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Features

INVESTIGATION OF ALLEGED HEALTH INCIDENTS ASSOCIATED WITH LAND APPLICATION OF SEWAGE SLUDGES

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ABSTRACT

The majority of U.S. sewage sludges are disposed by application to land for use as a soil amendment. Class B sludges, containing a complex mix of chemical and biological contaminants, comprise the majority. Residents near land application sites report illness. Symptoms of more than 328 people involved in 39 incidents in 15 states are described. Investigation and tracking of the incidents by agencies is poor. Only one of 10 EPA regions provided substantial information on the incidents in their region. Investigations, when conducted, focused on compliance with regulations. No substantial health-related investigations were conducted by federal, state, or local officials. A system for tracking and investigation is needed. Analysis of the limited data suggests that surface-applied Class B sludges present the greatest risk and should be eliminated. However, even under less risky application scenarios, the potential for off-site movement of chemicals, pathogens, and biological agents suggests that their use should be eliminated.

OBJECTIVE

We conducted investigations into the numerous incidents in which residents living near sites where sewage sludges are land applied have reported illness. We compiled information about the health complaints. In order to find out what tracking and investigations had been carried out by the responsible authorities, we sought any information that federal and state agencies had about these incidents. Information regarding the sludge management practices associated with the

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incidents could be used to determine whether there are practices posing particularly high risk.

WHAT'S IN A NAME

Sewage sludges are a "viscous, semisolid mixture of bacteria and virus-laden organic matter, toxic metals, synthetic organic chemicals, and settled solids removed from domestic and industrial wastewater at sewage treatment plants" [1]. Wastewater from three-quarters of American households [2] flows into the 16,000 municipal wastewater treatment plants (WWTPs) in the United States [3]. The flow into WWTPs includes not only domestic sewage, but many other wastes. Wastewater from businesses and industries enters the sewer system, as does street runoff in many communities. Leachates from landfills, Superfund sites, and other industrial clean-up projects are often directed to WWTPs.

The role of WWTPs is to treat the influent wastewater to produce a water effluent that meets standards established under the Clean Water Act (CWA). Treatment processes include settling to remove solids (primary treatment) which is generally followed by a biological process that reduces the organic matter content and hence the oxygen-depleting potential of the wastewater (secondary treatment). Further treatment (tertiary treatment) is occasionally required to reduce a particular pollutant such as phosphorus. Sewage sludges are the byproducts of these processes. They are what remains after the treatment processes have cleaned the water to acceptable levels.

As the degree of treatment of wastewater has increased over the years, so has the amount of sludge. In 1998, the United States generated an estimated 6.9 million tons (dry weight) of sewage sludges and that is projected to increase to 8.2 million tons by 2010 [4]. For many years sewage sludges in coastal communities were dumped in the ocean. That practice became illegal in the early 1990s. Today, primary options for sludge disposal include landfilling, incineration and land application (use as a soil amendment for crops or land reclamation). Generally the least-cost option, land application has become the most prevalent disposal method in the United States [5].

Sewage sludges contain nutrients (nitrogen and phosphorus) and organic matter. But they also contain pathogens and contaminants. Before land application, sludges must be treated to reduce pathogens. They are not, however, treated to reduce other contaminants. Sewage sludges that meet standards for land application have been sanitized by the industry and EPA by referring to them as "biosolids" [6].

THE REGULATORY FRAMEWORK

The disposition of sewage sludges is regulated under the federal Clean Water Act. Rules promulgated in 1993 regulate land application (CFR40 Part 503,

hereinafter "Part 503"). Standards based on human health and agricultural productivity are set for nine elements (arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc) and technology-based standards are set for pathogens and vector-attraction reduction. Sludges that are treated to reduce but not eliminate pathogens are called Class B. Those that are treated with a goal of pathogen elimination are called Class A. A few site restrictions are established for Class B sludges under federal rules. Class A sludges that meet the EPA standards for nine elements and vector-attraction reduction may be distributed without restriction and without labeling as to their origin or pollutant content.

These federal standards provide minimum standards and states may adopt stricter rules. Municipalities also may regulate land application and the scope of municipal authority varies from state to state [7].

The Part 503 rules are "self-implementing," which means that EPA does not review and permit land application, but rather requires the regulated entity to follow the rules and keep documentation of compliance. Some periodic testing of sludges is required for nitrogen, nine elements, and in some cases indicator pathogens. The required frequency of testing varies from once a month to once a year depending on the size of the WWTP.

Standards for the land application of sewage sludges vary from country to country in Europe, but are generally far more stringent in northern Europe than in the United States [8]. And unlike in the United States, a number of organic chemicals in European sludges are regulated [9]. The differences are due to different approaches to environmental protection and risk assessment.

The United States establishes standards based on a risk assessment approach, where standards may vary substantially depending on target organisms and the numerous assumptions made in calculating risks [10]. Rather than risk assessment, a number of European countries utilize a precautionary approach, setting standards based on non-degradation of soils. They also limit the frequency and quantity of land application of sludges.

REPORTS OF ILLNESS

Many of the risks to people, agriculture, and the environment posed by land application of sewage sludges are chronic and may only be evident after long-term exposure. Such effects are difficult to measure and document. In the last several years, however, illnesses have been reported by residents living near sludge land application sites in a variety of locations. Anecdotal evidence of illness among neighbors to Class B sludge land application sites is mounting [11]. New sites at which people are complaining of illness are being reported approximately monthly. Allegations range from headaches and respiratory problems to death.

Table 1 describes 39 incidents in 15 states affecting more than 328 people. These are complaints the authors were aware of as of July, 2002. The sources of information in Tables 1 and 2 are from newspaper accounts, reports from state agencies, or from the affected individuals. It has not been confirmed by scientific investigation that these persons became ill due to land application of sludges. Estimates of the number of individuals affected (Table 1) are low because numerous accounts indicated that many people were ill. When specific numbers were not provided, such incidents were counted as the minimum number possible (two individuals). We attempted to eliminate incidents that may have been associated with practices other than land application of sludges (composting facilities, for example), but were unable to confirm that land application of sewage sludge took place at all the locations in Table 1.

There is a set of symptoms that are common among neighbors to the sludge land application sites we investigated. Most common are respiratory and gastro-intestinal symptoms, skin disorders and headaches. Other symptoms frequently reported by numerous people include nosebleeds, burning eyes, throat or nose, flu-like symptoms, and fatigue (Table 1). Among those affected, these symptoms are known as "sludge syndrome." Such symptoms might be caused by exposure to irritating chemicals such as ammonia and organic amines, endotoxins, and pathogens.

Medical providers are unfamiliar with the sludge exposure and are thus unlikely to consider an association between a patient's symptoms and sludge. In addition, people living near sludge application sites know little or nothing about the material and are often economically disadvantaged, with few resources to devote to investigation or medical care. For example, it was five years after a child in Pennsylvania, Tony Behun, died of an infection after riding his motorbike through Class B sludge that his parents learned about sewage sludges and came to believe that his death was due to the sludge exposure. The increasing number of reported incidents may reflect the growing awareness of the issue in communities across the country and in Canada.

POTENTIAL EXPOSURE

There are many gaps in the scientific basis of the land application rules [12]. Two potential routes of exposure of residents to chemicals, endotoxins (microbial byproducts), and pathogens are of particular concern and have not been considered under current rules. Airborne transport of particles blown from application sites onto nearby properties appears to present a potentially significant source of exposure [13]. A modeling study conducted in the arid southwest indicated that risks to persons living within 100 meters of the application site exposed for 8 hours under average wind conditions would be predicted to have a 94 percent chance of viral infection [14]. Risks varied with distance from the site, duration of exposure and wind velocity (Table 3). It is likely that in

more humid, cooler areas risks would be even greater due to higher rates of pathogen survival.

Water runoff from land application sites presents another route for off-site exposure to the chemicals and pathogens in the land-applied sludge. Federal rules do not require any setback from homes or neighboring property. They also allow sludges to be applied to the surface of the soil without incorporation. Surface application would likely increase the potential for off-site transport via runoff.

Complicating the picture is that sludges contain a mixture of pathogens and chemicals. There is some evidence that the simultaneous exposure to some chemical irritants and endotoxins in sludges may increase the risk of infection from exposure to pathogens [15]. Irritation of mucous membranes and other tissues by airborne chemicals and endotoxins emitted from sludges may predispose people to infection by providing a port of entry for pathogens.

FEDERAL AND STATE AGENCY RESPONSE

In the spring of 2002, we conducted research into the alleged health incidents listed in Table 1. Making use of anecdotal reports [16], we attempted to compile information about each incident. Using e-mail, we contacted the biosolids coordinator in each of the 10 EPA regional offices and also the biosolids coordinators in 14 states in which an incident was reported [17]. We requested the opportunity to talk with them or to receive reports regarding the incidents, any investigation of the health complaints, and information they had about the type of sludge applied and management practices at the site.

Table 4 shows the responses received from EPA more than two months after the inquiry. Only one of the 10 regions provided detailed responses. Four did not reply. Two asked that we file Freedom of Information (FOI) requests. Three provided no information but directed us to state agencies [18].

EPA resources devoted to the biosolids program are inadequate [19] which may partly explain the results shown in Table 4. The U.S. EPA Office of the Inspector General investigated the EPA biosolids program in 2000 and again in 2002. In 2000, it found that the staff level for the biosolids program was inadequate to ensure compliance with land application requirements [20]. In 2002, it found that staffing levels had in fact declined in the intervening two years [21]. More EPA resources are needed [22].

In addition to contacting regional EPA offices, state biosolids coordinators in the 14 states identified in Table 5 were contacted by e-mail in the spring of 2002. Table 5 shows the responses received. Nine provided information, five did not respond, and three were unaware of the incident in their state.

At the federal level there is no national tracking system for complaints related to sewage sludges [23]. Citizens are often unsure of how and to whom they should report complaints about land application. In talking with complainants, some of whom had a record of having contacted state or federal biosolids staff, we found

Table 1. Alleged Health Incidents Associated with Land Application of Sewage Sludges

Location of incident	State	Number affected	Symptoms																					Miscellaneous complaints
			A	B	C	D	E	F	G	H	I	L	M	N	P	R	S	T	V	W	X	Y	Z	
Grand Bay	AL	>15	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	*e. coli* poisoning, muscle bone-joint aches, thyroid problems, growths on eyes, mouth, and tongue sores, sore throat, bronchitis, tonsillitis, pneumonia
Corona (Riverside County)*	CA	37 +				X	X		X	X			X	X	X	X			X			X		
Menifee (Riverside County)	CA	100 +	X			X			X	X	X		X	X	X	X	X	X	X				X	Dehydration, seizures, ear infections, pneumonococcal and staphylococcus infections; mouth, nose, and throat blisters; blisters on fingers and toes
Riverside County (general)	CA	##	X			X		X	X	X					X	X	X							Blood infections, fungus in lungs, sore throats
Solano County	CA	##														X								
Winchester (Riverside County)	CA	~ 6				X			X	X		X	X	X	X	X	X					X	X	*Helicobacter pylori* bacterial disease, seizures, throat blisters
Desoto County	FL	> 24	X		X	X	X	X	X	X	X		X	X	X	X	X		X		X	X		Bacterial ear infections, heart palpitations, rotavirus, bronchitis, fever, mastoid infection, sinusitis, pneumonia, pleurisy

Laurel Hills (Okaloosa County)*	FL	2																				*Blastocystitis hominis* intestinal parasites
Polk County*	FL	4		X			X	X			X	X		X	X	X						
Sarasota	FL	##	X		X	X		X		X			X						X			Sore throat
Davenport*	IA	##																				Cancer clusters, non-hodgkins lymphoma
Prole*	IA	##	X			X							X		X							
Brandywine	MD	~ 3				X		X		X	X		X					X	X			
Unity*	ME	3					X	X									X			X		Hair loss, nose sores
Sparta*	MO	2							X													Blood contaminants
Canaan*	NH	1																				Numbness of limbs
Greenland	NH	20 +	X	X				X		X	X	X	X		X	X						Death, pleurisy
Manchester	NH	##				X					X		X			X			X			
Elkton*	OH	1 +				X					X				X	X		X	X			
Germantown*	OH	8	X					X	X	X	X		X					X	X			
Warren*	OH	1					X	X	X		X		X									
Waynesville*	OH	2			X		X	X		X	X		X					X				Palpitations

Table 1. (Cont'd.)

Location of incident	State	Number affected	Symptoms																					Miscellaneous complaints
			A	B	C	D	E	F	G	H	I	L	M	N	P	R	S	T	V	W	X	Y	Z	
Xenia*	OH	1 +														X					X			
Lehartsville; Berks County	PA	2																						Boils, severe pain on right side, heart irregularities
Robesonia, Heidelberg Township; Berks County	PA	4				X						X				X								Death, sore throat, viral/staphylococcal pneumonia
Osceola Mills; Rush Township; Centre County	PA	9					X	X	X	X		X	X	X		X			X					Death, dizziness, fever, numbness, sore throats
Point Marion; Diliner	PA	##					X		X	X			X	X		X			X		X	X	X	Chest pains, itchiness, sinus problems
Snoe Shoe & Clarence; Snow Shoe Township; Centre County	PA	1				X				X				X									X	
Upper Mt. Bethel Township*	PA	##																						NA
Ridgetop*	TN	##																						Strokes, lung malformations

Fort Bend County*	TX	4							X			X		X								
Sierra Blanca; Hudspeth County	TX	##	X				X								X							Mouth blisters
Bumpass	VA	4 +	X			X		X	X				X		X							Pruritus
Culpepper	VA	~ 7	X	X	X		X	X	X	X		X	X		X				X		X	
Cumberland	VA	##	X		X	X		X	X	X												
Loundon County	VA	~ 37	X		X	X	X		X		X	X	X	X	X	X		X			X	Pneumonia, cardiomyopathy
Toms Brook	VA	##	X		X	X									X							
Lynden	WA	4								X												*Blastocystitis hominis,* mycoplasma pneumonia, nickel toxicitythyroid problems
Whitewater; Walworth County*	WI	2				X			X				X			X					X	Nose scabs
TOTAL > > > 328																						

Note: * = Not confirmed if land-application of sludge took place. ## = Unknown number of victims (considered 2 (two) victims for counting purposes).

(*See next page for Key to Symptoms*)

Key to Symptoms in Table 1

Symbol	Symptom description	Symbol	Symptom description
A	Allergies, asthma	N	Nausea
B	Birth complications (i.e., premature birth, congenital defects)	P	Nosebleeds
C	Cysts, abscesses	R	Respiratory complications, difficulty breathing
D	Dry heaves/coughing	S	Skin rashes
E	Eye problems (i.e., burning eyes, tearing eyes)	T	Tumors
F	Flu-like symptoms	V	Vomiting
G	Gastrointestinal complications, stomach cramping	W	Weight loss
H	Headaches	X	Burning throat
I	Immunodeficiency problems	Y	Burning nose
L	Lesions	Z	Fatigue
M	Mucous		

numerous examples in which the agencies had no record of the complaints. A system for tracking complaints is clearly needed [24]. Two of the states we contacted and who responded to our inquiry, New Hampshire and Virginia, have established a tracking system for complaints related to sludge application.

Our research failed to find any substantial investigation of alleged health incidents by federal, state, or local officials. A recent report by the National Academy of Sciences also failed to find any documented scientific studies [25]. Meanwhile, the Canadian Infectious Diseases Society (CIDS) called for a moratorium on the spreading of sewage sludges [26]. It based this action on concerns about the potential for pathogens to survive and remain pathogenic and the lack of sufficient data to ensure protection of humans from disease.

Those responsible for regulation of land application of sludges at both the federal and state level are not properly equipped to conduct health-related investigations. When complaints were investigated, agency investigations focused on whether there had been violations of the relevant regulations, such as whether setback requirements were followed [27]. Qualified experts at the federal and state level, such as those at the Center for Disease Control and Prevention or at state health departments, have not thus far been engaged in any scientific investigation of the incidents involving exposure of residents. Local health departments are sometimes involved, but do not generally possess the necessary experience and expertise.

Agency reports regarding these incidents, when available, are often compromised by misunderstandings, lack of data, or a significant time interval between the illness and the investigation. For example, in the Osceola Mills, Pennsylvania case that involved the death of an 11-year-old child who rode his motorbike through sludge at a mine reclamation site, the Pennsylvania Department of Health "did not conduct an investigation into Tony Behun's death" [28]. Any investigation would have been hampered by the fact that several years had elapsed between the death and the possible attribution to contact with sludge. In another example, one of the more thorough local health department reports states that "(S)tudies have consistently shown that once biosolids have been applied and been allowed to dry, pathogens contained in them are not transported by air" [29]. No citation is given. However, the National Academy of Sciences found that the potential for off-site transport of bioaerosols containing pathogens is a potentially important and unevaluated pathway of exposure [30].

The single published investigation of health incidents related to land application of sludges determined that at the 10 sites investigated, coughing, burning throat, burning eyes and headaches were the most common symptoms experienced within an hour of exposure. Difficulty breathing, nausea and vomiting, fatigue and flu-like symptoms were reported within 24 hours of exposure. Infections of the skin and respiratory tract with *Staphylococcus aureus* were prevalent [31]. *Staphylococcus* are a common bacteria found in sludges [32], in the human gut, and in the environment.

Table 2. Sludge Management Practices at Sites of Alleged Health Incidents

Incident**	State	Sludge type	Land use	Spreading process	Stockpiled	Notes
Grand Bay	AL	B	Agriculture	Surface-applied	No	
Riverside County	CA	Many B sources, some failed to meet Class B pathogen reduction requirements, some anaerobically digested, some aerobically digested	Agriculture	Disced in	No Class B Yes Class A and manure	Spread daily Violations of Class B standards for some land-applied sludges
Solano County	CA	B, anaerobically digested	Agriculture	Surface-applied	Yes	
Desoto County	FL	B, lime-stabilized	Agriculture			
Sarasota County	FL	B	Agriculture	Surface-applied liquid; disced in cake	Yes	
Brandywine	MD	B, lime-stabilized sludge	Mine reclamation	Disced in	No	Strong odor Up to 46 drytons/ac applied to 78 acres over 3 months
Greenland	NH	B, lime-stabilized sludge	Agriculture	Top-dressed and chain-harrowed (dragged)	Yes	
Manchester	NH	Class A compost	Compost storage		Yes	Unstable malodorous compost
Lehartsville	PA	B, cake	Agriculture	Surface-applied		

Table 2. (Cont'd.)

Incident**	State	Sludge type	Land use	Spreading process	Stockpiled	Notes
Robesonia	PA	B, lime-stabilized, dewatered cake	Agriculture			300 acres, applied 5x/wk, ~1400dry T/yr violations noted in 1988 and 90 (spread on frozen ground, stock-piled, not incorporated)
Osceola Mills	PA	B, lime-stabilized cake	Mine reclamation			11-yr-old rode motorbike through sludge; 60 dry T/acre
Port Marion	PA	B				
Snowshoe	PA	B, lime-stabilized				City of Philadelphia cited by PA DEP for malodors
Sierra Blanca	TX	B				
Bumpass	VA	B, lime-stabilized, one anaerobically digested		Cake biosolids surface-applied	No	
Culpepper	VA	B, lime-stabilized, one anaerobically digested		Cake biosolids surface-applied	No	
Cumberland	VA	B				
Loundon County	VA	B		Surface-applied		
Tom's Brook	VA	1.5% sludge			No	Mix of food processing wastes and sludge
Lynden	WA	B, aerobically-digested				

Table 3. Predicted Percent Chance of Viral Infection Resulting from Exposure to Land-Applied Sludges (after Dowd et al. [14])

	Distance from sludge source	
Hours exposed	100 m (328 ft.)	500 m (1640 ft.)
Wind speed of 20 m/sec (45 mi/hr)		
1 hr	91%	61%
8 hr	100%	100%
24 hr	100%	100%
Wind speed of 10 m/sec (22 mi/hr)		
1 hr	60%	21%
8 hr	99%	85%
24 hr	100%	100%
Wind speed of 5 m/sec (11 mi/hr)—U.S. average		
1 hr	29%	0.3%
8 hr	94%	22%
24 hr	100%	52%
Wind speed of 2 m/sec (4 mi/hr)		
1 hr	6%	0.02%
8 hr	40%	0.2%
24 hr	78%	0.6%

Compliance with the regulations does not ensure protection of public health. In one of only two incidents that did not involve Class B sludges, composted sewage sludge was stockpiled adjacent to a school, the state biosolids coordinator investigated claims of nausea and vomiting. He found that the compost was still biologically active and undergoing rapid decomposition, resulting in strong odors. He concluded that this stockpiled sludge compost was the cause of the symptoms experienced by some children. He also noted that there were no violations of sludge management rules [33].

There has been no systematic collection of data regarding management practices or sludge characteristics at the sites where health allegations have been made. Table 2 shows the information we were able to gather from our research. Sources of information included site neighbors and federal, state, and local agencies. Most of the incidents are associated with surface application of sludges, which is a legal practice in most localities.

Table 4. Response of USEPA Regional Biosolids Staff to Inquiry Regarding Incidents (as of July 24, 2002)

EPA Region	Responded	Did not respond	Suggested contacting state biosolid coordinators for information	Required Freedom of Information Act letter for further information
Region 1		X		
Region 2				X
Region 3			X	
Region 4				X
Region 5			X	
Region 6		X		
Region 7		X		
Region 8		X		
Region 9	X			
Region 10			X	

OVERSIGHT

It has been noted that EPA resources devoted to the biosolids program are inadequate [34], which may partly explain the results shown in Table 4. The EPA Office of the Inspector General found that "EPA does not have an effective program for ensuring compliance with the land application requirements of Part 503. Accordingly, while EPA promotes land application, EPA cannot assure the public that current land application practices are protective of human health and the environment" [35]. This statement was made in the report published in 2000 based on the EPA staffing level of 18 people in 1998. Staffing levels continued to decline. In 2000, EPA had only 10 staff devoted to regulation and oversight of sludge [36]. EPA has also failed to invest in the research it committed to when the Part 503 rules were promulgated. At that time the Office of Research and Development within EPA recognized significant knowledge gaps which are described in the preamble to the rule [37].

Our review of required compliance monitoring data for several WWTPs in New York State that land apply their sludges showed that there was no effective internal review of those data. Laboratory and reporting errors were evident. Decimal point errors were evident for several contaminants and the same value was repeated for several contaminants. In addition, reported values for lead,

Table 5. Response of State Agency Biosolids Staff to Inquiry Regarding Incidents (as of July 24, 2002)

State	Responded	No response	Responded to inquiry but not aware of incident
AL			X
FL		X	
IA		X	
MD	X		
ME	X		
NC	X		
NH	X		
OH			X
PA	X		
TN		X	
TX		X	
VA	X		
WA	X		
WI	X		

for example, were unrealistically low, below levels reported elsewhere in any sludges. There is thus little confidence regarding the quality of the sludges applied or of the ability to detect and prevent violations.

EPA has suggested that, given their limited resources, sewage sludges are low risk and thus low priority as compared to, for example, hazardous wastes. It is difficult to compare these two materials, though both have toxic constituents. The risk may be relative to exposure. In contrast to hazardous wastes that are managed in highly engineered systems, sewage sludges may be spread on land including farms and home gardens used for food production or on recreational areas. They are spread on lands immediately adjacent to residences, schools, and nursing homes.

Another rationale used to suggest the low risk posed by sewage sludges is that only a small proportion of agricultural lands in the United States receive sludge application. However, the distribution of farmland and sludge generation is not uniform across the United States. Sludges from densely populated regions are routinely exported to rural areas. Export is controversial, often generating opposition in the receiving locality and leading to adoption of local restrictive ordinances.

PATHOGENS AND ODORS

Sludges contain an array of pathogens including bacteria, viruses, protozoa, and parasitic worms derived from the input of the population contributing wastes to the WWTPs [38]. Required testing of sludges for pathogens is very limited and is based on the concept of "indicator" organisms. Indicator organisms, specifically fecal coliforms, *Salmonella* and *Ascaris,* are used to determine the hygienic status of sludges. The concept of using one or several pathogens to provide an indication of the effectiveness of treatment in reducing all pathogens is worthwhile since it is impractical to test for all of the potential sludge-borne pathogens. However, there are serious limitations in using these indicators and there is a need to develop protocols for alternative indicators [39].

Alternative indicator organisms have been suggested for more than twenty years [40]. There is also recognition that the detection of various pathogens in sludges is highly variable both among sludges and over time for sludge generated at a single treatment plant [41]. A new survey of pathogens in sludges is needed [42].

Treatment is required before sewage sludges can be land applied, but the majority of sludges used on agricultural land and in reclamation of mined lands are Class B sludges that still contain detectable pathogen loads [43]. Workers applying the sludges [44] and neighbors to land application sites may be exposed to pathogens through several pathways including direct contact on the site, sludge runoff, infiltration into groundwater and wells, and airborne transport off-site [45].

Odors are the most frequent cause of complaints surrounding land application. Until recently, odors have been dismissed as a purely esthetic or quality-of-life issue. However, there is evidence that exposure to odor-causing chemicals can cause illness and that some airborne contaminants can cause a variety of symptoms including eye, nose, and throat irritation, headache, nausea, diarrhea, hoarseness, sore throat, cough, chest tightness, nasal congestion, palpitations, shortness of breath, stress, drowsiness, and alterations in mood [46]. These are some of the symptoms reported by some residents living near sludge land application sites (Table 1).

Methods of sludge application are likely to influence the impact of pathogens, odors, and irritants. However, little to no research has been done to document the impact of different management practices. Under the 503 rules, several management requirements are established that are relevant to potential exposure of people to pathogens in Class B sewage sludges. These include a 10 m setback from watercourses, a requirement that public access be restricted to the site for a specified time period, and restrictions on how soon after application animals may be allowed to graze or crops can be harvested. The implementation method for the public access restriction is not specified and is usually based on posting

of signs with no physical barriers. No setbacks from residences or drinking water wells are required under federal rules.

In addition to pathogens, endotoxins, molds, and fungi are possible constituents in sludges that can cause disease. The combination of these biological agents and irritant chemicals in sludges may present particular risks [47].

No formal assessment of the risks posed by pathogens in Class B sludges has been conducted, nor has the potential interaction between chemicals in sludges that can cause respiratory irritation with pathogens been considered [48]. Exposure to persons living near application sites to these contaminants may pose the most acute risk, especially to children, the elderly, the immune-compromised, and other susceptible populations. The potential for illness resulting from airborne movement of pathogens has not been considered under the current rules [49]. This, along with movement in runoff from sludged sites, is likely to be the most prevalent route of exposure of neighbors to pathogens and contaminants in Class B sludges.

In contrast to the many investigations of the impact of sludge use on plants and soils, little research has been conducted that addresses the health impacts of land application. One study of farm families in Ohio is often cited as evidence that sludge application does not cause disease [50]. The paper found no significant health differences between persons living on farms where sludges had and had not been applied. The authors specifically state, however, that "[c]aution should be exercised in using these data to predict health risks associated with sludges containing higher levels of disease agents and with higher sludge application rates and larger acreages treated per farm than used in this study." The study clearly did not study "worst case" conditions since sludges were incorporated into the soils (none were surface applied or stockpiled), were applied at relatively low rates (0.9-4 tons/acre), and were relatively odor-free, indicating that they were well treated and stabilized. Since the sludges themselves were not tested, they may or may not have contained pathogens. There were also methodological constraints, including the fact that approximately 70 percent of the original 297 participants dropped out before the three-year study was completed.

CONCLUSIONS AND RECOMMENDATIONS

Disposal of sewage sludges via spreading on agricultural, forest, and mine lands is a growing practice. The complex mix of biological agents and chemical contaminants contained in sewage sludges exposes workers and people living near sites where they are used as soil amendments to risks that are poorly understood. These risks include acute risks as well as chronic risks posed by potential long-term exposure. Recent reports from neighbors to land application sites of illness and even death suggest that pathogens, endotoxins and

contaminants coming from land application sites may pose an acute and immediate risk.

Only one scientific investigation of the numerous anecdotal reports of illness associated with land application sites has been carried out. Health professionals in communities faced with sludge application must be made aware of the potential risks and symptoms experienced by neighbors elsewhere so that proper diagnoses can be made and the true magnitude and nature of illness attributable to land application of sewage sludges can be assessed. Information should be provided to local health departments and medical professionals in areas where land application of sludges takes place so that they are prepared to respond to reported illnesses.

Systematic tracking of health incidents and scientific investigation of incidents is urgently needed. Persons experiencing illness need to know to whom to report their complaints. Given the current lack of tracking, they should keep records of their complaints and should send them to local, state, and federal agencies. Involvement of the Center for Disease Control or other agency qualified to conduct health investigations is needed to investigate the reports of illness associated with land application of sludges.

The factors with regard to sludge type and treatment, environmental conditions and sludge management practices that may contribute to illness have not been investigated, so we are unable to identify recommendations or requirements that may protect public health. Until investigations are carried out that answer these questions, land application of Class B sludges should be viewed as a practice that subjects neighbors and workers to substantial risk of disease.

The practice of applying sewage sludges to the surface of land without incorporation into the soil appears to present a particularly high risk. It would be prudent to eliminate such applications of Class B sludges. Even under less risky application scenarios, there are risks of illness associated with application of Class B sludges. The potential for off-site movement of chemicals, pathogens and endotoxins suggests that use of Class B sludges should be eliminated. Class A sludges have been treated to further reduce pathogens, but would not have reduced levels of chemical contaminants or endotoxins. Thus, the potential health risks posed by Class A sludges associated with chemical contaminants and endotoxins may warrant reconsideration of putting them on land.

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