Risk of Infectious Disease from Use of Sludge on Land and Methods to Reduce These Risks

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16. ABSTRACT

Virtually all of the infectious organisms in wastewater end up in the sludge removed in the course of wastewater treatment. The health risks to humans when sludges are applied to land depend on the densities of these organisms, reductions that occur when the sludge is processed, the hardiness of the organisms on or in the land surfaces, and the available pathways to man. This presentation discusses each of these issues for pathogenic bacteria, viruses, protozoa, and helminths. The combination of sludge processing requirements and other controls, such as control of access and type of crops growing, used by the U.S. EPA in their regulations governing sludge use on land are presented and discussed.

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RISK OF INFECTIOUS DISEASE FROM USE OF SLUDGE ON LAND AND METHODS TO REDUCE THESE RISKS

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Wastewater from a community is extensively contaminated with organisms that cause infectious disease. Primarily these are organisms that are discharged through the intestinal tract. Modern drinking water and wastewater systems are based on an appreciation of the high disease hazards present in wastewater. The organisms of concern are: bacteria, viruses, protozoa, and the eggs of helminths (parasitic worms). All of these materials, even viruses, end up in high densities in the sludge. Viruses, although very small, are highly adsorbed or contained in solids, so proportion removed with sludge is very high.

The questions we must ask about these organisms are the following:

a) Are these organisms in sludge at infective levels?
b) Are they reduced adequately by treatment?
c) Are there pathways that could lead to infection in man?
d) Do the organism densities decline rapidly with time when sludge is applied to land?

The first part of this presentation will discuss items a, c, and d for each class of organisms in turn. Item b will be discussed briefly but will be taken up in more detail later.

Bacteria

The pathogenic bacteria of major concern which are found in sludge are listed in Table 1. Symptoms of diseases produced by these organisms are discussed elsewhere (ref. 1). These diseases are frequently serious and sometimes life-threatening. Densities of the causative bacteria are reduced by conventional treatment. A substantial dose of pathogenic bacteria (many thousands of CFU's-colony forming units--in some cases) is generally needed to cause disease and frequently densities are low enough that ingestion of an infectious dose seems unlikely. However, most of these bacteria can regrow if provided with a nutritious substrate, so even low densities are of concern in certain circumstances.

Pathways to man include aerosols, animals, crops, drinking water from surface or groundwater sources, vectors, and fomites. Results in the literature indicate that bacteria live on soil and crops long enough to be of sustantial concern (see Table 2). The aerosol route seems to be a minor hazard that can be minimized by good application techniques. Bacteria are relatively large and are filtered by most soils, excepting coarse sandy soil and thin soils over fissured bed rock. Surface runoff is of concern, as is transmission by crops and livestock. Transmission by vectors and fomites can be minimized by proper pretreatment of sludge and by good housekeeping.

Viruses

Human viruses commonly found in wastewater are presented in Table 3. Symptoms of these diseases are discussed by Kowal (1). Illnesses produced range from mild to extremely serious.

Pathways to man are similar to those for bacteria, and most concerns about disease transmission are similar. Viruses survive about as long as bacteria on soil and plants and may survive considerably longer when carried deep into the soil. Transmission via animals is possible because some animals can be infected by human viruses. However, this risk is unproven and may be slight., Potential for transmission to groundwater is greater than for bacteria. Viruses normally adsorb strongly to solids including soil granules. However, a change in the ionic condition of water may cause them to desorb. There have been reports of considerable movement of viruses after a heavy rainfall.

Viruses cannot regrow outside of living organisms, so hazard of transmission is reduced. On the other hand, infective dose for viruses can be very low, so caution must still be exercised when sludge containing viruses is used.

Protozoa

Types of protozoa which may be found in wastewater and sludge are shown in Table 4. According to Kowal (1), only three species are of major significance for transmission of disease to humans through wastewater: Entamoeba histolytica, Giardia lamblia, and Balantidium coli. These organisms are hazardous when they survive wastewater treatment. All of these organisms are greatly reduced in densities by sludge treatment processes and especially by exposure on the soil. Pathways to man from sludge application by transport to surface or groundwater are not considered significant. The primary protective factor is their short life on the soil. Any measure imposed to protect against viruses and bacteria will surely be protective against protozoa. These agents are much more dangerous to humans when discharged with wastewater into a receiving stream, primarily because they can reach a swimming area or a drinking water source in a matter of hours after discharge.

Helminths

Pathogenic helminths of major concern are listed in Table 5. Reimers et al. (2, 3) have found Ascaris, Trichuris, and Toxocara to be the most frequently recovered helminth eggs in municipal sewage sludge in the United States. Taenia saginata and T. solium, the beef and pork tapeworm, are relatively rare in the United States but are fairly common in some areas of the world.

The pathways to man are slightly different for helminths than for viruses and bacteria. Because of the relatively large size of the eggs, they are filtered by the soil, and it is highly unlikely that they will reach or travel with groundwater. They are relatively high in density and tend not to be carried to surface waters by runoff. On the other hand, they are extremely resistant to ordinary environmental conditions and some survive in the soil for periods exceeding a year. The soil can

present a hazard long after any evidence of sludge use has disappeared. They can be ingested by grazing animals, by humans who eat crops grown on sludge amended soil, or by children with pica (an occasionally encountered habit of some children to consume dirt while at play). Like viruses, helminths and their eggs cannot multiply outside of their host. Their infective dose is very low--generally one egg is sufficient to produce an infection. Unless the infection is massive, which is unlikely, the illness produced is not severe. Any potential cycle of infection is to be guarded against. Such occurrences can take place when vegetables supplied to a city are grown on farms irrigated with the city's improperly treated sewage. Then infections of nearly all the inhabitants of the city becomes possible, and has occurred.

Reduction in Organism Density by Conventional Treatment

The conventional means of treatment of wastewater solids are the wastewater treatment process itself, anaerobic digestion at 35°C, aerobic digestion at ambient temperatures, lime treatment to pH 12, storage in lagoons, and drying on sand beds. All of these processes produce substantial reductions in densities of bacterial and viral pathogens. For example, the sludge solids from conventional treatment (primary treatment followed by the activated sludge process) have about one-tenth the density of organisms of fecal origin as the incoming wastewater solids. Anaerobic digestion produces an additional reduction of about the same magnitude. However, there is substantial and measurable survival. The helminth eggs are almost unaffected, perhaps reduced by half, by processing through digestion or even lime treatment. Since sludge after conventional treatment still contains pathogens, it is clear that some protection must be provided when sludge is used on land to minimize risk to human health.

Further Processing That Disinfects Sludge

In some cases, sludges or their products are used under conditions where human contact is substantial. In these cases, sludges should contain no pathogenic organisms. There are three types of treatment available: exposure to certain chemicals, high energy radiation, or to temperature in excess of 55°C (time of exposure depends on temperature). All three of these treatments eliminate pathogenic bacteria and viruses; unfortunately, helminth eggs are extremely resistant to chemical treatment. Consequently, only high energy radiation or exposure to temperatures above 55°C reliably destroys all three classes of organisms of concern. The processes available that provide these treatments are:

composting when temperatures exceed 55°c
thermophilic anaerobic digestion (> 55°C)
thermophilic aerobic digestion (> 55°C)
pasteurization
gamma ray irradiation using radioactive isotopes
electron beam irradiation

Processing conditions found acceptable to the U. S. EPA are presented in their regulations which are attached (See Appendix II B of "Part 257-Criteria for Classification of Solid Waste Disposal Facilities and Practices," which is attached). Thermophilic anaerobic digestion is not in the EPA listing of acceptable processes, primarily because there was no experience in the United States with this process above 49°C. Recent research experience indicates that

55°C can be achieved. Under this circumstance, thermophilic anaerobic digestion will qualify as a suitable process to disinfect sludge. Another process that may eventually qualify is long term storage (in excess of two years) of sludge in lagoons in warm climates. EPA research not yet published indicates promising results.

EPA's Control Approach

EPA's approach to control of risk of infectious disease from sludge utilization is contained in Paragraph 257.3-6 in the attached regulation. EPA divided sludge use into three classes:

a) If sludge is not treated after removal from the wastewater processing step, it can not be used on the land surface.

b) If sludge is treated by certain processes such as anaerobic digestion at 35°C for 15 days, or lime treatment to pH 12, it can be used on the soil surface under certain restrictions. The restrictions require controlled access for 12 months after use of sludge, crops for direct human consumption that can touch the sludge can not be grown for 18 months, and grazing of animals whose products are consumed by humans can not occur until one month after sludge application.

c) If sludge is treated by a process that disinfects it and reduces attraction of vectors, it can be used on the soil surface with no restrictions related to transmission of infectious disease.

These regulations are being considered for revision by EPA, with a proposed revision due to be published in September of 1986. The basic ideas noted above are thought to be sound and will probably form the structure of the new regulation, although numerous minor changes are anticipated.

REFERENCES

(1) Kowal, N. E., "Health Effects of Land Application of Municipal Sludge," 78 pages, EPA-600/1-85/015, September 1985.

(2) Reimers, R. S., Little, M. D., Englande, A. J., Leftwich, D. B., Bowman, D. C., and Wilkinson, R. F., 1981. "Investigation of Parasites in Southern Sludges and Disinfection by Standard Sludge Treatment Processes." EPA-600/2-81-166, U. S. Environmental Protection Agency, Cincinnati, Ohio.

(3) Reimers, R. S., Little, M.D., Englande, A. J., McDonnell, D. B., Bowman, D. D., and Hughes, J. M., 1984. "Investigation of Parasites in Sludges and Disinfection Techniques," U. S. Environmental Protection Agency, Cincinnati, Ohio.

Table 1. **Pathogenic Bacteria of Major Concern**

Name	Nonhuman Reservoir
Campylobacter jejuni	Cattle, dogs, cats, poultry
Escherichia coli (pathogenic strains)	--
Leptospira spp.	Domestic and wild mammals, rats
*Salmonella paratyphi A, B, C**	--
Salmonella typhi	--
Salmonella spp.	Domestic and wild mammals, birds, turtles
Shigella sonnei, S. flexneri, S. boydii, S. dysenteriae	--
Vibrio cholerae	--
Yersinia enterocolitica, Y. pseudotuberculosis	Wild and domestic birds and mammals

*Correct nomenclature: *Salmonella paratyphi* A, *S. schottmuelleri, S. hirschfeldi,* respectively.

Source: Table 2 in Reference 1.

Table 2. **Survival Times of Pathogens on Soil and Plants**

	Soil		Plants	
Pathogen	Absolute Maximum	Common Maximum	Absolute Maximum	Common Maximum
Bacteria	1 year	2 months	6 months	1 month
Viruses	6 months	3 months	2 months	1 month
Protozoa	10 days	2 days	5 days	2 days
Helminths	7 years	2 years	5 months	1 month

Source: Table 1 in Reference 1.

Table 3. **Human Wastewater Viruses**

Enteroviruses
Poliovirus
Coxsackievirus A
Coxsackievirus B
Echovirus
New Enteroviruses
Hepatitis A Virus
Rotavirus ("Duovirus," "Reovirus-like Agent")
Norwalk-Like Agents (Norwalk, Hawaii, Montgomery County, etc.)
Adenovirus
Reovirus
Papovavirus
Astrovirus
Calicivirus
Coronavirus-Like Particles

Source: Table 10 in Reference 1.

Table 4. **Types of Protozoa in Wastewater**

Name	Protozoan Class	Nonhuman Reservoir
HUMAN PATHOGENS		
Entamoeba histolytica	Ameba	Domestic and wild mammals
Giardia lamblia	Flagellate	Beavers, dogs, sheep
Balantidium coli	Ciliate	Pigs, other mammals
Toxoplasma gondii	Sporozoan (Coccidia)	Cats
Dientamoeba fragilis	Ameba	
Isospora belli	Sporozoan (Coccidia)	
I. hominis	Sporozoan (Coccidia)	
HUMAN COMMENSALS		
Endolimax nana	Ameba	
Entamoeba coli	Ameba	
Iodamoeba butschlii	Ameba	
ANIMAL PATHOGENS		
Eimeria spp.	Sporozoan (Coccidia)	Fish, birds, mammals
Entamoeba spp.	Ameba	Rodents, etc.
Giardia spp.	Flagellate	Dogs, cats, wild mammals
Isospora spp.	Sporozoan (Coccidia)	Dogs, cats

Source: Table 15 in Reference 1.

Table 5. **Pathogenic Helminths of Major Concern**

Pathogen	Common Name	Disease	Nonhuman Reservoir
NEMATODES (Roundworms)			
Enterobius vermicularis	Pinworm	Enterobiasis	
Ascaris lumbricoides	Roundworm	Ascariasis	
A. suum	Swine roundworm	Ascariasis	Pig*
Trichuris trichiura	Whipworm	Trichuriasis	
Necator americanus	Hookworm	Necatoriasis	
Ancylostoma duodenale	Hookworm	Ancylostomiasis	
A. braziliense	Cat hookworm	Cutaneous larva migrans	Cat, dog*
A. caninum	Dog hookworm	Cutaneous larva migrans	Dog*
Strongyloides stercoralis	Threadworm	Strongyloidiasis	Dog
Toxocara canis	Dog roundworm	Visceral larva migrans	Dog*
T. cati	Cat roundworm	Visceral larva migrans	Cat*
CESTODES (Tapeworms)			
*Taenia saginata***	Beef tapeworm	Taeniasis	
T. solium	Pork tapeworm	Taeniasis, Cysticerosis	
Hymenolepis nana	Dwarf tapeworm	Taeniasis	Rat, mouse
Echinococcus granulosus	Dog tapeworm	Unilocular hydatid disease	Dog*
E. multilocularis		Alveolar hydatid disease	Dog, fox, cat*

*Definitive host; man only incidentally infested.
**Eggs not infective for man.

Source: Table 17 in Reference 1.

From the "U.S. Code of Federal Regulations," revised July 1, 1984.

PART 257—CRITERIA FOR CLASSIFICATION OF SOLID WASTE DISPOSAL FACILITIES AND PRACTICES

Sec.

AUTHORITY: Sec. 1008(a)(3) and sec. 4004(a), Pub. L. 94-580, 90 Stat. 2803 and 2815 (42 U.S.C. 6907(a)(3) and 6944(a)); sec. 405(d), Pub. L. 95-217, 91 Stat. 1606 (33 U.S.C. 1345(d)).

SOURCE: 44 FR 53460, Sept. 13, 1979, unless otherwise noted.

§ 257.1 Scope and purpose.

(a) These criteria are for use under the Resource Conservation and Recovery Act (the Act) in determining which solid waste disposal facilities and practices pose a reasonable proba-

bility of adverse effects on health or the environment. Unless otherwise provided, these criteria are adopted for purposes of both Section 1008(a)(3) and Section 4004(a) of the Act.

(1) Facilities failing to satisfy criteria adopted for purposes of Section 4004(a) will be considered open dumps for purposes of State solid waste management planning under the Act.

(2) Practices failing to satisfy criteria adopted for purposes of Section 1008(a)(3) constitute open dumping, which is prohibited under Section 4005 of the Act.

(b) These criteria also provide guidelines for sludge utilization and disposal under Section 405(d) of the Clean Water Act, as amended. To comply with Section 405(e) the owner or operator of any publicly owned treatment works must not violate these criteria in the disposal of sludge on the land.

(c) These criteria apply to all solid waste disposal facilities and practices with the following exceptions:

(1) The criteria do not apply to agricultural wastes, including manures and crop residues, returned to the soil as fertilizers or soil conditioners.

(2) The criteria do not apply to overburden resulting from mining operations intended for return to the mine site.

(3) The criteria do not apply to the land application of domestic sewage or treated domestic sewage. The criteria do apply to disposal of sludges generated by treatment of domestic sewage.

(4) The criteria do not apply to the location and operation of septic tanks. The criteria do, however, apply to the disposal of septic tank pumpings.

(5) The criteria do not apply to solid or dissolved materials in irrigation return flows.

(6) The criteria do not apply to industrial discharges which are point sources subject to permits under Section 402 of the Clean Water Act, as amended.

(7) The criteria do not apply to source, special nuclear or byproduct material as defined by the Atomic Energy Act, as amended (68 Stat. 923).

(8) The criteria do not apply to hazardous waste disposal facilities which are subject to regulation under Subtitle C of the Act.

(9) The criteria do not apply to disposal of solid waste by underground well injection subject to the regulations (40 CFR Part 146) for the Underground Injection Control Program (UICP) under the Safe Drinking Water Act, as amended, 42 U.S.C. 3007 et seq.

[44 FR 53460, Sept. 13, 1979, as amended at 46 FR 47052, Sept. 23, 1981]

§ 257.2 Definitions.

The definitions set forth in Section 1004 of the Act apply to this part. Special definitions of general concern to this part are provided below, and definitions especially pertinent to particular sections of this part are provided in those sections.

"Disposal" means the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including ground waters.

"Facility" means any land and appurtenances thereto used for the disposal of solid wastes.

"Leachate" means liquid that has passed through or emerged from solid waste and contains soluble, suspended or miscible materials removed from such wastes.

"Open dump" means a facility for the disposal of solid waste which does not comply with this part.

"Practice" means the act of disposal of solid waste.

"Sanitary landfill" means a facility for the disposal of solid waste which complies with this part.

"Sludge" means any solid, semisolid, or liquid waste generated from a municipal, commercial, or industrial wastewater treatment plant, water supply treatment plant, or air pollution control facility or any other such waste having similar characteristics and effect.

"Solid waste" means any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities, but does not include solid or dissolved materials in domestic sewage, or solid or dissolved material in irrigation return flows or industrial discharges which are point sources subject to permits under Section 402 of the Federal Water Pollution Control Act, as amended (86 Stat. 880), or source, special nuclear, or byproduct material as defined by the Atomic Energy Act of 1954, as amended (68 Stat. 923).

"State" means any of the several States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, American Samoa, and the Commonwealth of the Northern Mariana Islands.

[44 FR 53460, Sept. 13, 1979; 44 FR 58910, Oct. 12, 1979]

§ 257.3 Criteria for classification of solid waste disposal facilities and practices.

Solid waste disposal facilities or practices which violate any of the following criteria pose a reasonable probability of adverse effects on health or the environment:

§ 257.3-1 Floodplains.

(a) Facilities or practices in floodplains shall not restrict the flow of the base flood, reduce the temporary water storage capacity of the floodplain, or result in washout of solid waste, so as to pose a hazard to human life, wildlife, or land or water resources.

(b) As used in this section:

(1) "Based flood" means a flood that has a 1 percent or greater chance of recurring in any year or a flood of a magnitude equalled or exceeded once in 100 years on the average over a significantly long period.

(2) "Floodplain" means the lowland and relatively flat areas adjoining inland and coastal waters, including flood-prone areas of offshore islands, which are inundated by the base flood.

(3) "Washout" means the carrying away of solid waste by waters of the base flood.

[44 FR 53460, Sept. 13, 1979; 44 FR 64708, Sept. 21, 1979]

§ 257.3-2 Endangered species.

(a) Facilities or practices shall not cause or contribute to the taking of any endangered or threatened species of plants, fish, or wildlife.

(b) The facility or practice shall not result in the destruction or adverse modification of the critical habitat of endangered or threatened species as identified in 50 CFR Part 17.

(c) As used in this section:

(1) "Endangered or threatened species" means any species listed as such pursuant to Section 4 of the Endangered Species Act.

(2) "Destruction or adverse modification" means a direct or indirect alteration of critical habitat which appreciably diminishes the likelihood of the survival and recovery of threatened or endangered species using that habitat.

(3) "Taking" means harassing, harming, pursuing, hunting, wounding, killing, trapping, capturing, or collecting or attempting to engage in such conduct.

§ 257.3-3 Surface water.

(a) For purposes of Section 4004(a) of the Act, a facility shall not cause a discharge of pollutants into waters of the United States that is in violation of the requirements of the National Pollutant Discharge Elimination System (NPDES) under Section 402 of the Clean Water Act, as amended.

(b) For purposes of Section 4004(a) of the Act, a facility shall not cause a discharge of dredged material or fill material to waters of the United States that is in violation of the requirements under Section 404 of the Clean Water Act, as amended.

(c) A facility or practice shall not cause non-point source pollution of waters of the United States that violates applicable legal requirements implementing an areawide or Statewide water quality management plan that has been approved by the Administrator under Section 208 of the Clean Water Act, as amended.

(d) Definitions of the terms "Discharge of dredged material", "Point source", "Pollutant", "Waters of the United States", and "Wetlands" can be

found in the Clean Water Act, as amended, 33 U.S.C. 1251 et seq., and implementing regulations, specifically 33 CFR Part 323 (42 FR 37122, July 19, 1977).

[44 FR 53460, Sept. 13, 1979, as amended at 46 FR 47052, Sept. 23, 1981]

§ 257.3-4 Ground water.

(a) A facility or practice shall not contaminate an underground drinking water source beyond the solid waste boundary or beyond an alternative boundary specified in accordance with paragraph (b) of this section.

(b)(1) For purposes of Section 1008(a)(3) of the Act or Section 405(d) of the CWA, a party charged with open dumping or a violation of Section 405(e) may demonstrate that compliance should be determined at an alternative boundary in lieu of the solid waste boundary. The court shall establish such an alternative boundary only if it finds that such a change would not result in contamination of ground water which may be needed or used for human consumption. This finding shall be based on analysis and consideration of all of the following factors that are relevant:

(i) The hydrogeological characteristics of the facility and surrounding land, including any natural attenuation and dilution characteristics of the aquifer;

(ii) The volume and physical and chemical characteristics of the leachate;

(iii) The quantity, quality, and direction of flow of ground water underlying the facility;

(iv) The proximity and withdrawal rates of ground-water users;

(v) The availability of alternative drinking water supplies;

(vi) The existing quality of the ground water, including other sources of contamination and their cumulative impacts on the ground water;

(vii) Public health, safety, and welfare effects.

(2) For purposes of Sections 4004(a) and 1008(a)(3), the State may establish an alternative boundary for a facility to be used in lieu of the solid waste boundary only if it finds that such a change would not result in the contamination of ground water which may be needed or used for human consumption. Such a finding shall be based on an analysis and consideration of all of the factors identified in paragraph (b)(1) of this section that are relevant.

(c) As used in this section:

(1) "Aquifer" means a geologic formation, group of formations, or portion of a formation capable of yielding usable quantities of ground water to wells or springs.

(2) "Contaminate" means introduce a substance that would cause:

(i) The concentration of that substance in the ground water to exceed the maximum contaminant level specified in Appendix I, or

(ii) An increase in the concentration of that substance in the ground water where the existing concentration of that substance exceeds the maximum contaminant level specified in Appendix I.

(3) "Ground water" means water below the land surface in the zone of saturation.

(4) "Underground drinking water source" means:

(i) An aquifer supplying drinking water for human consumption, or

(ii) An aquifer in which the ground water contains less than 10,000 mg/l total dissolved solids.

(5) "Solid waste boundary" means the outermost perimeter of the solid waste (projected in the horizontal plane) as it would exist at completion of the disposal activity.

[44 FR 53460, Sept. 13, 1979, as amended at 46 FR 47052, Sept. 23, 1981]

§ 257.3-5 Application to land used for the production of food-chain crops (interim final).

(a) *Cadmium.* A facility or practice concerning application of solid waste to within one meter (three feet) of the surface of land used for the production of food-chain crops shall not exist or occur, unless in compliance with all requirements of paragraph (a)(1) (i) through (iii) of this section or all requirements of paragraph (a)(2) (i) through (iv) of this section.

(1)(i) The pH of the solid waste and soil mixture is 6.5 or greater at the time of each solid waste application, except for solid waste containing cadmium at concentrations of 2 mg/kg (dry weight) or less.

(ii) The annual application of cadmium from solid waste does not exceed 0.5 kilograms per hectare (kg/ha) on land used for production of tobacco, leafy vegetables or root crops grown for human consumption. For other food-chain crops, the annual cadmium application rate does not exceed:

Time period	Annual Cd application rate (kg/ha)
Present to June 30, 1984	2.0
July 1, 1984 to Dec. 31, 1986	1.25
Beginning Jan. 1, 1987	0.5

(iii) The cumulative application of cadmium from solid waste does not exceed the levels in either paragraph (a)(1)(iii)(A) of this section or paragraph (a)(1)(iii)(B) of this section.

(A)

Soil cation exchange capacity (meq/100g)	Maximum cumulative application (kg/ha)	
	Background soil pH less than 6.5	Background soil pH more than 6.5
Less than 5	5	5
5 to 15	5	10
More than 15	5	20

(B) For soils with a background pH of less than 6.5, the cumulative cadmium application rate does not exceed the levels below: *Provided,* That the pH of the solid waste and soil mixture is adjusted to and maintained at 6.5 or greater whenever food-chain crops are grown.

Soil cation exchange capacity (meq/100g)	Maximum cumulative application (kg/ha)
Less than 5	5
5 to 15	10
More than 15	20

(2)(i) The only food-chain crop produced is animal feed.

(ii) The pH of the solid waste and soil mixture is 6.5 or greater at the time of solid waste application or at the time the crop is planted, whichever occurs later, and this pH level is maintained whenever food-chain crops are grown.

(iii) There is a facility operating plan which demonstrates how the animal feed will be distributed to preclude ingestion by humans. The facility operating plan describes measures to be taken to safeguard against possible health hazards from cadmium entering the food chain, which may result from alternative land uses.

(iv) Future property owners are notified by a stipulation in the land record or property deed which states that the property has received solid waste at high cadmium application rates and that food-chain crops should not be grown, due to a possible health hazard.

(b) *Polychlorinated Biphenyls (PCBs).* Solid waste containing concentrations of PCBs equal to or greater than 10 mg/kg (dry weight) is incorporated into the soil when applied to land used for producing animal feed, including pasture crops for animals raised for milk. Incorporation of the solid waste into the soil is required if it is assured that the PCB content is less than 0.2 mg/kg (actual weight) in animal feed or less than 1.5 mg/kg (fat basis) in milk.

(c) As used in this section:

(1) "Animal feed" means animals, any crop grown for consumption by animals, forage, and such as pasture crops, corn grain.

(2) "Background soil pH" means the pH of the soil prior to the addition of substances that alter the hydrogen ion concentration.

(3) "Cation exchange capacity" means the sum of exchangeable cations a soil can absorb expressed in milli-equivalents per 100 grams of soil as determined by sampling the soil to the depth of cultivation or solid waste placement, whichever is greater, and analyzing by the summation method for distinctly acid soils or sodium acetate method for neutral, calcareous or saline soils ("Methods of Soil Analysis, Agronomy Monograph No. 9." C. A. Black, ed., American Society of Agronomy, Madison, Wisc. pp 891-901, 1965).

(4) "Food-chain crops" means tobacco, crops grown for human consumption, and animal feed for animals whose products are consumed by humans.

(5) "Incorporated into the soil" means the injection of solid waste beneath the surface of the soil or the mixing of solid waste with the surface soil.

(6) "Pasture crops" means crops such as legumes, grasses, grain stubble and stover which are consumed by animals while grazing.

(7) "pH" means the logarithm of the reciprocal of hydrogen ion concentration.

(8) "Root crops" means plants whose edible parts are grown below the surface of the soil.

(9) "Soil pH" is the value obtained by sampling the soil to the depth of cultivation or solid waste placement, whichever is greater, and analyzing by the electrometric method. ("Methods of Soil Analysis, Agronomy Monograph No. 9," C.A. Black, ed., American Society of Agronomy, Madison, Wisconsin, pp. 914-926, 1965.)

[44 FR 53460, Sept. 13, 1979; 44 FR 54708, Sept. 21, 1979]

§ 257.3-6 Disease.

(a) *Disease Vectors.* The facility or practice shall not exist or occur unless the on-site population of disease vectors is minimized through the periodic application of cover material or other techniques as appropriate so as to protect public health.

(b) *Sewage sludge and septic tank pumpings (Interim Final).* A facility or practice involving disposal of sewage sludge or septic tank pumpings shall not exist or occur unless in compliance with paragraphs (b) (1), (2) or (3) of this section.

(1) Sewage sludge that is applied to the land surface or is incorporated into the soil is treated by a Process to Significantly Reduce Pathogens prior to application or incorporation. Public access to the facility is controlled for at least 12 months, and grazing by animals whose products are consumed by humans is prevented for at least one month. Processes to Significantly Reduce Pathogens are listed in Appendix II, Section A. (These provisions do not apply to sewage sludge disposed of by a trenching or burial operation.)

(2) Septic tank pumpings that are applied to the land surface or incorporated into the soil are treated by a Process to Significantly Reduce Pathogens (as listed in Appendix II, Section A), prior to application or incorporation, unless public access to the facility is controlled for at least 12 months and unless grazing by animals whose products are consumed by humans is prevented for at least one month. (These provisions do not apply to septic tank pumpings disposed of by a trenching or burial operation.)

(3) Sewage sludge or septic tank pumpings that are applied to the land surface or are incorporated into the soil are treated by a Process to Further Reduce Pathogens, prior to application or incorporation, if crops for direct human consumption are grown within 18 months subsequent to application or incorporation. Such treatment is not required if there is no contact between the solid waste and the edible portion of the crop; however, in this case the solid waste is treated by a Process to Significantly Reduce Pathogens, prior to application; public access to the facility is controlled for at least 12 months; and grazing by animals whose products are consumed by humans is prevented for at least one month. If crops for direct human consumption are not grown within 18 months of application or incorporation, the requirements of paragraphs (b) (1) and (2) of this section apply. Processes to Further Reduce Pathogens are listed in Appendix II, Section B.

(c) As used in this section:

(1) "Crops for direct human consumption" means crops that are consumed by humans without processing to minimize pathogens prior to distribution to the consumer.

(2) "Disease vector" means rodents, flies, and mosquitoes capable of transmitting disease to humans.

(3) "Incorporated into the soil" means the injection of solid waste beneath the surface of the soil or the mixing of solid waste with the surface soil.

(4) "Periodic application of cover material" means the application and compaction of soil or other suitable material over disposed solid waste at the end of each operating day or at such frequencies and in such a manner as to reduce the risk of fire and to impede vectors access to the waste.

(5) "Trenching or burial operation" means the placement of sewage sludge or septic tank pumpings in a trench or other natural or man-made depression and the covering with soil or other suitable material at the end of each operating day such that the wastes do not migrate to the surface.

[44 FR 53460, Sept. 13, 1979; 44 FR 54708, Sept. 21, 1979]

§ 257.3-7 Air.

(a) The facility or practice shall not engage in open burning of residential, commercial, institutional or industrial solid waste. This requirement does not apply to infrequent burning of agricultural wastes in the field, silvicultural wastes for forest management purposes, land-clearing debris, diseased trees, debris from emergency clean-up operations, and ordnance.

(b) For purposes of Section 4004(a) of the Act, the facility shall not violate applicable requirements developed under a State Implementation Plan (SIP) approved or promulgated by the Administrator pursuant to Section 110 of the Clean Air Act, as amended.

(c) As used in this section "open burning" means the combustion of solid waste without (1) control of combustion air to maintain adequate temperature for efficient combustion, (2) containment of the combustion reaction in an enclosed device to provide sufficient residence time and mixing for complete combustion, and (3) control of the emission of the combustion products.

[44 FR 53460, Sept. 13, 1979; 44 FR 54708, Sept. 21, 1979, as amended at 46 FR 47052, Sept. 23, 1981]

§ 257.3-8 Safety.

(a) *Explosive gases.* The concentration of explosive gases generated by the facility or practice shall not exceed:

(1) Twenty-five percent (25%) of the lower explosive limit for the gases in facility structures (excluding gas control or recovery system components); and

(2) The lower explosive limit for the gases at the property boundary.

(b) *Fires.* A facility or practice shall not pose a hazard to the safety of persons or property from fires. This may be accomplished through compliance with § 257.3-7 and through the periodic application of cover material or other techniques as appropriate.

(c) *Bird hazards to aircraft.* A facility or practice disposing of putrescible wastes that may attract birds and which occurs within 10,000 feet (3,048 meters) of any airport runway used by turbojet aircraft or within 5,000 feet (1,524 meters) of any airport runway used by only piston-type aircraft shall not pose a bird hazard to aircraft.

(d) *Access.* A facility or practice shall not allow uncontrolled public access so as to expose the public to potential health and safety hazards at the disposal site.

(e) As used in this section:

(1) "Airport" means public-use airport open to the public without prior permission and without restrictions within the physical capacities of available facilities.

(2) "Bird hazard" means an increase in the likelihood of bird/aircraft collisions that may cause damage to the aircraft or injury to its occupants.

(3) "Explosive gas" means methane (CH_4).

(4) "Facility structures" means any buildings and sheds or utility or drainage lines on the facility.

(5) "Lower explosive limit" means the lowest percent by volume of a mixture of explosive gases which will propagate a flame in air at 25°C and atmospheric pressure.

(6) "Periodic application of cover material" means the application and compaction of soil or other suitable material over disposed solid waste at the end of each operating day or at such frequencies and in such a manner as to reduce the risk of fire and to impede disease vectors' access to the waste.

(7) "Putrescible wastes" means solid waste which contains organic matter capable of being decomposed by microorganisms and of such a character and

proportion as to be capable of attracting or providing food for birds.

§ 257.4 Effective date.

These criteria become effective October 15, 1979.

APPENDIX I

The maximum contaminant levels promulgated herein are for use in determining whether solid waste disposal activities comply with the ground-water criteria (§ 257.3-4). Analytical methods for these contaminants may be found in 40 CFR Part 141 which should be consulted in its entirety.

1. *Maximum contaminant levels for inorganic chemicals.* The following are the maximum levels of inorganic chemicals other than fluoride:

Contaminant	Level (milligrams per liter)
Arsenic	0.05
Barium	1
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10
Selenium	0.01
Silver	0.05

The maximum contaminant levels for fluoride are:

Temperature[1] degrees Fahrenheit	Degrees Celsius	Level (milligrams per liter)
53.7 and below	12 and below	2.4
53.8 to 58.3	12.1 to 14.6	2.2
58.4 to 63.8	14.7 to 17.6	2.0
63.9 to 70.6	17.7 to 21.4	1.8
70.7 to 79.2	21.5 to 26.2	1.6
79.3 to 90.5	26.3 to 32.5	1.4

[1] Annual average of the maximum daily air temperature.

2. *Maximum contaminant levels for organic chemicals.* The following are the maximum contaminant levels for organic chemicals:

	Level (milligrams per liter)
(a) Chlorinated hydrocarbons:	
Endrin (1,2,3,4,10,10-Hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo, endo-5,8-dimethano naphthalene)	0.0002
Lindane (1,2,3,4,5,6-Hexachlorocyclohexane, gamma isomer)	0.004
Methoxychlor (1,1,1-Trichloro-2,2-bis (p-methoxyphenyl) ethane)	0.1
Toxaphene ($C_{10}H_{10}Cl_8$-Technical chlorinated camphene, 67 to 69 percent chlorine)	0.005
(b) Chlorophenoxys:	
2,4-D (2,4-Dichlorophenoxy-acetic acid)	0.1
2,4,5-TP Silvex (2,4,5-Trichlorophen- oxy-propionic acid)	0.01

3. *Maximum microbiological contaminant levels.* The maximum contaminant level for coliform bacteria from any one well is as follows:

(a) using the membrane filter technique:

(1) Four coliform bacteria per 100 milliliters if one sample is taken, or

(2) Four coliform bacteria per 100 milliliters in more than one sample of all the samples analyzed in one month.

(b) Using the five tube most probable number procedure, (the fermentation tube method) in accordance with the analytical recommendations set forth in "Standard Methods for Examination of Water and Waste Water", American Public Health Association, 13th Ed. pp. 662-668, and using a Standard sample, each portion being one fifth of the sample:

(1) If the standard portion is 10 milliliters, coliform in any five consecutive samples from a well shall not be present in three or more of the 25 portions, or

(2) If the standard portion is 100 milliliters, coliform in any five consecutive samples from a well shall not be present in five portions in any of five samples or in more than fifteen of the 25 portions.

4. *Maximum contaminant levels for radium-226, radium-228, and gross alpha particle radioactivity.* The following are the maximum contaminant levels for radium-226, radium-228, and gross alpha particle radioactivity:

(a) Combined radium-226 and radium-228—5 pCi/l;

(b) Gross alpha particle activity (including radium-226 but excluding radon and uranium)—15 pCi/l.

APPENDIX II

A. Processes to Significantly Reduce Pathogens

Aerobic digestion: The process is conducted by agitating sludge with air or oxygen to maintain aerobic conditions at residence times ranging from 60 days at 15° C to 40 days at 20° C, with a volatile solids reduction of at least 38 percent.

Air Drying: Liquid sludge is allowed to drain and/or dry on under-drained sand beds, or paved or unpaved basins in which the sludge is at a depth of nine inches. A minimum of three months is needed, two months of which temperatures average on a daily basis above 0° C.

Anaerobic digestion: The process is conducted in the absence of air at residence times ranging from 60 days at 20° C to 15 days at 35° to 55° C, with a volatile solids reduction of at least 38 percent.

Composting: Using the within-vessel, static aerated pile or windrow composting methods, the solid waste is maintained at minimum operating conditions of 40° C for 5 days. For four hours during this period the temperature exceeds 55° C.

Lime Stabilization: Sufficient lime is added to produce a pH of 12 after 2 hours of contact.

Other methods: Other methods or operating conditions may be acceptable if pathogens and vector attraction of the waste (volatile solids) are reduced to an extent equivalent to the reduction achieved by any of the above methods.

B. Processes to Further Reduce Pathogens

Composting: Using the within-vessel composting method, the solid waste is maintained at operating conditions of 55° C or greater for three days. Using the static aerated pile composting method, the solid waste is maintained at operating conditions of 55° C or greater for three days. Using the windrow composting method, the solid waste attains a temperature of 55° C or greater for at least 15 days during the composting period. Also, during the high temperature period, there will be a minimum of five turnings of the windrow.

Heat drying: Dewatered sludge cake is dried by direct or indirect contact with hot gases, and moisture content is reduced to 10 percent or lower. Sludge particles reach temperatures well in excess of 80° C, or the wet bulb temperature of the gas stream in contact with the sludge at the point where it leaves the dryer is in excess of 80° C.

Heat treatment: Liquid sludge is heated to temperatures of 180° C for 30 minutes.

Thermophilic Aerobic Digestion: Liquid sludge is agitated with air or oxygen to maintain aerobic conditions at residence times of 10 days at 55-60° C, with a volatile solids reduction of at least 38 percent.

Other methods: Other methods or operating conditions may be acceptable if pathogens and vector attraction of the waste (volatile solids) are reduced to an extent equivalent to the reduction achieved by any of the above methods.

Any of the processes listed below, if added to the processes described in Section A above, further reduce pathogens. Because the processes listed below, on their own, do not reduce the attraction of disease vectors, they are only add-on in nature.

Beta ray irradiation: Sludge is irradiated with beta rays from an accelerator at dosages of at least 1.0 megarad at room temperature (ca. 20° C).

Gamma ray irradiation: Sludge is irradiated with gamma rays from certain isotopes, such as ^{60}Cobalt and ^{137}Cesium, at dosages of at least 1.0 megarad at room temperature (ca. 20° C).

Pasteurization: Sludge is maintained for at least 30 minutes at a minimum temperature of 70° C.

Other methods: Other methods or operating conditions may be acceptable if pathogens are reduced to an extent equivalent to the reduction achieved by any of the above add-on methods.