Relationship Between Industrial Pretreatment & Biosolids

18th Annual New England Pretreatment Coordinators Workshop

Ned Beecher • North East Biosolids & Residuals Association
Wednesday, October 26, 2016
Pretreatment protects biosolids

- prevent the introduction of pollutants into a POTW that will interfere with its operation, including interference with its use or disposal of municipal sludge,

- prevent the introduction of pollutants into a POTW that will pass through the treatment works or otherwise be incompatible with it, and

- improve opportunities to recycle and reclaim municipal and industrial wastewaters and sludges.

--from the U. S. EPA Pretreatment Program website
Biosolids quality concerns

- “heavy metals”

- microconstituents, chemicals of emerging concern (CECs), pharmaceuticals & personal care products (PPCPs), antibiotics, flame retardants, etc., etc.

- pathogens

- public perception
  - being able to point to what you do for industrial pretreatment is huge in addressing questions about biosolids quality & impacts
Historic “sludges...” to “biosolids”

Next 2 slides courtesy of Rufus Chaney, PhD, U. S. Dept. of Agriculture.
Before Regulations, Bad Practices Occurred.


Biosolids applied 1967-1975; approx. 20 t/ha
Biosolids contained 700 mg Cd/kg, Cd:Zn=10%
Field soil contained 8.2 mg Cd/kg, Cd:Zn = 15%.

<table>
<thead>
<tr>
<th>Farm Trt</th>
<th>1975 pH</th>
<th>Chard mg/kg DW</th>
<th>Lettuce mg/kg DW</th>
<th>Soybean mg/kg DW</th>
<th>Oat mg/kg DW</th>
<th>Soybean mg/kg DW</th>
<th>Oat mg/kg DW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biosolids</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nil</td>
<td>5.7</td>
<td>70.4</td>
<td>49.9</td>
<td>2.64</td>
<td>3.38</td>
<td>2.05</td>
<td>2.24</td>
</tr>
<tr>
<td>Limed</td>
<td>6.4</td>
<td>17.7</td>
<td>9.9</td>
<td>0.65</td>
<td>0.54</td>
<td>0.46</td>
<td>0.28</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nil</td>
<td>5.2</td>
<td>0.9</td>
<td>1.5</td>
<td>0.16</td>
<td>0.11</td>
<td>0.11</td>
<td>0.08</td>
</tr>
<tr>
<td>Limed</td>
<td>6.2</td>
<td>0.5</td>
<td>0.6</td>
<td>0.13</td>
<td>0.07</td>
<td>0.03</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Cd Examples From Old Reports

• Long term sludge utilization farms in NE:
  - City 9  Elizabethtown, PA  169 Cd  0.033 Cd:Zn
  - City 13  Pottstown, PA  700 Cd  0.150 Cd:Zn
  - City 25  St. Marys, PA  970 Cd  0.780 Cd:Zn
  - City 1  York, PA  150 Cd  0.028 Cd:Zn
  - City 2  Harrisburg, PA  160 Cd  0.049 Cd:Zn

• Purdue study of high metal sludges:
  - Frankfort, IN.  284 Cd  0.042 Cd:Zn
  - Anderson, IN.  247 Cd  0.048 Cd:Zn
  - Merion, IN.  1210 Cd  0.637 Cd:Zn

• Literature reports:
  - Fort Collins, CO.  98 Cd  0.056 Cd:Zn
  - Chicago, IL  210 Cd  0.051 Cd:Zn
Pretreatment has worked

Slide courtesy of Richard Stehouwer, PhD, Penn State Univ.

Cadmium concentration over time, showing a downward trend from 1978 to 2000. The graph includes median values, 90th percentiles, and error bars ranging from 25th to 75th percentile. The coefficient of determination ($r^2$) is 0.93.
How much is little enough?

“Heavy metals,” other elements of concern, chemicals – they are inevitably there in measurable concentrations.

What levels are acceptable in biosolids applied to soils, so as to not cause harm to human health or the environment?
Federal Part 503 Regulations - 1993

- 40 CFR Part 503 defined acceptable levels of 9 (10) metals
- Based on risk assessment
- Require biosolids applications according to agronomic needs, which reduces total mass of contaminants
- Based on the principal of absorptive capacity of the soil
The presence of a contaminant in biosolids does not mean there is risk; its fate and impact on humans and the environment must be evaluated.

Next 2 slides courtesy of Rufus Chaney, PhD, U. S. Dept. of Agriculture.

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Highly Exposed Individual</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Soil→Plant→Human</td>
<td>Farm markets; 2.5% of food</td>
</tr>
<tr>
<td>2. Soil→Plant→Human</td>
<td>Home gardens; 60% of garden foods for lifetime; 1000 t/ha</td>
</tr>
<tr>
<td>3. Soil→Human</td>
<td>200 mg/day soil/dust ingestion; 1000 t/ha</td>
</tr>
<tr>
<td>4. Soil→Plant→Animal→Human</td>
<td>Farms; 45% home-grown meat; 1000 t/ha</td>
</tr>
<tr>
<td>5. Soil→Animal→Human</td>
<td>Grazing ruminants; soil is 2.5% of annual diet; 45% home-grown meat.</td>
</tr>
<tr>
<td>6. Soil→Plant→Livestock</td>
<td>100% of livestock feeds grown on soils; 1000 t/ha</td>
</tr>
<tr>
<td>7. Soil→Livestock</td>
<td>Grazing ruminants; 2.5% soil in diet.</td>
</tr>
<tr>
<td>Pathway</td>
<td>Highly Exposed Individual</td>
</tr>
<tr>
<td>---------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>8. Soil ➔ Plant</td>
<td>Sensitive crops; strongly acidic; 1000 t/ha.</td>
</tr>
<tr>
<td>9. Soil ➔ Soil Biota</td>
<td>Earthworms; microbes; metabolic function of soil; 1000 t/ha.</td>
</tr>
<tr>
<td>10. Soil Biota ➔ Soil Biota Predator</td>
<td>Shrews; 1/3 of diet presumed to be earthworms full of soil; 1000 t/ha.</td>
</tr>
<tr>
<td>11. Soil ➔ Airborne Dust ➔ Human</td>
<td>Tractor operator; 1000 t/ha.</td>
</tr>
<tr>
<td>12. Soil ➔ Surface water ➔ Human</td>
<td>Subsistence fishers.</td>
</tr>
<tr>
<td>13. Soil ➔ Air ➔ Human</td>
<td>Farm households</td>
</tr>
</tbody>
</table>
### Perspective on metals land applied

*Table 5*

Estimated Total Metals Applied to Land From Various Products

<table>
<thead>
<tr>
<th>Metal</th>
<th>Biosolids (t)</th>
<th>Swine Manure (t)</th>
<th>Poultry Manure (t)</th>
<th>Phosphate Fertilizer (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>14.2</td>
<td>33.3</td>
<td>189</td>
<td>49.7</td>
</tr>
<tr>
<td>Cadmium</td>
<td>12.59</td>
<td>22.5</td>
<td>33</td>
<td>286</td>
</tr>
<tr>
<td>Chromium</td>
<td>168</td>
<td>NA</td>
<td>NA</td>
<td>761</td>
</tr>
<tr>
<td>Copper</td>
<td>1,202</td>
<td>2,745</td>
<td>6,743</td>
<td>249</td>
</tr>
<tr>
<td>Lead</td>
<td>215</td>
<td>68.4</td>
<td>667</td>
<td>53.7</td>
</tr>
<tr>
<td>Mercury</td>
<td>5.07</td>
<td>NA</td>
<td>NA</td>
<td>0.0</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>34.2</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Nickel</td>
<td>94.1</td>
<td>264</td>
<td>NA</td>
<td>121</td>
</tr>
<tr>
<td>Selenium</td>
<td>10.89</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Zinc</td>
<td>2,081</td>
<td>4,995</td>
<td>8,729</td>
<td>1,057</td>
</tr>
</tbody>
</table>

**Notes:**

Moss et al., 2002, WERF
Pretreatment helps POTWs meet 503.

- Part 503 includes 2 tiers of metals standards.
- Almost all current biosolids in the U. S. meet the higher quality “EQ” standard (lower metals)
- New England states have even lower numerical standards for metals.
- Today’s biosolids are clean enough for widespread use – thanks to pretreatment & P2.
40+ Years of Research

...has shown the benefits & manageable risks

Biosolids improve soils.
Findings: Organic residuals improve soils
Univ. of Washington study, 2011

Numerous studies demonstrate the benefits derived from adding organic matter, such as biosolids, to soils: higher carbon content (carbon sequestration), increased microbial activity, increased water-holding capacity, and lower bulk density (which means easier tillage & handling).
Managing BIOSOLIDS & other organic residuals: What’s ideal for sustainability?

MAXIMIZE BENEFICIAL USES OF RESOURCES

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Benefits</th>
<th>Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>valuable in agriculture in dry times</td>
<td>cost of transport</td>
</tr>
<tr>
<td>Organic matter</td>
<td>vital to soils</td>
<td>putrescible, odor</td>
</tr>
<tr>
<td>Nutrients</td>
<td>plant &amp; animal food</td>
<td>impacts to water</td>
</tr>
<tr>
<td>Energy</td>
<td>renewable, displaces oil/gas</td>
<td>air emissions, no use of nutrients &amp; organic matter if incinerated</td>
</tr>
</tbody>
</table>

MANAGE TO MINIMIZE POTENTIAL RISKS

Reduce/control/mitigate trace elements (e.g. metals), pathogens, synthetic and natural organic chemical compounds, odors, nuisances
Examples of why your work is critical

- Look where biosolids are used; you want to protect those places.
- Look how biosolids solve important environmental concerns; you want to ensure biosolids can continue to be used.
Biosolids management in U. S.:
7,180,000 dry U. S. tons/year (~35.9 million wet tons)

55% is used on soils

These data need updating...
Biosolids use: Agriculture

- Bulk material markets: animal feed crops (corn, hay), grains (wheat, hops), soy, other commodity crops

- Prices:
  - Class B - $0 - $30 / wet ton
  - Class A – up to $60 / ton

- Trend: increasing demand; waiting lists in some areas

Moorhead, MN: Feed corn grown with liquid injected, Class B, anaerobically-digested biosolids, July 2012
Biosolids use: Forestry

Only in some areas
Speeds up harvest cycle in actively managed stands
Price:
- Class B $0 - minimal

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

Photo courtesy of Philadelphia Water Dept.
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), parks, lawns, growing turfgrass (e.g. in RI), sports fields (hi-spec turf)

- Prices:
  - Class A bulk – up to $60 / ton
  - Class A bagged/retail – up to $450 / ton

- Trend: increasing demand for quality, consistent products
Horticulture, landscaping: Class A products are 22+% of beneficial use in the U.S.
Making & using biosolids compost

- The Great Lawn, Central Park NYC
- Static pile composting, Southboro, MA
- Streambank stabilization, PA
- Spectacle Island, Boston, MA
- Fabric-covered composting, Moncton, NB
- Co-composting w/ MSW, Marlboro, MA
- Central Valley, California

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Making & using biosolids compost

before

after
Biosolids Use: Topsoil Blending

- Bulk biosolids given or sold to topsoil blenders
- Prices: vary, often $0
- A way to use less processed material
- Topsoils used for reclamation, landfill cover, highway embankments, construction sites
- Trend: steady use

Topsoil blending with paper mill residuals and biosolids, central MA, 2006
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
- Prices: vary, often $0
  - Uses a lot of biosolids
- 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
Biosolids Use: Landfill Leachate Treatment

Slide courtesy of Sylvis, Vancouver, BC
A biosolids treatment process that results in biosolids to be used or discarded.

Trend: Huge interest & activity now, across the continent.
The different microconstituents... 
...antibiotics to pharmaceuticals to \textit{dibenzo-p-dioxins}
Concentrations of TOrCs in biosolids

Clark and Smith, 2010

Fig. 1. Typical concentrations of selected ‘emerging’ organic contaminants in sewage sludge (mg kg$^{-1}$ dw).
Chemicals of greatest concern in biosolids have…

- High log $K_{ow}$ - octanol-water partition coefficient
- High toxicity (to some species)
- Long half-lives (persistent)
- Bioaccumulative
- Dioxins/furans are excellent example: thoroughly studied and not found to require regulation (EPA, 2003)

Far greater concerns and impacts are in the WRRF effluent and receiving aquatic environment.
Greatest concern for plant uptake:

Absorption & membrane permeability are more likely when…

- $\text{Log } K_{ow} < 3$
- Molecular Weight $< 300$
- H-bond donors $< 3$
- H-bond acceptors $< 6$

Useful for screening compounds for further risk assessment. Vast majority of TOrCs in biosolids do not meet these criteria.

Kumar and Gupta, 2015
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.
How much more concentrated is BPA in these receipts than in biosolids?

- a) Equal
- b) 400x
- c) 4000x

BPA in credit card receipts = 8-17 g/kg

BPA in biosolids = 0.1-4.6 mg/kg

Modified from Sally Brown, PhD, Univ. of WA
NORTHWEST BIOSOLIDS

Biosolids: Understanding the risk

Putting it into perspective - how does using biosolids or compost made with biosolids compare to chemical exposures in everyday life?

Number of years of contact = 1 dose

From NW Biosolids fact sheet
Biosolids & soils: Remarkable media for managing TOrCs!
Q: Where do we want to put TOrCs? (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 TOrCs.

“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
Best management to address TOrCs

Focus on biosolids quality.  
Source reduction works.  Enforce industrial 
pretreatment.  Support phase-outs of persistent
TOrCs.

<table>
<thead>
<tr>
<th>Year</th>
<th>Cadmium</th>
<th>Chromium</th>
<th>Copper</th>
<th>Lead</th>
<th>Nickel</th>
<th>Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>33</td>
<td>712</td>
<td>700</td>
<td>1,261</td>
<td>148</td>
<td>2,031</td>
</tr>
<tr>
<td>1983</td>
<td>12.5</td>
<td>360</td>
<td>361</td>
<td>421</td>
<td>79</td>
<td>1,701</td>
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<tr>
<td>1993</td>
<td>7.3</td>
<td>209</td>
<td>764</td>
<td>225</td>
<td>51</td>
<td>1,444</td>
</tr>
<tr>
<td>2000</td>
<td>4.2</td>
<td>115</td>
<td>566</td>
<td>178</td>
<td>53</td>
<td>1,619</td>
</tr>
</tbody>
</table>

Philadelphia Water District biosolids quality over time, courtesy of Bill Toffey.
What biosolids generators & managers can do…

Focus on biosolids quality.

• When possible, use treatment processes that degrade TOs: biological processes are most effective.

• Use multiple processes, e.g. anaerobic digestion followed by composting & application.
What biosolids managers can do…

Use Best Management Practices.

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

ned.beecher@nebiosolids.org

603-323-7654