# Impact of two on-site sanitation solutions on human health risks associated with the aquifer pathway and exposure to pathogens from shallow water supply wells

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## Background

The health risks associated with faecal groundwater contamination from on-site sanitation is critical, in residential settings where households are using water from shallow wells for drinking and domestic purposes. The potential impact on human health needs to be demonstrated quantitatively to give political motivation to tackle the issue.

## Aim

- To quantitatively assess the human health risks associated with microbial pollution of water supply wells from nearby on-site sanitation (OSS) installations
- To combine microbial risk assessment with underlying hydrogeological processes impacted by natural- and technical barriers in their effects on pathogen reduction throughout the aquifer pathway
- To exemplify the approach with; a simple “wet” latrine and a compact greywater filter system
- To estimate safe setback distances, based on a recommended tolerable risk

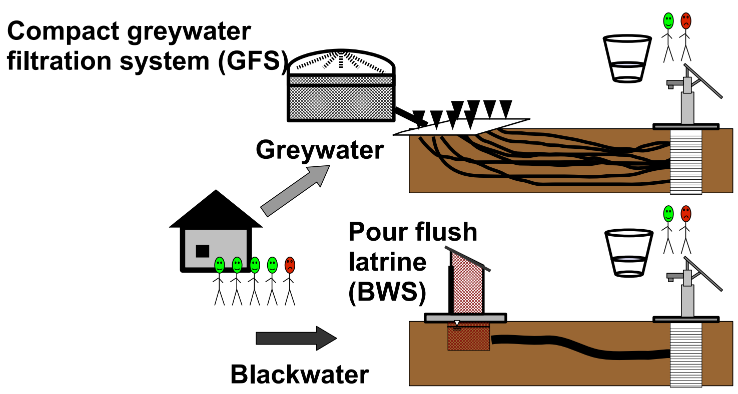


Figure 1 Conceptual sketch of the two studied OSS systems

## Methodology

The daily/yearly health risk is demonstrated by hazardous events where residents in a household are connected to a OSS system and are infected by pathogens like EHEC (type of E. coli) or Rotavirus (Figure 1). The barrier reduction in the “wet” blackwater system (BWS) is modeled as a single flow reactor, with a net reduction rate based on pathogen inactivation in feces. Values for the greywater filter system (GFS) are based on samples during 2 years using indicator bacteria and model viruses to estimate reduction parameter uncertainty for the system. Steady state filtrations with first order decay, models reduction in the GFS and the residence time is based on tracer tests.

The groundwater transport modeling follows the framework by Dagan et al. (1992). The effluent from OSS units are assumed to be directly discharged to groundwater and transported in the direction of the average flow. For the blackwater system a relatively narrow effluent plume is assumed and conceptualized as a single stream-tube. The greywater filtration system exemplifies larger volumetric flow rates, with the effluent distributed over a ~10 $m^2$ infiltrating area. Here, multiple stream-tubes connects to the receptor well (Figure 1). The transport is advection dominated and is governed by the spatially variable hydraulic conductivity, described by the geometric mean, log variance and integral scale. The statistic parameters are based on a shallow laterite aquifer in Kerala India. For simplicity hydraulic gradient, porosity, reversible/irreversible deposition processes and inactivation are assumed uniform.

Risk assessment is based on the QMRA framework (Haas et al., 1999). The exposure is related to the pathogen input in grey/blackwater, reduction in the barriers and water consumption. Dose response models allow for translation of a daily ingested dose to a risk of infection. By comparison to a tolerable risk level, safe setback distances are estimated.

## Results

The safe setback distance for EHEC *E. coli* and Rotavirus in a rather low conductive formation with geometric mean $K_G$ ~5 m/d, ln K variance ~1 and integral scale ~1 is shown in Figure 2. Two hypothetical physiochemical aquifer environments are modeled, with a typical and a conservative pathogen reversible-/irreversible deposition.

For the conservative aquifer environment health risks are below the tolerable level at a expected setback distance greater than 7 m for both systems, if assessment is based on *E. coli* (Figure 2). With Rotavirus a expected setback distance >25 m and >18 m is needed for the BWS and GFS respectively.

The uncertainty of safe setback distance in Figure 2, is inherited from the filter reduction rate parameter in the GFS and the single stream-tube transport for the BWS.

The sensitivity of aquifer transport parameters on safe setback distance is shown in Figure 3; integral scale (ln K) for BWS under the typical conditions (A) inactivation rate for the GFS under the conservative conditions (B).

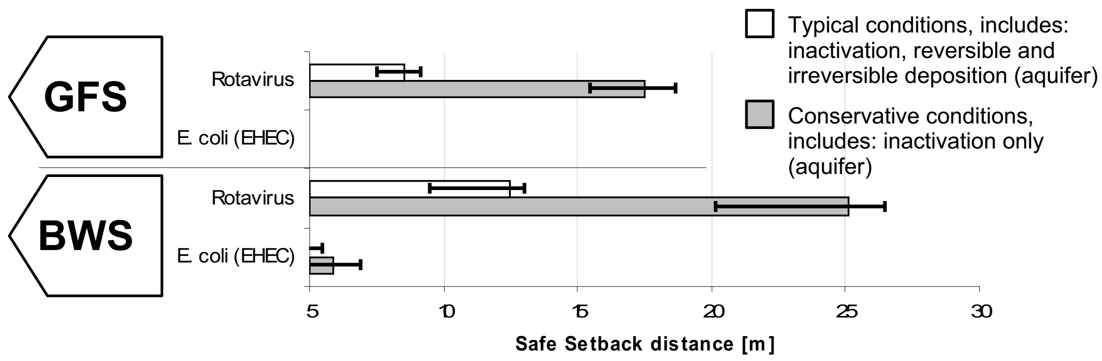


Figure 2 The expected value and 95% confidence interval of safe setback distance for the blackwater (BWS) and greywater (GFS) OSS system.

The safe setback distance is sensitive to both integral scale, the inactivation parameter and deposition parameters as seen in Figure 2 and Figure 3.

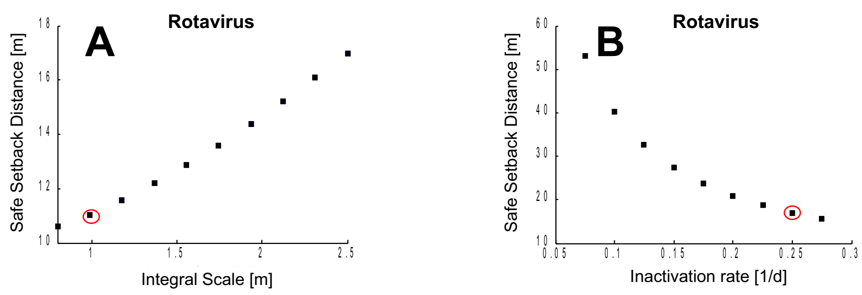


Figure 3 Sensitivity of A) integral scale of log hydraulic conductivity and B) inactivation rate in the aquifer on the median safe setback distance. Red circle marks the values used in modeling (Figure 2) .

## Conclusions

- By combining the technical barrier function with a pathogen transport model and dose response models, an annual risk of infection is quantified and a safe setback distance can be estimated for the actual risk scenario
- The blackwater system requires a greater setback distance to assure a tolerable risk level, compared to the greywater filter system for the given risk scenario
- A safe setback distance based on *E .coli* bacteria does not assure a tolerable risk level for viruses
- Aquifer flow and transport properties such as the spatial variability of hydraulic conductivity, inactivation and deposition processes, may greatly effect the outcome of the health risk assessment and increase the safe setback distance considerably

**References:**

Dagan, G.; Cvetkovic, V. & Shapiro, A. (1992), 'A solute flux approach to transport in heterogeneous formations, 1, The general framework', *Water Resources Research* **28**(5), 1369-1376.

Haas, C. N.; Rose, J. B. & Gerba, C. P. (1999), Quantitative Microbial Risk Assessment, John Wiley & Sons.