

## **Extending the risk assessment framework for pathogens in biosolids: Ground water pathway**

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Current U. S. Environmental Protection Agency regulations for the land application of biosolids are not based on quantitative microbial risk assessment. A framework has been developed to assess microbial risk to human health from exposure to pathogens in land-applied biosolids (Eisenberg et al. 2006). For the groundwater pathway, the existing framework identified groundwater exposure through both unsaturated and saturated soil, and predicted single event risk and annual risk under non-rainfall conditions for the general population. This study extends the framework by 1) considering the effect of wet weather events on groundwater transport; and 2) predicting cumulative risk for the maximum reasonably exposed individuals. The groundwater transport model and risk assessment model were implemented in a spreadsheet programming environment, which offers a familiar and flexible user interface to conduct site-specific risk assessment without losing accuracy (Gurian et al. 2004).

The groundwater transport model is one of five exposure pathways included in the overall risk assessment framework. The model was modified to account for wet weather events because the saturating wetting front produced by rainfall dramatically advances pathogen transport in soil above the water table (Figure 1). Linked models of pathogen transport vertically through the unsaturated zone and horizontally via groundwater flow through a saturated aquifer were developed. For the vertical transport, two cases were considered. In the first case, saturating rainfall events, in which the infiltrating wetting front reaches the underlying ground-water table, an analytical solution to the advection-dispersion equation was used to predict pathogen

attenuation (Bedient et al. 1997). In the second case, non-saturating rainfall events, in addition to the saturated wetting zone, pathogen attenuation through the unsaturated zone below the wetting front was modeled by applying the final value theorem of Laplace transformation to previously developed governing equations (Faulkner et al. 2003). Horizontal transport through the saturated zone was modeled using an analytical solution to the advection-dispersion equation, incorporating the effects of adsorption to soil and pathogen decay.

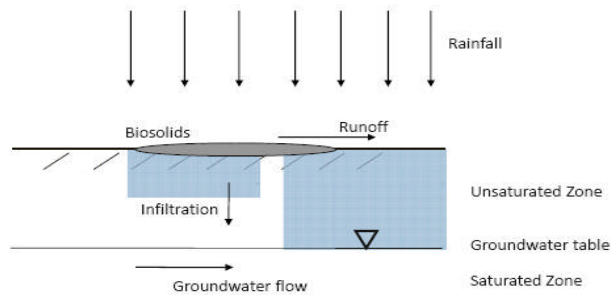


Figure 1 Ground-water exposure model

Intensity-Duration-Frequency analysis of historical precipitation data for Ingham County, MI was used to determine the critical rainfall, which produces the maximum infiltration for each return period. Cumulative infiltration is measured by the depth of the wetting front. The wetting

front,  $Z$ , is calculated by  $Z = \frac{I}{\theta_s - \theta_0}$ , where  $I$  is the cumulative infiltration predicted by the Joint Green-Ampt Model (Zhang 2009),  $\theta_s$  is saturated volumetric water content, and  $\theta_0$  is Initial volumetric water content. Intensities and durations of critical rainfalls for each return period were found. The return period values were used to estimate the probability of rainfall per day, which is associated with daily risk of infection and included in the cumulative risk calculation.

The subsequent work followed the established risk assessment framework. Hazard identification consisted of developing a list of potential pathogens of concern originating from biosolids, and included bacteria, viruses, and parasites. Pathogen doses were estimated from the

groundwater exposure model described above and were used to calculate daily risk of infection and cumulative risk of infection per application period. Instead of population average risks, risks for highly exposed individuals, such as workers applying the biosolids and residents at the minimum allowable setback distance, were emphasized in this study.

The groundwater transport and fate model, as well as the risk assessment model, were implemented in a spreadsheet environment. This spreadsheet-based model is a user-friendly program capable of determining the effects of soil texture class, pathogens of concern, and setback distances on overall risk using site-specific data. Future work will focus on developing the overall risk assessment model and incorporating other exposure pathways such as inhalation of aerosols, consumption of surface water, and direct ingestion of soil. The cumulative risk would be available when informed with complete pathogen-specific data. Once coupled with site-specific data, this model can provide a technical basis to interpret the health risk of biosolids-associated pathogens. It can be used by environmental managers to set criteria for allowable pathogen concentrations in biosolids and setback distances, based on corresponding acceptable levels of risk.

## **Reference**

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