PHOSPHATE INDUSTRY
IN THE BALANCE OF SUSTAINABLE DEVELOPMENT AND CIRCULAR ECONOMY

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CIRCULAR ECONOMY

Circular economy (CE) is sustainable development strategy

It is characterized in closed loop flows of materials in production, distribution and consumption.

(Su et al., 2013; Ghisellini et al., 2016)

CLEANER INNOVATIONS - implement the concept of sustainable development, which combines activities in a number of areas

THE TECHNICAL AREA

is considered to be the most significant one due to the minimization of environmental destruction through the interference into the technological process thanks to the achievements of technical sciences

Pawlowski, A., How many dimensions does sustainable development have?, Sustainable Development 2008, 16, 81-90.
CLEANER INNOVATIONS

assume three levels of activity, which may be chosen individually in order to improve the production process:

The basic process remains unchanged, significant modifications are carried out before and, above all, after the main process.

This is a solution which conditions the best effects. requires considerable accessibility of workforce, techniques, finances, and it must be accompanied by an increase in the profitability of a given company.

The first stage in the implementation of cleaner technologies, thus allowing the control and generation of savings in the stream flows of matter, energy and raw materials.

Misra K. B. (Ed.) Clean Production Environmental and Economic Perspectives, Springer
Assessment of the phosphate industry:

- Significant feedstock problems
- Negative environmental impact
- Excessive energy-consumption

Mineral sources of soil phosphorus originally come from rock, that has taken around 10–15 million years to form. Plants, in turn, obtain phosphorus from soils, and animals obtain phosphorus from food (plants or lower trophic-level animals).
PHOSPHORUS - CRITICAL ELEMENT

**LIFE**

- Biogenic element
- Energy carrier in cells
- Nucleic acids component
- Bone component

**DEATH**

- Firearms, grenades, napalm component
- Chemical weapons, war gases (tabun, sarin, soman, VX)
- Pesticides
- Drugs (Dezomorphine, the so-called crocodile, methamphetamine)

**Import to EU 2010-2014**

- Morocco 31%
- Russia 18%
- Syrian Arab Republic 12%
- Algeria 12%
- Jordan 7%
- Israel 6%
- Other non-EU countries 10%
- Egypt, Arab Rep. 4%

Total import: 6.4 million tonnes

**Supply forecast**

- Phosphate rock: X + + ++ + + 0

**2017 CRMs (27)**

<table>
<thead>
<tr>
<th>Material</th>
<th>2017 Criticality</th>
<th>Demand Forecast</th>
<th>Supply Forecast</th>
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<tbody>
<tr>
<td>Antimony</td>
<td>No</td>
<td>5 years</td>
<td>5 years</td>
</tr>
<tr>
<td>Baryte</td>
<td>Yes</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Beryllium</td>
<td>Yes</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Bismuth</td>
<td>Yes</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Borate</td>
<td>Yes</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Yes</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Coking coal</td>
<td>Yes</td>
<td>+</td>
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</tr>
<tr>
<td>Indium</td>
<td>Yes</td>
<td>+</td>
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<tr>
<td>Phosphorus</td>
<td>Yes</td>
<td>+</td>
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</table>

**Study on the review of the list of critical raw materials, EU Commission, 2017**
PHOSPHATE INDUSTRY - Non-renewable resources as an input material

ores with a lower concentration of the main component, a higher level of impurities, in places requiring the use of more advanced technologies

<table>
<thead>
<tr>
<th>Country</th>
<th>Years</th>
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<tbody>
<tr>
<td>Tunisia</td>
<td>20</td>
</tr>
<tr>
<td>Israel</td>
<td>36</td>
</tr>
<tr>
<td>China</td>
<td>37</td>
</tr>
<tr>
<td>Brazil</td>
<td>40</td>
</tr>
<tr>
<td>USA</td>
<td>41</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>70</td>
</tr>
<tr>
<td>Egypt</td>
<td>119</td>
</tr>
<tr>
<td>Russia</td>
<td>130</td>
</tr>
<tr>
<td>Jordan</td>
<td>217</td>
</tr>
<tr>
<td>World average</td>
<td>305</td>
</tr>
<tr>
<td>Others</td>
<td>362</td>
</tr>
<tr>
<td>Morocco/Western Sahara</td>
<td>1667</td>
</tr>
</tbody>
</table>

Static resource lifetime reserves/production „early warning indicator”

PHOSPHATE INDUSTRY – POLISH CASE

WASTE
Group 06: 2 149.7 thousand tons
Total mass on landfills till 2013: 112 806.4 thousand tons

PHOSPHATE ROCK
949 000 tons
308 000 tons \( P_2O_5 \)
from Algiers, Egypt and Syria

ELEMENTAL PHOSPHORUS
25 000 tons from Kazakhstan

WASTE
06 09 - waste from the production, preparation, marketing and use of phosphorous chemicals with chemical processes of phosphorus processing
1 533.4 thousand tons
Recovery rate <20%

Technical (phosphoric) acid
Fertilizer ammonium phosphate (MAP, DAP)
Forage calcium phosphate,
Sodium phosphates,
Triple superphosphate,
Phosphorus oxide technical,
Technical phosphorus sulphide,
Phosphorus chloride technical

949 000 tons

25 000 tons from Kazakhstan

5 000 tons from Egypt

19.07 mln tons waste during 2004-2010

Environmentally friendly solutions include:

- Improvement of the phosphorus balance in waste streams
- Feedstock flow release and replacement: application of waste raw materials available on a domestic market
- Change of the production technology: single-stage production method of sodium tripolyphosphate, Hemihydrate technology for phosphoric acid production
PHOSPHATE INDUSTRY - SUSTAINABLE SOLUTIONS

Environmental technologies introduce a constant improvement on processes, products and services through the protection of raw materials.

**STRATEGIES FOR RAW MATERIALS**

- the limitation of feedstock flow (decreased exploitation),
- feedstock flow release (quality, longer exploitation),
- feedstock flow recycling (re-use)
- feedstock flow replacement (renewable materials)
CLEANER INNOVATIONS IN THE PRODUCTION OF PHOSPHATE SALTS

PROCESS INPUTS

phosphorus raw materials

phosphoric acid

PROCESS

FEEDSTOCK FLOW RELEASE
Quality of wet-process phosphoric acid and its purification

FEEDSTOCK FLOW REPLACEMENT
Sewage sludge ash as alternative raw material for fertilisers

PROCESS OUTPUTS

sodium tripoliposphate (STPP)

multicomponent fertilisers

PROCESS MODIFICAATON:
Improvement of phosphorus balance in waste streams from STPP production
SEWAGE SLUDGE ASH VS PHOSPHATE ROCK

Evaluation of the raw material potential of ashes after the combustion of sewage sludge generated in Poland

Selected industrial objects have been characterized. Technological sequences and the amount of ashes generated have been followed.

- **Total annual capacity of existing installations**: 170,620 Mg d.s. of sewage sludge
- **The actual annual potential of mono-combustion**: 100,000 Mg d.s. of sewage sludge
- **The amount of ash produced in Poland**: 43,000 Mg

The technology of combustion in a fluidized bed furnace, grate furnace. Process residues are transferred to external companies, solidified or stored, in accordance with processes D5, R5.

M. Smol, J. Kulczycka, A. Henclik, K. Gorazda, Z. Wzorek, “The possible use of Sewage sludge Ash in the construction industry as a way towards a circular economy”, Journal of Cleaner Production, 2015, 95, s.45-54,
Technological challenges:

- In thermochemical methods, low iron content in ashes is required.
- Extraction of ash using hydrochloric and sulfuric acid (VI) involves the generation of additional waste in the form of calcium chloride or phosphogypsum.
- High recovery efficiency.
- Process flexibility.

important factors:

- the origin of sewage sludge
- methods applied in sewage treatment plant
- combustion technology

TRL 5

Extraction  Neutralisation  Filtration  Granulation

feedstock flow replacement (renewable materials)

The application of a grate furnace for the incineration of sewage sludge reduces the utilization of ash in extraction processes.

<table>
<thead>
<tr>
<th>component</th>
<th>SSA B</th>
<th>SSA A</th>
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</thead>
<tbody>
<tr>
<td>P [%]</td>
<td>9.92</td>
<td>10.83</td>
</tr>
<tr>
<td>Fe [%]</td>
<td>6.01</td>
<td>8.69</td>
</tr>
<tr>
<td>Ca [%]</td>
<td>11.2</td>
<td>11.7</td>
</tr>
<tr>
<td>Mg [%]</td>
<td>2.67</td>
<td>1.17</td>
</tr>
<tr>
<td>Al [%]</td>
<td>4.67</td>
<td>2.26</td>
</tr>
<tr>
<td>K [%]</td>
<td>1.25</td>
<td>1.30</td>
</tr>
<tr>
<td>Zn [mg/kg]</td>
<td>605</td>
<td>2681</td>
</tr>
<tr>
<td>Pb [mg/kg]</td>
<td>3.47</td>
<td>78.8</td>
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<tr>
<td>Cu [mg/kg]</td>
<td>1015</td>
<td>849</td>
</tr>
<tr>
<td>Ni [mg/kg]</td>
<td>120</td>
<td>95</td>
</tr>
<tr>
<td>Cr [mg/kg]</td>
<td>148</td>
<td>165</td>
</tr>
<tr>
<td>Cd [mg/kg]</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>Co [mg/kg]</td>
<td>10.7</td>
<td>14.6</td>
</tr>
<tr>
<td>Sr [mg/kg]</td>
<td>552</td>
<td>319</td>
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</table>

<table>
<thead>
<tr>
<th>Plant Location</th>
<th>Combusted Sewage sludge [t d.s./d]</th>
<th>Combustion Technology</th>
<th>Temperature</th>
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</thead>
<tbody>
<tr>
<td>Kielce</td>
<td>19</td>
<td>fluidal</td>
<td>850-900°C</td>
</tr>
<tr>
<td>Szczecin</td>
<td>40</td>
<td>grate</td>
<td>850-1000°C</td>
</tr>
</tbody>
</table>

feedstock flow replacement (renewable materials)

**High content of Al in ash reduces its utilization in extraction processes**

The mass ratio of Al/P in ash applied as feedstock not higher than 0.7 was accepted as the limit value.

**High content of Ca in ash reduces its utilization in extraction processes**

Mass ratio of Ca/P in ash applied as feedstock, which is not higher than 1.4, was accepted as the limit value.

It was confirmed that *differences in the composition of ashes obtained at different periods of sewage treatment plant operation remain without a significant impact* on the extraction parameters.

feedstock flow replacement (renewable materials)

PHOSPHORUS EXTRACTION

NUTRIENTS RECOVERY

NEUTRALISATION

FLUID FERTILISERS SUSPENSION FERTILISERS NP, NPK SOLID FERTILISERS

HNO₃, H₃PO₄

CaO, NH₃, MBM ash, Biomas ash

CONCLUSIONS

Developed cleaner innovations ensure:

- using renewable phosphorus raw materials, i.e. ash after combustion of sewage sludge from Thermal Stations of Sewage Sludge Utilization for the production of mineral fertilizers

- recovery of the critical element - phosphorus from waste with a yield above 80%,

- recirculation to the environment of approx. 4 000 tones of $P$ in Polish case; being the equivalent of 31 thousand Mg of imported phosphorus ore

3.3% of the imported phosphate rock
CONCLUSIONS

Consumption of nutrients like N, P and K
(world: 170 mln Mg, EU: 12 mln Mg)

recovery from concentrated renewable sources:
animal by-product,
sewage sludge,
nutrient-rich biomass
*after thermal treatment*
salts precipitated form nutrient-rich streams

present potential of phosphorus substitution by renewable concentrated inorganic sources is **only 17-38%**