EURASIAN WATER CONFERENCE
3rd ASEM Seminar on Urban Water Management
Urban solutions for global challenges
13-14 September 2018 Budapest
www.asemwaterbudapest2018.hu
Biosolids and sludge from wastewater: The Matters
Connecting Urban and Rural Communities with Challenges

Ninghu Su
James Cook University
Cairns, Queensland, Australia
Outline

• The issues on biosolids and sludge generally and examples in Australia, China, and Europe;

• Concerns over the presence of heavy metals, emerging pollutants (pharmaceuticals and personal care products) in wastewater, biosolids and sludge used on land;

• The challenges and problems confronting urban, rural and environmental practitioners and the whole community.
1. Freshwater withdrawals, use and wastewater at a global scale

Source: UN Water, 2017

- Agriculture uses 70% of total water withdrawals
  - 38% for agricultural water use;
  - 32% agricultural drainage;
- Municipal and Industrial wastewater: 24%
  - Industrial wastewater: 16%
  - Municipal wastewater: 8%
- Municipal and Industrial consumptions:
  - Municipal: 3%
  - Industrial consumption: 3%
2. Status of the wastewater

Source: UN Water Development Report 2017: Wastewater: Untapped Resources

- One of the internationally applied guidelines for wastewater use is the WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater in Agriculture (WHO, 2006a).
- The wastewater quality guidelines for agricultural use developed by FAO (1985; 1992) focus on evaluating the suitability of water for irrigation and identifying possible restrictions in use.
- Effective policies and regulations for wastewater use and resource recovery are mostly lacking at the national level, being only implemented in a small number of countries, including Israel, Jordan, Mexico, Tunisia and Turkey, where wastewater irrigation is a well-established practice.
2. Global wastewater and biosolids
Source: UNESCO, 2017

- On average, the municipal and industrial wastewater generated worldwide
  - Low-income countries: only 8% undergoes treatment of any kind;
  - Lower middle-income countries: 28%;
  - Upper middle-income countries treat about 38%
  - High-income countries treat about 70%;
- Globally, over 80% of all wastewater is discharged without treatment.
- Biosolids and sludge generated during wastewater treatment are therefore proportional to these figures.
2. Global wastewater and biosolids
Source: UNESCO, 2017

• Agriculture can be a source of pollutants:
  – organic matter, pathogens, metals and emerging pollutants.
• Over the last 20 years, new agricultural pollutants have emerged:
  – antibiotics, vaccines, growth promoters and hormones that may be released from livestock and aquaculture farms.
• The use of municipal wastewater is a common practice in many parts of the World
  – Middle East, North Africa, Australia, the Mediterranean, China, Mexico and the USA.
• The practice has been most successful in urban and peri-urban areas, implying that rural areas are problems for attention.
3. Biosolids use in several industrial countries

(Sharma et al., Waste Management, vol. 64, 2017)
4. Example of biosolids use: Biosolids statistics in Australia

Source: Australia & New Zealand Biosolids Partnership

- Overall agricultural use of the total biosolids:
  - 55% in 2010
  - 59% in 2013
  - 64% in 2015
  - 75% in 2016/17
4.1. Typical biosolids breakdown (Australia)

Source: Australian Dept. Sustainability, Environment, Water and Population, June 2012

- The major health and environmental concerns are:
  - Inert matter
  - Micro-nutrients
  - Other compounds
### 4.2. Timelines and regulated chemicals in wastewater, sludge/biosolids in Australia

**Source:** Australian Dept. Sustainability, Environment, Water and Population, June 2012

<table>
<thead>
<tr>
<th>Year</th>
<th>Guideline</th>
<th>Contaminant</th>
<th>NSW, Qld, National, Tas, Vic, WA</th>
<th>SA</th>
<th>EU</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>EU Sludge Directive</td>
<td>Arsenic</td>
<td>Y</td>
<td>-</td>
<td>-</td>
<td>Y</td>
</tr>
<tr>
<td>1987</td>
<td>NSW Agriculture</td>
<td>Cadmium</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>1993</td>
<td>US EPA 40CRF503 rule</td>
<td>Chromium</td>
<td>Y</td>
<td>Y</td>
<td>-</td>
<td>Y</td>
</tr>
<tr>
<td>1996</td>
<td>SA EPA</td>
<td>Copper</td>
<td>Y</td>
<td>-</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>1997</td>
<td>NSW EPA</td>
<td>Lead</td>
<td>Y</td>
<td>-</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>1999</td>
<td>Tasmanian EPA</td>
<td>Mercury</td>
<td>Y</td>
<td>Y</td>
<td>-</td>
<td>Y</td>
</tr>
<tr>
<td>2001</td>
<td>Qld EPA Operational policy</td>
<td>Nickel</td>
<td>Y</td>
<td>Y</td>
<td>-</td>
<td>Y</td>
</tr>
<tr>
<td>2001</td>
<td>Safe Sludge Matrix (UK Water and British Retail Consortium)</td>
<td>Selenium</td>
<td>Y</td>
<td>-</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>2002</td>
<td>WA EPA</td>
<td>Zinc</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>2003</td>
<td>NZWWA supported by Ministry for the Environment</td>
<td>Hexachlorobenzene</td>
<td>Y</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2004</td>
<td>Vic EPA</td>
<td>Benzene hexachloride total</td>
<td>Y</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2004</td>
<td>National Water Quality Management Strategy (National guideline)</td>
<td>Lindane</td>
<td>Y</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2009</td>
<td>SA EPA (draft)</td>
<td>Dieldrin</td>
<td>Y</td>
<td>Y</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2010</td>
<td>WA EPA (draft)</td>
<td>Hexachloroplatin</td>
<td>Y</td>
<td>Y</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DDD</td>
<td>Y</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DCE</td>
<td>Y</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DDT</td>
<td>Y</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total DDT analogs</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PCB Total</td>
<td>Y</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aldrin</td>
<td>Y</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chlordanes</td>
<td>Y</td>
<td>Y</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total dioxins</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Notes:**
1. WA includes DDT analogs
2. Vic doesn’t have a limit for BHC
4.3. Examples
Modern timelines for sludge and biosolids applications in Australia and China and resultant contamination

• **China** (Zhang *et al.*, Forestry Economics, vol. 6, 2014):
  – 1957: wastewater irrigation started;
  – 2002: pollution of rice by cadmium is first reported as “Cadmium Rice”, 45 years since 1957;
  – 2011-2013: “Cadmium Rice” incidence is further reported as major environmental problems;
  – 2014: Official national data released on heavy metal contamination, which maps the extent of pollution;

  – 1970: sludge disposal on land recorded;
  – 1987: Biosolids Guidelines issued in the State of New South Wales;
  – 1993: biosolids beneficial use started;
  – 2017: 75% of biosolids and unknown quantity of sludge are applied to agricultural land;
5. Health and Environmental Concerns

- The presence of heavy metals and other emerging contaminants in biosolids and sludge are major concerns for human, animal and environmental health.
- There contaminants appear in different forms
  - on Land/soil and in waters of different states;
  - Food chains
    - Soil and water contamination;
    - Crop update and retention;
    - Food and forage contamination;
    - Health concerns
5.1. Heavy metal contamination of soils

Sources:
Food and Agriculture Organisation, UN (2015)
European Environmental Agency (2014);
Ministry of Environmental Protection, China (2014)

- Waste disposal and industrial activities are the most important sources of soil contamination overall;
- The most frequent contaminants are heavy metals and mineral oils.
5.2. Heavy metal contamination as one form of soil contamination in Australia

Source: FAO, Status of the world’s Soil Resources (2015)

- The pattern of contamination in Australia is similar to that of other developed countries.
- Industry, including the petroleum industry, mineral mining, chemical manufacture and processing facilities, and agricultural activities with their use of P fertilizer and pesticides, have caused soil contamination with heavy metals, hydrocarbons, mineral salts, particulates, etc.
- The total number of contaminated sites is estimated at 80,000 across Australia (DECA, 2010), with approximately 1,000 actual or potentially contaminated sites in South Australia (SKM, 2013).
5.3. Heavy metal contamination of soils in Australia

- The most commonly detectable Heavy metals/metalloids from biosolids (Hayes et al. *Advances in Agronomy*. vol. 104, 2009)
  - Pb, Ni, Cd, Cr, Cu, Zn

- They originate primarily from the contamination of domestic wastes with industrial wastewater.

- “The greatest environmental concern for long-term biosolids use in Australia” (Pritchard et al., *Water Sci. & Technol.* vol. 61., 2010)
  - Cd, Cu, Zn.

Duration to the risk limit: Heavy metal contamination of soils in China
Source: Ding et al., *Environ. Sci. Pollut. Research* vol 24, 2017
5.4. Heavy metal pollution of agricultural soils and regulatory standards around the world

Source: He et al., J. Environmental Indicators, vol. 9, 2015

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of pollution sites</th>
<th>% of heavy metal(loids) pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global</td>
<td>&gt;10000000</td>
<td>&gt;50</td>
</tr>
<tr>
<td>USA</td>
<td>&gt;100000</td>
<td>&gt;70</td>
</tr>
<tr>
<td>European Union</td>
<td>&gt;80000</td>
<td>37</td>
</tr>
<tr>
<td>Australia</td>
<td>&gt;50000</td>
<td>&gt;60</td>
</tr>
<tr>
<td>China</td>
<td>1.0 million km²</td>
<td>&gt;80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Country</th>
<th>As</th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Hg</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>20</td>
<td>3</td>
<td>50</td>
<td>100</td>
<td>1</td>
<td>60</td>
<td>300</td>
<td>200</td>
</tr>
<tr>
<td>Canada</td>
<td>20</td>
<td>3</td>
<td>250</td>
<td>150</td>
<td>0.8</td>
<td>100</td>
<td>200</td>
<td>500</td>
</tr>
<tr>
<td>China</td>
<td>20-40</td>
<td>0.3-0.6</td>
<td>150-300</td>
<td>50-200</td>
<td>0.3-1.0</td>
<td>40-60</td>
<td>80</td>
<td>200-300</td>
</tr>
<tr>
<td>Germany</td>
<td>50</td>
<td>5</td>
<td>500</td>
<td>200</td>
<td>5</td>
<td>200</td>
<td>1000</td>
<td>600</td>
</tr>
<tr>
<td>Tanzania</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>200</td>
<td>2</td>
<td>100</td>
<td>200</td>
<td>150</td>
</tr>
<tr>
<td>Netherlands</td>
<td>76</td>
<td>13</td>
<td>180</td>
<td>190</td>
<td>36</td>
<td>100</td>
<td>530</td>
<td>720</td>
</tr>
<tr>
<td>NZ</td>
<td>17</td>
<td>3</td>
<td>290</td>
<td>&gt;104</td>
<td>200</td>
<td>N/A</td>
<td>160</td>
<td>N/A</td>
</tr>
<tr>
<td>UK</td>
<td>43</td>
<td>1.8</td>
<td>N/A</td>
<td>N/A</td>
<td>26</td>
<td>230</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>USA</td>
<td>0.11</td>
<td>0.48</td>
<td>11</td>
<td>270</td>
<td>1</td>
<td>72</td>
<td>200</td>
<td>1100</td>
</tr>
</tbody>
</table>

Unit: mg/kg
5.5. Heavy metals in wastewater

Heavy metals are measured/monitored but not removed during wastewater treatment processes in Eastern States of Queensland and New South Wales, Australia.

- Arsenic (As)
- Cadmium (Cd)
- Chromium (Cr)
- Copper (Cu)
- Lead (Pb)
- Mercury (Hg)
- Nickel (Ni)
- Selenium (Se)
- Zinc (Zn)
- Total Solids %

- HCB
- BHC (other than g-BHC)
- Lindane
- Dieldrin
- Heptachlor
- DDD
- DDE
- DDT
- Total DDTs
- PCB

- Aldrin
- Chlordane
- Ammonia N
- Conductivity (mS/cm)
- Nitrate as N
- Nitrite as N
- Total N (Kjeldahl)
- pH (pH units)
### 5.6. A sample data sheet from a wastewater treatment plant in Australia

Mean heavy metal data sheet from a wastewater treatment plant in Australia 2014-2018. Unit: mg/kg

<table>
<thead>
<tr>
<th>Metal</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadmium</td>
<td>1.338</td>
<td>1.338</td>
<td>1.247</td>
<td>1.055</td>
<td>1.435</td>
</tr>
<tr>
<td>Copper</td>
<td>535.000</td>
<td>639.375</td>
<td>586.817</td>
<td>478.462</td>
<td>456.111</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.790</td>
<td>0.959</td>
<td>0.724</td>
<td>0.623</td>
<td>0.604</td>
</tr>
<tr>
<td>Selenium</td>
<td>3.850</td>
<td>4.469</td>
<td>3.901</td>
<td>4.000</td>
<td>3.633</td>
</tr>
<tr>
<td>Zinc</td>
<td>680.556</td>
<td>762.5</td>
<td>606.367</td>
<td>576.923</td>
<td>607.222</td>
</tr>
</tbody>
</table>

He et al. J. Environmental Indicators, 2015
6. Concerns

• Neither are heavy metals removed nor emerging pollutants measured during wastewater treatment processes in Eastern States (Queensland and New South Wales) of Australia

• Either biosolids or sludge/slurry are transported for application on land and for other uses.

• Contaminants can accumulate in soils and other environments to cause various damages.
  – Physical, chemical
  – Biological
6.1. Example 1: Cadmium mass balance following applying biosolids


- In limited reports on Cd distributions in plant organs following the biosolids application, plant leaves are more effective in uptaking Cd.
6.2. Example 2: Cadmium mass balance following applying biosolids


In the limited reports on Cd balance following the biosolids application:

• Soil retained the most;
• Leachates followed;
• Plants retained some;

![Mass balance – all species](image)
6.3. Example 3: Biosolids as fertilizer for pine trees: Pollutant leaching potential out of the root zone following applying biosolids.

Su et al. Measurement and modelled scenarios in a radiate pine plantation, New Zealand, unpublished.
• “Cadmium Rice” in China
  (http://www.xinhuanet.com/gzgdm/index.htm)
  — wastewater irrigation over the past decades resulted in gradual cadmium accumulation in soils and increased concentrations in crops.
6.5. Example 5: Duration to the heavy metal contamination limit.

Heavy metal contamination of soils in China
Source: Ding et al., Environ. Sci. Pollut. Research. vol 24, 2017
### 6.6. Example 6: Soil contamination in China as of 2014


<table>
<thead>
<tr>
<th>Area</th>
<th>% of polluted sampled areas</th>
<th>Major pollutants</th>
<th>Pollution levels, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Inorganics: 82.8% of total; followed by organic and other forms</td>
<td>Trace</td>
</tr>
<tr>
<td>Overall nationally</td>
<td>16.1</td>
<td>Ni, Cu, As, Hg, Pb, DDT, PAH</td>
<td>11.2</td>
</tr>
<tr>
<td>Farmland</td>
<td>19.4</td>
<td>Cd, Ni, Cu, As, Hg, Pb, DDT, PAH</td>
<td>13.7</td>
</tr>
<tr>
<td>Woodland</td>
<td>10.0</td>
<td>As, Cd, DDT</td>
<td>5.9</td>
</tr>
<tr>
<td>Grassland</td>
<td>10.4</td>
<td>Ni, Cd, As</td>
<td>7.6</td>
</tr>
<tr>
<td>Other types of land</td>
<td>11.4%</td>
<td>Ni, Cd</td>
<td>8.4</td>
</tr>
</tbody>
</table>
### 6.6. Example 6: Soil contamination in China as of 2014


<table>
<thead>
<tr>
<th>Heavy metals</th>
<th>Incidence %</th>
<th>Pollution Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trace</td>
<td>Slight</td>
</tr>
<tr>
<td>Cd</td>
<td>7.0</td>
<td>5.2</td>
</tr>
<tr>
<td>Hg</td>
<td>1.6</td>
<td>1.2</td>
</tr>
<tr>
<td>As</td>
<td>2.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Cu</td>
<td>2.1</td>
<td>1.6</td>
</tr>
<tr>
<td>Pb</td>
<td>1.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Cr</td>
<td>1.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Zn</td>
<td>0.9</td>
<td>0.75</td>
</tr>
<tr>
<td>Ni</td>
<td>4.8</td>
<td>3.9</td>
</tr>
</tbody>
</table>
6.7. Example 7: Heavy metal contamination of soils in China

6.8. Example 8: Duration to the risk limit: Heavy metal contamination of soils in China

7. Emerging pollutants
Source: UNESCO, 2011, 2017

• The main categories of emerging pollutants present in wastewater (concentrated in biosolids and sludge) are
  – pharmaceuticals (e.g. antibiotics, analgesics, anti-inflammatory drugs etc.);
  – steroids and hormones;
  – personal care products;
• Emerging pollutants are found in varying concentrations
  – in treated and untreated municipal wastewater;
  – industrial effluents and agricultural runoff that seeps into rivers, lakes and coastal waters;
• Emerging pollutants have also been detected in drinking water (Raghav, et al., 2013), as conventional wastewater treatment and water purification processes are not effective in removing them.
7.1. Example of emerging pollutants: Antibiotics

- World antibiotics usage: 100,000 to 200,000 tons per year (Kummerer, *Chemosphere*, 2009; Laxminarayan et al., *Lancet Infect. Dis.*, 2013).

- Example: 15 antibiotics were detected in a rural catchment in Southern China (Source: Chen et al. *Water*, 2018).

8. Questions Relating to Emerging pollutants

1. Will hormones and chemicals cause genetic mutations in microbial communities and animals in the environment? 
   – What are the consequences if they occur?

2. Will microbial resistance to antibiotics develop in the environment? 
   – What are the consequences if they occur?
9. Heavy metals in European soils

Summary statistics of heavy metal concentrations.

<table>
<thead>
<tr>
<th>Element</th>
<th>Concentration (mg/kg)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Name</td>
<td>Min</td>
<td>Max</td>
<td>Mean</td>
</tr>
<tr>
<td>Cd</td>
<td></td>
<td>0.02</td>
<td>3.17</td>
<td>0.09</td>
</tr>
<tr>
<td>As</td>
<td></td>
<td>0.46</td>
<td>252.53</td>
<td>3.72</td>
</tr>
<tr>
<td>Co</td>
<td></td>
<td>0.32</td>
<td>91.89</td>
<td>6.35</td>
</tr>
<tr>
<td>Cr</td>
<td></td>
<td>1.57</td>
<td>273.94</td>
<td>21.72</td>
</tr>
<tr>
<td>Cu</td>
<td></td>
<td>0.91</td>
<td>159.07</td>
<td>13.01</td>
</tr>
<tr>
<td>Hg</td>
<td></td>
<td>0</td>
<td>1.59</td>
<td>0.04</td>
</tr>
<tr>
<td>Mn</td>
<td></td>
<td>9.62</td>
<td>2285.23</td>
<td>373.05</td>
</tr>
<tr>
<td>Ni</td>
<td></td>
<td>0.36</td>
<td>466.48</td>
<td>18.36</td>
</tr>
<tr>
<td>Pb</td>
<td></td>
<td>1.63</td>
<td>151.12</td>
<td>15.3</td>
</tr>
<tr>
<td>Sb</td>
<td></td>
<td>0.01</td>
<td>10.91</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Regulatory standards for heavy metals
Source: He et al., J. Environmental Indicators. 2015
Unit: mg/kg

<table>
<thead>
<tr>
<th>Country</th>
<th>As</th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Hg</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>20</td>
<td>3</td>
<td>50</td>
<td>100</td>
<td>1</td>
<td>60</td>
<td>300</td>
<td>200</td>
</tr>
<tr>
<td>Canada</td>
<td>20</td>
<td>3</td>
<td>250</td>
<td>150</td>
<td>0.8</td>
<td>100</td>
<td>200</td>
<td>500</td>
</tr>
<tr>
<td>China</td>
<td>20-40</td>
<td>0.3-0.6</td>
<td>150-300</td>
<td>50-200</td>
<td>0.3-1.0</td>
<td>40-60</td>
<td>80</td>
<td>200-300</td>
</tr>
<tr>
<td>Germany</td>
<td>50</td>
<td>5</td>
<td>500</td>
<td>200</td>
<td>5</td>
<td>200</td>
<td>1000</td>
<td>600</td>
</tr>
<tr>
<td>Tanzania</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>200</td>
<td>2</td>
<td>100</td>
<td>200</td>
<td>150</td>
</tr>
<tr>
<td>Netherlands</td>
<td>76</td>
<td>13</td>
<td>180</td>
<td>190</td>
<td>36</td>
<td>100</td>
<td>530</td>
<td>720</td>
</tr>
<tr>
<td>NZ</td>
<td>17</td>
<td>3</td>
<td>290</td>
<td>&gt;10^4</td>
<td>200</td>
<td>N/A</td>
<td>160</td>
<td>N/A</td>
</tr>
<tr>
<td>UK</td>
<td>43</td>
<td>1.8</td>
<td>N/A</td>
<td>N/A</td>
<td>26</td>
<td>230</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>USA</td>
<td>0.11</td>
<td>0.48</td>
<td>11</td>
<td>270</td>
<td>1</td>
<td>72</td>
<td>200</td>
<td>1100</td>
</tr>
</tbody>
</table>
10. Concerns Relating to emerging pollutants and heavy metals

1. Will microbial resistance to antibiotics develop in the environment?
2. Will hormones and chemicals cause genetic mutations in microbial communities and animals in the environment?
3. Are chronic diseases, obesity and other health problems related to emerging contaminants and heavy metals in food chains?
4. How to cost-effectively to remove heavy metals from wastewater, biosolids and sludge? There are techniques such as struvite (magnesium ammonium phosphate) which can cause Mg pollution if not used properly;
5. How to cost-effectively to remove emerging contaminants from wastewater, biosolids and sludge?
6. How to reduce wastes from humans?
7. How are research and policies at regional national and international levels to be developed, funded and supported?
Summary

- **Heavy metals**, and other contaminants are concerns when biosolids and sludge are applied on soils and land;
  - Their accumulation in soils has resulted in crisis in human and environmental health in some regions such as in Southern China;
  - The potential risks of land contamination and environmental pollution in some regions are concerns even there is no immediate crisis in Australia;
  - In EU countries, heavy metal contamination is also

- **Emerging pollutants** in biosolids and sludge and their impacts are concerns but have not been addressed (UNESCO, 2011, 2017)
  - The effects of individual pollutants on human and ecosystem health have been only marginally evaluated, whereas their cumulative effects have not been studied at all;
  - Emerging pollutants are rarely controlled or monitored;
  - Further research is needed to assess their impacts on human health and the environment.
Acknowledgements

1. Cooperation with Mr John Bishop, Principal Engineer, Cairns Regional Council, Queensland, Australia;

2. Some results on simulated effluent leaching potentials were completed in cooperation with colleagues in New Zealand funded by the New Zealand Foundation for Research, Science and Technology.

Thank you