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Urban contamination of Triassic sandstone with microbial pathogens

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The transmission of disease through contaminated groundwater resources is well documented. There are now known to be over 100 viral, bacterial and protozoan pathogens contaminating groundwater released from leaky sewer systems, septic tanks or pit latrines. Much interest exists, worldwide, in removing viruses by soil passage either for protection of groundwater or as treatment of surface water that is subsequently used for drinking water purposes. In recent years, a number of studies have been carried out to improve the understanding of transport mechanisms controlling virus removal in the subsurface, where most studies were carried out in relatively fast flowing aquifer media like sands and gravels. The parameters controlling the fate and transport of viruses in the subsurface are highly important to determine protection zones and setback distances.

The UK Triassic sandstone aquifer is the second biggest aquifer of the UK used for water supply. Compared to the above documented aquifers its relatively slow water flow velocities and its low degree of heterogeneity suggest a low vulnerability of this aquifer on microbial contamination. However, recent investigations of microbial water quality have detected coliphage (a group of viruses that infect bacterial cells) and enteric viruses to depths of 60m below ground. Therefore, a project was undertaken to investigate the parameters controlling the fate and transport of viruses in the Triassic sandstone aquifer. This incorporated studying and comparing lab column experiments of selected bacteriophages with small scale field experiments on a test site in Birmingham. As pathogenic viruses cannot be released into aquifers due to the immediate threat to public health robust and reliable surrogates are needed to assess the charac-

teristics of pathogenic viruses in a typical UK aquifer. Bacteriophages are an obvious alternative due to their similar characteristics to mammalian viral pathogens.

Three types of forced gradient field experiments were run over the past 18 months all applying and recovering phage in conjunction with fluorescein and the distance between injection and recovery borehole was 7m. In a first step, four homogeneous sections of the sandstone were selected for the four different phages (MS2, PRD1, ΦX174 and H40/1) and each one tested by sealing a section with inflatable packers in both the injection and the recovery borehole. As a result, a high percentage of fluorescein was recovered for each experiment (40-60%) but no phages were detected in the observation well. In a second step, a highly conductive fracture was selected and sealed again with packers to study the transport behaviour through known fractures. However, still no phage was detected in the observation borehole. However, it is worth mentioning that the chosen fracture was very clay rich thus potentially highly effective in removing viruses. As a last test, the entire open borehole was tested and found occasional detects of phages in the first couple of days.

The series of results suggest that, even though Triassic Sandstone is highly efficient in removing viruses from ground water, some small numbers of detects have to be expected – at least over distances of meters to tens of meters – because they are very effectively transported through local fractures. If it is considered that the low counts detected during the last experiment represent a dilution of the injected solution of the order of 10^6-10^8 it is not surprising that fluorescein with an input/background ratio of only about 10^4 was not able to detect these low volumes of fast flowing groundwater. Note that the high concentrations of the phage pulses injected for the field experiments were 2-6 orders of magnitude higher than the concentrations usually found in sewage systems but they were injected as a pulse rather than continuously over years to decades. The typical transport distances of pathogenic viruses in the homogeneous sections of the aquifer were assessed for continuous injection conditions such as from leaky sewers with typically up to 10^4 viruses per litre and found distances of only 0.2 to 14 meters (for flow velocities of 1 to 100 m/a respectively) to reach concentrations below 1 virus per litre. The viruses detected to depths of 60 meters below ground therefore must have travelled through preferential pathways and bulk flow appears to be of minor importance for groundwater safety. However, most regional groundwater models used for drinking water protection rely on the concept of bulk flow and usually neglect preferential flow paths. In order to improve the degree of protection of urban groundwater from viruses it is, therefore, seen as highly important to adapt current concepts or develop new concepts and implement them in today's groundwater models.