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Project Summary

Preliminary Risk Assessment for Viruses in Municipal Sewage Sludge Applied to Land

This preliminary risk assessment focuses on the probability of human infection from enteric viral pathogens in municipal sewage sludge applied to land. Based on the Pathogen Risk Assessment computer model and methodology described in *Pathogen Risk Assessment for Land Application of Municipal Sludge*, this study reports (1) the results of a literature review designed to find the data required to model human exposures to pathogenic viruses in sewage sludge and (2) the results of numerous site-specific computer simulations run with the Pathogen Risk Assessment Model using a wide range of values for the input parameters: minimum infective dose, density in sludge, die-off rates and transport in environmental media.

Counties in California, Florida, Iowa, New Mexico, Tennessee and Washington were selected for site-specific application of the model. Model runs predicted probabilities of infection of a human receptor exposed to pathogenic viruses by a variety of pathways arising from using sludge-amended soil to grow vegetable crops, lawns, or forage for cattle used for meat or milk.

Information needs are identified to guide further research, and model modifications are recommended.

This Project Summary was developed by EPA's Environmental Criteria and Assessment Office, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

This preliminary risk assessment study focuses on the probability of human infection from enteric viral pathogens in municipal sludge applied to land. Based on the Pathogen Risk Assessment computer model and methodology described in *Pathogen Risk Assessment for Land Application of Municipal Sludge*, this study reports (1) the results of a literature review designed to find the data on pathogenic viruses required by the pathogens methodology and (2) the results of numerous site-specific computer simulations, running the Pathogen Risk Assessment Model with a wide range of values for the parameters required. The parameters required for viruses are (1) minimum infective dose (MID); (2) density of infective viruses in treated sludge destined for land application; (3) inactivation rates in soil, dry particulates, liquid aerosols and water; and (4) dispersion in the environment, i.e., transport in water, soil and air. Human receptors whose probability of infection by viruses is calculated by this model include: (1) an onsite person exposed by ingestion of soil, vegetables or forage, or by inhalation and subsequent ingestion of aerosols; (2) an offsite person exposed to particulate or liquid aerosols carried by wind; (3) a food consumer who eats vegetable crops, meat or milk produced on sludge-amended soil; (4) a groundwater drinker who consumes water from a well near but not on the sludge application site; and (5) a pond swimmer who ingests a small amount of water while swimming in an onsite pond that receives the surface runoff from the application site.

To provide diversity in geographic location, topography, soil type, rainfall pattern and temperature, six locations were selected for site-specific application of the model: Anderson County, TN; Chaves County, NM; Clinton County, IA; Highlands County, FL; Kern County, CA; and Yakima County, WA.

Procedure

This analysis assumes that viruses are transported into subsurface soil and subsequently into groundwater and are included in any droplet aerosols formed by spray application, as well as in any particulate aerosols formed by disturbance of the soil by wind or by cultivation. It also assumes that the viruses are inactivated at a characteristic rate that depends on the ambient temperature and the medium in which they are found.

An initial sensitivity analysis was performed using site-specific data for Anderson County, TN. Main program variables used in the model run were varied over a range of values. In general, the default value of a given parameter was compared with a reasonable higher and a reasonable lower value. Many of the parameters of the model seemed to have little bearing on the probability of infection, apparently because they ultimately had no effect on the number of viral particles to which the human receptor was exposed in each exposure compartment or because they exerted their effect on survival or transport after the maximum probability of infection had occurred. In model runs using data from all sites, variables showing no effect on maximum probability of infection were eliminated from further consideration.

Infective doses have been reported in the literature to be as low as 1 infective particle, although this number varies according to the type of virus and the laboratory method used for detection. As a conservative assumption, this minimum value was used for the model runs. Literature values for virus density in treated sludge were so variable that no single number could be selected as typical. However, 2000 virus particles/kg was chosen as representative of viral density in composted sludge and 100,000 particles/kg in digested sludge. Inactivation rates reported in the literature (often given as log reductions in numbers of virus particles per hour) range from 7.1×10^{-5} to 1.6×10^{-1} logs/hour in soil, 1.6×10^{-4} to 1.4×10^{-1} logs/hour in water, and 4.9×10^{-5} to 8×10^{-7} logs/second in aerosols. Like the density values, these rates are quite variable. Because these literature rates were lower than the default values for the model runs, inactivation rates were decreased in soil, water and droplet aerosols for many of the computer simulations. Information on dispersion of viruses in the environment is limited in its applicability to generating a rate of transport in environmental media.

Results and Discussion

Using baseline values for parameters, the maximum probabilities of infection were evaluated. Results show that the inactivation rate of virus particles is extremely important in determining whether a groundwater well is likely to become contaminated and in determining how long surface soil or surface water is likely to remain infectious. The results also demonstrate the importance of accurate characterization of inactivation rates for viruses of different kinds in the various transport and exposure media.

In all model runs, the probability of infection offsite was calculated as zero, indicating that the calculated quantities of liquid and dry particulate aerosols and concentrations of viruses in the aerosols were too low to provide an infective dose to the modeled receptor.

Consumption of contaminated vegetable crops was shown by model calculations to be a potential source of human infection, provided that inactivation rates were sufficiently low or harvesting times were sufficiently close to application of the sludge. In addition, infection via food crops was sensitive to the relative fractions of pathogens transferred among surface soil, subsurface soil, and crop surface and to the type of crop or fraction of the total crop grown above-ground, below-ground, or on-ground.

Contamination of meat or milk by viruses from sewage sludge did not appear to pose a significant risk to human health.

Transport of viruses via groundwater to an offsite well was not shown by this model to be a major risk, but exposure by contaminated groundwater was shown to be likely if the rate of inactivation of viruses in water was less than the default values. The probability of infection was related to the periodic introduction of pathogens to groundwater by the infiltration of rainwater. The most important parameter related to subsurface transport of viruses appeared to be the inactivation rate of viruses in water. The results also showed an increase in probability of infection at the offsite well whenever the time required for the viruses to reach the well was decreased.

Exposure to contaminated surface water, represented by the swimmer in an onsite pond, was the most significant source of infection. A peak in probability of infection occurred after each rainfall, when additional contaminated surface water and soil were washed into the pond.

Conclusions and Recommendations

Although detailed data on survival and transport of viruses in soil are limited, the model appears to confirm the general observations in the literature that viruses in treated sewage sludge present a potential health risk, justifying land-use restrictions. However, model runs implied that restrictions may be overly conservative.

Model runs show significant onsite exposures. A probability of infection greater than 1×10^{-4} (tentatively chosen as a benchmark for sufficient protection of human health) is likely during application and incorporation of liquid treated sludge for agricultural practices. If the initial viral concentrations in composted sludge are higher than about 50/kg, the user is likely to be at risk of infection. A person applying sludge or present at the application site during or soon after sludge application could probably reduce the risk by wearing a protective mask and washing thoroughly before handling food.

The most significant potential source of infection was exposure to runoff water and transported sediment after rainfall. Model runs indicated that it would be prudent to limit access to runoff water and sediment from a sludge-amended field, either by mulching to reduce runoff, ditching and/or diking to contain the runoff or restricting access to any onsite ponds receiving runoff.

Reports of offsite infection by viruses in sludge-amended soil (particulate aerosols) or in aerosols from liquid treated sludge were not found. Model runs confirm the low probability of offsite infection.

U.S. EPA restrictions on growing food crops in sludge-amended soil, while necessary for protection against potential health hazards from parasites, appear to be more stringent than required by typical or even worst-case inactivation rates for viruses on crops. Model results suggest that the appropriate waiting period before access to sludge-amended land or consumption of crops grown thereon should probably be variable, depending not only on intended land use, as is currently the case, but also on sludge application rate and pathogen concentration. In calculating a safe waiting period, conservative assumptions should be made about amounts of soil ingested with crops.

The following information is needed to improve the usefulness of the Pathogen Risk Assessment Model and to allow for a more reliable risk assessment of the land application of sewage sludge:

- Simple and accurate standardized methods for detecting and quantifying, by type, pathogenic viruses in treated sludge destined for land application, in final distributed and marketed sludge products, and in environmental media;
- Improved understanding of minimum infective doses, particularly low-dose effects and minimum infective doses for sensitive subjects;
- More accurate persistence and transport data on all pathogenic viruses of major concern in sludge;
- Development of an index of soil types that would correlate capacity for solute transport with suitability for sludge application (also valuable for onsite waste disposal or solid waste disposal);
- Research on subsurface injection of sludge and the relative probability of virus transport in groundwater; and
- Epidemiologic studies evaluating enteric viral transmission.

The following revisions would improve the accuracy of the model:

- Revision of default parameter values, especially for inactivation rates in aerosols and temperature-dependent inactivation rates in soil and water;
- Revision of temperature-dependent inactivation algorithms;
- Incorporation of factors for humidity and temperature in inactivation equations for aerosols;
- Incorporation of subroutines for subsurface transport under conditions of transient flow; and
- Incorporation of factors to allow for subsurface transport through solution channels, cracks, etc.

In addition, field validation of the model's predictions is necessary before the Pathogen Risk Assessment Model can be considered an accurate predictor of health risk.

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Norm Kowal is the EPA Project Officer (see below).

The complete report, entitled "Preliminary Risk Assessment for Viruses in Municipal Sewage Sludge Applied to Land,"(Order No. PB92-182336/AS; Cost: $26.00; subject to change) will be available only from:

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