United States
Environmental Protection
Agency
Research and Development

Office of Health and
Environmental Assessment
Washington DC 20460
EPA/600/S6-91/001 July 1991

EPA

Project Summary

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

This preliminary risk assessment focuses on the probability of human infection from protozoa and helminths, usually referred to as parasites, in municipal sewage sludge applied to land. It is based on the Pathogen Risk Assessment computer model and methodology described in *Pathogen Risk Assessment for Land Application of Municipal Sludge*. The report documents (1) the results of a literature review designed to find data on parasites 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 parasites are density in sludge, transport and die-off rates in environmental media, and minimum infective dose. Locations selected for site-specific application of the model included counties in California, Florida, Iowa, New Mexico, Tennessee, and Washington. Model runs predicted probabilities of infection of a human receptor exposed to pathogenic parasites by a variety of pathways arising from the use of sludge-amended soil to grow vegetable crops, lawns, or forage for cattle used for meat or milk. Data gaps are identified and research priorities 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 focuses on the probability of human infection from protozoa and helminths, usually referred to as parasites, in municipal sludge applied to land. It is based on the Pathogen Risk Assessment computer model and methodology described in *Pathogen Risk Assessment for Land Application of Municipal Sludge*.

Parasites are of health significance in land application practices because they tend to become concentrated in sludge during sewage treatment processes and because they can remain viable as environmentally stable protozoan cysts or helminth ova for months or years under favorable conditions. Although epidemiological studies suggest little risk to human health from parasites in treated municipal sludge or wastewater applied to land, their low minimum infective dose and persistence in soil mean that the issue cannot be dismissed.

Procedure

The report documents (1) the results of a literature review designed to find data on parasites 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 most important parameters required for parasites are (1) density of viable parasites in treated sludge destined for land application; (2) die-off rates in soil, dry particulates, liquid aerosols, and water; (3) dispersion in the environment, i.e., transport in water, soil and air; and (4) minimum infective dose, which for parasites is assumed to be MID = 1 since single eggs of helminths and single cysts of protozoa have produced infections in humans. Of these parameters, density is site-specific and requires a standard method for enumerating parasites, die-off rate data are very limited, transport data are essentially nonexistent, and infective dose has been determined to be MID = 1.

Locations selected for site-specific application of the model include Anderson County, Tennessee; Chaves County, New Mexico; Clinton County, Iowa; Highlands County, Florida; Kern County, California; and Yakima County, Washington. The sites were chosen to provide diversity in geographic location, topography, soil type, rainfall pattern and temperature.

Results and Discussion

Density and viability of parasites in sludge are site-specific, based on source of wastes, species of parasites present, climate, and efficacy of sludge treatment. Densities of parasites have been reported to be generally higher in sludges from southern than from northern states. However, accurate risk assessment would require site-specific analysis of density levels by standard methods for enumerating parasites in sludges and soil. Parasite densities reported in the literature range from 100-2000 ova/kg dry wt in dried sludge and 0-30,000 cysts or ova/kg in liquid sludge; however, the values are highly dispersed and geometric means are in the range of 200-2000 ova/kg dry wt. According to EPA regulations, composted sludge for distribution and marketing (D&M) must have no more than 1 ovum/g or cyst/g volatile sludge solids. Based on the literature ranges, values suggested for use in the Pathogen Risk Assessment model are 5000 ova or cysts/kg for liquid sludge, 500 ova or cysts/kg for dried sludge and 1000 ova or cysts/kg for composted (D&M) sludge. The value used in the risk assessment was 5000 ova or cysts/kg for all practices

During storage under unfavorable conditions, ova and cysts may become inactive (non-infective) before they die. Death may be followed by disintegration. Although some of the studies discussed include information on infectivity, in many cases only viability of eggs and cysts was reported, and some studies reported only occurrence, not viability.

Inactivation of parasites appears to be most closely tied to temperature during treatment or storage, with higher temperatures contributing to increased inactivation. Temperatures in the 45 -55°C range are likely to kill resistant parasites within a few hours. Alternate freezing and thawing reduce viability more rapidly and to a greater extent than constant above- or below-freezing temperatures.

Field studies of parasite-contaminated sludge applied to agricultural plots, however, have not produced a direct statistical correlation between viable *Ascaris* ova concentration and solar radiation, relative humidity or soil temperatures. In fact, no statistical correlation was found between parasite egg concentration and chemical, physical or biological parameters.

Data on die-off rates are very limited, but a published 90% die-off time of 270 days implies an exponential rate of $10^{(-0.000154)}$/hour. Published ranges for die-off are approximately $10^{(-0.001)}$/hour to $10^{(-0.0005)}$/hour at ambient temperature. Based on these ranges, suggested values in the model for die-off of ova and cysts are:

During application/incorporation
- 0 for Temp <20°C;
- $10^{(-0.000178)}$ or 0.00041/hour for 20≤Temp<40;
- $10^{(-0.456)}$ or 0.65/hour for Temp≥40;

In moist soil
- 0 for Temp < 20°C or for 8 hours after irrigation;
- $10^{(-0.00023)}$ or 0.000533/hour for 20 ≤ Temp < 40;
- $10^{(-0.667)}$/hour or 0.7845/hour for 40 ≤ Temp ≤ 50;
- $10^{(-0.125)}$ or 0.25/hour for Temp>50;

On crop surfaces
- $10^{(-0.667)}$ or 0.7845/hour at all temperatures;

In water
- $10^{(-0.00023)}$ or 0.000533/hour at all temperatures.

Model runs showed that within narrow limits, the probability of human infection by parasites as a result of exposure to soil contaminated with sewage sludge is proportional to the concentration of organisms in the sludge, the amount of sludge applied and the amount of contaminated soil to which the individual is exposed, either by casual contact or ingestion of food grown in the contaminated soil. Many of the parameters of the model seemed to have little bearing on the probability of infection, apparently because they had no effect on the number of organisms to which the human receptor was exposed in each exposure compartment or they exerted their effect after the time of maximum exposure. The probability of infection was sensitive to the rate of inactivation or die-off of the parasite ova or cysts and to the method of application. According to the model, human exposure via subsurface application of sewage sludge would be unlikely because it is believed that ova or cysts cannot move significant distances through soil.

The model predicted that the most significant potential source of infection would be exposure to runoff water and sediment transported to an onsite pond 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 diking to contain the runoff or restricting access to any onsite ponds receiving runoff.

Various model runs predicted that it was unlikely that a significant number of ova or cysts would be transported off-site either by droplet aerosols or wind-blown dusts. The model also predicted that parasite, moving through the soil column into groundwater was unlikely. Therefore, one can infer, based on the model parameters used, that there is relatively little risk to human health from parasitic infection via inhalation of contaminated fugitive dust emissions or ingestion of contaminated groundwater.

Using a benchmark probability of infection of $1x10^{-4}$ as an indicator of sufficient protection of human health, a waiting period appeared to be unnecessary for consumption of aboveground crops contaminated with 0.1 g soil/crop unit. A waiting period of 18 months appeared to be adequate for belowground crops, whose consumption is currently forbidden for 5 years after sludge application.

The current version of the Pathogen Risk Assessment model does not address some of the properties of parasite survival in soil. Mathematical descriptions of the die-off of parasite ova, cysts and oocysts as a function of temperature and moisture are not yet adequate to allow construction of algorithms for die-off rates. It may be appropriate to add a diurnal cycle to the model's temperature algorithm. Other changes may be limited by the constraint that the model should run on a personal computer.

Conclusions and Recommendations

Although detailed data on survival and transport of parasites in soil are lacking, the Pathogen Risk Assessment model appears to confirm the general observations in the literature that parasites are persistent, justifying land-use restrictions. Model runs implied that restrictions on the consumption of belowground crops may be overly conservative, and they indicated that the most significant potential source of infection would be exposure to parasites in runoff water and sediment transported to an onsite pond after rainfall.

The following research priorities are recommended to allow development of a definitive risk assessment for parasites in land-applied sludge:

For Helminths:

- Standard quantitative methods for examining helminths in sludge and soil samples;
- Data on transport in water, soil and aerosols;
- Die-off rates in water, soil and aerosols;
- The relationship of those decay rates to environmental conditions, previous sludge treatment, method of sludge application and various effects of crop cover.

For Protozoa:

- Quantitative methods for examining protozoa in sludge and soil samples; and
- Quantitative data on occurrence and survivability of protozoa in treated sludge.

If results indicate that protozoa survive in sludge, the following additional research needs to become a priority:

- Data on transport in water, soil and aerosols;
- Die-off rates in water, soil and aerosols;
- The relationship of hose decay rates to environmental conditions, previous sludge treatment, method of sludge application and various effects of crop cover.

☆U.S. GOVERNMENT PRINTING OFFICE: 1991 - 548-028/40016

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

The complete report, entitled "Preliminary Risk Assessment for Parasites in Municipal Sewage Sludge Applied to Land," (Order No. PB91-182352/AS; Cost: $23.00, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Environmental Criteria and Assessment Office
U.S. Environmental Protection Agency
Cincinnati, OH 45268

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati, OH 45268

BULK RATE
POSTAGE & FEES PAID
EPA PERMIT NO. G-35

Official Business
Penalty for Private Use $300

EPA/600/S6-91/001