsha, Hunan 410082, China
[d] The Sericultural Research Institute of Hunan Province, Changsha, Hunan 410127, China

ARTICLE INFO

Article history:
Received 20 July 2016
Received in revised form 20 March 2017
Accepted 22 March 2017
Available online 23 March 2017

Keywords:
Bioaugmentation
Bacterial transport
Advection-dispersion
Adsorption
Straining
Surfactants

ABSTRACT

The success of bioaugmentation processes for groundwater bioremediation requires efficient transport of bacteria in the subsurface environment. In this paper, the factors that influence transport of bacterial cells in porous media are reviewed and the effects of surfactants on the transport are discussed. Movement of bacterial cells in porous media is a process driven by advection and hydrodynamic dispersion forces of fluids. Immobilization of bacterial cells takes place due to processes such as adsorption and straining. Blocking and ripening along with bacterial migration process decrease and increase the retention of cells in porous media, respectively. Physicochemical properties of the porous media, groundwater chemistry, and properties of the bacterial cells affect the transport behavior. Surfactants have the potential to modify bacterial surface properties for both bacterial cells and medium solids, and thus enhance bacterial transport.

Contents

* Corresponding authors at: State Key Laboratory of Water Resources and Hydropower Engineering Science, Wuhan University, Wuhan, Hubei 430072, China.
E-mail addresses: zhonghua21cn@126.com (H. Zhong), gsliu0615@163.com (G. Liu).

http://dx.doi.org/10.1016/j.biotechadv.2017.03.009
0734-9750/

1. Introduction

In recent years, accidental release and improper disposal of solvents and petroleum-based products are recognized as the major causes of spreading organic contamination for soil and groundwater (Soga et al., 2004). Frequently, these organic compounds form non-aqueous phase liquids (NAPLs) in the soils and persist for significantly long periods of time, comprising long-term sources of contamination (Bai et al., 1997a; Rogers and Logan, 2000). This gives rise to a concern in developing innovative and sound remediation technologies for plume and source zone management, such as chemical flushing (Agaoglu et al., 2012; Park and Bielefeldt, 2005), chemical oxidation (Siegrist et al., 1999; Yeh et al., 2003), gas and steam treatment (Mohamed et al., 2007; Rogers and Ong, 2000), thermal treatment (Tse et al., 2001; Zhao et al., 2014) and bioremediation (Mutnuri et al., 2005; Swaathy et al., 2014; Wang et al., 2010). Bioremediation has the potential to permanently and cost-effectively eliminate contaminants through biochemical mineralization, which is in contrast to harsh chemical and physical treatments (Sturman et al., 1995). Thus, bioremediation attracts increasing attention as a green route for remediation (Dash et al., 2013).

For the implementation of bioremediation efforts (bioaugmentation in particular), understanding the fate and transport of bacteria in porous media is of great importance. Bacterial transport is a type of colloid transport driven by advection and hydrodynamic dispersion forces of fluid. Other processes, such as adsorption and straining, tend to immobilize cell particles and cause retention. Blocking or ripening behavior may accompany bacterial migration process to weaken or enhance cell retention. Many factors, such as properties of soil solids, properties of bacterial cells, and groundwater hydraulics and chemistry, influence the transport behavior (Zhong et al., 2016).

Surfactants (i.e., biosurfactants, synthetic surfactants) are amphiphilic molecules containing polar and non-polar groups and possess surface- or interface-related properties (Mulligan, 2009). Biosurfactants are produced by microbes and have several advantages over synthetic surfactants, e.g., biodegradability and low toxicity, strong surface activity, and high efficiency even at extreme environmental conditions (Gautam and Tyagi, 2006; Nitschke and Costa, 2007; Singh and Cameotra, 2004; Sobrinho et al., 2008). In addition, biosurfactants can be obtained from renewable substrates and suitable for large-scale production (Nitschke et al., 2005; Sarubbo et al., 2007).

Many surfactants, e.g., sodium dodecyl sulfate (SDS), Tween-20, Tween-80, Triton X-100, Triton X-705, Brij and rhamnolipid biosurfactants, have been used to enhance the transport of bacteria in porous media for bioaugmentation applications (Bai et al., 1997b; Brown and Jaffé, 2001; Chen et al., 2004; Li and Logan, 1999; Zhong et al., 2016). These surfactants were observed to be effective in altering surface properties for both bacterial cells and porous media, and consequently the transport behavior of bacterial cells in the porous media. The concrete mechanisms for such effects, however, are still not clear. Therefore, exploration in the effect of surfactants on the transport of bacteria in porous media is of importance for bioremediation of organic-contaminated soils and groundwater.

In this review, the theoretical bases associated with bacterial transport in porous media were firstly outlined (Section 2). Then theories and models for bacterial transport are reviewed (Section 3). Then factors affecting the transport and the possible mechanisms are updated (Section 4). Finally surfactants and their effects on bacterial transport are summarized (Section 5).

2. Processes and theoretical bases for bacterial transport in the porous media

2.1. Advection-dispersion

The processes that are associated with bacterial transport are shown in Fig. 1. Similar to transport of solute molecules, bacterial transport in the soil is driven by hydraulic forces of groundwater flow, showing basic characteristics of solute transport, i.e., advection and hydrodynamic dispersion (Fig. 1). Advection is a process that bacteria suspended in water transport with the movement of fluid. Hydrodynamic dispersion includes diffusion and mechanical dispersion. Diffusion is a process of bacterial movement from a region with a high cell concentration to a low-concentration region due to Brownian motion of colloid particles. Diffusion is not significant for bacterial cells due to relatively large size of the cells as colloidal particles (0.3–10 μm) (Chrysikopoulos and Sim, 1996). Due to the heterogeneity of the soil particles and pore structure, the direction and velocity of water flow vary at pore scale, causing both longitudinal and cross-sectional mixing of particles (mechanical dispersion). Mechanical dispersion is more important for bacterial transport compared to diffusion. Water flow velocity is the most important factor for advection and dispersion processes.

2.2. Straining

Straining is the process of trapping colloid particles in the pore throats that are too small to allow particle passage (Porubcan and Xu, 2011) (Fig. 1). Straining has been demonstrated as an important process