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Determining straining of *Escherichia coli* from breakthrough curves

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Abstract

Though coliform bacteria are used world wide as an indication of faecal pollution, the parameters determining the transport of *Escherichia coli* in aquifers are relatively unknown, especially for the period after the clean bed collision phase brought about by prolonged infiltration of waste water. In this research, the breakthrough curves of *E. coli* after total flushing of 50–200 pore volumes were studied for various influent concentrations in various sediments at different pore water flow velocities. The results indicated that straining in Dead End Pores (DEPs) was an important process that dominated bacteria breakthrough in fine-grained sediment (0.06–0.2 mm). The filling of the DEP space with bacteria took 5–65 pore volumes and was dependent on concentration. Column breakthrough curves were modelled and from this the DEP volumes were determined. These volumes (0.21–0.35% of total column volume) corresponded well with values calculated with a formula based on purely geometrical considerations and also with values calculated with a pore size density function. For this function the so-called Van Genuchten parameters of the sediments used in the experiments were determined. The results indicate that straining might be a dominant process affecting colloid transport in the natural environment and therefore it is concluded that proper

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knowledge of the pore size distribution is crucial to an understanding of the retention of bacteria.

Keywords: Escherichia coli; Colloid deposition; Colloid transport; Straining; Groundwater flow; Pore size distribution

1. Introduction

In some developing countries in arid regions, the main source of drinking water is groundwater abstracted from dug or drilled wells. As wastewater collection systems are uncommon in these countries, most households dispose of their solid and liquid waste via soakaways (or pit latrines). In some cases, the distance from pit latrine to abstraction well is small (less than 200 m) and there is then a real risk of the abstracted water being contaminated with pathogens (Foppen, 2002).

Total Coliforms (TC) and Faecal Coliforms (FC) are commonly used as indicators of pathogens related to faecal contamination of groundwater as they are simple and relatively cheap to determine and give a good indication of the microbiological contamination. The main bacterial strain in TC and FC is *Escherichia coli*, which is rod shaped with an average length of 2–4 μm and an average diameter of 1 μm (Matthess et al., 1991b). In general, *E. coli* is hydrophilic (van Loosdrecht et al., 1987b) and its zeta potential, which is a measure of the charge near the surface of the bacterium, varies between −10 and −30 mV (van Loosdrecht et al., 1987a).

When it comes to assessing the risk of microbiological pollution or predicting the distance a wastewater plume with its microbiological load can travel in aquifers it seems appropriate to assess first the behaviour of *E. coli* in terms of its potential to travel various distances in aquifers. Various studies have focused on the transport behaviour of *E. coli*. The most well known field experiments were carried out by Caldwell and Parr (1937), who followed the breakthrough of "*B. coli*" (and "*B. aerogenes*") in time and space by taking daily samples of groundwater in more than 100 observation wells at regular distances downstream from a pit latrine. Lewis et al. (1982) summarised a number of field studies focusing on the distance TC and/or FC bacteria travelled in aquifers. They concluded that bacteria can travel several hundred metres in aquifers; the actual distance travelled depends on groundwater flow velocity, survival rate, initial concentration, dilution and dispersion of groundwater, and the sensitivity of the method used to detect bacteria. A more recent field study by Sinton et al. (1997) on wastewater infiltration and wastewater injection experiments supports this conclusion. Matthess et al. (1991a,b) used filtration theory (Yao et al., 1971) to describe the transport of *E. coli* ATCC 11229 in laboratory columns. The columns with a fixed inner diameter of 9.9 cm and various heights (from 0.1 to 0.6 m) contained sediment of various grain sizes and were seeded with *E. coli* for a total duration of 1–5 pore volumes at various pore water flow velocities. The results indicated two types of *E. coli* breakthrough. At low pore water velocities of around 0.7–1.5 m/day, breakthrough reached a plateau phase at low C/C_0 value (type 1); at higher pore water flow velocities