Virus Movement in Urban Groundwaters

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Background and aims: Urban aquifers are important resources, yet they are also at risk from infiltration, either managed or unmanaged, of polluted urban runoff. Until recently it had been thought that viruses from human and animal wastes would be strongly attenuated in predominantly intergranular flow systems. However, recent research has shown that this is not the case, and that viruses are not infrequently present in waters from deep urban sandstone wells, and to depths of up to many tens of metres. The few available laboratory and field experiments have indicated a wide range of attenuation, depending on conditions. Accordingly, the present project is attempting to: (i) determine the controls on virus movement in sandstone groundwaters; and (ii) use the findings to suggest an appropriate method for assessing the risk of virus contamination in wellwaters. The approach centres on a field experiment which was carried out in May 2008: here we describe the preliminary interpretation.

The experiment: The main experiment undertaken consisted of a tracer test of about a month's duration. A suspension of the bacteriophage MS2, a commonly-used experimental surrogate for human viruses, made up in groundwater, was injected into a 50 m deep sandstone borehole located 7.6m from a 50 m deep pumping borehole: a similar injection, but of fluorescein, preceded the phage injection by 24 hours. The main pump in the recovery borehole was located close to the water table resulting in upflow throughout the borehole. In addition to the samples taken from the main pump, a sampling pump was used to extract samples from 5 depths in the recovery borehole, switching in sequence from one depth to the next. The water sampled from the 6 depths was passed through virus filters, and separate streams were sampled for chemistry and passed through an on-line particle sizer and an on-line fluorimeter. The concentrations determined at the recovery borehole for each of the 6 levels sampled were used to obtain breakthrough curves for each interval. Flows from each of the intervals during pumping was determined prior to the tracer test using a 'spinner' flow meter / packer assembly.

Results and preliminary interpretation: Fluorescein breakthroughs were complex. Although interpretation is not yet complete, it is clear that mass recovery was close to 100% and both fracture and matrix pathways are important in all the intervals. Much of the fluorescein mass breaks through earlier than might be expected from dividing the total pore volume by the pumping rate. The lower-, and possibly the upper- most intervals appear to have drawn in water from below and above the test zone. Even ignoring these two intervals, fluorescein mass recoveries do not reflect discharges in the abstraction well, suggesting that porosity variations and/or multiple permeability effects are important. Phage recovery was also very high, with total recovered plaque-forming units exceeding the number of units present in the injected tracer as a result of break-up of virus aggregates in the system. Breakthrough concentrations in the uppermost interval appear to be underestimated, and the causes of this are being investigated. The high number recovery contrasts strongly with some previous field and laboratory experiments, but agrees with laboratory experiments undertaken in the presence of inorganic colloids. Breakthrough curves are much less detailed than for fluorescein, as it was possible only to analyze one sample per day from each interval. Nevertheless, the breakthrough curves indicate a broadly similar shape to those of the fluorescein, though delayed by factors of up to two in different intervals. However, the numbers of phage recovered in each interval are not proportional to the fluorescein mass recoveries (or the discharges). Numerical modelling interpretation continues with the aim of developing a quantitative understanding of the system.

Preliminary conclusions: Phage are mobile within the sandstone groundwaters, moving through at least 3 of the 6 intervals monitored. It is highly likely, therefore, that, contrary to the usual assumption, human viruses are also mobile in sandstone aquifers, and possibly in other intergranular-flow dominated systems. Evaluating risk probably cannot be based on discharge distributions alone.