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Project Summary

Pathogen Risk Assessment Methodology for Municipal Sewage Sludge Landfilling and Surface Disposal

This document describes a methodology and associated computer model, sludge-only landfill or surface disposal (SLDGFILL), for assessing the risk to humans of pathogens from disposal of treated municipal sewage sludge. The purpose of the SLDGFILL model is to determine the probability of infection of a human receptor from pathogens in a sludge-only landfill (monofill) or in a surface disposal site. The ultimate objective for the model is to assist the U.S. Environmental Protection Agency (EPA) in developing technical criteria for regulatory activities. More immediate objectives include the use of the model to perform actual pathogen risk assessments and to identify research needs.

This Project Summary was developed by EPA's National Center for Environmental Assessment, Cincinnati, OH, to announce the availability of a software program that is fully described in a separate document of the same title (see software package ordering information at back).

Specific enteric bacteria, viruses, protozoa, and helminths are identified as the pathogens of concern in sludge. The exposure pathway addressed by the SLDGFILL model is the ingestion by a human receptor of groundwater from a drinking water well that has been infiltrated by microbial pathogens from a sludge disposal site. Viruses were identified by the sensitivity analysis as the principal organism for which the model demonstrates a potentially significant health hazard.

Quantity of treated sludge, application frequency, and other parameters specific to a sludge disposal site are entered initially by the user. Pathogen parameters required for SLDGFILL include (1) density of pathogens in treated municipal sewage sludge destined for landfilling or surface disposal; (2) infectivity; (3) inactivation rates in sludge, soil, and groundwater; and (4) dispersion or transport in the environment. The parameters to which the model proved to be most sensitive are pathogen density in sludge, infective dose, inactivation rate in water, and sludge-to-soil resuspension coefficient.

The model test results imply that the total number of sludge pathogens in the surface disposal site is less important to health risk than is the concentration in the sludge. To limit risk offsite, it may be useful to regulate the concentration of sludge pathogens, either by monitoring sludge treatment or by diluting highly contaminated sludge with less contaminated sludge, compost, clay, or other material.

The range of reported minimum infective doses for pathogenic bacteria is 10 - 10^{11} organisms; for viruses, the range is 9 X 10^{-1} - 9 X 10^{4} virus particles, 2 X 10^{-1} - 5.5 X 10^{6} PFU, or 1 - 1 X $10^{7.6}$ $TCID_{50}$; for protozoa, the range is 1 - 100 cysts; and for helminths, 1 egg has been known to cause infection.

For the model, survival of pathogens in soil and water is presented in terms of inactivation rate constants (log_{10} day^{-1}), which may differ by several orders of magnitude even for a specific pathogen. Low temperatures and median pH levels prolong pathogen survival in water, and those factors as well as moisture content contribute to increased survival in sludge and soil. The ranking of pathogen persistence in the environment, from longest to shortest, is helminth eggs, viruses, bacteria, and protozoan cysts.

The depth to the groundwater presents the greatest barrier to the transport of pathogens and, hence, to exposure and risk. Filtration and adsorption are the processes responsible for limiting pathogen transport through the unsaturated zone. The size of the organism, therefore, determines which pathogen will be transported the greatest distance. In general, viruses, the smallest of the pathogens considered, have the potential to travel farther in the environment. Large particles like helminth eggs and protozoan cysts typically do not migrate into groundwater because of the physical barrier provided by the soil, unless there are vertical cracks or fissures. Due to their persistence, potential for transport, and low infectious dose, viruses seem to represent the worst case when estimating human health risk from landfilling or surface disposal of sewage sludge.

The SLDGFILL model for pathogen risk assessment has been run with many combinations of input parameters to simulate the transport of sewage sludge pathogens from a landfill or surface disposal site to a nearby drinking water well. The subsequent risk of infection to humans who drink from the well was estimated for each run. The probability of infection is calculated using a beta-Poisson model. Conservative exposure assumptions include a drinking water consumption rate of 2 L/day and parameters describing highly infective pathogens. The model indicates that risk from pathogens in groundwater near a surface disposal site or landfill is typically below a level of concern. However, if a risk exists, viruses are more likely to be the source of that risk than bacteria or parasites.

The parameters to which the SLDGFILL model are most sensitive are resuspension coefficients, which describe the adsorption of pathogens to sludge and soil particles. Other parameters to which the model is sensitive are infective dose, pathogen density in sludge, and inactivation rate in water. Data on infective doses are scarce, making further research necessary for reliable use of the model to predict health risks. It is likely that viruses present a greater health risk because they are expected to have a lower minimum infective dose and are more readily transported through soil.

Future research should be oriented toward satisfying the following information needs to allow more realistic modeling of human health risk from pathogens in landfilled and surface-disposed municipal sludge:

- field data on subsurface transport, in both the saturated and unsaturated zones, of bacteria and viruses;
- inactivation rates of pathogens under field conditions in sludge, soil, and water;
- solids-to-water suspension factors applicable to sludge- and soil-bound pathogens;
- leaching characteristics of sludge-bound pathogens;
- interaction of factors affecting pathogen resuspension from sludge and soil; and
- parameters needed to describe infective doses of selected indicator species and strains of pathogens in sludge.

This Project Summary was written by the staff of Science Applications International Corporation, Oak Ridge, TN 37831.
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The complete document, consisting of paper copy and computer diskette, entitled "Pathogen Risk Assessment Methodology for Municipal Sewage Sludge Landfilling and Surface Disposal," (Order No. PB96-501911; Cost: $X.00, subject to change) will be available only from

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