Concerns with Application of Sewage Sludge Products on Farm Land

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Sewage Sludge Generation

- Influents are from homes, hospitals, research facilities, industries, businesses and street runoff
- Some industrial discharges to WWTPs are allowed
- WWTPs are designed to clean water
- Contaminants preferentially concentrated from wastewater into sewage sludges (e.g., at least 90-95% of persistent organic pollutants and metals in wastewater end up in sludge)
- Biodegradation of many of the organic pollutants is minimal
- Sewage sludge quality varies over time at any single WWTP
- Sewage sludge quality varies widely at different WWTPs

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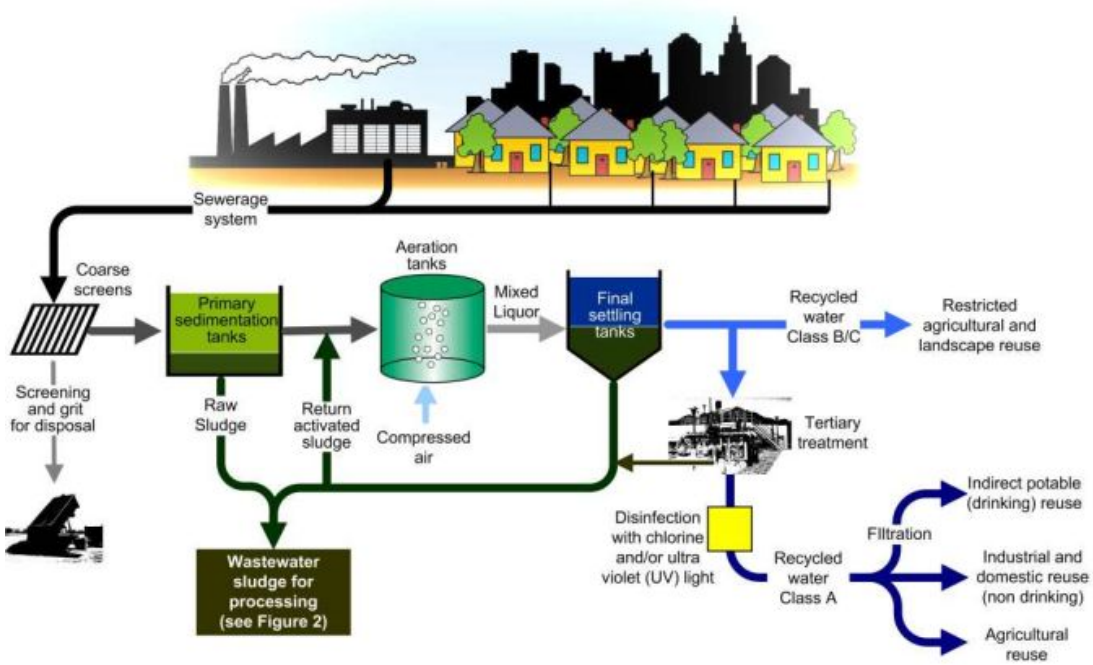
A Simplified Diagram of Sewer Wastewater Treatment



Note: The EPA's National Pretreatment Program permits each point source (business or industry) to discharge thousands of pounds of toxic waste into the sewer. In principle, EPA regulates 126 priority pollutants in discharge, including synthetic chemicals and the metals:

Beryllium Cadmium Chromium Copper Lead Mercury Nickel Selenium Silver Thallium Zinc

Why apply sludges on farms ?

- Recycle N and P from human waste
- Soil benefits - nutrients, organic matter
- Income or off-set of N and P fertilizer costs to farmer
- Low cost disposal option for municipality

50-60% of US sludges are land applied

Average NPK nutrient values of NYS sewage sludges (2009 DEC data)

Total N = 4.51 ± 2.05
Total P = 1.93 ± 1.10
Total K = 0.20 ± 0.16

Application rates in NYS are based on N requirement of the crop.

Note : this is not a balanced fertilizer- Application based on N requirement overapplies P and underapplies K

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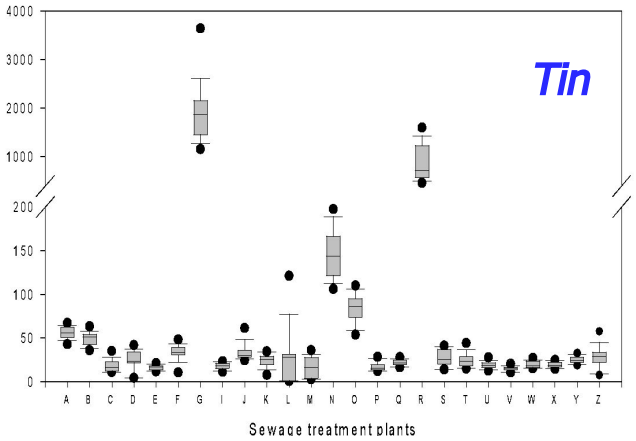
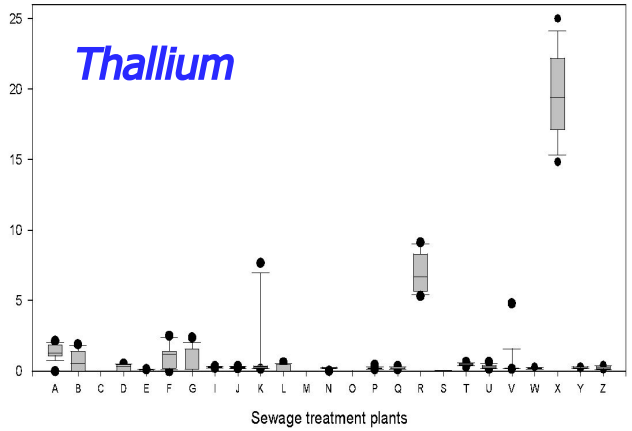
EPA and NY DEC Rules for Toxins In Land-Applied Sludge

- **Only 9 (EPA) or 10 (DEC) metals have sludge quality (ppm) and/or soil loading (lbs/acre) limits**
- **Limits are based on an outdated 1993 risk assessment using inadequate data and non-cautious assumptions**
- **<u>No</u> synthetic (organic) chemicals are regulated**
- **Present-day sludges commonly contain chemicals/toxic metals that are not regulated because earlier EPA research had not looked for or detected them**

Tin concentrations in Ontario sewage biosolids



Thallium concentrations in Ontario sewage biosolids



Data courtesy of J. Hargreaves, Univ. of Guelph and Ontario M.O.E.

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EPA Terminology

Class B sludge -pathogens reduced to levels thought to protect public health UNDER SPECIFIC USE CONDITIONS (site restrictions apply)

Class A sludge - treated to further REDUCE pathogens (based on salmonella or coliform bacteria counts) so that no pathogen-related restrictions apply

"Exceptional Quality" (EQ) – there is no "official" definition of EQ in the 503 Rule. The term is , however, commonly used to describe class A biosolids with concentrations of the 9 EPA regulated metals lower than the risk-derived limits (e.g., 39 ppm Cd, 2800 ppm Zn)

EQ sludges can be farm-applied without regard for total toxic metal loading on soil

EQ metal levels allow much higher metal loading on soil than standards of most other countries

EQ classification in no way indicates the levels of toxic synthetic chemicals or non-regulated metals in sludges

Table 1. Standards for land application of sewage sludges

Contaminant	***NYS DEC***[1]	***EPA 503***	***EPA 503***	***NYS DEC***[4]	***Cornell Field Crop Guide***[5]
	Monthly Average/ Maximum (ppm)	*EQ limit (ppm)*	*Ceiling limit (ppm)*[3]	*Cumulative limit (lb/ac)*	*Recommended Maximum Concentration (ppm)*
	Sludge Concentration	*Sludge Concentration*	*Sludge Concentration*	*Applied to Soil*	*Soil Concentration*
Arsenic	41/75	41	75	none	1-10[6]
Cadmium	21/85	39	85	3/4	2[7]
Chromium	1,000/1,000	none	none	300/446	[8]
Copper	1,500/4,300	1,500	4,300	75/112	40-100[9]
Lead	300/840	300	840	267/267	[10]
Mercury	10/57	17	57	none	1[11]
Molybdenum	40/75	none[2]	75	none	2-4[12]
Nickel	200/420	420	420	30/45	25-50[13]
Selenium	100/100	100	100	none	5[14]
Zinc	2,500/7,500	2,800	7,500	150/223	75-200[15]

Note: Concentrations are in dry weight.

DEC soil cumulative loading limits do not apply to Class A products that meet the sludge metal concentration limits

EPA and DEC-permitted loadings of metals on soils allow Cornell recommendations to be exceeded

The DEC cumulative limits allow a calculation of "site life" for a farm or field

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Concerns about using sludges on farmland

Contaminants (pathogens, metals, synthetic chemicals)

- potential food crop contamination
- potential dairy product and meat contamination
- reduced forage quality due to contaminant uptake and effects on livestock health
- possible groundwater contamination

Excess nutrients

- too much N and P for livestock farms

Odor and bioaerosols (pathogens & endotoxins)

- Off-site impacts on human health

Variable and unpredictable composition of sludge

Pathogens in Class B Sewage Sludge

- Bacteria (incl. *E. coli* O-157), viruses, protozoa (Giardia, Cryptosporidium), helminths (parasitic worms).
- > 100 species of bacterial pathogens recently identified in a sludge
- Only testing required is for fecal coliform and/or salmonella bacteria (no virus testing)
- < 2 million coliform/gram required for land spreading of class B sludge
- Pathogenic viruses shed in human feces include adenovirus, astrovirus, calicivirus, enterovirus , Hepatitis A (HAV), Hepatitis E (HEV), rotavirus
- Anaerobic digestion by WWTP reduces viral numbers , but 100-10,000 per kg remain in sludge*
- All these enteric viruses are relatively heat resistant and tolerant of acid conditions
- Viruses have lower infective doses (1-100) than bacteria (100-1,000,000)
- Controlled composting (131° F or 55°C for 2 weeks) can inactivate essentially all these viruses

*Soares et al., 1994. J.Environ. Sci. Health

Environmental Fate of Pathogens in Land-Applied Sewage Sludge

-enteric viruses and some bacteria can persist for a long time after application to soil (6 months or longer)

-cool, wet conditions favor long-term survival of viruses/bacteria

- viruses cannot multiply during sludge storage or after application to land, but some bacterial pathogens re-grow

*- viruses known to move through soils as far as 25-30 m into well water**

*- pathogenic bacteria can migrate to shallow groundwater rapidly via pref. flow ***

**Goyal et al., Water Res., 1984*
***Arnaud et al., J. Env. Qual. 2015*

Danish Environmental Protection Agency Report. Occurrence and survival of Viruses in composted human faeces. 2000

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Are Pathogens a Concern in Class A Sludges ?

- **EPA position is that Class A "biosolids" are pathogen-free when either *Salmonella* spp. are absent or fecal coliforms are < 1000/dry gram**
- **Recent research reveals that class A "biosolids" are not pathogen-free, and that fecal coliform removal is a poor indicator of non-Salmonella pathogen content in biosolids[1]**
- **Regrowth of some pathogenic bacteria in Class A materials can occur in storage, after field application, or upon mixing with fresh organic material[2]**
- **Sludge products and composts meeting Class A/EQ standards at the point of origin may exceed pathogen standards later**

1. Viau, E et al. (2011). Environ. Sci. Technol. 45, 5459-5469
2. Zaleski et al.(2005). J. Residuals Science & Technol., 2,49.

"the failure of measurements of single indicator organism to correlate with pathogens suggests that public health is not adequately protected by simple monitoring schemes based on detection of a single indicator"

Harwood et al. (2005) Applied & Environ. Micro., 71, 3163-3170. University of South Florida. (cited 203 times to date)

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Metals and other Potentially Toxic Chemicals in Sewage Sludges

EPA Targeted National Sewage Sludge Survey -2009

145 analyte concentrations reported in sewage sludges, including metals, organics, brominated fire retardants, pharmaceuticals, steroids, hormones

Sewage sludges sampled from 74 POTWs that are considered to statistically represent 3,337 POTWs in USA with secondary treatment and flow rates of > 1 million gallons per day. (Smaller plants contribute only about 6% of total flow)

Single time point of sampling for each POTW, 84 samples in total

Some significant contaminants appear not to have been included in survey (e.g., dioxins, bisphenol-A, tungsten)

Inorganics in WWTP Sewage Sludges (mg/kg)

Contaminant	Low	Median	90th percentile	High	Plant I.D.
Ba	75	430	1,240	3,460	74
Be	0.04	0.27	0.89	2.34	55
Mn	34.8	400	2,960	14,900	24
Mo	2.51	10.6	36.9	132	19
Ag	1.94	13.1	40.1	856	27
Sb	0.01	1.54	4.03	26.6	19
As	1.18	4.97	13.3	49.2	55
B	5.70	31.9	107	204	19
Cd	0.21	1.74	7.04	11.8	34
Cr	6.74	34.6	213	1,160	57
Co	0.87	4.44	16.5	290	37
Cu	115	449	955	2,580	74
Fe	1,580	15,500	59,300	299,000	19
Pb	5.81	45.5	173	450	74
Hg	0.17	0.83	2.60	8.26	74
Ni	7.44	23.3	120	526	71

Contaminant	Low	Median	90th percentile	High	Plant I.D.
P	2,620	17,600	35,100	118,000	19
Se	1.10	6.10	13.8	24.7	74
Na	154	927	5,770	26,600	62
Tl	0.02	0.12	0.38	1.68	55
Sn	7.50	36.4	82.2	522	7
Ti	11.6	83.1	453	7,020	18
V	2.04	13.3	107	617	4
Zn	216	770	1,570	8,550	57
NO_3^- /NO_2^-	1.60	13.6	405	6,120	35
fluoride	7.60	49.9	98	234	73
water-sol. P	11.0	370	2,050	9,550	54

Synthetic Organic Chemicals in Sludge

- Many thousand chemicals in use, including many introduced since EPA 503 Rule
- Some of these chemicals (e.g., fire retardants) are very persistent and long-lived in soils (POPs)
- Few studied for toxicity
- Few studied for crop uptake potential
- None regulated for agricultural land application in US under EPA Part 503:

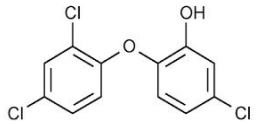
All eliminated by EPA from regulation due to:

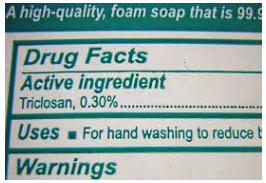
-calculated low hazard index or cancer risk
- no longer being produced (e.g., PCBs)
- detected in < 10% of sludges in NSSS
- lack of data

Pharmaceuticals in US MSW Sewage Sludges (µg/kg)

EPA Targeted Survey Data

chemical	*low*	*median*	*90%*	*high*	*Plant ID*
epitetracycline	41.4	541	2,070	4,380	67
azithromycin	8.45	224	2,140	6,530	19
carbamazepine	8.74	37.6	320	6,030	74
cimetidine	nd	163	2,600	9,780	19
ciprofloxacin	74.5	5,560	18,600	47,500	19
diphenhydramine	36.7	562	1,810	5,730	3
doxycycline	33.8	489	1,160	5,090	9
erythromycin	1.69	16.4	74.9	180	9
fluoxetine	nd	150	359	3,130	70
miconazole	7.28	433	1,500	9,210	54
ofloxacin	25.3	3,720	16,200	58,100	20
tetracycline	38.3	540	2,600	5,270	70
triclocarban	187	20,600	71,900	441,000	20
triclosan	334	8,000	26,700	133,000	34





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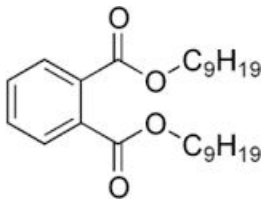
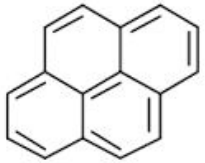
PAHs and Plasticizers in US MSW Sludges

EPA Targeted Survey Data

Selected Organics

Contaminant (ug/kg)	Low	Median	90 percentile	High	Max Plan I.D.
chloroaniline	51	763	2,200	5,900	20
fluoranthene	45	560	4,000	12,000	8
pyrene	44.2	720	4,200	14,000	13
2-methylnaphthalene	10.0	200	870	4,600	22
benzo(a)pyrene	25.8	320	2,000	4,500	53
bis(2-ethylhexyl) phthalate	657	24,000	130,000	310,000	5





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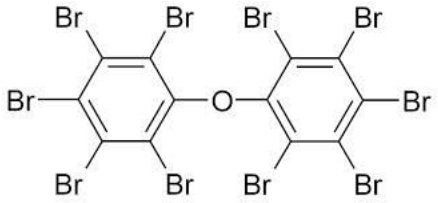
Polybrominated Fire Retardants (PBDE's) in US MSW Sludges

EPA Targeted Survey Data

Congener ID	low	median	90%	high	Max Plant
BDE 47	73,000	520,000	1,100,000	5,000,000	74
BDE 99	64,000	550,000	1,100,000	4,000,000	74
BDE 153	9,100	55,000	110,000	410,000	74
BDE 209	150,000	1,100,000	5,700,000	17,000,000	5 (74)
BDE 28	2,200	7,600	24,000	160,000	48
BDE 66	1,800	10,000	28,000	110,000	48
BDE 85	3,200	20,000	45,000	150,000	74
BDE 100	13,000	110,000	230,000	1,100,000	74
BDE 138	1,900	6,200	17,000	100,000	5
BDE 154	7,700	42,000	95,000	440,000	74
BDE 183	2,100	9,300	25,000	120,000	1

(ng/kg)



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EPA 503 Rules Have Not Prevented Land Contamination

EPA has concerns about illegal dumping into POTWs:

"Every discharge has the potential to affect the POTW. Unlike discharges from IUs directly connected to the POTW, the makeup of a load of hauled waste is virtually unknown without some type of monitoring, be it visual or analytical. Most waste haulers are reputable business people who provide a valuable service to the public and industry; However, the unique attributes of hauled waste can be devastating when unethical haulers dump incompatible wastes at POTWs"

From "USEPA. June 2011. Introduction to the National Pretreatment Program. Office of Wastewater Management. EPA-833-B-11-001

U.S. ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF INSPECTOR GENERAL

More Action Is Needed to Protect Water Resources From Unmonitored Hazardous Chemicals

Report No. 14-P-0363 **September 29, 2014**

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The U.S. EPA's Inspector General (U.S. EPA 2000) found that,

> while EPA promotes land application, EPA cannot assure the public that current land application practices are protective of human health and the environment.

From "Land Application of Treated Sewage Sludge: Community Health and Environmental Justice"

A. Lowman, M.A. McDonald, S. Wing, N. Muhammad (2013)
Environmental Health Perspectives, 121,537.
Dept. of Epidemiology, Univ. of North Carolina

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The 2002 National Research Council report,
"Biosolids Applied to Land"
recognizing the inadequacy of the 503 rules based on a quantitative risk assessment approach, recommended focusing on health end points and environmental tracking:

" even if a summary index of an adverse response to mixtures was available, it would not necessarily reflect the total hazards of exposure to biosolids because of the inability to identify all of its hazardous constituents and their potential for interaction in vivo . . . ***thus it is not possible to conduct a risk assessment for biosolids at this time (or perhaps ever)*** *that will lead to risk-management strategies that will provide adequate health protection without some form of ongoing monitoring and surveillance . . .* ***the degree of uncertainty requires some form of active health and environmental tracking.****"*

The Case for Caution

Because:

- **Our ability to confidently predict risks from land application is very limited**
  - **Contaminants concentrate in sewage sludges**
  - **Many unevaluated, "emerging" contaminants in sludges (503 looked only at indicator pathogens and 9 metals)**
  - **Present US standards are based on an outdated risk assessment with many shortcomings**
- **Liability rests largely with the farmer**
- **If there are problems, it is hard to prove cause**
- **Enforcement and monitoring are inadequate**
- **There have been many anecdotal reports of illness**
- **Farmland where our food is grown must be protected for future generations**