



# Biosolids and Soil

## Remarkable Media for Managing Microconstituents

Ned Beecher • North East Biosolids & Residuals Association (NEBRA)

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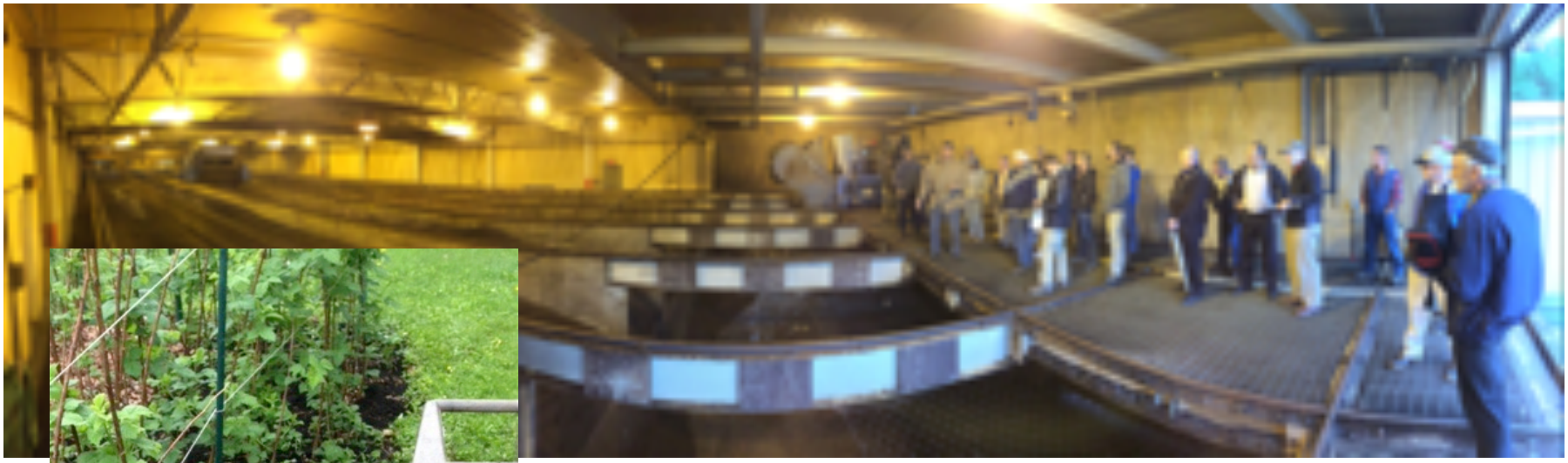
Lewiston-Auburn WPCA biosolids composting facility



# Biosolids Use

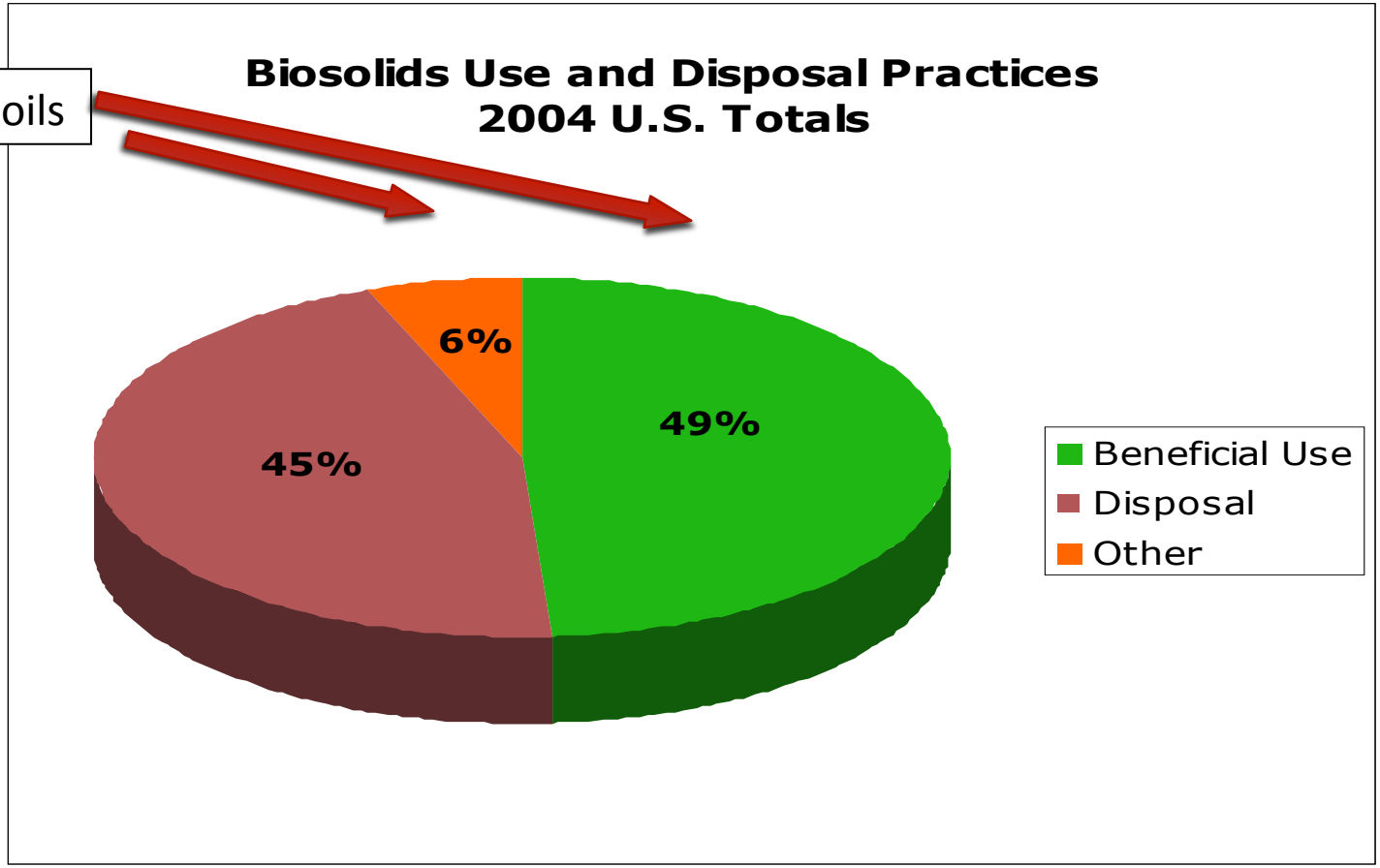

# Biosolids improve soils and address environmental challenges.



# USA total wastewater solids:

## 7,180,000 dry U. S. tons/year (~35.9 million wet tons)

55% is used on soils



# Agriculture:
## Denver, CO

In the drier west, biosolids improve the water-holding capacity of the soil.


# Agriculture

Central Valley, CA

Virginia


# Biosolids use: Forestry

Photos courtesy of King County, WA
http://dnr.metrokc.gov/WTD/biosolids/

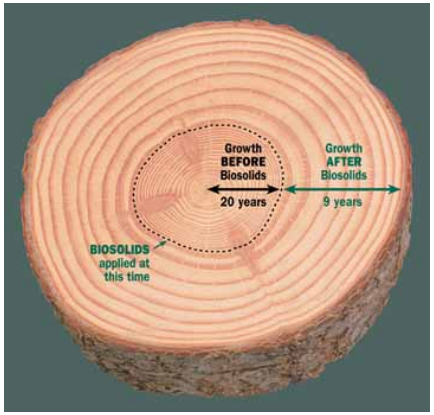
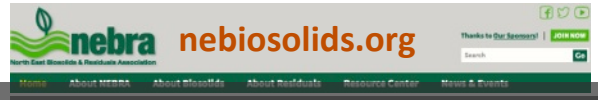





Photo courtesy of Philadelphia Water Dept.

- Only in some areas
- Speeds up harvest cycle in actively managed stands




# Biosolids use: Horticulture / Landscaping / Turf

Biosolids compost use on my home garden – raspberries, May 2014

- Class A bulk material markets: potting mixes (e.g. Tagro), golf courses (e.g. Milorganite & Bay State Fertilizer), parks, lawns, growing turfgrass (e.g. in RI), sports fields (hi-spec turf)
- Trend: increasing demand for the quality, consistent products


# Horticulture / Landscaping / Turf

**before**

**after**

**Mid-1980s - photos courtesy of Eliot Epstein, Ph.D., and Orgro**


# Biosolids Use: Topsoil Blending

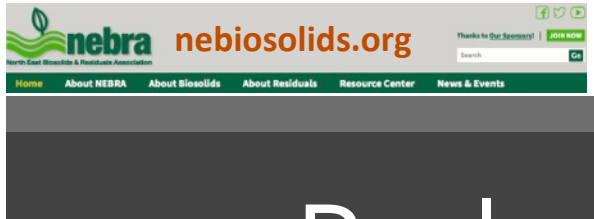
Topsoil blending with paper mill residuals and biosolids, central MA, 2006

- Bulk biosolids given or sold to topsoil blenders
- A way to use less processed material
- Topsoils used for reclamation, landfill cover, highway embankments, construction sites
- Trend:  steady use


# Reclamation of Disturbed Sites

Spectacle Island in Boston Harbor was reclaimed with biosolids compost and other recycled organics, 2004.

- Bulk material market
- Used to restore healthy soil ecosystem and either native vegetation or cropland
- Trend: increasing use, because of huge benefits – biosolids use is best practice for this kind of reclamation




# Reclamation of Disturbed Sites

Pennsylvania mine
before

Same Pennsylvania mine
after

Photos courtesy Bill Toffey, MABA


# Innovative Biosolids Uses:

## e.g. Carbon Sequestration Plantations

Slide courtesy of Sylvis, Vancouver, BC


# Microconstituents in biosolids

- Traces of myriad chemicals in biosolids is not new.
- What is new is ability to measure in ppb, ppt, ppq.
- 30+ years of research have led to understanding how various sentinel, high-use chemicals behave and how particular groups of chemicals behave.
  - Impacts measured in aquatic environment
  - No signficant impacts from biosolids pathways when researching real world, field conditions.


# Microconstituents in biosolids

Clark and Smith, 2010

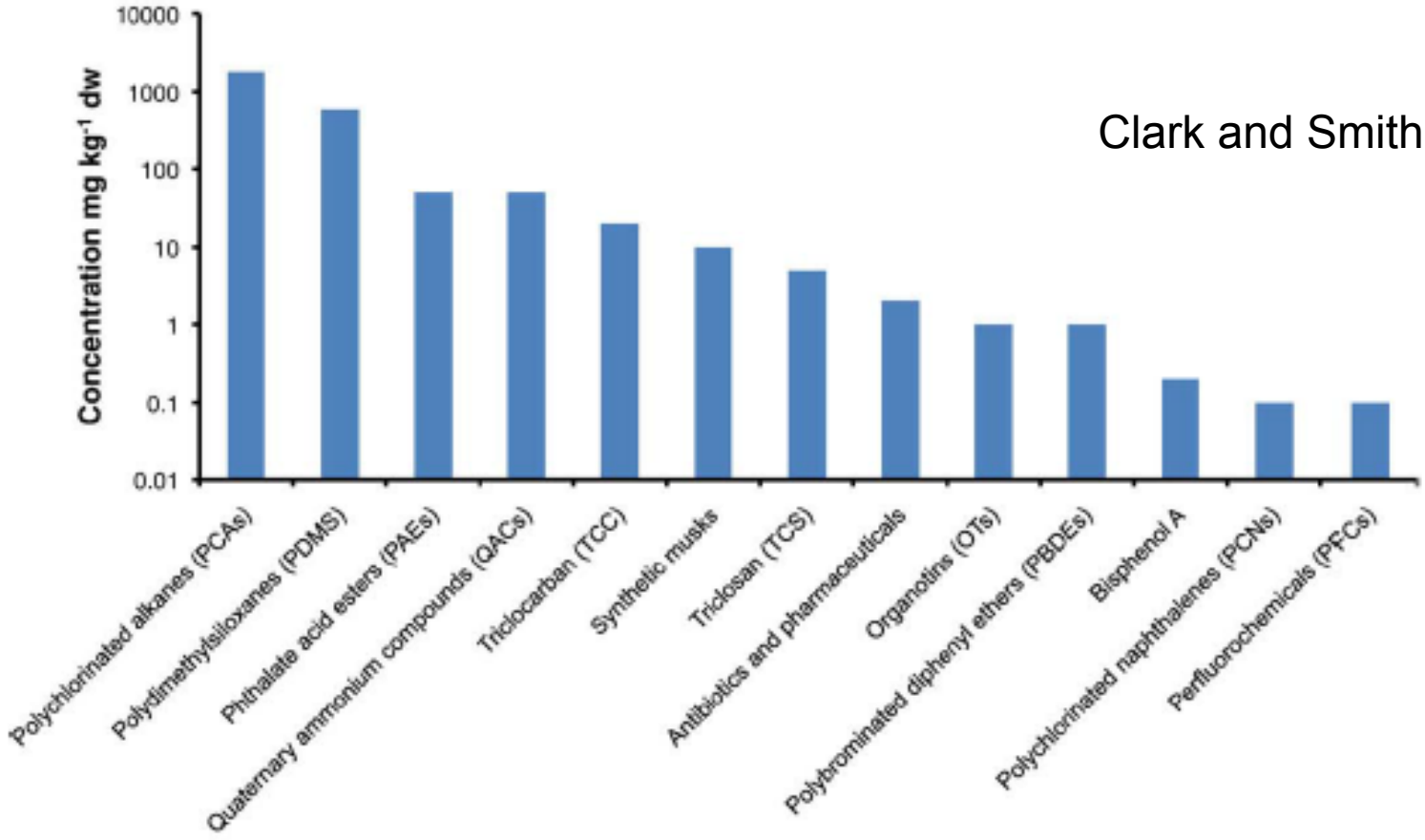



**Fig. 1.** Typical concentrations of selected 'emerging' organic contaminants in sewage sludge (mg kg$^{-1}$ dw).

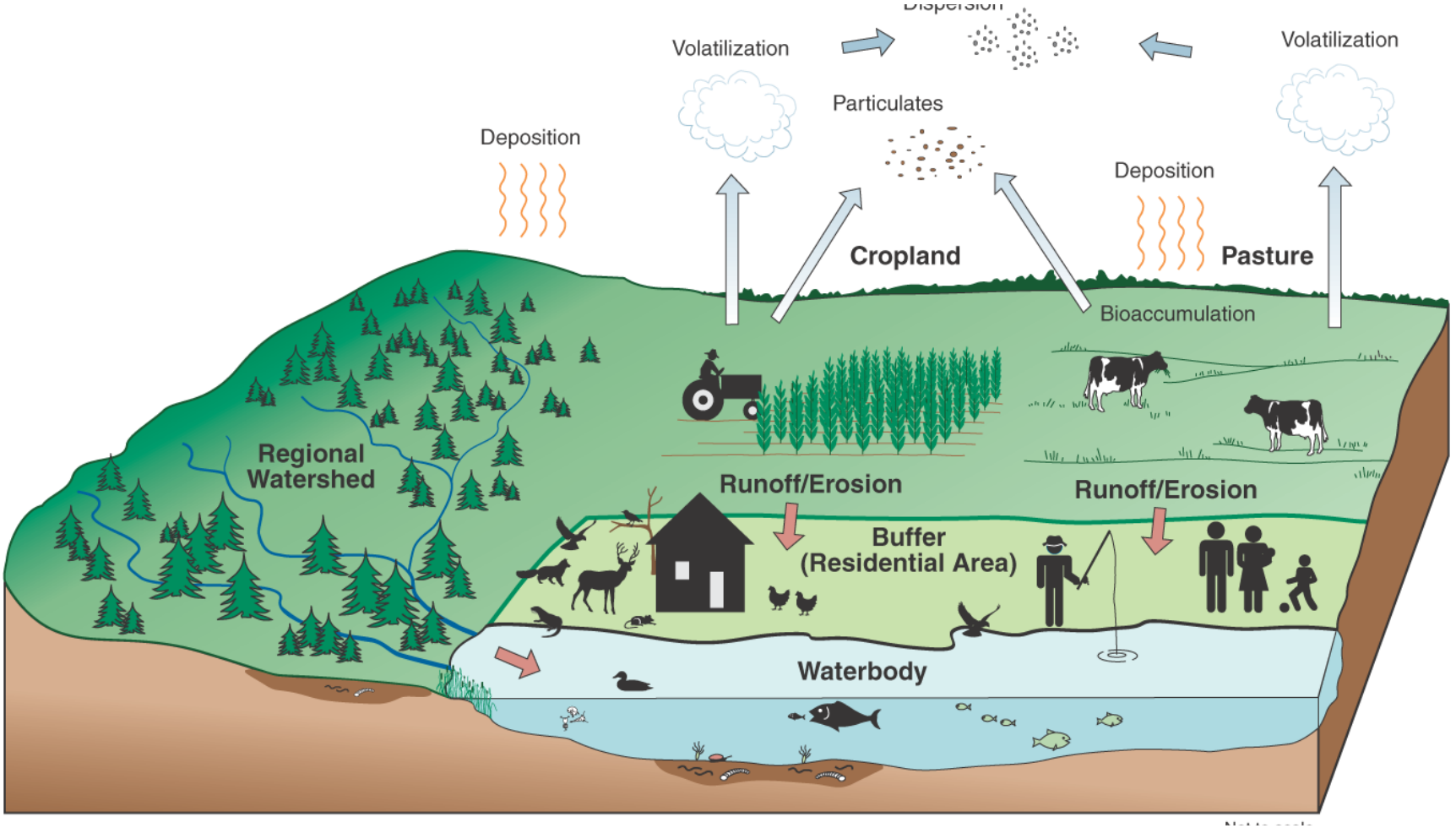

# Context for the Wu et al. study


- Triclosan (TCS)
  - In toothpaste: 3,000 mg/kg
  - Wu et al. maximum measured concentration in plant (conservative scenario): 0.1 mg/kg
  - Typical land application calculated estimated soil concentration: 0.05 mg/kg
  - TCS (& TCC) decompose in soil at a moderate rate.
  - Young, (Univ. of CA, Davis): “increased nitrogen added with biosolids stimulates nitrogen cycling sufficiently to offset any detrimental impacts on the nitrogen cycling caused by Triclosan at realistic application concentrations.”


# Plant uptake: Sabourin et al. 2012

"Biosolids at application, and crop samples following harvest, were analyzed for 118 pharmaceuticals and transformation products, 17 hormones or hormone transformation products, and 6 parabens. Analyte concentrations in the biosolids were consistent with those detected in other surveys. Eight of the 141 analytes were detected in one or two crop replicates at concentrations ranging from 0.33 to 6.25 ng/g [ppb] dry weight, but no analytes were consistently detected above the detection limit in all triplicate treated plots. Overall, this study suggests that the potential for micropollutant uptake into crops under normal farming conditions is low."


# EPA Biosolids Dioxin Risk Assessment




# Context for dioxin

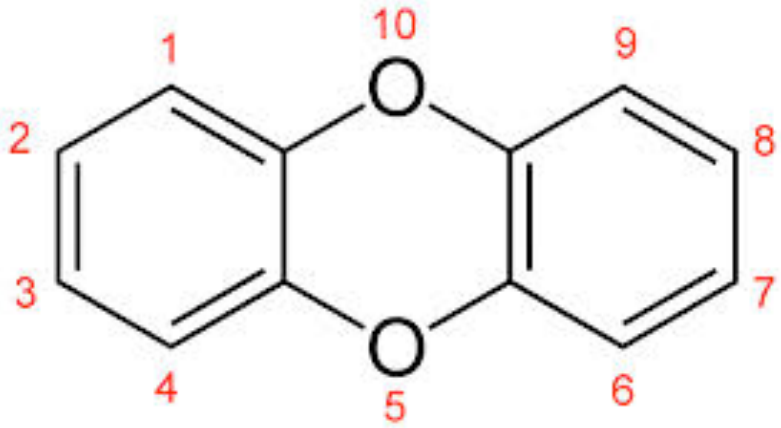
| Source | Concentration (ppt TEQ dry weight) |
|---|---|
| Maine Biosolids Average (31 samples 1995-1997) | 6.3 |
| Maine Biosolids Regulatory Limit | 27 |
| U.S. soils average (rural) EPA data | 4 |
| U.S. soils average (urban) EPA data | 19 |
| Leaf and yard waste composts (range of 29 samples) | 5 - 91 |
| Cow Manure (6 samples from 2003 European study) | 3.6 |
| Fish (EPA data) | 0.59 |
| Ben & Jerry's Vanilla Ice Cream (1 sample) | 0.79 |
| Times Beach, Missouri | Up to 340,000 |

Slide courtesy of Andrew Carpenter, Northern Tilth


# Context for dioxin…
# …after 30 applications of biosolids

The levels of dioxins in soil were only 79.9, 115.5, and 247.5 ng toxic equivalents (TEQs) kg−1 in the 0, 504, and 2016 Mg biosolids ha−1 plots, respectively. Dioxins were not detected in the corn grain, and only trace levels (6.8–7.5 ng TEQs kg−1) were found in the corn stover; however, these values were not statistically different between control and biosolids amended soils.

– Hundahl et al., 2008




# Bioassays…

## …a logical & efficient approach to assessing potential impacts


# Puddephat / McCarthy research

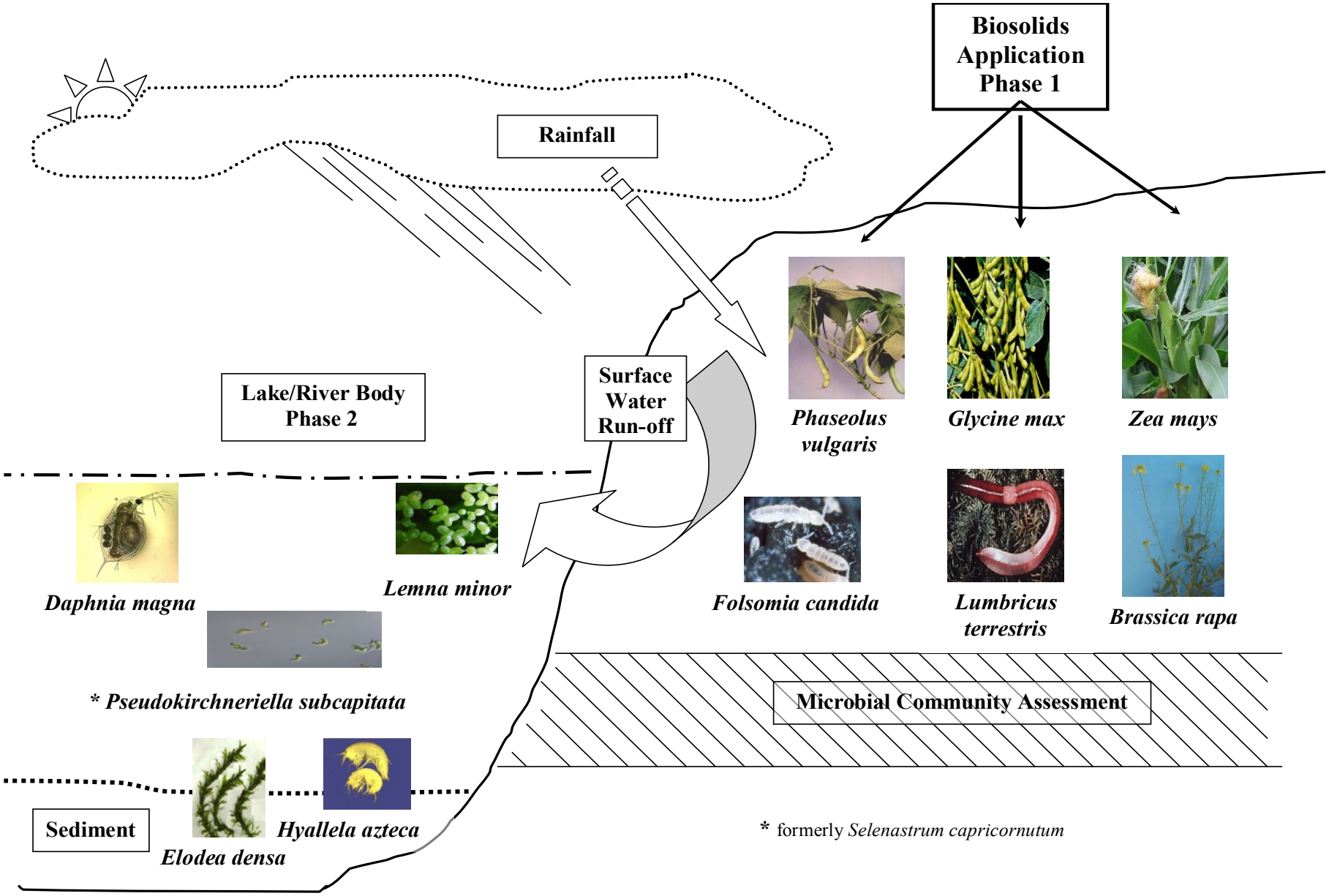



**Figure 1.** Possible contamination pathways and specific bioassays for the assessment of biosolids application impact.


# Conclusions of Puddephat / McCarthy research:

McCarthy, 2011:

- sub-acute, acute, chronic, and reproductive bioassays indicated no deleterious impact of selected biosolids on selected biota under controlled, laboratory conditions
- use of multi-organism, environmentally-relevant bioassays adds scientific veracity to assessing the sustainability of the land-application process

Puddephat, 2013:

"The findings showed that biosolids had little negative impact on the terrestrial biota examined and as a general rule, there was no impact observed. Where effects were observed, the majority of instances were positive. In the few instances where there was negative impact observed, for example in the initial growth stages of the plant bioassays, with further development of the organism, there was no longer a significant difference between the reference and treatment plants."



# What does it mean for biosolids management?

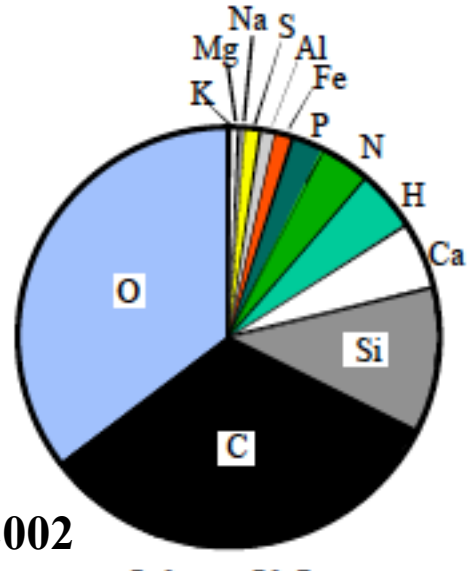

# What does it mean?

***Remember:***

Biosolids are mostly water, organic matter, and inerts.
Microconstituents of potential concern = < 2%, maybe.

**U. S. EPA measured elements in biosolids, 2007 TSSS:**

Carbon ---- 31.4% or 314,000 mg/Kg
Oxygen --- 20.4% or 204,000 mg/Kg
Silicon --- 5.1% or 51,000 mg/Kg
Hydrogen -- 4.1% or 41,000 mg/Kg
Nitrogen --- 4.0% or 40,000 mg/Kg
Sulfur --- 1.2% or 12,000 mg/Kg




**Univ. of WA estimate of elements in biosolids, 2002**


# What does it mean?

**Perspective**:

4 times as much antimicrobials used in agriculture than humans

U. S. manure: ~ 1.1 billion wet tons / year

U. S. biosolids: ~ 36 million wet tons / year

Microconstituents in wastewater are removed/broken down during treatment or remain in effluent or solids. A few increase in concentrations due to biochemical processes.

Microconstituents in biosolids are generally strongly adsorbed to organic matter and in mineral form (hydrophilic compounds are in effluent). Their generally high log $K_{ow}$ values mean that solid phase retention is great and that release is small, that leaching through soils and subsequent groundwater contamination is likely small, that water solubility is likely low, and that availability to organisms dependent on water solubility (plant uptake) is likely small.

Decades of research on organic compounds in soils provide understanding for microconstituents/PPCPs: most degrade (half-lives vary, but most are less than six months).

Pot studies spiked with fresh chemicals (PPCPs, etc.) are not representative of field conditions.


# What does it mean?

**Remember**:

1 ppm = 1 second in 11.6 days

1 ppb = 1 second in 31.7 years

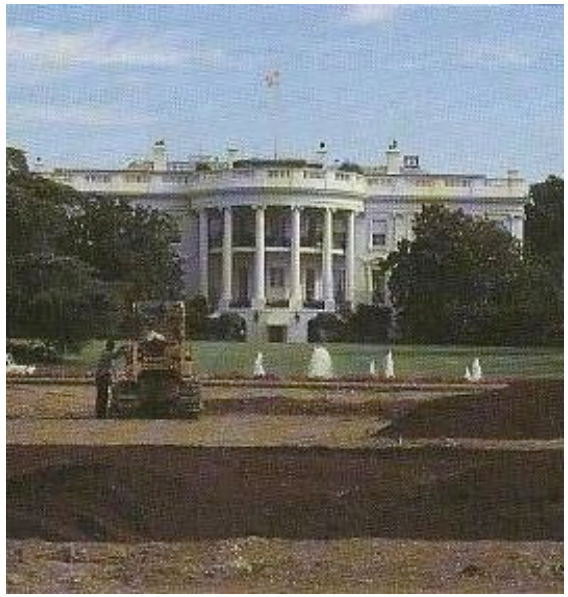
1 ppt = 1 second in 31,700 years

Healthy, microbially-active soils are the best medium for treatment of traces of organic chemicals.

Significant impacts to biota have been measured in aquatic environments, but not in biosolids-amended soils.

Risk to human health through biosolids-application-to-soil pathways appear to be negligible. Far greater human exposure to most are through daily use of products.

Source reduction should focus on persistent compounds with known or potential toxicity.

# Biosolids & soils: Remarkable media for managing MCs!


# Q: Where do we want to put microconstituents?
(We can't remove every bit from wastewater.)

## A. When possible, avoid disposal in wastewater. Once in wastewater, get them into the solids.

Biosolids management options include:

1. Solids incineration = destruction of MCs
2. Solids landfilling = sequestration & decomposition of MCs
3. Use on soils = sequestration & decomposition, with some potential for migration in environment.

Rationale:

- Complex management choices require maximizing benefits and minimizing risks. There is no pure & perfect solution.
- Benefits of recycling biosolids to soils are greater than risks.
- Use of biosolids on soils is the most sustainable biosolids management option, by many metrics (GHG emissions, nutrient cycling, soil improvement, fertilizer displacement, conservation of resources (recycling P, a critical, limited resource), etc.


# Q: Where do we want to put microconstituents?

(We can't remove every bit from wastewater.)

## A: Get them into the solids…and into soils…

…because healthy soils (e.g. enriched with biosolids and/or other organic amendments) are the best media for degrading most microconstituents.

"These terrestrial systems have orders of magnitude greater microbial capability and residence time to achieve decomposition and assimilation compared with aquatic systems."

– Overcash, Sims, Sims, and Neiman, 2005


# What biosolids managers can do…

## Focus on biosolids quality.

Source reduction works. Enforce industrial pretreatment. Support phase-outs of persistent MCs.

| Year | Cadmium | Chromium | Copper | Lead | Nickel | Zinc |
|---|---|---|---|---|---|---|
| 1973 | 33 | 712 | 700 | 1,261 | 148 | 2,031 |
| 1983 | 12.5 | 360 | 361 | 421 | 79 | 1,701 |
| 1993 | 7.3 | 209 | 764 | 225 | 51 | 1,444 |
| 2000 | 4.2 | 115 | 566 | 178 | 53 | 1,619 |

Philadelphia Water District biosolids quality over time, courtesy of Bill Toffey.


# What biosolids managers can do…

## Focus on biosolids quality.

- Support education about drug disposal: http://www.nodrugsdownthedrain.org/NoDrugs/
- Support drug take-back programs. http://www.deadiversion.usdoj.gov/drug_disposal/takeback/
- Test biosolids product(s) for most common or concerning microconstituents, just so you know. Compare your results to published results.


# What biosolids managers can do…

## Focus on biosolids quality.

- When possible, use treatment processes that degrade MCs: biological processes are most effective.
- Use multiple processes, e.g. anaerobic digestion followed by composting & application.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# What biosolids managers can do…

## Use Best Management Practices.

- Apply at agronomic rate*, which limits total mass of MCs while providing optimum level of benefits.
- Maintain setbacks from surface & groundwater*, which keeps MCs out of the more sensitive aquatic environment.
- Apply to aerated soils and incorporate when possible, which aids decomposition of MCs and avoids direct ingestion.
- Use the same BMPs for manures/other residuals.
- Follow research & update BMPs.


# Go to www.nebiosolids.org…


Biosolids: Naturally Sustainable


http://www.endless-films.com/site/?portfolio=biosolids

- Click to “About Biosolids” for summary information & best resources
- Further explore the science behind use of biosolids
- See “Resources” section for more about “microconstituents” – including copy of this full presentation


**Thanks for… your invitation, your attention, & your questions and comments.**

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