Bio-based fertilizers: a practical approach towards circular economy

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From a linear economy
To a circular economy

The Circular Economy Package Adopted by the Commission on 2\textsuperscript{nd} December 2015:

• Action Plan
• Communication
• List of Follow-up Initiatives (Annex)
• Legislative proposal on waste
Key action areas

Production

Consumption

Innovation, Investment, Monitoring

Secondary raw materials

Waste Management
Priority sectors

Biomass & Bio-based Products

Plastics

Construction & Demolition

Critical Raw Materials

Food Waste
Circular Economy—”closing the loop” of product life cycles through greater recycling

- The value of products, materials and resources is maintained in the economy for as long as possible
- Waste generation is minimised
- Brings economic, social and environmental gains
Why? From a Global Perspective...

- 9 billion people by 2030 is estimated - a challenge is to meet demand for goods. Feeding the larger, better-fed, longer-living human population
- IFA predicts that food requirements by 2050 will be 50 to 80% greater than they are now
- All Will fertilizer Growth track population Growth?
- Global solid wastes is estimated to increase from 1.3 to 2.2 billion tons by 2025.
- The exponential growth in nutrient use is overwhelming the absorptive capacity of natural nutrient cycles
- Waste and the growing leakage of nutrients into the environment are more important challenges of nutrients management and a more urgent threat to food sustainability/security than resource finiteness.
- SOLUTION: Changes in nutrient use efficiency—many contributing technologies
The fertilizer sector, since its very beginning in the 19th century, has always been circular and based on re-use and recycling.
Recycling of nutrients, especially phosphates, from waste streams into high quality mineral fertilizers.

Examples:

- Ashes from wood, meat & bone meal, manure
- Struvite from wastewater (NH$_4$MgPO$_4$·6 H$_2$O)
- Calcium phosphate and ammonium sulphate from manure
**P is finite resource**
- Finitity,
- Increasing demand,
- Quality

**Almost no P rock in Europe**
- Geopolitical dependency

**N is energy demanding**
- Large impact on food production

**N & P cause environmental problems**
- Water & air quality

Since 2014 Rock Phosphate identified as one of 14 “scarce” raw materials: very limited sources in EU and “geopolitical complicated” suppliers

**Closing the P cycle & other nutrients**
What can be done?

1. Removing barriers in legislation that prevent the creation of a market

2. Raising awareness, sharing successful examples of phosphorus recycling

3. Facilitating set-up of concrete project and business cases
Nutrients leakage

- Low efficiency and high leakage in 4 sectors:
  - Fertilising crops with manure and mineral fertilisers
  - Feeding livestock and managing their waste
  - Processing food and feeding humans
  - Managing human waste

- Signs of this over-extended system:
  - Eutrophication of waters (N and P) - Damage to terrestrial and aquatic/marine biodiversity
  - Pollution of air - nitrogen oxides, particulates, ammonia;
    Greenhouse gases - nitrous oxide and methane
NITROGEN FLOWS FOR THE EU27
ONLY 14% OF INPUT N REACHES HUMAN CONSUMPTION

MT PER ANNUM

<table>
<thead>
<tr>
<th></th>
<th>N2</th>
<th>N2O</th>
<th>NH3</th>
<th>NOx</th>
<th>Emissions to air</th>
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<tbody>
<tr>
<td>Feed import 2.7</td>
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<td>N in mineral fertiliser 10.9</td>
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<td>Atm. deposit 2.1</td>
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<td>Biol. fixation 1.0</td>
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<td>EU27 agricultural sector</td>
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<tr>
<td>Crops</td>
<td>N in applied manure 7.2</td>
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<tr>
<td>Livestock</td>
<td>Gras 2.4</td>
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<td></td>
<td>Fodder 5.0</td>
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<td></td>
<td>Losses 1.0</td>
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<td>EU27 food system</td>
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<tr>
<td>Processing</td>
<td>N in vegetable products 1.1</td>
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<td></td>
<td>Waste and other uses 2.8</td>
<td></td>
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<tr>
<td>Human intake</td>
<td></td>
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</tr>
</tbody>
</table>

Import products 0.04

N leaching and runoff 5.0

Emissions to groundwater and surface waters

7,3

Leip et al (2014)
I must clarify how we calculate the 20%. If we look at human uptake compared to total input into the system it looks like 14 percent 2.4 over 16.74.

Allan Buckwell; 20/3/2016
PHOSPHORUS FLOWS IN THE EU27

ONLY 30% OF INPUT P REACHES HUMAN CONSUMPTION

The Phosphorus cycle

van Dijk et al. 2016
1) MANURE

Challenges:
- efficiency and nutrient recovery:
- Improve handling, storage
- Process manure to more concentrated product
2) SEWAGE SLUDGE

Challenges:
- Increase recovery.
- Specification of nutrient content.
- Concerns about soil, plant and human health.
3) FOOD WASTE

- **Less information is available.**
- **Definitions of waste vary among member states.**
- **Biodegradable/organic waste**
  - compost
  - digestate
- **Slaughterhouse waste**
  - Most incinerated
Fertilizer technologies for circular economy elaborated by team from WUST:

- Accredited Laboratory for ISO 17025 (ILAC MRA)
  - Fertilizer macro- and micronutrients, toxic elements; ICP-OES, ICP-MS, Kjeldahl N
- Experience in elaboration of technologies of bio-based fertilizers and bio-plant protection products (plant growth biostimulants, bio-fertilizers)
- Working in full R&D cycle: from the concept, through lab tests, scale-up (large-laboratory, quarter technical) ending with evaluation of applicative properties of product (in vitro and in vivo (germination tests, pot trials, field experiments)
- Ending with technological offer for industry
4 new groups of fertilisers from bio-based streams were proposed:

1. Biomass-Based Micronutrient Fertilisers (BBMF),
2. Protein Hydrolysate-Based Fertilisers (PHBF; e.g., feathers),
3. Animal Feces-Based Fertilisers (AFBF; e.g., animal waste, sewage sludge, biochar),
4. Slaughter By-Products-Based Fertilisers (SBBF; e.g., feathers, bones).
### Table 1.3: Macro-element content (%) in selected bio-based products

<table>
<thead>
<tr>
<th>Renewable fertiliser sources</th>
<th>N</th>
<th>P$_2$O$_5$</th>
<th>K$_2$O</th>
<th>S</th>
<th>MgO</th>
<th>CaO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry feathers</td>
<td>15.5</td>
<td>0.32</td>
<td>0.24</td>
<td>2.32</td>
<td>0.22</td>
<td>0.4</td>
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<tr>
<td>Bones – poultry</td>
<td>7.15</td>
<td>18.72</td>
<td>0.16</td>
<td>0.153</td>
<td>0.85</td>
<td>34.1</td>
</tr>
<tr>
<td>Swine bone meals</td>
<td>6.06</td>
<td>16.82</td>
<td>0.25</td>
<td>0.84</td>
<td>0.49</td>
<td>28.5</td>
</tr>
<tr>
<td>Farmyard manure</td>
<td>0.52</td>
<td>0.22</td>
<td>0.58</td>
<td>0.078</td>
<td>0.13</td>
<td>0.024</td>
</tr>
<tr>
<td>Poultry manure</td>
<td>1.94</td>
<td>1.44</td>
<td>0.93</td>
<td>0.055</td>
<td>0.92</td>
<td>0.015</td>
</tr>
<tr>
<td>Swine manure</td>
<td>0.33</td>
<td>0.039</td>
<td>0.54</td>
<td>0.081</td>
<td>0.012</td>
<td>0.031</td>
</tr>
<tr>
<td>Cattle manure</td>
<td>0.42</td>
<td>0.049</td>
<td>0.39</td>
<td>0.063</td>
<td>0.013</td>
<td>0.028</td>
</tr>
<tr>
<td>Oak ash</td>
<td>0.01</td>
<td>4.9</td>
<td>8.94</td>
<td>0.32</td>
<td>0.59</td>
<td>34.8</td>
</tr>
<tr>
<td>Urban biowaste</td>
<td>2.88</td>
<td>0.57</td>
<td>1.00</td>
<td>0.19</td>
<td>0.17</td>
<td>1.58</td>
</tr>
</tbody>
</table>
1) Biomass-Based Micronutrient Fertilisers (BBMF)
1) **Biomass-Based Micronutrient Fertilisers (BBMF)**

- **Formula** - biomass enriched with fertilizer microelements in the biosorption process. Different types of the biomass can be enriched with microelement ions via biosorption process, for example: biochar, spent mushroom substrate, post-extraction residues (supercritical fluid extraction with carbon dioxide; SFE-CO2) from berries seeds, post-extraction residues (SFE-CO2) from biomass of micro- and macroalgae.

- **Results**
  - Field experiments on **corn** with the use of enriched with Zn, Mn and Cu ions biomass of **spent mushroom substrate (SMS)** and **post-extraction residues from Spirulina sp.** (SP). The highest yield was obtained for enriched SP tested at a dose 100% - 7.8 t/ha.
2) Protein Hydrolysate-Based Fertilisers (PHBF; e.g., feathers),
2) Protein Hydrolysate-Based Fertilisers (PHBF)

- **Formula** - protein hydrolysates enriched with micronutrient ions obtained from feathers as a source of protein

- **Results**

Field experiments on winter wheat and tomatoes with the use of two products obtained by hydrolysis of feathers: AminoPrim and AminoHort containing amino acids, respectively 15 and 20% and microelements, respectively 0.27 and 2.1%. Yield and content of micronutrients was significantly higher than in control groups.
3) Animal Faeces - Based Fertilisers (AFBF)
3) Animal Faeces -Based Fertilisers (AFBF)

Formula - hydrolysate of animal waste with wood ash and sewage sludge

Results

Field experiments on were performed on rapeseed, where obtained solid and liquid fertilizers were applied in two doses - 100 and 200%. In 200% dose of NPK solid fertilizer obtained yield was 10% higher than in control groups.
4) Slaughter By-Products-Based Fertilisers (SBBF)
4) **Slaughter By-Products-Based Fertilisers (SBBF)**

- **Formula**
  - Solid fertilizer I - feathers, sulphuric acid, ammonia water, calcium carbonate, ash, magnesite
  - Solid fertilizer II - feathers, sulphuric acid, ammonia water, calcium carbonate, zinc sulphate, manganese sulphate, copper sulphate, ash, magnesite

- **Results**
  - The field experiments were performed on lupine and mustard. The content of macro- and microelements in the cultivated plants was 2-10% higher than in control groups.
  - The production of above-mentioned fertilisers will be supported with an on-line system including database on bio-feedstock (e.g., accessibility of the biomass, chemical composition) and fertiliser composer covering the demand of given plant species for different nutrients, considering local climate and soils compositions. Bio-based fertilisers can be manufactured at a pilot scale and their utilitarian properties will be examined.
THINGS TO DO TO IMPLEMENT THE IDEA OF CIRCULAR ECONOMY:

1. Readiness of technologies
2. Legislation, pollutants, registration REACH
3. Organization of bio-wastes collection system to assure availability of secondary raw materials
4. Market Stimulants Direct Subsidies
   - Fiscal Reliefs
5. Penalties
   - Surpluses fertiliser taxes
   - Landfill and Incineration prohibitions/Gate Fees
   - Tax on nutrients leakage
   - Tax on using non-renewable raw materials
Only then circular economy would become a fact, not only theory...

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