Sources of Pathogenic Microorganisms and Their Fate during Land Application of Wastes

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ABSTRACT

The hazards associated with pathogens in land-applied animal and human wastes have long been recognized. Management of these risks requires an understanding of sources, concentrations, and removal by processes that may be used to treat the wastes; survival in the environment; and exposure to sensitive populations. The major sources are animal feeding operations, municipal wastewater treatment plant effluents, biosolids, and on-site treatment systems. More than 150 known enteric pathogens may be present in the untreated wastes, and one new enteric pathogen has been discovered every year over the past decade. There has been increasing demand that risks associated with the land treatment and application be better defined. For risks to be quantified, more data are needed on the concentrations of pathogens in wastes, the effectiveness of treatment processes, standardization of detection methodology, and better quantification of exposure.

The transmission of pathogens by land application of untreated animal and human feces has been known for more than 100 years. In the late 19th and early 20th centuries, limits were placed on the land application of human feces and untreated wastes from major cities in the developed world. With advances in wastewater treatment and waste solids treatment and advances in our knowledge about the fate of pathogens in the environment, it became feasible to safely recycle these wastes through land application. Today, the major sources of human and animal pathogens in the environment originate from animal feeding operations, decentralized wastewater treatment systems (e.g., septic tanks), wastewater treatment effluents, and treated sewage sludges (biosolids). The goal of this review is to identify (i) the types of wastes applied to land in which pathogens may be present, (ii) current concerns with the risks of these practices, and (iii) future research needs. The intent is not to provide a detailed review of pathogen detection methods, pathogen concentrations, and pathogen fate; such detailed reviews are available elsewhere (Hutchison et al., 2004; Santamaria and Toranzos, 2003; Dumontet et al., 2001; Cole et al., 1999).

ANIMAL FEEDING OPERATIONS

In the United States, there are 238 000 animal feeding operations (AFOs) producing 317 million Mg of manure annually, which includes the liquid and solids discharged from the animals along with bedding materials (USEPA, 2001). This figure does not include the manure from grazing animals. Animal feeding operations generate approximately 100 times as much manure as municipal wastewater treatment plants produce sewage sludge in this country.

More than 150 microbial pathogens have been identified from all animal species that can be transmitted to humans by various routes (USDA, 1992; USEPA, 1998). Pathogens can be transmitted from animals to humans when manure is used as a fertilizer for food crops eaten raw and by storm water runoff from manured surface-to-surface waters or by its percolation to ground water. Table 1 shows the sources of common zoonotic diseases on farms (Cole et al., 1999). Surveys of waterborne disease outbreaks compiled by the Center for Disease Control and Prevention from 1986 to 1998 show that for all those instances where the microbial agent could be identified, the causative agent most likely originated from a farm animal source (Centers for Disease Control and Prevention, 1998). These organisms are *Campylobacter* spp., *Salmonella* spp. (nontyphoid), *Listeria monocytogenes*, *E. coli* O157:H7, *Cryptosporidium parvum*, and *Giardia lamblia*. All of these microbial agents are endemic in many cattle herds and poultry flocks.

Livestock held in confined animal feeding operations (CAFOs) serve as an important reservoir for significant human pathogens (zoonotic). Table 2 identifies cases where serious disease outbreaks have occurred due to contact with pathogens from a manure source (Smith and Perdek, 2003).

Properly treated manure is an effective and safe fertilizer, but untreated or improperly treated manure may contain pathogens that can contaminate fresh produce in the field or nearby surface waters and water supplies (Cole et al., 1999). Manure should be composted to effectively eliminate pathogens and applied appropriately to minimize the possibility of pathogen survival and subsequent crop contamination. An indication of the level of concern that the World Health Organization, USEPA, and the State of California place on the issue of proper application of recyclable materials to land is shown in Table 3, which presents microbiological quality guidelines and standards for the application of wastewaters to land.

In 2001 the USEPA and USDA held an expert meeting, "Emerging Infectious Disease Agents and Issues Associated with Animal Manures, Biosolids and Similar Byproducts" (Smith et al., 2004). Several issues and research needs were identified at the workshop and in related literature. New organisms of concern were identified including the bacteria *E. coli* O157:H7, *Listeria*, and *Helicobacter*; the viruses poliovirus, coxsackie-

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virus, echovirus, hepatitis A, rotavirus, and Norwalk agents; and the parasites *Cryptosporidium*, *Cyclospora*, *Toxoplasma*, *Microsporidia*, and *Giardia*. The microbiological methods for *Salmonella* spp., enteric viruses, and helminth ova still require standardization and validation. In the past it has been felt that enteric viruses were largely species specific; however, recent studies indicate that hepatitis E virus can be transmitted to man from swine (Yazaki et al., 2003; Worm et al., 2002). Work is needed to better document the presence of pathogens and other organisms in manure and their fate through the various treatment regimes, including survival in or on the soil or on crops after application of the treated wastes. Field validation of treatment processes (including data to directly relate process controls to initial and final pathogen and indicator densities) is needed. Studies should include the presence, movement, and microbial content of aerosols during land application. Research needs identified for manure include completing an infectious disease incidents database; identifying applicable treatment technologies for reducing pathogens (and possibly vector attractiveness) from experiences with agricultural wastes and industrial and municipal wastes (for example, anaerobic digestion, aerobic digestion, lime treatment, composting); developing information regarding the degree to which food or water-borne illness pathogens can survive in manure-treated soils or migrate onto harvestable plant parts; and preparing a guidance manual for meeting requirements of new CAFO regulations. Processes with the potential for reducing the pathogen content of animal wastes are listed in Table 4.

DECENTRALIZED WASTEWATER TREATMENT SYSTEMS

Decentralized (on-site wastewater treatment systems) systems collect, treat, and release (theoretically) to the land about 15 billion liters (4 billion gallons) of treated effluent per day from an estimated 26 million homes, businesses, and recreational facilities nationwide (United States Census Bureau, 1999). Approximately 23% of the estimated 115 million occupied homes in the United States are served by on-site systems (United States Census Bureau, 1999). Treatment traditionally has involved clarification in an underground septic tank and discharge to a soil sorption system. Newer, alternative systems may employ a variety of treatment processes including aeration, filtration, clarification, disinfection, and discharge to either subsurface soils or surface waterways.

Table 1. Sources of common zoonotic diseases transmitted by farm animals (Cole et al., 1999).

Infectious agent	Most common animal source
Salmonella spp.	cattle, chickens, swine, other species
Pathogenic *Escherichia coli*	cattle
Yersinia enterocolitica	pigs
Leptospira spp.	cattle, pigs
Campylobacter spp.	cattle
Brucella spp.	chickens
Erysipelothrix rhusiopathiae	cattle, pigs
Listeria monocytogenes	ruminants (include cattle and deer)
Cryptosporidium parvum	cattle
Giardia lamblia	cattle

Poorly treated wastewater from on-site systems can contain parasites, bacteria, and viruses. Pathogens, too, can be transported for significant distances in ground water or surface waters (Keswick and Gerba, 1980). State and tribal agencies report that on-site septic systems currently constitute the third most common source of ground water contamination and that these systems have failed because of inappropriate siting or design or inadequate long-term maintenance (USEPA, 1996a). In the 1996 Clean Water Needs Survey (USEPA, 1996b), states and tribes also identified more than 500 communities with failed septic systems that caused public health problems. The discharge of partially treated sewage from malfunctioning on-site systems was identified as a principal or contributing source of degradation in 32% of all harvest-limited shellfish growing areas. On-site wastewater treatment systems contribute to contamination of drinking water sources. The USEPA estimates that 168 000 viral illnesses and 34 000 bacterial illnesses occur each year as a result of consumption of drinking water from systems that rely on improperly treated ground water (USEPA, 1996b). Recent research has also demonstrated that a relationship exists between septic tank density and illness in children (Borchardt et al., 2003).

Septic tanks will undoubtedly continue to play a role in waste treatment in the future. However, specific data on the performance of technologies for pathogen removal are seldom available. Thus, better information on pathogen removal by these systems is needed so the potential for pathogen contamination of ground water can be reduced. The potential for ground water contami-

Table 2. Examples of manure-related human outbreaks (Smith and Perdek, 2003).

Location	Year	Pathogen	Impact	Suspected source
Walkerton, ON, Canada	2000	*E. coli* O157:H7 and *Campylobacter* spp.	6 deaths, 2300 cases	runoff from farm fields entering town's water supply
Washington County, NY	1999	*E. coli* O157:H7 and *Campylobacter* spp.	2 deaths, 116 cases	runoff at fairgrounds
Carrollton, GA	1989	*Cryptosporidium parvum*	13 000 cases	manure runoff
Swindon and Oxfordshire, UK	1989	*Cryptosporidium parvum*	516 excess cases	runoff from farm fields
Bradford, UK	1994	*Cryptosporidium parvum*	125 cases	storm runoff from farm fields
Milwaukee, WI	1993	*Cryptosporidium parvum*	400 000 cases, 87 deaths	animal manure and/or human excrement
Maine and others	1993	*E. coli* O157:H7	several illnesses	animal manure spread in apple orchard
Sakai City, Japan	1995	*E. coli* O157:H7	12 680 cases, 425 hospitalized, 3 deaths	animal manure used in fields growing alfalfa sprouts
Cabool, MO	1990	*E. coli* O157:H7	243 cases, 4 deaths	water line breaks in farm community

nation is often a site-specific problem; that is, it depends on the type of soil and depth to ground water (Keswick and Gerba, 1980). More information on soil characteristics that control pathogen transport, transport of viruses through the unsaturated zone, and predictive models on viral survival for some of the newly recognized enteric viruses is needed (Chu et al., 2003). This information will aid the development of a more unified guidance for the state and local regulatory authorities that are responsible for primary oversight in the United States.

WASTEWATER TREATMENT PLANT EFFLUENTS AND SEWAGE SLUDGE

Today there are more than 16 000 wastewater treatment plants in the United States treating approximately 150 billion liters of wastewater per day (USEPA, 1997). Pathogens present in sewage and sludge are shown in Table 5 together with their associated disease or symptoms. The list of pathogens is similar to those of concern in animal wastes except for the enteric viruses, for which humans are the only or primary source. During the course of typical wastewater treatment, the microorganisms in sewage are reduced in number, becoming concentrated in the sewage sludge. However, some pathogens are still present in the effluent, which can contaminate recreational waters and drinking water supplies (Rose et al., 1996). Additionally, effluent is used in many water-short areas of the United States, with or without disinfection, for crop and landscape irrigation. Wastewater is also applied to the soil to recharge ground water and as a method of further treatment (National Research Council, 1994). An expert review sponsored by the World Health Organization of all epidemiological evidence resulted in the recommendation that treated wastewater contain less than one viable intestinal nematode egg per liter (on an arithmetic mean basis) for restricted or nonrestricted irrigation, and <1000 fecal coliform bacteria per 100 mL (on a geometric mean basis) for unrestricted irrigation (Blumenthal et al., 2000). Unfortunately, none of these standards were developed using a quantitative microbial risk-based assessment. The World Health Organization did not consider risks from enteric viruses in wastewater significant in developing countries because of other potential sources. In reality, risks of serious illness and mortality are far greater from enteric viruses than from helminths (Gerba and Rose, 2003). The greater concentration of pathogens relative to indicators (e.g., fecal coliforms) in developing countries vs. developed countries was also not considered. The concentration of pathogens in wastewater and sewage sludge is directly related to the incidence of enteric infections within a community. This is an important consideration because, today, significant amounts of produce grown in developing countries are exported to the developed world. Failure to recognize the importance of different standards for the developing world vs. the developed world has already resulted in outbreaks of hepatitis A virus, *Cyclospora*, and *Cryptosporidium* associated with produce imported into the United States in recent

Table 3. Microbiological quality guidelines and standards for application of wastes to land.

Reference	Reuse conditions	Helminths	Fecal coliforms	*Salmonella* spp.	Enteric viruses
World Health Organization (1989)	crops likely to be eaten raw	≤1/L	≤1000/100 mL	NR†	NR
World Health Organization (1989)	pasture and fodder and industrial crops	≤1/L	NR	NR	NR
Blumenthal et al. (2000)	crops likely to be eaten raw	≤0.1/L	≤1000/100 mL	NR	NR
Blumenthal et al. (2000)	spray irrigation of pasture and fodder and industrial crops	≤1/L	100 000/100 mL	NR	NR
USEPA (1993)	unrestricted irrigation of municipal Class A sewage sludge	<1 helminth ova/4 g total solids (dry weight)	<1000/g total solids (dry weight)	<3 to 4 g total solids (dry weight)	<1 PFU/4 g total solids (dry weight)
USEPA (1993)	application of municipal Class B sewage sludge	NR	<2 × 10^6/g total solids (dry weight)	NR	NR
State of North Carolina (1996)	land discharge of reclaimed domestic wastewater	NR	14/100 mL	NR	NR
State of California (1978)	irrigation of food crops, high exposure landscapes	NR	<2.2/100 mL‡	NR	NR
State of California (1978)	irrigation of dairy pastures, low-exposure landscapes	NR	<23/100 mL‡	NR	NR

† NR, no standard recommended.
‡ Standard for fecal or total coliforms.

Table 4. Processes to significantly reduce pathogens (PSRPs).†

Process	Description
Facultative lagoons and storage	Animal waste and manure is treated or stored in a lagoon system at a temperature of ≤5°C (≤34°F) for a period of at least 6 mo or at a temperature of >5°C (34°F) for a period of at least 4 mo. Because all wastes must be in a lagoon for the specified period, two lagoons probably will be needed so that while one is filling, the other can be aging. This avoids short-circuiting.
Air-drying	Animal waste and manure is dried on sand beds or on paved or unpaved basins. The animal waste and manure dries for a minimum of 3 mo. During two of the three months, the ambient average daily temperature is above 0°C (32°F).
Composting	Using either the within-vessel, static aerated pile, or windrow composting methods, the temperature of the animal waste and manure is raised to 40°C (104°F) or higher and remains at 40°C (104°F) or higher for 5 d. For 4 h during the 5-d period, the temperature in the compost pile exceeds 55°C (131°F).
Anaerobic digestion	Animal waste and manure is treated in the absence of air for a specific mean cell residence time (i.e., solids retention time) at a specific temperature. Values for the mean cell residence time and temperature shall be between 15 d at 35°C to 55°C (131°F) and 60 d at 20°C (68°F).
Aerobic digestion	Animal waste and manure is agitated with air or oxygen to maintain aerobic conditions for a specific mean cell residence time (i.e., solids retention time) at a specific temperature. Values for the mean cell residence time and temperature shall be between 40 d at 20°C (68°F) and 60 d at 15°C (59°F).
Lime stabilization	Sufficient lime is added to the animal waste and manure to raise the pH of the animal wastes and manure to 12 for ≥2 h of contact.

† More detailed information on these technologies appears in USEPA (1999).

years (Ho et al., 2002; Centers for Disease Control and Prevention, 2003).

Currently there are no USEPA microbial standards for reclaimed wastewater. Each state is responsible for the development of treatment guidelines and standards (Crook, 1998). The USEPA is currently revising and updating the *Process Design Manual for Land Treatment of Municipal Wastewater* (1981) and working with the United States Agency for International Development and others to revise the manual, *Guidelines for Water Reuse* (1992). The quality of reclaimed water must be appropriate to its intended use. Irrigation of public-access lands or vegetables to be consumed without processing requires a higher level of wastewater treatment before reuse than is needed for lower degrees of public exposure, such as pasture irrigation. Secondary treatment, or even tertiary treatment followed by disinfection, may be necessary. Most standards for the reuse of wastewater do not involve the testing for pathogenic microorganisms. Until recently, Arizona required testing for viruses and *Giardia* in reclaimed wastewater (Crook, 1998). Recent studies have shown that viable *Cryptosporidium* oocysts are present in tertiary treated reclaimed wastewater (Quintero-Betancourt et al., 2003). This has led to a call for standards for *Cryptosporidium* reclaimed waters (York and Walker-Coleman, 2000). The increased use of ultraviolet light may lessen this concern because *Giardia* and *Cryptosporidium* are easily inactivated by this disinfectant (Qian et al., 2004); however, viruses are very resistant to ultraviolet light (Gerba et al., 2002b). In the future, dual disinfection systems may be necessary to deal with the array of pathogens present in reclaimed wastewaters.

Approximately 5 million dry Mg of sewage sludge per year is generated in the United States, of which 60% is land-applied (National Research Council, 2002). In some states, such as Arizona, 95% of the generated biosolids is applied to agricultural land. Land-applied sewage sludges (biosolids) should be highly processed to minimize pathogens and vector attraction (USEPA, 1993). If the treated sludge (biosolids) is used with crops that may be eaten raw, comes into contact with the public, or is marketed, the sludge must be treated in such a way that pathogenic microorganisms are reduced below detection limits (referred to as Class A biosolids). Pathogens of concern, and those also used as indicators

Table 5. Principal pathogens of concern in municipal wastewater and sewage sludge.

Pathogen of concern	Disease or symptoms for organism
	Bacteria
Salmonella spp.	salmonellosis (food poisoning), typhoid
Shigella spp.	bacillary dysentery
Yersinia spp.	acute gastroenteritis (diarrhea, abdominal pain)
Vibrio cholerae	cholera
Campylobacter jejuni	gastroenteritis
Escherichia coli (pathogenic strains)	gastroenteritis
	Viruses
Poliovirus	poliomyelitis
Coxsackievirus	meningitis, pneumonia, hepatitis, fever
Echovirus	meningitis, paralysis, encephalitis, fever
Hepatitis A virus	infectious hepatitis
Rotavirus	acute gastroenteritis with severe diarrhea
Human caliciviruses	epidemic gastroenteritis with severe diarrhea
Reovirus	respiratory infections, gastroenteritis
Hepatitis E virus	hepatitis
TT hepatitis	hepatitis
Astroviruses	gastroenteritis
Adenoviruses	respiratory tract infections, gastroenteritis
	Protozoa
Cryptosporidium	gastroenteritis, cryptosporidiosis
Entamoeba histolytica	acute enteritis
Giardia lamblia	giardiasis (diarrhea and abdominal cramps)
Balantidium coli	diarrhea, dysentery
Toxoplasma gondii	toxoplasmosis
	Helminth worms
Ascaris lumbricoides	digestive disturbances, abdominal pain
Ascaris suum	can have symptoms including coughing, chest pain
Trichuris trichiura	abdominal pain, diarrhea, anemia, weight loss
Toxocara canis	fever, abdominal discomfort, muscle aches
Taenia sasginata	nervousness, insomnia, anorexia
Taenia solium	nervousness, insomnia, anorexia
Necator americanus	hookworm disease
Hymenolepis nana	taeniasis

of all possible pathogens in this instance, are *Salmonella* spp., enteroviruses, and *Ascaris* spp. Processes (Table 4) employed for achieving this level of treatment usually involve holding the sludge at a temperature between 50 and 85°C for varying periods of time (Straub et al., 1993). Other biosolids used in agriculture, but not used on crops consumed raw, must receive a minimal level of treatment (anaerobic digestion, aerobic digestion, or lime treatment) to significantly reduce the level of pathogens (referred to as Class B biosolids). The fecal coliform concentration can be reduced by two log (99%), and the *Salmonella* spp. concentrations are estimated to be reduced by one log (Straub et al., 1993). However, some pathogenic organisms may still be present, requiring regulation to limit exposure. These measures include restricting public access to the land application site, controlling animal grazing, and preventing crop harvesting for various periods depending on the crop and method of biosolids application (USEPA, 1993).

This guidance is based on what we know about the survival times of pathogens on soil and plants (Table 6), and provided the framework or setting for 40 CFR 503, *Standards for the Use or Disposal of Sewage Sludge* (USEPA, 1993). The standards require sludge to be treated to such a level that pathogenic microorganisms are reduced to below the detection limit before land-applying. Alternatively, the sludge can be treated to a lesser degree, but adequate time must be allowed for the sludge to remain in, or on, the land for natural attenuation to further reduce the pathogens before use of the land for cropping or public access.

Both approaches (Class A alone and Class B with access and cropping restrictions) are expected to achieve the same level of risk reduction. Because vectors can also spread infectious diseases, vector attraction control is necessary. Control can be accomplished with biological processes to remove the vectors' food (biodegradable organics) with chemical treatment (e.g., lime addition) or physical processes (e.g., drying or providing a physical barrier).

Land application of biosolids often involves the potential generation of aerosols (Brooks et al., 2004). Methods of application include the use of slingers, manure spreaders, spray tankers, and spray irrigation. While an earlier studied failed to show significant levels of enteric microorganisms during the spray application of biosolids (Sorber et al., 1984), recent concern has focused on the potential for low-level transmission of pathogens by this route (Dowd et al., 2000; Lewis and Gattie, 2002). Results of a recent survey of indicators and pathogens in aerosols from a variety of application methods across the United States suggest that these risks to the general population with current guidelines under the 503 regulations are not significant (Brooks et al., 2004).

Table 6. Survival times of pathogens on soil and plants.

	Soil		Plants	
Pathogen	**Absolute maximum**	**Common maximum**	**Absolute maximum**	**Common maximum**
Bacteria	**1 yr**	**2 mo**	**6 mo**	**1 mo**
Viruses	**6 mo**	**3 mo**	**2 mo**	**1 mo**
Protozoa	**10 d**	**2 d**	**5 d**	**2 d**
Helminths	**7 yr**	**2 yr**	**5 mo**	**1 mo**

The National Research Council recently released a report, *Biosolids Applied to Land: Advancing Standards and Practices* (National Research Council, 2002). The Council's charge was to conduct an independent evaluation of the technical methods and approaches used to establish the chemical and pathogen standards for biosolids, focusing specifically on human health protection rather than ecological or agricultural issues. The Council noted that additional scientific work is needed to reduce persistent uncertainty about the potential for adverse human health effects from exposure to biosolids. They went on to say that, "To assure the public and to protect public health, there is a critical need to update the scientific basis of the rule to (1) ensure that the chemical and pathogen standards are supported by current scientific data and risk-assessment methods, (2) demonstrate effective enforcement of the Part 503 rule, and (3) validate the effectiveness of biosolids management practices."

THE ROLE OF RISK ASSESSMENT

Quantitative microbial risk assessment (QMRA) has evolved rapidly over the last decade. The USEPA has used QMRA to develop treatment standards for waterborne enteric viral and protozoan pathogens under the Surface Treatment Rule of the Safe Drinking Water Act (Regli et al., 1991). The approach has also been adopted by the World Health Organization in the development of guidelines and standards for the management of water-related diseases (Fewtrell and Bartram, 2001). To address the risks posed by contacting land-applied wastes, the organisms of concern and their infectivity need to be identified. The infectivity of an organism is the relationship between the numbers ingested or inhaled or that may come into contact with the skin and the probability of infection (Haas et al., 1999). Such information is available for many of the enteric pathogens of concern from human feeding or inhalation studies (Haas et al., 1999; Crabtree et al., 1997). Analysis of existing dose–response data suggests that that there is no "minimal infectious dose" for enteric pathogens (Haas et al., 1999). The term "minimum infectious dose" is often used in the literature, but the number is actually the infectious dose fifty (ID_{50}), or the number of organisms that results in 50% of the exposed individuals becoming infected. The infectivity of enteric viruses is much greater than enteric bacteria. Thus, the probability of becoming infected with ingestion of one virus is much greater than the probability of becoming infected with one bacterium. Currently, the human rotavirus is the most infectious enteric pathogen known with 10 to 15% of individuals ingesting the virus becoming infected (Gerba et al., 1996b). Infection does not lead necessarily to illness. In general, about half of the individuals infected with an enteric pathogen become ill (Rose et al., 1995; Haas et al., 1999). Mortality from enteric pathogens is generally less than 1%; however, the risk is much greater for infants, young children, the elderly, and immunocompromised individuals (Gerba et al., 1996a).

Eisenberg et al. (2004) recently described a risk-based model of waterborne pathogens exposures, modified to account for properties unique to biosolids. The goal of such models is the prediction of infection from pathogens in the biosolids under different exposure scenarios. Gerba et al. (2002a) used a risk assessment approach and data for an anaerobically digested sludge to estimate risks of pathogen infection from exposure to the land-applied Class B material. The greatest amount of uncertainty in such quantitative microbial risk assessments is from the estimation of exposure (Haas et al., 1999). Risks from land application of wastes can be better quantified with more information on actual ingestion or inhalation rates, and duration of exposure during these activities. Data on the concentrations of pathogens in the different types of wastes after treatment are also needed. Since the 40 CFR 503 (USEPA, 1993) regulations have been in effect, treatment has become more standardized, resulting in better performance. Thus, the concentration of pathogens in treated biosolids may be less than 12 to 15 yr ago when the last surveys where conducted (Straub et al., 1993). Methods for the detection of pathogens need to be standardized, and methods should be developed for some of the newly recognized pathogens or pathogens for which data are limited in wastes (National Research Council, 2002).

FUTURE CONCERNS WITH PATHOGENS IN THE ENVIRONMENT

Concerns about the potential health risks from pathogens associated with the land application of wastes will continue into the foreseeable future. Over the last decade, at least one new pathogen per year that could be transmitted through the environment has been recognized as a new public health threat (World Health Organization, 2003). This is due to a number of factors including (i) changes in the way we produce our food supply; (ii) the international transportation of food and people on a global scale; (iii) advances in molecular biology, which allow us to identify new pathogens and trace their source; (iv) the evolution of pathogens; (v) changing demographics of the population (older and more immune-compromised individuals who have a greater risk of serious illness are increasing in number); and (vi) application of microbial risk assessment to quantify risks from environmentally transmitted pathogens.

The application of microbial risk assessment demands better data on the survival and transport of specific pathogens during the land application of wastes. Information is needed on the effects of treatment processes, transport, and survival of emerging and newly recognized pathogens; the concentration of pathogens in wastes; and the potential for the regrowth of bacterial pathogens after treatment. Only with this information can we be assured that we are using the best management practices to protect our water and food supplies.

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