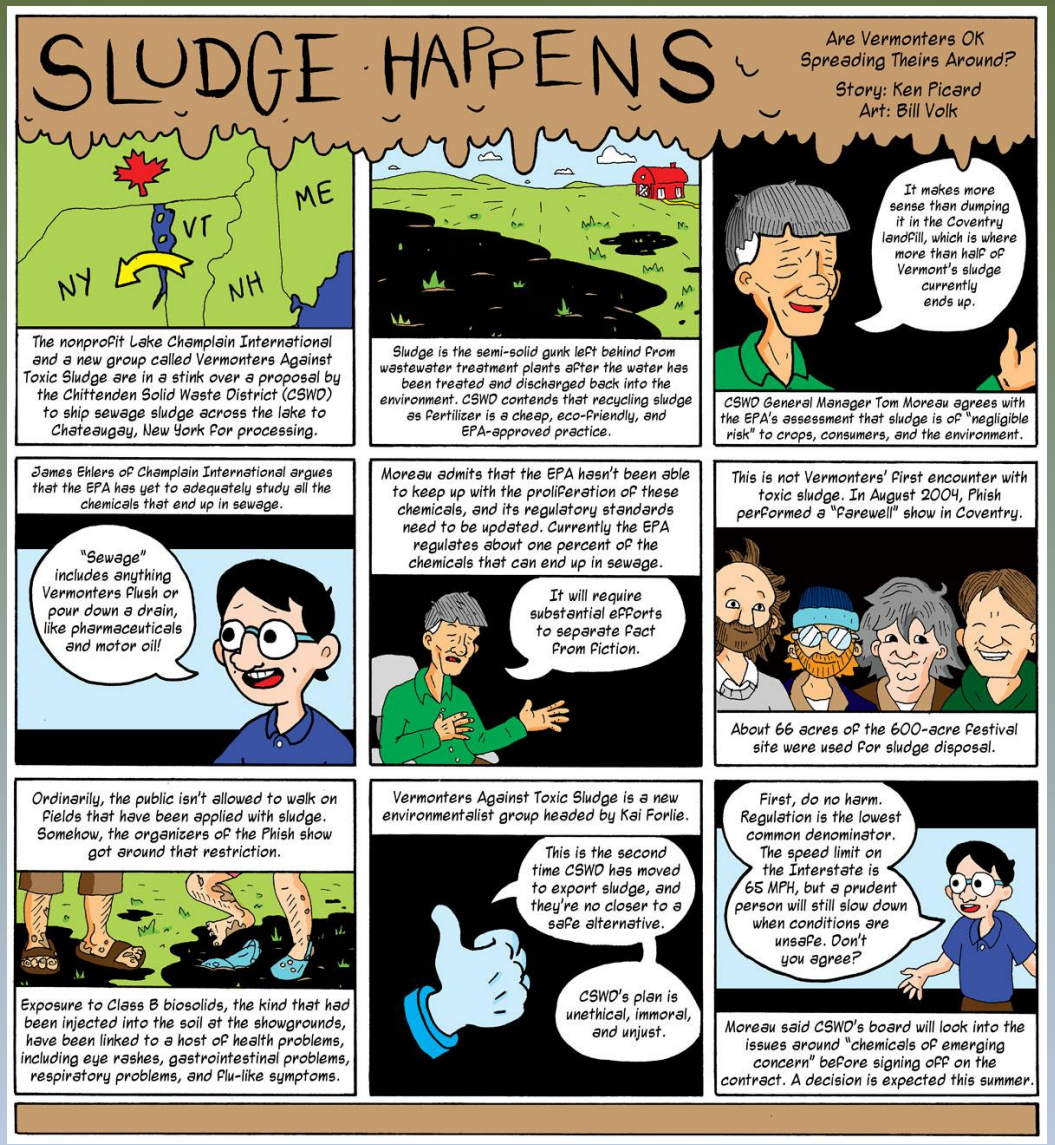
FORUM:
Wastewater Treatment Sludge and Septage Management in Vermont

December 9, 2015

VERMONT

“CSWD plan to send sludge to N.Y. draws criticism”
- VTDIGGER , Jan 2013



VERMONT DEPARTMENT OF ENVIRONMENTAL CONSERVATION
WATERSHED MANAGEMENT DIVISION
WASTEWATER PROGRAM

November 2013 Public Forum: Biosolids Management in Vermont

Chittenden Solid Waste District (CSWD)

Casella/New England Organics

Resource Management Inc. (RMI)

Vermonters Against Toxic Sludge / Toxic Actions Center

Northeast Biosolids & Residuals Association (NEBRA)

Rich Earth Institute (REI)

Local Farmers

VT DEC

Draft White Paper:

"Wastewater Treatment Sludge and Septage Management in Vermont"

September 2015

I.	Introduction
II.	***Residual Waste and Biosolids***
III.	***Current Biosolids Management: U.S., New England, and Vermont***
IV.	***Biosolids Regulation: Federal and Vermont***
V.	***Emerging Contaminants in Biosolids***
VI.	***Transport & Fate of Biosolids Bourne CECs in the Environment***
VII.	***Emerging Concerns for Pathogens***
VIII.	Reported Adverse Impacts to Human and Animal Health
IX.	Septage

To present a broad picture of the current state of biosolids management (Vermont) and of related scientific research

"It is not the intent of this paper to establish policy or regulation or to promote one means of residuals management over another."

II. Residual Wastes

Sludge (EPA defined): the solid, semisolid or liquid untreated residue generated during the treatment of domestic sewage in a treatment facility

Sludge -> Biosolids

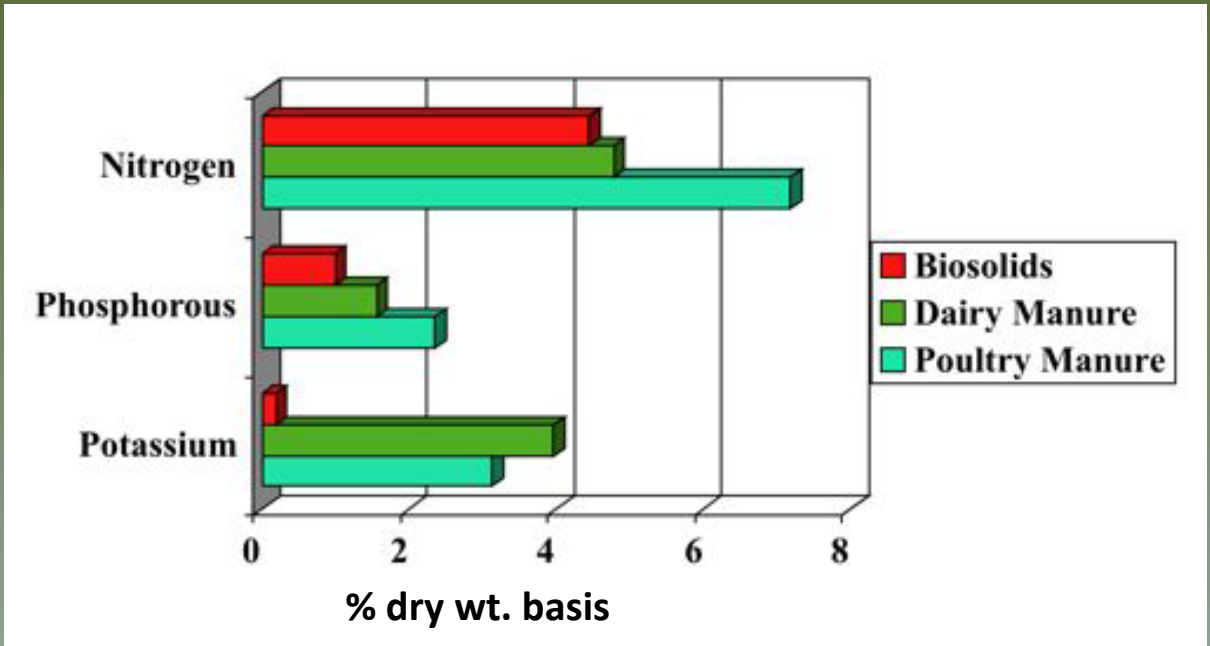
* The nutrient-rich organic materials resulting from the ***treatment*** of sewage sludge (EPA)

* Organic matter ***recycled*** from sewage, especially for use in agriculture (Oxford Dictionary)

When ***treated and processed***, sewage sludge becomes biosolids which can be ***recycled*** and applied as fertilizer to sustainably improve and maintain productive soils and stimulate plant growth (EPA)

Sludge Management Options

Biosolids - Soil Amendment



- Supplies essential plant macro and micronutrients
- Adds organic matter to soil
- Reduces soil erosion
- Increases water holding capacity
- Improves soil structure

- Conserves landfill space
- Reduces methane emissions from landfills

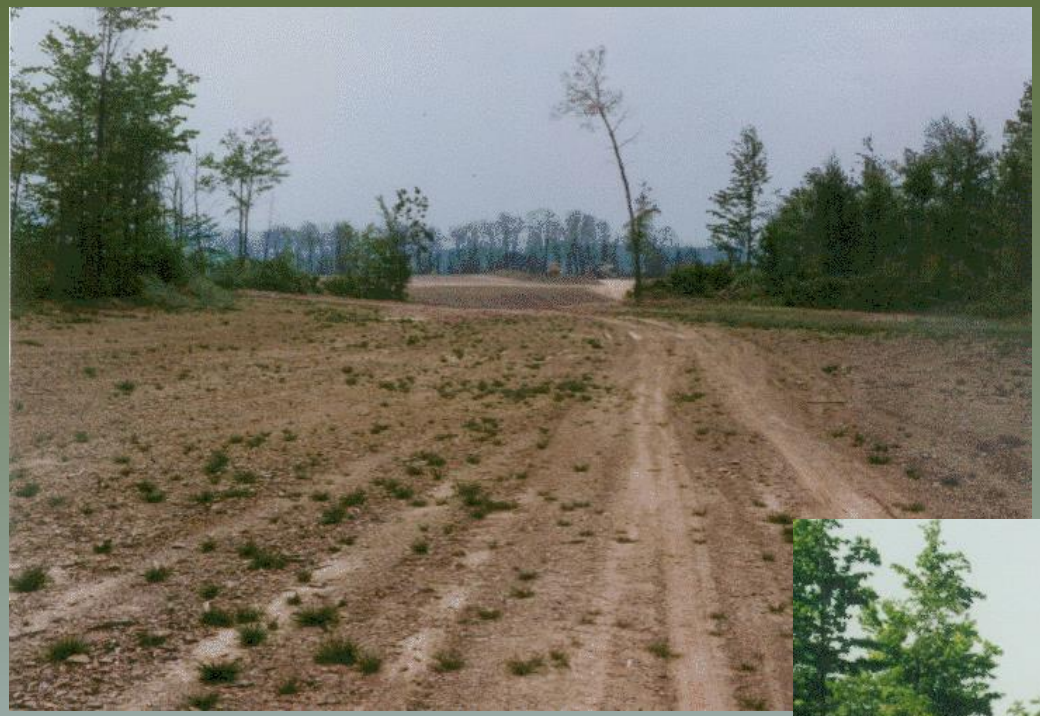
Biosolids - Manufactured Top Soils

Photos courtesy of NEBRA

Biosolids – Land Reclamation

Photos courtesy of NEBRA

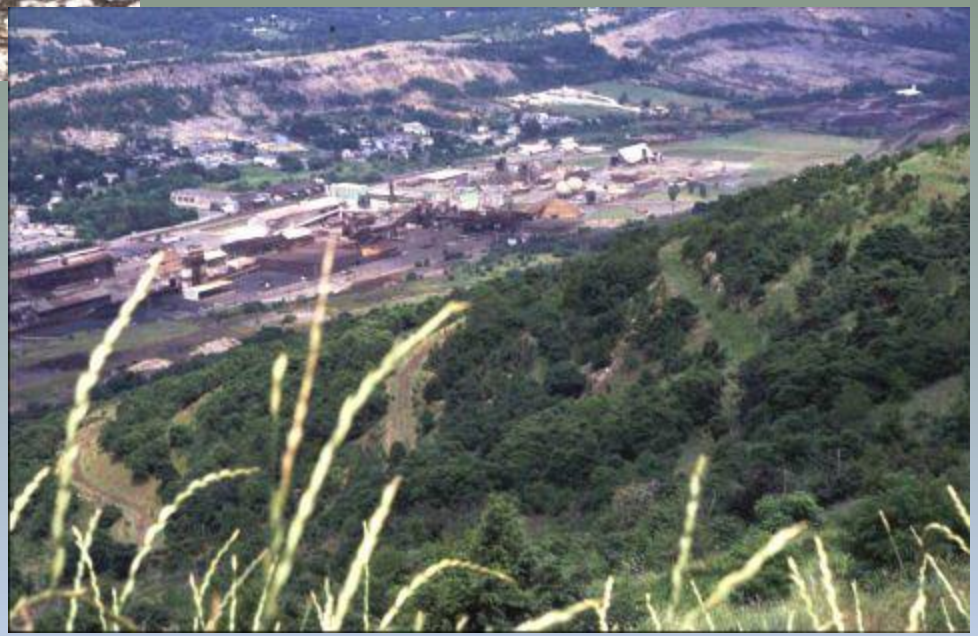
Biosolids – Land Reclamation



Mine Reclamation,
Clearfield County, PA
85 acres restored

Photos courtesy of NEBRA

Biosolids – Land Reclamation



Palmerton Zinc Superfund site
(Zinc Smelting)
Palmerton, PA

Photos courtesy of NEBRA

Septage – Land Reclamation

Londonderry, VT -

- Excavated for landfill cover
- Septage land application
- Established vegetative cover
- Erosion control

Beneficial Use

Vermont statutes at 10 V.S.A. 6604 (c): Vermont Solid Waste Management Plan “shall set forth a comprehensive statewide program for the collection, treatment, ***beneficial use***, and disposal of septage and sludge.”

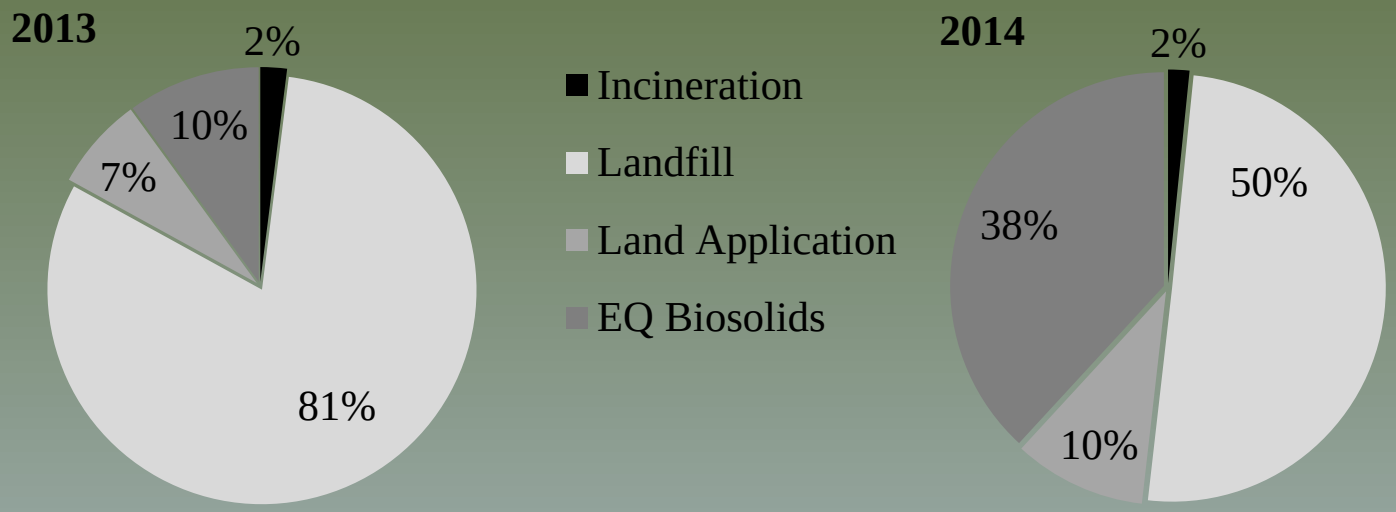
III. Current Biosolids Management: U.S., New England and Vermont

U.S.	VERMONT
BIOSOLIDS	
~ 7.1 M dry tons per year	8900 dry tons per year
< 1% of Ag land	~ 0.06% of Ag land (~750 acres)
~ 50% land applied	~ 50% land applied
SEPTAGE	
> 20% of homes	55% of population
4.0 B gallons *per day*	47 M gallons (2014)
?	6.65 M gal land applied (~ 250 acres or 0.02% Ag land)

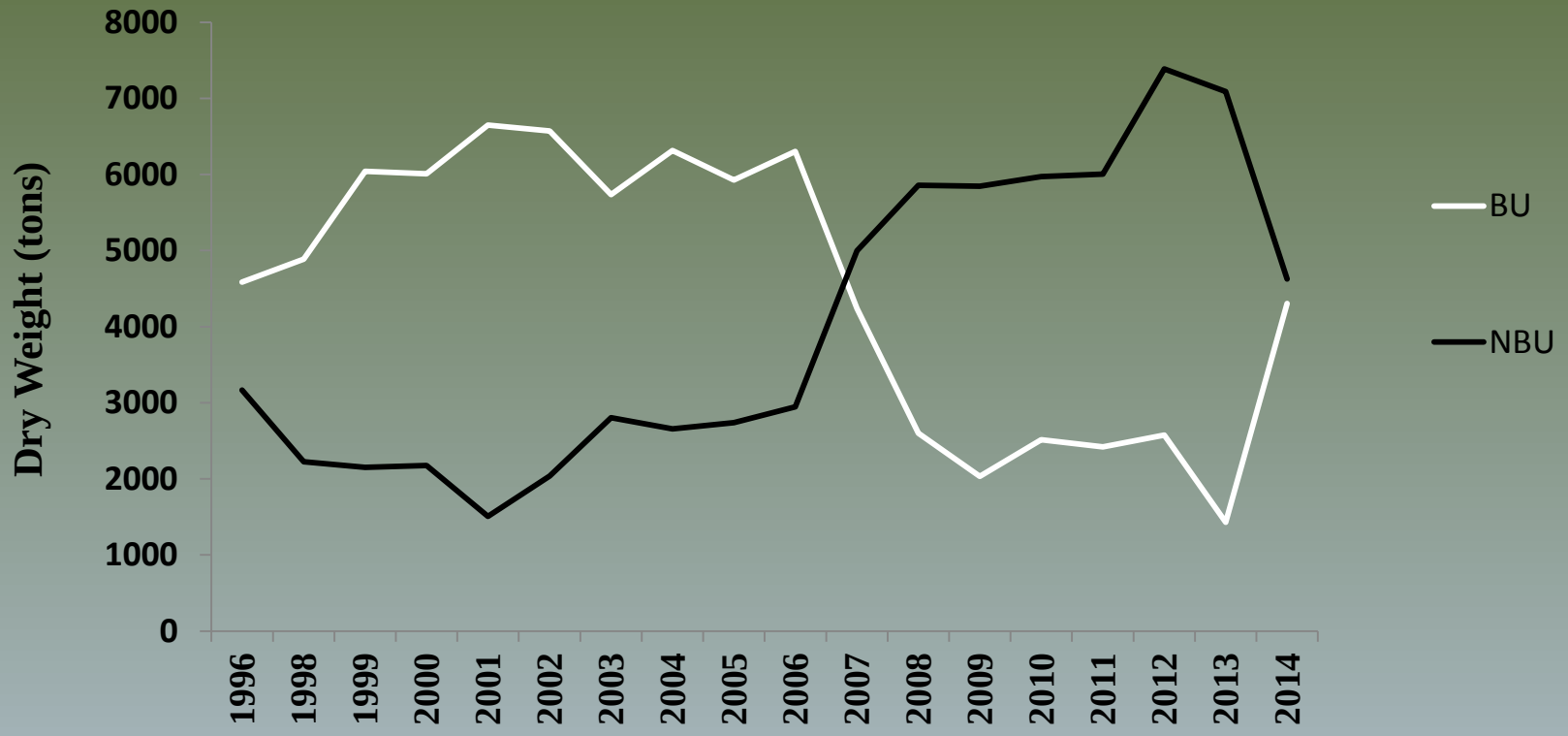
Sludge disposal option percentages (%) and dry weights by NE states in 2011.						
	CT	**MA**	**ME**	**NH**	**RI**	**VT**
Incinerate	99	36	0	16	76	**2**
Landfill	0	25	26	18	2	**69**
Reuse (land app or EQ)	1	49	74	66	22	**29**
Dry Weight (dry tons/year)	118,000	201,700	29,900	28,300	27,500	**8,400**

Beecher, 2012

Vermont sludge management in 2013 and 2014.



Trends in Beneficial (BU) vs Non Beneficial Use (NBU) of Biosolids



IV. Biosolids Regulation: Federal and Vermont

1962 VT DOH address pathogen concerns from sludge managed via land application

1970s VT DEC draft guidelines for solids management with numeric pollutant limits

1979 40 CFR Part 257 – first federal regulations for the land application of solid waste

1981 Vermont guidelines revised based on Part 257

1988 EPA Ocean Dumping Ban Act

1989 first VT Solid Waste Management Rules – revised most recently in 2012

1992 EPA closes Deepwater Municipal Sludge Site -> 40M tons of sludge disposed

1993 40 CFR Part 503 *"Standards for the Use or Disposal of Sewage Sludge"*

40 CFR Part 503
"Standards for the Use or Disposal of Sewage Sludge"

Established Regulation for Biosolids Management:

- Land Disposal
- Incineration
- Landfill
- **Land Application . . .**

Pollutant Limits: As, Cd, Cr, Cu, Pb, Hg, Mo, Ni, Se, Zn

Vector Attraction Reduction:

38% reduction in volatile solids during sludge treatment
Subsurface Injection
Lime stabilization (pH > 12)

Pathogen Reduction: Class B, Class A, Exceptional Quality (EQ)

EQ: meets Class A standards for pathogen, VAR, metals and may be marketed to general public without permit

Exposure Pathways used in EPA Part 503 Land Application Risk Assessment		
Exposure Pathway	**Description of Highly Exposed Individual**	**Limiting Pathway**
Biosolids>soil>plant>human	Human (not home gardener) lifetime ingestion of plants grown in amended soil	None
Biosolids>soil>plant>human	Human (home gardener) lifetime ingestion of plants grown in amended soil	None
Biosolids>human	Child directly ingesting biosolids	As, Cd, Pb, Hg, Se
Biosolids>soil>plant>animal>human	Human lifetime ingestion of animal products raised on forage grown on biosolids amended soil	None
Biosolids>soil>animal>human	Human lifetime ingestion of animal products from animals directly ingesting biosolids	None
Biosolids>soil>plant>animal	Animal lifetime ingestion of plants grown on biosolids amended soil	Mo
Biosolids>soil>animal	Animal lifetime direct ingestion of biosolids	None
Biosolids>soil>plant	Plant toxicity from biosolids amended soil	Cr, Cu, Ni, Zn
Biosolids>soil>soil organism	Soil organism ingestion of soil/biosolids mix	None
Biosolids>soil>soil organism>soil organism predator	Predator of soil organisms that have ingested biosolids amended soil	None
Biosolids>soil>airborne dust>human	Adult human lifetime inhalation of dust from biosolids amended soil	None
Biosolids>soil>surface water>human	Human lifetime drinking surface water and ingestion of fish contaminated with pollutants in biosolids	None
Biosolids>air>human	Human lifetime inhalation of pollutants in biosolids that volatilize to air	None
Biosolids>soil>groundwater>human	Human lifetime drinking well water containing pollutants leached from biosolids	None

Highly Exposed Individual – **Each pollutant limit is set to protect a highly exposed individual (plant or animal) from any reasonably anticipated adverse effects of a pollutant.**
Human (not home gardener) lifetime ingestion of plants grown in amended soil
Human (home gardener) lifetime ingestion of plants grown in amended soil
Child directly ingesting biosolids (PICA)
Human lifetime ingestion of animal products raised on forage grown on biosolids amended soil
Human lifetime ingestion of animal products from animals directly ingesting biosolids
Adult human lifetime inhalation of dust from biosolids amended soil
Human lifetime drinking surface water and ingestion of fish contaminated with pollutants in biosolids
Human lifetime inhalation of pollutants in biosolids that volatilize to air
Human lifetime drinking well water containing pollutants leached from biosolids
Animal lifetime ingestion of plants grown on biosolids amended soil
Animal lifetime direct ingestion of biosolids
Plant toxicity from biosolids amended soil
Soil organism ingestion of soil/biosolids mix
Predator of soil organisms that have ingested biosolids amended soil

Pathogen Reduction

- A federally sponsored technical group
- Provides recommendations on process equivalencies for pathogen reduction in sewage sludge to government and industry
- Helps EPA permit officials make decisions about new technologies
- Guides and assembles research
- Distributes information to the states and the biosolids industry

How does VT compare to Fed Regs?

Comparison of pollutant concentration (mg/kg, dry wt.) standards for land app											
	As	**Cd**	**Cr**	**Cu**	**Pb**	**Hg**	**Mo**	**Ni**	**Se**	**Zn**	**PCB**
EPA 503.13 Table 1	75	85	N/R	4300	840	57	75	420	100	7500	N/R
EPA 503.13 Table 3	41	39	N/R	1500	300	17	N/R	420	100	2800	N/R
VT	15	21	1200	1500	300	10	75	420	100	2800	10
N/R = no regulatory standard established											

How does VT compare to Fed Regs?

Comparison of monitoring requirements for land application sites		
	Vermont	**40 CFR 503.16**
Biosolids	Every batch applied or a minimum of once per year	Varies based on mass produced
Groundwater	Minimum: once per year	None
Soil	Minimum: once per year	None
Plant Tissue	Once per permit cycle	None

How does VT compare to Fed Regs?

Comparison of minimum required isolation distance for diffuse disposal		
	Vermont	**40 CFR 503**
Water table (at app)	3’	None
Bedrock	3’	None
Surface water	100’ (injection = 50’)	10 meters or ~33’
Property line	50’	None
Residences, schools, etc.	100’	None
Drinking water sources	300’	None

Biosolids management facilities may not be sited in:

* Class I and Class II Groundwater areas
* Class I and II and III wetlands
* National Wildlife Refuge
* Wildlife Management Area administered by the Vermont Dept of F&W
* designated threatened or endangered species habitat
* watershed for a Class A Water
* within 500’ of an Outstanding Natural Resource Water
* within Zone 1 or 2 of a Public Water Supply Source Protection Area
* within the floodway portion of a 100 year floodplain

Land Application of Class B biosolids or stabilized septage - Site Use Restrictions:

- to frozen or snow covered ground is prohibited
- where there is less than 36” of unsaturated soil is prohibited
- public access restricted for a period of 12 months following the last biosolids application
- maintained soil pH in the range of 6.5 – 8.0 S.U.

Land Application of Class B biosolids or stabilized septage - Site Use Restrictions:

- domestic food source animals may not be grazed for 6 months following the last application
- no production of crops for direct human consumption for a minimum of 36 months following the last application event (38 months if the harvested part grows below ground)
- feed crops may not be harvested for a minimum of 5 weeks following the last application
- silage may not be fed to animals for a minimum of 4 months following the last application
- turf may not be harvested for a minimum of 1 year following the last application

V. Emerging Contaminants in Biosolids

1970s-80s	EPA Source Control and Industrial WW Pre Treatment Programs
1982	“40 City Study” (survey)
1988	National Sewage Sludge Survey
1993	Surveys used to establish Part 503 Rules
1996	National Academy of Sciences/National Research Council review
2002	NAS/NRC review of biosolids use on food and feed crops
2003	Dioxin review
2006-07	**Targeted National Sewage Sludge Survey**
	- 74 WWTPS
	- 35 States
	- 145 analytes
	- PAHs, semi-volatiles, flame retardants, pharms, hormones , etc

V. Emerging Contaminants in Biosolids

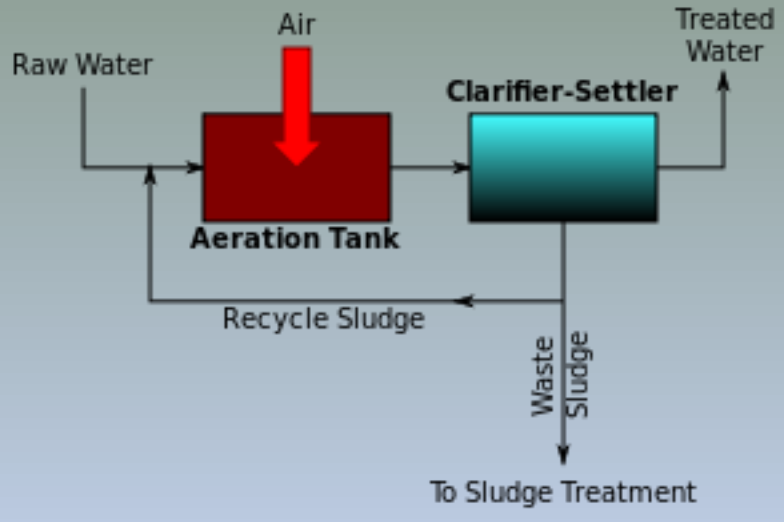
- Micro-constituents
- Wastewater Micro-Pollutants (**WMPs**)
- Compounds/Contaminants of Emerging Concern (**CECs**)
- Trace Organic Compounds (**TOCs**)
- Endocrine Disrupting Chemicals (**EDCs**)
- Pharmaceuticals and Personal Care Products (**PPCPs**)
- Organic Wastewater Contaminants (**OWCs**)
- Anthropogenic Waste Indicators (**AWI**)

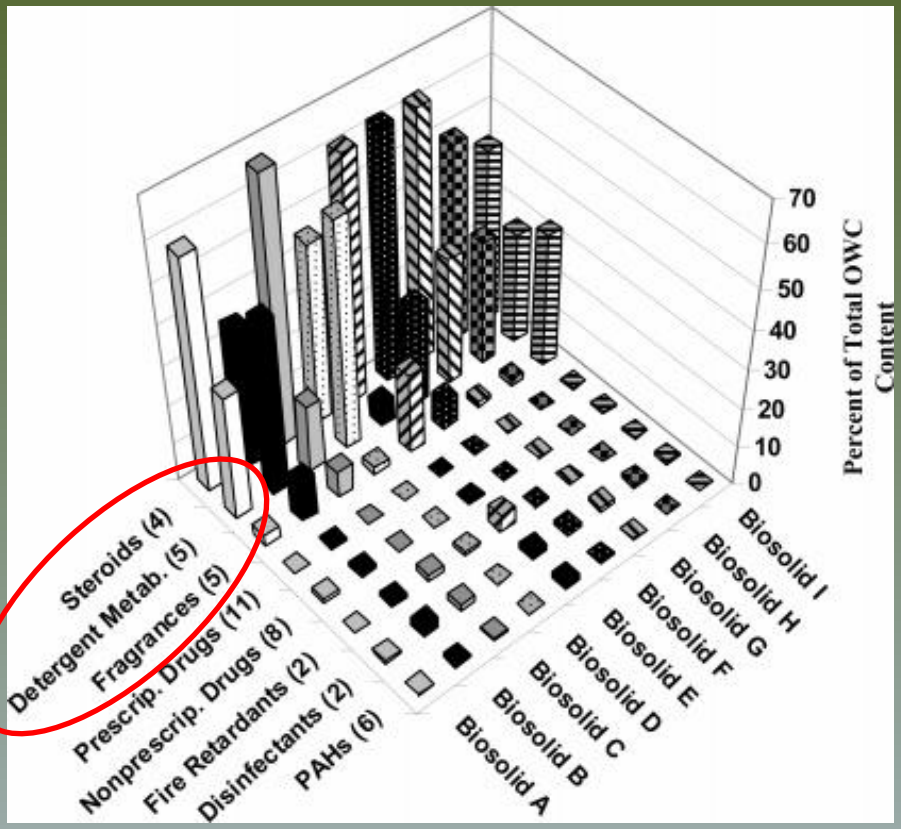
CECs and WWTP

- Removal occurs in WWTPs secondary treatment via biodegradation and/or by **adsorption to the solid material** wasted from the system

- Many CECs enter and leave the WWTP unaltered or incompletely removed because HRT/SRT vs half life

- CECs with large octanol-water partitioning coefficients ($\mathbf{K_{ow}}$) partition preferentially into the organic-rich biosolids phase during treatment. (The higher to K_{OW}, the more non-polar the compound)





Kinney et al. 2006 "Survey of OWCs in Biosolids Destined for Land Application"

"Big 3" in Biosolids:

Steroids
Detergent Metabolites
Fragrances

- 9 different biosolids, WWTPs in 7 states, analyzed for 87 different OWCs

Treating Contaminants of Emerging Concern

Aug 2010

Table 4. Removal of 16 Selected Analytes by Full-Scale Activated Sludge Treatment

Analyte	Group	Drinking Water				Treated Effluent				Municipal Wastewater			
		Avg % Removal	Min Removal	Max Removal	# Systems Used to Calculate Removal	Avg % Removal	Min Removal	Max Removal	# Systems Used to Calculate Removal	Avg % Removal	Min Removal	Max Removal	# Systems Used to Calculate Removal
Bisphenol A	Other	NR	NR	NR	0	NR	NR	NR	0	78	11	100	41
Caffeine	PPCP	NR	NR	NR	0	30	2.6	48	3	94	85	100	7
Carbamazepine	PPCP	NR	NR	NR	0	22	3.5	40	2	22	< 10	60	5
DEET	pesticide	NR	NR	NR	0	46	17	> 74	2	54	16	> 84	7
Diclofenac	PPCP	NR	NR	NR	0	47	18	> 82	3	44	7.1	> 99	23
Estradiol	S/H	NR	NR	NR	0	NR	NR	NR	0	88	44	100	49
Estrone	S/H	NR	NR	NR	0	74	> 58	90	2	77	1.8	100	46
Galaxolide	PPCP	NR	NR	NR	0	NR	NR	NR	0	56	9	99	25
Gemfibrozil	PPCP	NR	NR	NR	0	75	59	92	2	77	38	> 99	13
Ibuprofen	PPCP	NR	NR	NR	0	28	5.6	50	2	90	43	100	32
Iopromide	PPCP	NR	NR	NR	0	55	55	55	1	69	50	83	3
Naproxen	PPCP	NR	NR	NR	0	98	> 98	> 98	1	85	47	100	18
Nonylphenol	NP/APEs	NR	NR	NR	0	NR	NR	NR	0	90	57	100	26
Sulfamethoxazole	PPCP	NR	NR	NR	0	49	25	93	3	58	9	99	15
Tri(chloroethyl) phosphate	Other	NR	NR	NR	0	6.5	6.5	6.5	1	27	4.5	50	2
Triclosan	PPCP	NR	NR	NR	0	79	> 79	> 79	1	89	> 67	100	22

NR – Not reported.

Study of 98 Full-Scale systems, 60 Lab-scale systems

Removal of PPCPs is compound specific

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Compounds partitioning into solids/sludge ….. and/or found in CSOs

Treating Contaminants of Emerging Concern

Aug 2010

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Endocrine Disruption (ED) compounds partition into solids/sludge

Treating Contaminants of Emerging Concern

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NR – Not reported.

Compounds partitioning into aqueous (WWTP effluent)

VI. Transport and Fate of Biosolids Bourne CECs in the Environment

Potential EXPOSURE PATHWAYS from land application…

- Soil consumption by grazing livestock
- Uptake into plants consumed by livestock and/or humans
- Terrestrial bioaccumulation
- Leaching/Run-off from land applied fields to surface and groundwater
- Bio-aerosol transport

Leaching/Run-off from land applied fields to surface and groundwater

- CECs that survive WW treatment are strongly bound to soil OM – insoluble ($\mathbf{K_{ow}}$)

- Gotschall et al (2012, 2013) vs Lapen et al (2008) - Impacts on tile drainage
- Yang et al (2012) vs Wong et al (2010) – viral contaminant runoff

  - Application rate
  - Management Practices – tillage, incorporation, vegetative cover
  - Depth/distance to tile drain, groundwater and surface water
  - Solids content of biosolids
  - Soil type – macropores, clay, etc
  - Climate, weather conditions, precipitation
  - EXPERIMENTAL METHODS - Selected PPCPs spiked into biosolids?
    - Simulated rain event volume/timing?

How has Vermont addressed?

App Rate Calcs & Site Life Tracking
Site Use Restrictions
Isolation Distances
Monitoring

Uptake into plants consumed by livestock and/or humans

20 recent studies of plant uptake of CECs

- 2 studies used hydroponic cultivation
    - No soil adsorption = greater uptake (Macherius et al. 2012)

- 9 studies used laboratory growth conditions
    - Soils spiked with test compounds - no biosolids used
    - overestimate bioaccumulation potential

- 4 studies used soil pots and biosoilds-amended soils
    - Lack physical and biological environmental exposure/conditions
    - Degradation rates/persistence
    - Overestimation of metal uptake (Chaney et al. 1999)

- 3 studies under field conditions with biosolids-amended soils
    - Gottschall et al. 2012 - no PPCPs detected in wheat grain
    - Hale et al. 2012 - no measurable uptake of PBDEs in corn
    - Sauborin et al. 2012 - no significant uptake in variety of crops

** Prosser et al. 2014 - negligible exposure to TCS in edible crops
** Prosser &Sibley 2015 - de minimis risk to human health

Uptake into plants consumed by livestock and/or humans

Livestock Exposure to CECs via consumption of…

- soil directly
- soil adhered to plants
- biosolids adhered to plants

Rideout & Teschke (2004) - Lit Review – **foodborne exposure to dioxins**

- dioxins are found in extremely small quantities in soil and biosolids-amended soil, they persist in the environment and can accumulate in the food chain
- large increases in dioxin were required to achieve measurable plant uptake

** EPA (2003) 5 year study - no significant cancer risk to human health or environment.

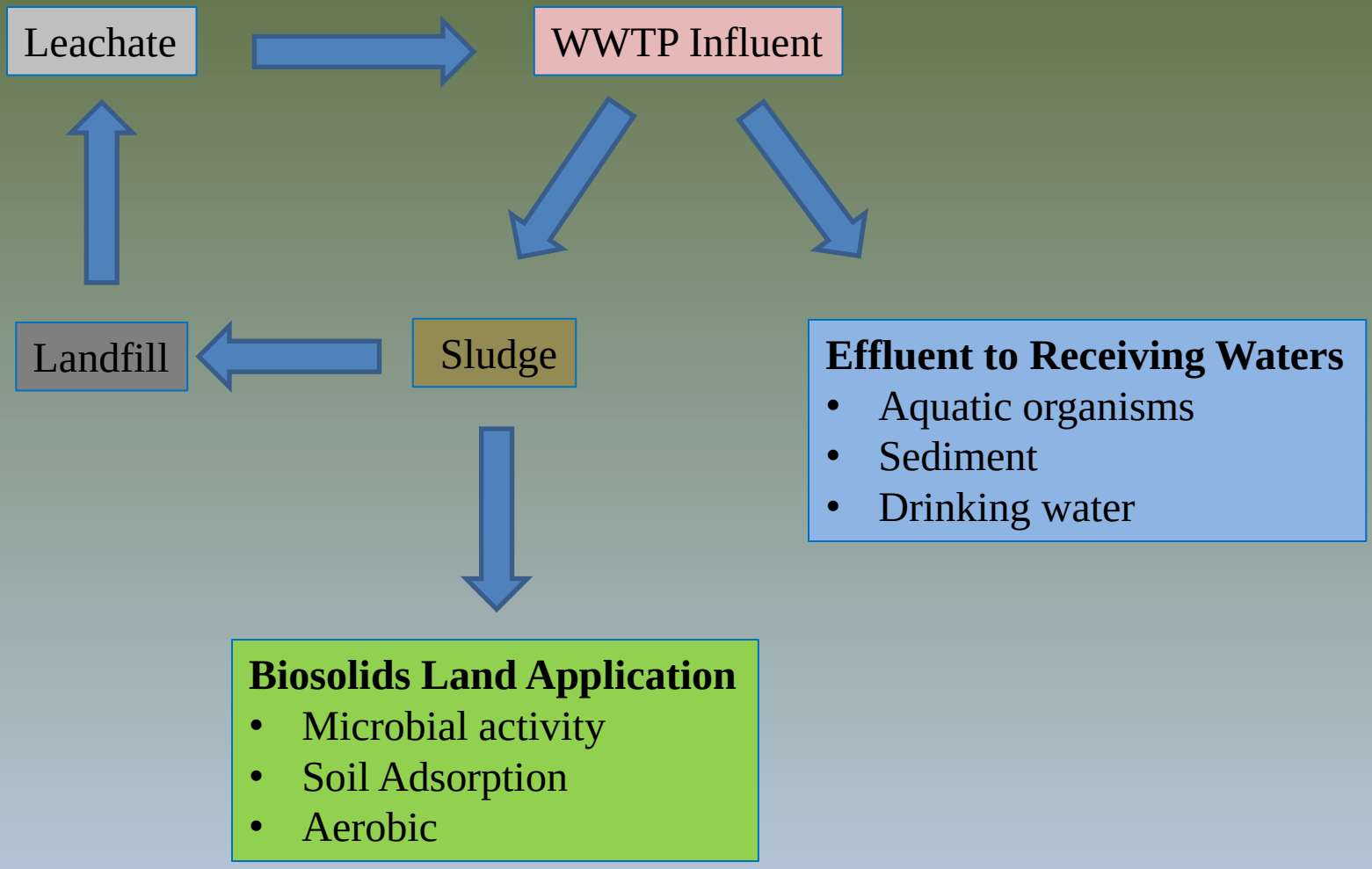
** Vermont's Site Use Restrictions: domestic food source animals may not be grazed for 6 months following the last application

VI. Transport and Fate of Biosolids Bourne CECs in the Environment

Key Points

- CECs that survive WWT are strongly bound to soil OM and relatively insoluble
- Steroids, Detergent Metabolites, Fragrances -> endocrine disruptors
- PBDEs are strongly sorbed in soil, relatively immobile, remain in soil (Pepper et al. 2008)
- Persistence in soil reduces opportunity for CECs to enter water
- EDs (detergent metabolites, hormones) in biosolids rapidly degrade following land app (Lorenzen et al. 2006, Roberts et al. 2006)

VI. Transport and Fate of Biosolids Bourne CECs in the Environment



VII. Emerging Concerns for Pathogens

Part 503 regulations pertaining pathogens established through treatment-based standards and land application guidelines rather than through risk or epidemiological analysis

- *Cryptosporidium*
- *E coli* O157:H7
- *Listeria*
- Adenoviruses
- *Salmonella*
- *Staphylococcus*
- hepatitis A
- hantavirus
- drug resistant pneumococci
- drug resistant enterococci
- prions

VII. Emerging Concerns for Pathogens

University of Arizona (Pepper , Brooks, Rusin, Gerba… et al.)

Pepper et al. 2008 - identify potential biological hazards associated with Land App of Class B biosolids

- Collected/analyzed biosolids samples from a single WWTF over 18 years: 1988-2006
- national study on the incidence of pathogens in anaerobically digested biosolids produced within WWTFs across the US between 2005 and 2008
- Part 503 Rule has been effective in reducing public exposure to pathogens relative to before the promulgation of the Part 503 Rules (**Pepper et al. 2010**)
    - *Staphylococcus* not detected in class A or B or bioaerosols
    - *Salmonella* and Coxsackie virus natural attenuation – UV, desiccation
    - Aerosols from land application from soil, not biosolids
    - limited transport of pathogens via aerosols due to **binding** to biosolids
    - Site restrictions allows time for the natural die-off of pathogens in the soil

VII. Emerging Concerns for Pathogens

Regrowth potential

- Regrowth of *Salmonella* after rain events if biosolids become saturated and anaerobic
- No regrowth occurred in Class A or B if land applied to soil regardless of saturation
- Reported risks from ingestion or aerosol inhalation following regrowth:
    - Class A and B land applied – low risk
    - Class A – significant risk
- covering stored biosolids and avoiding saturated anaerobic conditions

VII. Emerging Concerns for Pathogens

Antibiotic-resistant bacteria and endotoxin in soil after land application

- 20 years of annual biosolids applications to replicated field-plots
- negligible increase in the percentage of antibiotic resistance bacteria
- no significant increases in the concentrations of endotoxins in soil were observed
- land application increased microbial diversity and enhanced microbial activity

VS

- correlation between anti-microbial Triclosan concentrations in stream sediments and the number of benthic bacteria resistant to Triclosan (**Drury et al. 2013**)

terrestrial systems have orders of magnitude greater microbial capability and residence times to achieve decomposition and assimilation of potential contaminants in biosolids (Overcash et al. 2005)

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