Reduction of micro organisms and natural organic matter in unsaturated zone – a column experiment

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ABSTRACT

This paper presents the results of a study (in Sweden) that investigated the microbiological barrier efficiency and the reduction of natural organic matter (NOM) in the unsaturated zone in artificial recharge of groundwater by pond infiltration. The aims were to:

1. Quantify the reduction of bacteria and virus utilising pulse-response experiments with indicator bacteria and bacteriophages as tracers.
2. Quantify the reduction of natural organic matter.
3. Investigate if a 30-cm layer of Iron Oxide Coated Olivine sand (IOCO) enhanced the reduction.

To simulate the artificial recharge system, five large columns were constructed and filled with 5.4 m of sand from the Gråbo glacial delta formation in western Sweden, with study cases of 1, 2 and 4 m of unsaturated zone and 2 m of saturated zone. Two columns contained 2.5 m of Gråbo sand including 0.3 m of IOCO-sand. For the study on the reduction of bacteria and virus, one pulse-response experiment was performed with diluted, primarily treated wastewater containing indicator organisms and three pulse-response experiments were performed by challenging the system with bacteriophages ΦX174 and MS-2 as model organisms of virus. For the study on the reduction of NOM, water samples were taken regularly during periods when pulse-response experiments were not performed.

The material from Gråbo originated from granite/gneiss with 40 % Quartz and 27 % Na-silicates, with a clay content of 2-3%. The water transport time was 13-44 h for 1-4 m of unsaturated zone and 39 h for 2 m of saturated zone. The hydraulic conductivity was 0.4 x 10-4 to 1.5 x 10-4 m/s. The unsaturated water head was –25 cm.

The microbiological barrier efficiency regarding virus was efficient in 4 m of unsaturated zone (3 log10). It was higher than disinfection with chlorine (2 log10) and as high as chemical precipitation (3-4 log10 for bacteria and virus). The efficiency was higher in unsaturated zone compared to saturated zone. IOCO-sand strongly enhanced the reduction of virus (in total 4-6 log10). The microbiological barrier efficiency regarding bacteria and protozoa was sufficient in 4 m of unsaturated zone (≥2.4 log10). It was similar to disinfection with chlorine (2 log10) and slightly lower than chemical precipitation (3-4 log10 for bacteria and virus). There was no obvious difference in efficiency between unsaturated and saturated condition. The removal of organic matter was sufficient in 4 m of unsaturated zone with up to 63% removal in CODMn. This was slightly lower in the saturated zone, especially regarding organic matter measured with UV-absorbance. IOCO-sand strongly enhanced the removal. The improvement was nearly 5-folded measured as UV-absorbance and 2-folded measured as CODMn.

Regarding removal efficiency for bacteria, virus as well as for the NOM, the result shows that IOCO sand should be considered for application, especially for the conditions of thinner unsaturated zone.