NC STATE UNIVERSITY

An Overview of the thinking behind Biosolids Regulations in the US

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Biosolids…

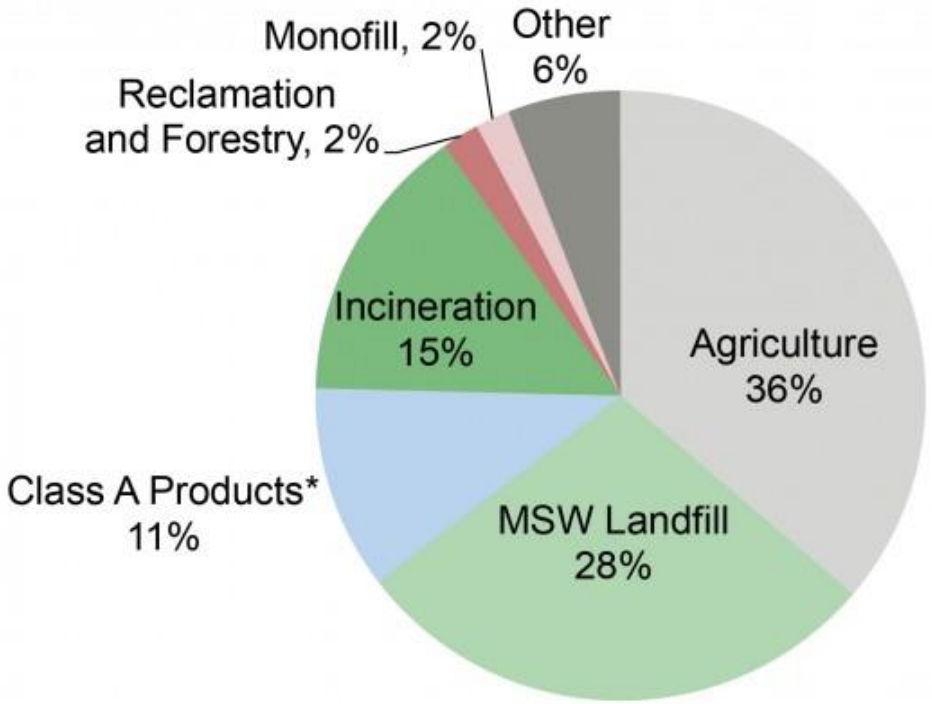
- Can be applied to land
- Cannot be applied to land
- Not sure

Biosolids in the US

- ~14,748 wastewater treatment plants (WWTPs; water reclamation facilities, WRFs)
  - (2016 US EPA, Clean Watershed Need Survey 2012- Report to Congress)
- Serving 238.2 million people
- Produce > 8 million tons (dry weight) sludge/year
- Treatment of sludge → 1/3 of total electricity use of a WWTP

Biosolids

- 55% of biosolids are beneficially used



CSS Factsheet, Univ. of Michigan

The role of the US EPA

- Mission
  - protect human health and the environment

- Best scientific information available
- Consulting stakeholders
- Best available technologies
- Public comments, public response

Regulatory Framework

- Residuals regulation is governed by

40 CFR Part 503

(Title 40 of the Code of Federal Regulations)

The Standards for the Use or Disposal of Sewage Sludge, Feb. 1993, amended several times

National Research Council, National Academy of Sciences

"There is no documented scientific evidence that the Part 503 Rule has failed to protect public health."

"[A] causal association between biosolids exposures and adverse health outcomes has not been documented."

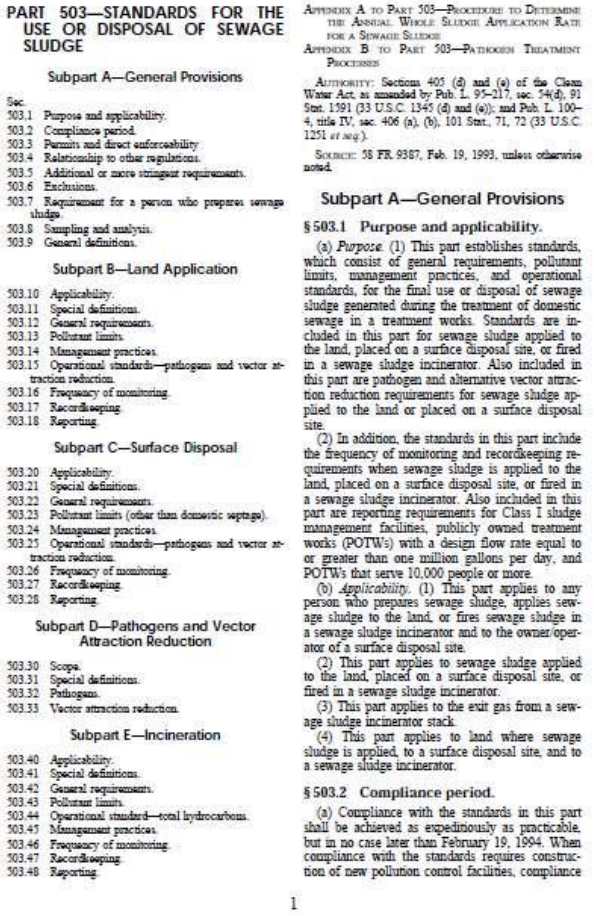
"There are no scientifically documented outbreaks or excess illnesses that have occurred from microorganisms in treated biosolids."

History

- Section 405 of the Clean Water Act 1977
- Research on ***risk assessment*** began in 1970s
- Development of 503 Rule began in 1984
- Amendments in 1987 – directed US EPA to research and promulgate regulations for disposal and use of sewage sludge
- 503 Rule proposed in 1989
- Published in Feb. 1993
- Reviewed by NRC, NAS (2002)

40 CFR Part 503

- General Provisions
- Land Application
- Surface Disposal
- Pathogen Reduction
- Vector Attraction Reduction
- Incineration



PART 503—STANDARDS FOR THE USE OR DISPOSAL OF SEWAGE SLUDGE

Subpart A—General Provisions

Sec.
503.1 Purpose and applicability.
503.2 Compliance period.
503.3 Permits and direct enforceability.
503.4 Relationship to other regulations.
503.5 Additional or more stringent requirements.
503.6 Exclusions.
503.7 Requirement for a person who prepares sewage sludge.
503.8 Sampling and analysis.
503.9 General definitions.

Subpart B—Land Application

503.10 Applicability.
503.11 Special definitions.
503.12 General requirements.
503.13 Pollutant limits.
503.14 Management practices.
503.15 Operational standards—pathogens and vector attraction reduction.
503.16 Frequency of monitoring.
503.17 Recordkeeping.
503.18 Reporting.

Subpart C—Surface Disposal

503.20 Applicability.
503.21 Special definitions.
503.22 General requirements.
503.23 Pollutant limits (other than domestic septage).
503.24 Management practices.
503.25 Operational standards—pathogens and vector attraction reduction.
503.26 Frequency of monitoring.
503.27 Recordkeeping.
503.28 Reporting.

Subpart D—Pathogens and Vector Attraction Reduction

503.30 Scope.
503.31 Special definitions.
503.32 Pathogens.
503.33 Vector attraction reduction.

Subpart E—Incineration

503.40 Applicability.
503.41 Special definitions.
503.42 General requirements.
503.43 Pollutant limits.
503.44 Operational standard—total hydrocarbons.
503.45 Management practices.
503.46 Frequency of monitoring.
503.47 Recordkeeping.
503.48 Reporting.

APPENDIX A TO PART 503—PROCEDURE TO DETERMINE THE ANNUAL WHOLE SLUDGE APPLICATION RATE FOR A SEWAGE SLUDGE

APPENDIX B TO PART 503—PATHOGEN TREATMENT PROCESSES

AUTHORITY: Sections 405 (d) and (e) of the Clean Water Act, as amended by Pub. L. 95–217, sec. 54(d), 91 Stat. 1591 (33 U.S.C. 1345 (d) and (e)); and Pub. L. 100–4, title IV, sec. 406 (a), (b), 101 Stat., 71, 72 (33 U.S.C. 1251 *et seq.*).

SOURCE: 58 FR 9387, Feb. 19, 1993, unless otherwise noted.

Subpart A—General Provisions

§ 503.1 Purpose and applicability.

(a) *Purpose.* (1) This part establishes standards, which consist of general requirements, pollutant limits, management practices, and operational standards, for the final use or disposal of sewage sludge generated during the treatment of domestic sewage in a treatment works. Standards are included in this part for sewage sludge applied to the land, placed on a surface disposal site, or fired in a sewage sludge incinerator. Also included in this part are pathogen and alternative vector attraction reduction requirements for sewage sludge applied to the land or placed on a surface disposal site.

(2) In addition, the standards in this part include the frequency of monitoring and recordkeeping requirements when sewage sludge is applied to the land, placed on a surface disposal site, or fired in a sewage sludge incinerator. Also included in this part are reporting requirements for Class I sludge management facilities, publicly owned treatment works (POTWs) with a design flow rate equal to or greater than one million gallons per day, and POTWs that serve 10,000 people or more.

(b) *Applicability.* (1) This part applies to any person who prepares sewage sludge, applies sewage sludge to the land, or fires sewage sludge in a sewage sludge incinerator and to the owner/operator of a surface disposal site.

(2) This part applies to sewage sludge applied to the land, placed on a surface disposal site, or fired in a sewage sludge incinerator.

(3) This part applies to the exit gas from a sewage sludge incinerator stack.

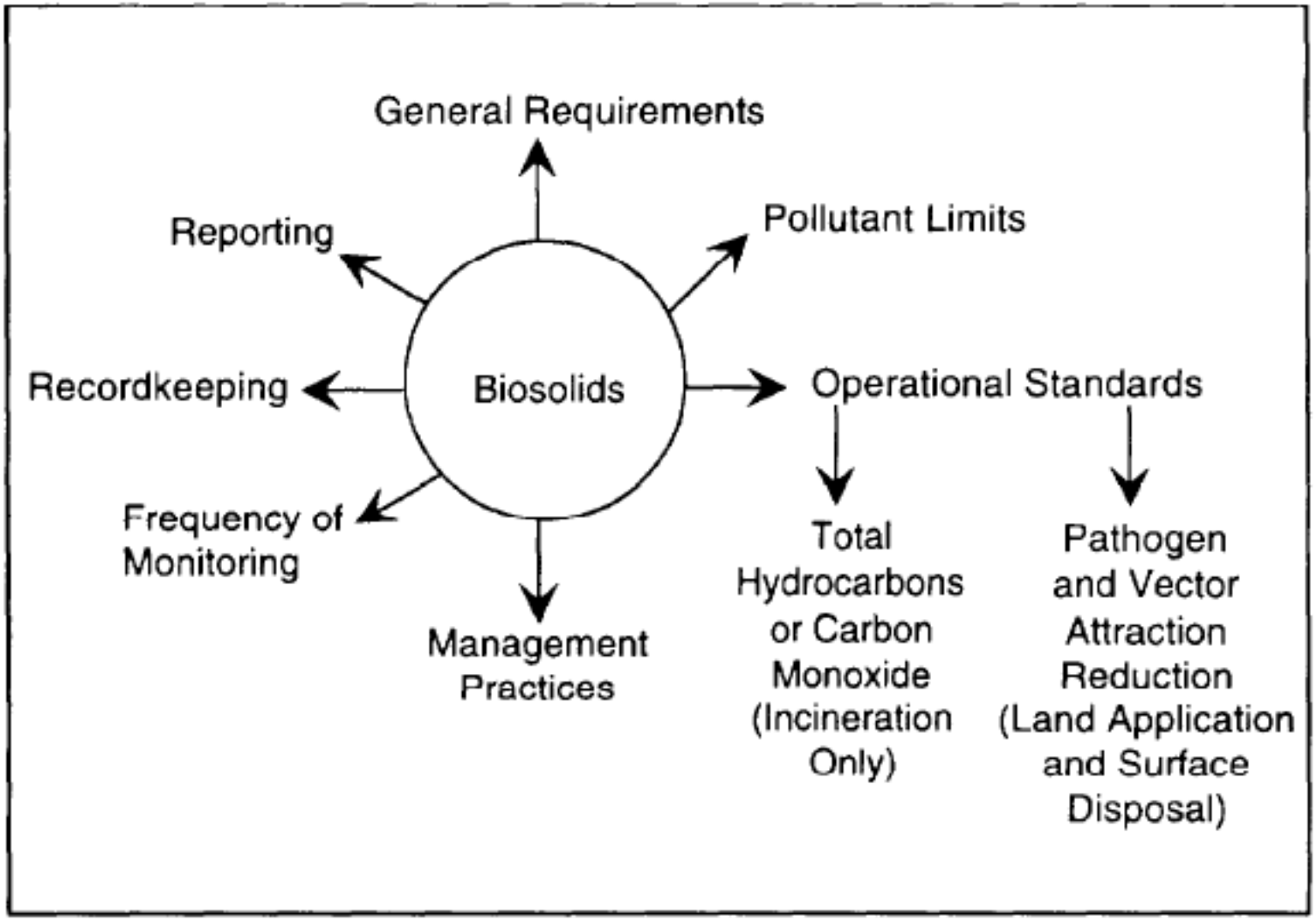
(4) This part applies to land where sewage sludge is applied, to a surface disposal site, and to a sewage sludge incinerator.

§ 503.2 Compliance period.

(a) Compliance with the standards in this part shall be achieved as expeditiously as practicable, but in no case later than February 19, 1994. When compliance with the standards requires construction of new pollution control facilities, compliance

1

General Provisions



General Provisions

- Applies to sewage sludge and septage
- Does not apply to grease interceptor wastes, industrial sludge, grit and screenings (40 CFR Part 258 - MSW in landfills)
- Monitoring, recordkeeping within 150 days
- Within 2 years if need new construction
- Annual reporting for > 1 MGD (3.78 MLD) and > 10,000 people

Land Application

- As fertilizer or soil conditioner, applied at agronomic rates

- Requirements
  - Non Hazardous
  - Criteria Pollutants
  - Pathogen Content
  - Vector Attraction Reduction

To be considered non-hazardous

- Must meet requirements of 40 CFR 261:
  - Ignitable
  - Corrosive
  - Reactive
  - Toxic

PART 261—IDENTIFICATION AND LISTING OF HAZARDOUS WASTE

Subpart A—General

Sec.
261.1 Purpose and scope.
261.2 Definition of solid waste.
261.3 Definition of hazardous waste.
261.4 Exclusions.
261.5 Special requirements for hazardous waste generated by conditionally exempt small quantity generators.
261.6 Requirements for recyclable materials.
261.7 Residues of hazardous waste in empty containers.
261.8 PCB wastes regulated under Toxic Substances Control Act.
261.9 Requirements for Universal Waste.

Subpart B—Criteria for Identifying the Characteristics of Hazardous Waste and for Listing Hazardous Waste

261.10 Criteria for identifying the characteristics of hazardous waste.
261.11 Criteria for listing hazardous waste.

Subpart C—Characteristics of Hazardous Waste

261.20 General.
261.21 Characteristic of ignitability.
261.22 Characteristic of corrosivity.
261.23 Characteristic of reactivity.
261.24 Toxicity characteristic.

Subpart D—Lists of Hazardous Wastes

261.30 General.
261.31 Hazardous wastes from non-specific sources.
261.32 Hazardous wastes from specific sources.
261.33 Discarded commercial chemical products, off-specification species, container residues, and spill residues thereof.
261.35 Deletion of certain hazardous waste codes following equipment cleaning and replacement.
261.38 Comparable/Syngas Fuel Exclusion.

APPENDIX I TO PART 261—REPRESENTATIVE SAMPLING METHODS

APPENDIX II TO PART 261—METHOD 1311 TOXICITY CHARACTERISTIC LEACHING PROCEDURE (TCLP)

APPENDIX III TO PART 261—CHEMICAL ANALYSIS TEST METHODS

APPENDIX IV TO PART 261—[RESERVED FOR RADIOACTIVE WASTE TEST METHODS]

APPENDIX V TO PART 261—[RESERVED FOR INCINERATOR WASTE TREATMENT SPECIFICATIONS]

APPENDIX VI TO PART 261—[RESERVED FOR ETIOLOGIC AGENTS]

APPENDIX VII TO PART 261—BASIS FOR LISTING HAZARDOUS WASTE

APPENDIX VIII TO PART 261—HAZARDOUS CONSTITUENTS

APPENDIX IX TO PART 261—WASTES EXCLUDED UNDER §§260.20 AND 260.22

AUTHORITY: 42 U.S.C. 6905, 6912(a), 6921, 6922, 6924(y) and 6938.

SOURCE: 45 FR 33119, May 19, 1980, unless otherwise noted.

Subpart A—General

§ 261.1 Purpose and scope.

(a) This part identifies those solid wastes which are subject to regulation as hazardous wastes under parts 262 through 265, 268, and parts 270, 271, and 124 of this chapter and which are subject to the notification requirements of section 3010 of RCRA. In this part:

(1) Subpart A defines the terms "solid waste" and "hazardous waste", identifies those wastes which are excluded from regulation under parts 262 through 266, 268 and 270 and establishes special management requirements for hazardous waste produced by conditionally exempt small quantity generators and hazardous waste which is recycled.

(2) Subpart B sets forth the criteria used by EPA to identify characteristics of hazardous waste and to list particular hazardous wastes.

(3) Subpart C identifies characteristics of hazardous waste.

(4) Subpart D lists particular hazardous wastes.

(b)(1) The definition of solid waste contained in this part applies only to wastes that also are hazardous for purposes of the regulations implementing subtitle C of RCRA. For example, it does not apply to materials (such as non-hazardous scrap paper, textiles, or rubber) that are not otherwise hazardous wastes and that are recycled.

(2) This part identifies only some of the materials which are solid wastes and hazardous wastes under sections 3007, 3013, and 7003 of RCRA. A material which is not defined as a solid waste in this part, or is not a hazardous waste identified or listed in this part, is still a solid waste and a hazardous waste for purposes of these sections if:

(i) In the case of sections 3007 and 3013, EPA has reason to believe that

1

Criteria pollutants: ceiling and "exceptional quality" limits

	Ceiling Limits Table 1 40 CFR 503.13 (mg/kg-dry)	EQ Limits Table 3 40 CFR 503.13 (mg/kg-dry)
Arsenic	75	41
Cadmium	85	39
Copper	4,300	1,500
Lead	840	300
Mercury	57	17
Molybdenum	75	
Nickel	420	420
Selenium	100	100
Zinc	7,500	2,800

If between EQ and Ceiling Limits, must track CPLR and APLR

	Cumulative PLR Table 2 40 CFR 503.13 (kg/hectare)	Annual PLR Table 4 40 CFR 503.13 (kg/year - hectare)
Arsenic	41	2.0
Cadmium	39	1.9
Copper	1,500	75
Lead	300	15
Mercury	17	0.85
Molybdenum		
Nickel	420	21
Selenium	100	5
Zinc	2,800	140

Annual Whole Sludge Application Rate

$$AWSAR = APLR / (C \times 0.001)$$

AWSAR = dry tons/ha per year

APLR = from previous table, kg/ha per year

C = pollutant concentration, mg/kg

Choose lowest AWSAR out of all pollutants

Pathogen Reduction Requirements

- Class A – below detection limits in 1993
  - < 1,000 MPN fecal coliform/ g solids (dry); OR
  - < 3 MPN Salmonella/ 4 g solids (dry)
  - ➢ 6 Alternatives to achieve Class A
    - ✓ 1. 60 C for > 20 min, other temperature-time combinations
    - ✓ 2. pH > 12 for 72 hours; 52 C for . 12 hours; after which air-dried to > 50% solids
    - ✓ 3. < 1 PFU enteric viruses /4 g dry solids; AND < 1 helminth ova /4 g dry solids
    - ✓ 4. Same as 3, or other processes
    - ✓ 5. PFRP
    - ✓ 6. Processes similar to PFRP

Processes to Further Reduce Pathogens (PFRP) – Class A

- 1. Composting - Using either the within-vessel composting method or the static aerated pile composting method, maintained at 55 degrees Celsius or higher for three days.
- Using the windrow composting method, the temperature of the sewage sludge is maintained at 55 degrees or higher for 15 days or longer. During the period when the compost is maintained at 55 degrees or higher, there shall be a minimum of five turnings of the windrow.

Processes to Further Reduce Pathogens (PFRP) – Class A

- 2. Heat drying - Sewage sludge is dried by direct or indirect contact with hot gases to reduce the moisture content of the sewage sludge to 10 percent or lower. Either the temperature of the sewage sludge particles exceeds 80 degrees Celsius or the wet bulb temperature of the gas in contact with the sewage sludge as the sewage sludge leaves the dryer exceeds 80 degrees Celsius.
- 3. Heat treatment - Liquid sewage sludge is heated to a temperature of 180 degrees Celsius or higher for 30 minutes.

Processes to Further Reduce Pathogens (PFRP) – Class A

- 4. Thermophilic aerobic digestion – Mean cell residence time of the sewage sludge is 10 days at 55 to 60 C.
- 5. Beta ray irradiation - beta rays from an accelerator at dosages of at least 1.0 megarad at room temperature (ca. 20 degrees Celsius).
- **(6)** Gamma ray irradiation - 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 ° Celsius).
- 7. Pasteurization - maintained at 70 degrees Celsius or higher for 30 minutes or longer.

Pathogen Reduction Requirements

- Class B – below detection limits **before public contact** (1993 methods), and equivalent to anaerobic digestion

3 Alternatives

- Alternative 1. < 2 x 10^6 MPN fecal coliform/ g solids (dry) (7 samples, geometric mean)

- Alternative 2. PSRP
- Alternative 3. Processes similar to PSRP

Processes to Significantly Reduce Pathogens (PSRP)- Class B

- ***Aerobic digestion*** –
  - 40 days @ 20 C; 60 days @15 C
- ***Air drying*** –
  - for 3 months; at least 2 months > 0 C
- ***Anaerobic digestion*** –
  - 5 days @ 35-55 C; 60 days at 20 C
- ***Composting*** -
  - > 40 C for > 5 days and 4 hours > 55 C
- ***Lime stabilization*** –
  - pH to 12 after 2 hours

Site Restrictions for Class B

- **Food crops**
  - above ground – 14 months after application
  - Below ground – 20 months if sludge unincorporated for > 4 months
  - Below ground – 38 months if unincorporated < 4 months
- **Feed crops, fiber crops** – 30 days
- **Grazing animals** – 30 days
- **Turf grass** – 1 year before harvesting
- **Public access-** 30 days or 1 year depending on potential for public exposure

Vector attraction reduction requirements are regulated under 40 CFR 503.33.

Table 2.3 Vector Attraction Reduction Methods

1. Volatile Solids Reduction by a minimum of 38 percent
2. Volatile Solids Reduction additional testing for anaerobic digestion
3. Volatile Solids Reduction additional testing for aerobic digestion
4. Specific Oxygen Uptake Rate (SOUR) equal to or less than 1.5 milligrams of oxygen per hour per gram of dry solids at 20 degrees Celsius (°C)
5. Aerobic process for a minimum of 14 days at a temperature of greater than 40°C and an average temperature greater than 45°C
6. pH of 12 or higher by alkaline addition, and the maintenance of at least pH 12 for two hours without addition of more alkaline material; then pH 11.5 or higher for an additional 22 hours
7. A total solids concentration equal to or greater than 75 percent for a material that does not include unstabilized solids generated in a primary treatment process prior to mixing with other materials
8. A total solids concentration equal to or greater than 90 percent for a material that contains unstabilized solids generated in a primary treatment process prior to mixing with other materials
9. Injection of liquid biosolids below the land surface
10. Incorporation of biosolids that have been surface applied or placed on a surface disposal site within 6 hours after application to or placement on the land
11. Biosolids placed in an active disposal unit shall be covered with soil or other material at the end of each operating day
12. The pH of domestic septage shall be raised to 12 or higher by alkaline addition and, without further alkaline addition, remain at 12 or higher for 30 minutes.

Biennial Reviews

- CWA (Section 405) requires review every 2 years
  - Toxicity
    - ✓ Reference dose, reference concentrations, cancer slope factor, lethal dose, lethal concentrations, chronic endpoints
  - Acceptable concentration data
  - Fate and transport data

2003 Review

- 803 chemicals found in sewage sludge
- Sufficient data = 40 out of 803
- Potential risk to human health and environment = 15 out of 40
- Exposure and hazard assessment = 9 out of 40

2005 Review

- EPA examined 137 chemicals
- Updated information for 19

Table 2. Selected Chemicals Evaluated in the Literature Search

Chemical	CAS Registry Number
Metals	
Antimony[1]	7440-36-0
Barium* [1]	7440-39-3
Beryllium*	7440-41-7
Cobalt[3]	7440-48-4
Iron[3]	7439-89-6
Manganese*	7439-96-5
Molybdenum[5]	7439-98-7
Silver*	7440-22-4
Thallium[2]	7440-28-0
Polycyclic Aromatic Hydrocarbon	
Benzo(a)pyrene[2]	50-32-8
Fluoranthene*	206-44-0
2-Methylnaphthalene[1]	91-57-6
Pyrene*	129-00-0
Semi-volatiles	
Bis(2-ethylhexyl)phthalate[2]	117-81-7
4-Chloroaniline*	106-47-8
Inorganic Ions	
Fluoride[2]	16984-48-8
Nitrate*	14797-55-8
Nitrite*	14797-65-0
Phosphate (total)[4]	14265-44-2

2007 Review

Table 2. List of Pollutants Evaluated During 2007 Biennial Review with Human Health Benchmarks

Constituent Name	CASRN	IRIS or OPP[1]	Class
Aluminum	7429-90-5		metal
Bisphenol A	80-05-7	IRIS	plasticizer
Cobalt	7440-48-4		metal
Cresol, p- (4-methylphenol)	106-44-5	IRIS	preservative
Phenanthrene	85-01-8		PAH
Phosphorus	7723-14-0	IRIS	nutrient
Triclosan	3380-34-5	OPP	disinfectant

1/ EPA's Integrated Risk Information System (IRIS) or EPA's Office of Pesticide Programs (OPP). If

- But no source concentration, ecological factors, fate and transport data

2009 Review

- 14 chemicals with human health benchmarks
- 35 chemicals lacking HHB data

Table 2. Pollutants Evaluated During the 2009 Biennial Review With Human Health Benchmarks

Constituent Name	CAS Number	Class
17β-Estradiol	50-28-2	hormone
Chlortetracycline	57-62-5	antibiotic
Decabromodiphenyl ether	1163-19-5	PBDE
Erythromycin	114-07-8	antibiotic
Lincomycin	154-21-2	antibiotic
Oxytetracycline	6153-64-6	antibiotic
Pentabromodiphenyl ether	32534-81-9	PBDE
Progesterone	57-83-0	hormone
Sulfamethazine	57-68-1	antibiotic
Testosterone	58-22-0	hormone
Tetracycline	60-54-8	antibiotic
Triclosan	3380-34-5	antimicrobial
Trimethoprim	738-70-5	antibiotic
Virginiamycin	21411-53-0	antibiotic

2009 Targeted National Sewage Sludge Survey

Table 4-2. Nationally-Representative Estimates of Detection Percentages in Biosolids for Analytes Included in the In-Depth Statistical Analysis

	Analytes	Detection Percentage
Metals	Barium	100%
	Beryllium	98.5%
	Manganese	100%
	Molybdenum	100%
	Silver	100%
Organics	4-Chloroaniline	74.4%
	Fluoranthene	89.5%
	Pyrene	84.9%
Classicals	Nitrate/Nitrite	100%
PBDEs	BDE-47	100%
	BDE-99	100%
	BDE-153	100%
	BDE-209	98.5%
Pharmaceuticals	4-Epitetracycline (ETC)	96.0%
	Azithromycin	96.0%
	Carbamazepine	96.0%
	Cimetidine	89.9%
	Ciprofloxacin	100%
	Diphenhydramine	100%
	Doxycycline	92.8%
	Erythromycin-Total	92.9%
	Fluoxetine	96.1%
	Miconazole	95.8%
	Ofloxacin	98.5%
	Tetracycline (TC)	97.5%
	Triclocarban	100%
	Triclosan	92.4%
Steroids and Hormones	Beta Stigmastanol	98.5%
	Campesterol	100%
	Cholestanol	100%
	Cholesterol	96.9%
	Coprostanol	100%
	Epicoprostanol	98.5%
	Stigmasterol	90.1%

2009 Targeted National Sewage Sludge Survey

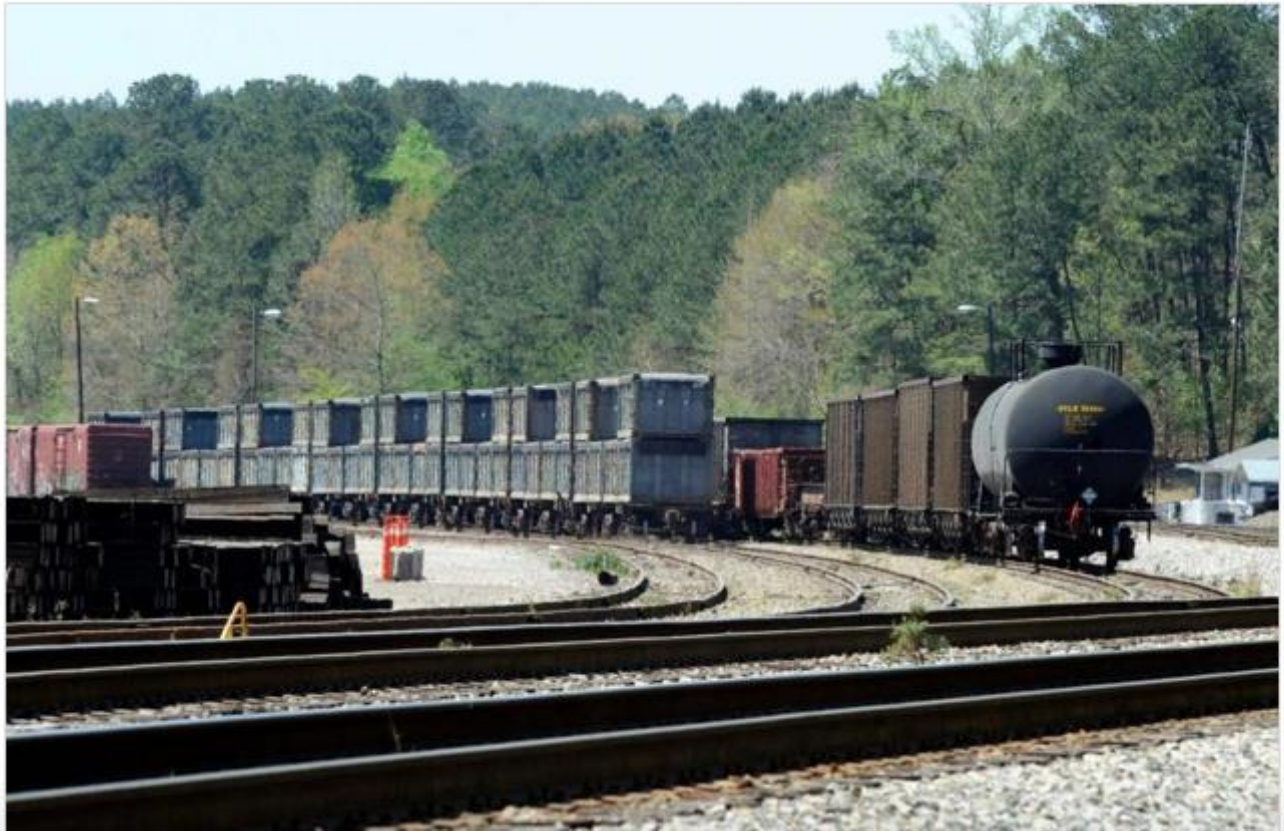
Table 4-3. Nationally-Representative Estimates of Detection Percentages in Biosolids for Analytes Not Included in the In-Depth Statistical Analysis

	Analytes	Detection Percentage	Analytes	Detection Percentage
Metals	Aluminum	100%	Mercury	100%
	Antimony	87.8%	Nickel	100%
	Arsenic	100%	Phosphorus	100%
	Boron	97.1%	Selenium	100%
	Cadmium	100%	Sodium	100%
	Calcium	100%	Thallium	94.1%
	Chromium	100%	Tin	94.1%
	Cobalt	100%	Titanium	98.5%
	Copper	100%	Vanadium	100%
	Iron	100%	Yttrium	100%
	Lead	100%	Zinc	100%
	Magnesium	100%		
Organics	2-Methylnaphthalene	40.9%	Bis(2-ethylhexyl) phthalate	100%
	Benzo(a)pyrene	77.1%		
Classicals	Fluoride	100%	Water-Extractable Phosphorus	100%
PBDEs	BDE-28	100%	BDE-138	65.5%
	BDE-66	100%	BDE-154	100%
	BDE-85	100%	BDE-183	100%
	BDE-100	100%		
Pharmaceuticals	1,7-Dimethylxanthine	4.7%	Lomefloxacin	2.9%
	4-EACTC	0%	Metformin	6.5%
	4-EATC	38.8%	Minocycline	48.2%
	4-ECTC	1.4%	Naproxen	50.5%
	4-EOTC	11.3%	Norfloxacin	36.2%
	Acetaminophen	3.0%	Norgestimate	0%
	Albuterol	1.5%	Ormetoprim	1.5%
	ACTC	1.5%	Oxacillin	0%
	Anhydrotetracycline (ATC)	64.9%	Oxolinic Acid	0.2%
	Caffeine	47.4%	Oxytetracycline (OTC)	38.2%
	Carbadox	0%	Penicillin G	0%
	Cefotaxime	0%	Penicillin V	0%
	Chlortetracycline (CTC)	1.4%	Ranitidine	60.6%
	Clarithromycin	54.8%	Roxithromycin	3.0%
	Clinafloxacin	0%	Sarafloxacin	2.9%
	Cloxacillin	0%	Sulfachloropyridazine	3.1%
	Codeine	23.3%	Sulfadiazine	4.5%
	Cotinine	47.4%	Sulfadimethoxine	7.0%
	Dehydronifedipine	23.0%	Sulfamerazine	0.1%
	Demeclocycline	4.6%	Sulfamethazine	2.8%
	Digoxigenin	0%	Sulfamethizole	0%
	Digoxin	0%	Sulfamethoxazole	40.8%
	Diltiazem	83.1%	Sulfanilamide	12.0%
	Enrofloxacin	15.8%	Sulfathiazole	0.1%
	Flumequine	0%	Thiabendazole	71.7%
	Gemfibrozil	87.8%	Trimethoprim	27.3%
	Ibuprofen	64.4%	Tylosin	0%
	Isochlortetracycline (ICTC)	1.4%	Virginiamycin	18.9%
	Lincomycin	4.6%	Warfarin	0%

Alabama Mayor: 'Poop Train' Finally Empty; Sludge Gone

An Alabama mayor says the last train car full of New York City sewage sludge that has stunk up her town has finally been emptied.

April 19, 2018, at 11:35 a.m.



Continuing pressure also exists for regulatory change on several fronts.

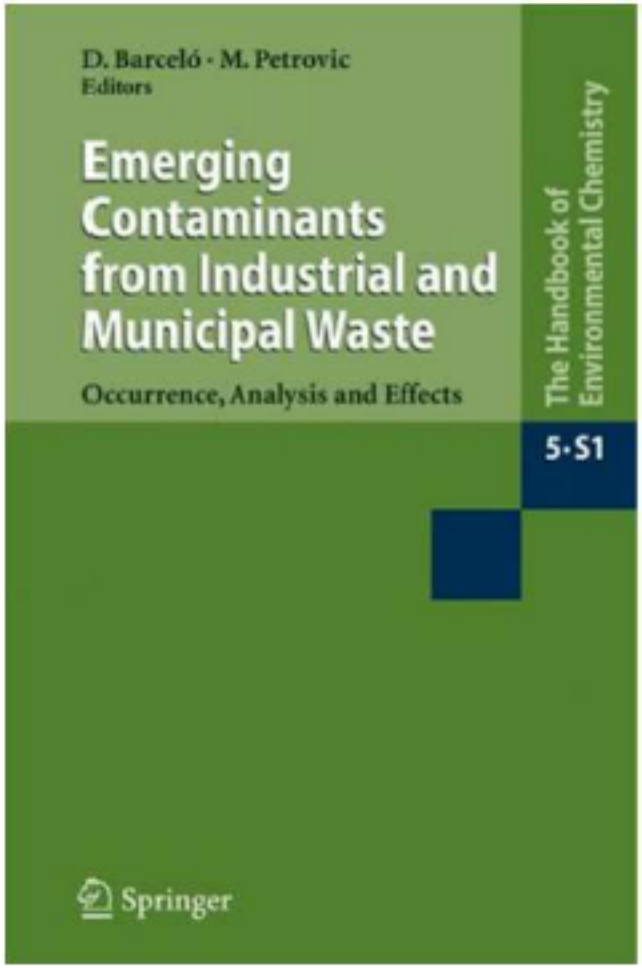
Emerging Contaminants

- Endocrine Disruptors
- Pharmaceuticals
- Personal Care Products
- Flame Retardants
- Dioxins
- Fluorinated Organics

Pathogens

- Bacteria
- Virus

Odors & Bioaerosols



Some thoughts (technical)

- Risk-based approach (Quantitative Risk Assessment) was used for criteria pollutants, but not pathogens

- Pathogen limits – not based on QMRA, but based on detection limits – time to re-evaluate? QMRA as a tool for developing treatment
- Additional indicators? e.g., *Clostridium perfringens*
- Geographic and site restrictions?
- Major and minor exposure pathways (also secondary transmission)

Thoughts- non technical

- True costs, true benefits
- Action in the context of imperfect, incomplete information
- Common goals and optimism