Cracow University of Technology, Poland

PHOSPHATE INDUSTRY HE BALANCE OF SUSTAINABLE DEVELOPMENT AND CIRCULAR ECONOMY

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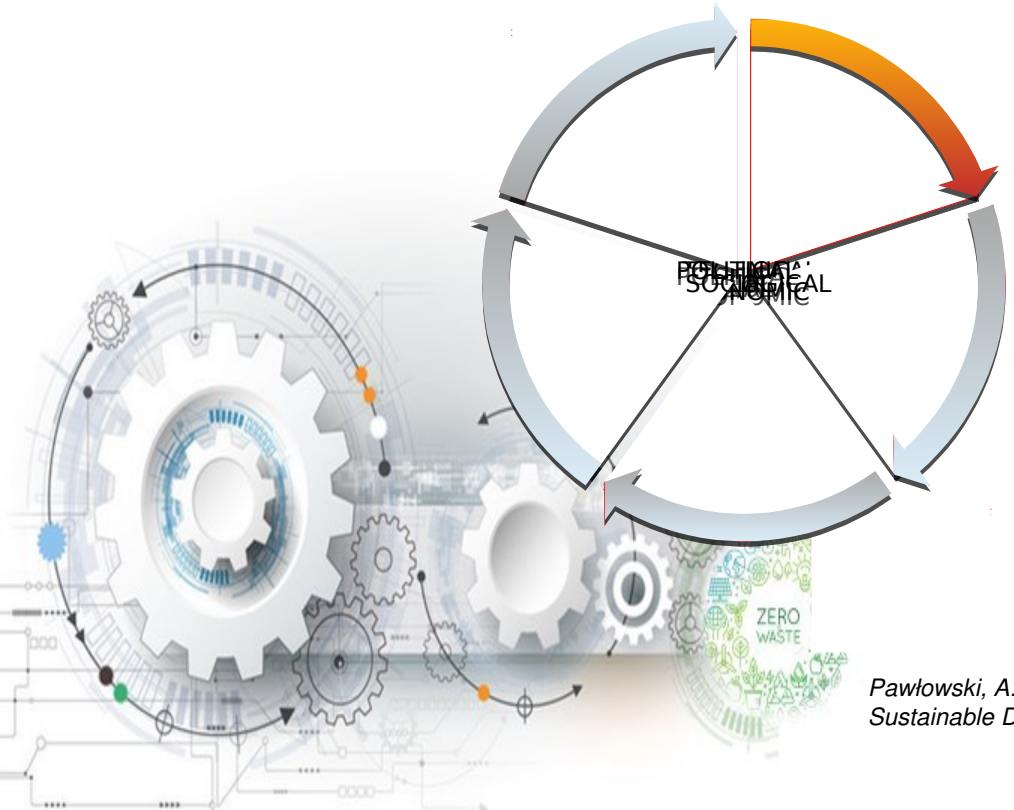
CIRCULAR ECONOMY

Circular economy (CE) is sustainable development strategy

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

Pawłowski, 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 productio

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

CHANGE of the technological 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

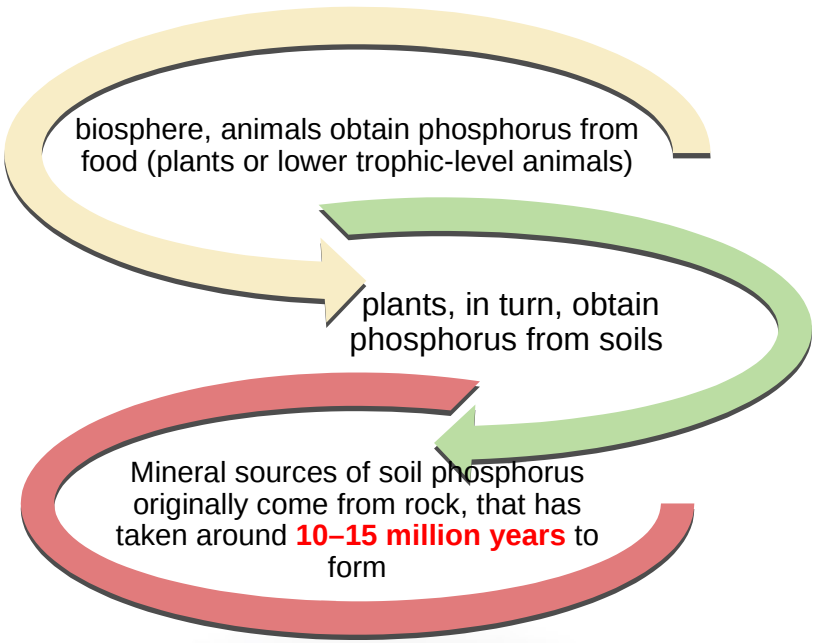
MODIFICATION of the technological process,

OPTIMIZATION of the existing technological process

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.

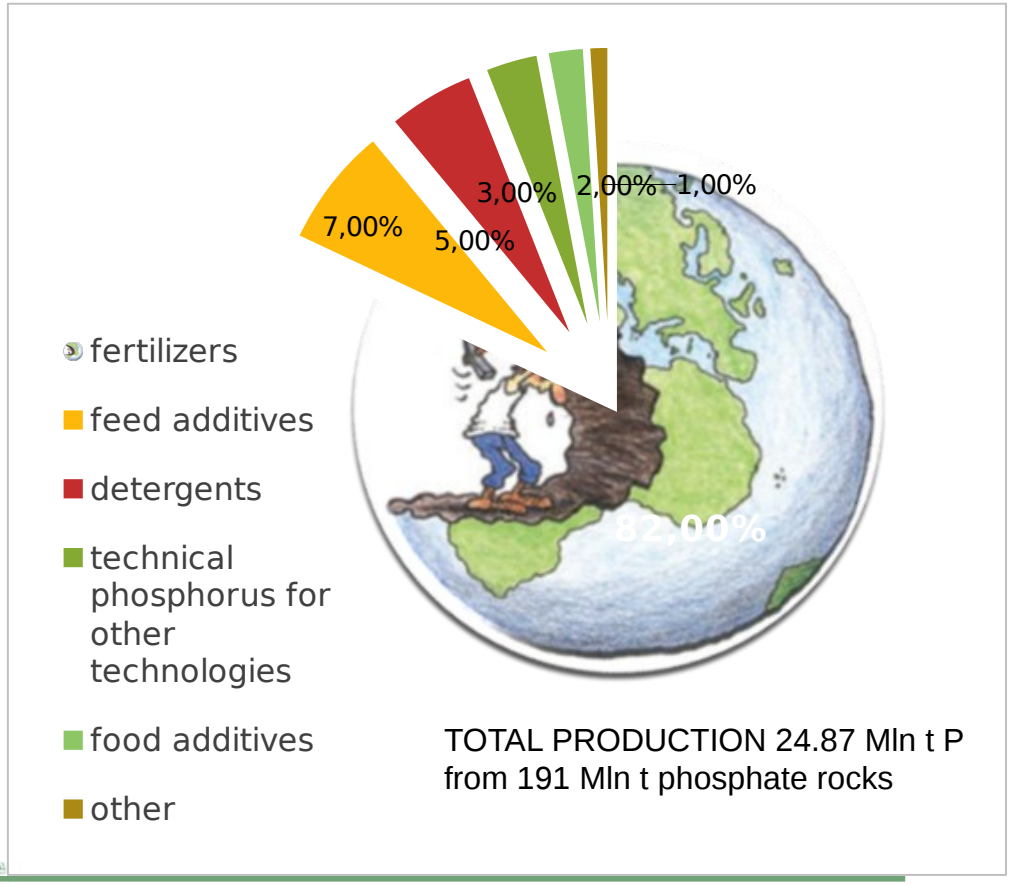
Misra K. B. (Ed.) Clean Production Environmental and Economic Perspectives, Springer

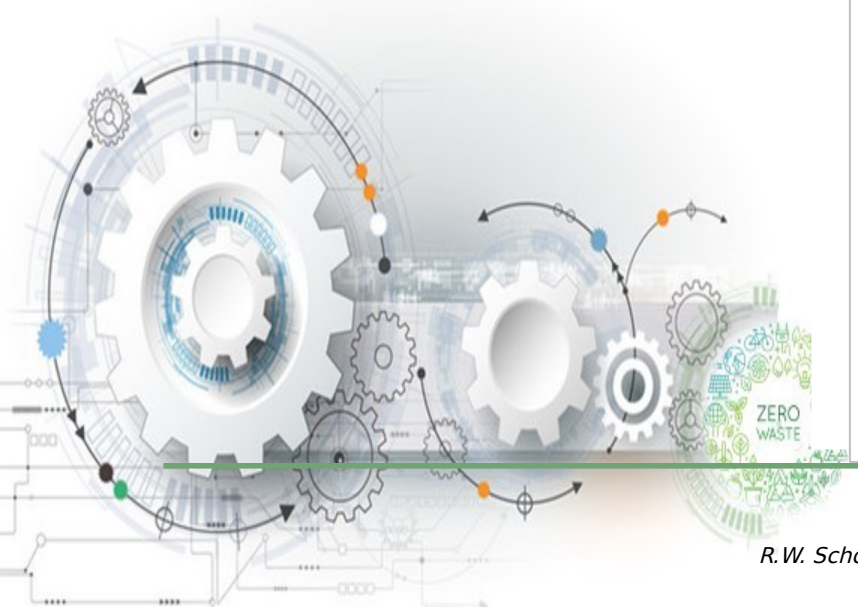
PHOSPHATE INDUSTRY



Assesment of the phosphate industry:

- significant feedstock problems
- negative environmental impact.
- excessive energy-consumption





G.M. Filippelli / Chemosphere 84 (2011) 759–766 761
R.W. Scholz et al. / Science of the Total Environment 461–462 (2013) 799–803

PHOSPHORUS – CRITICAL ELEMENT

LIFE

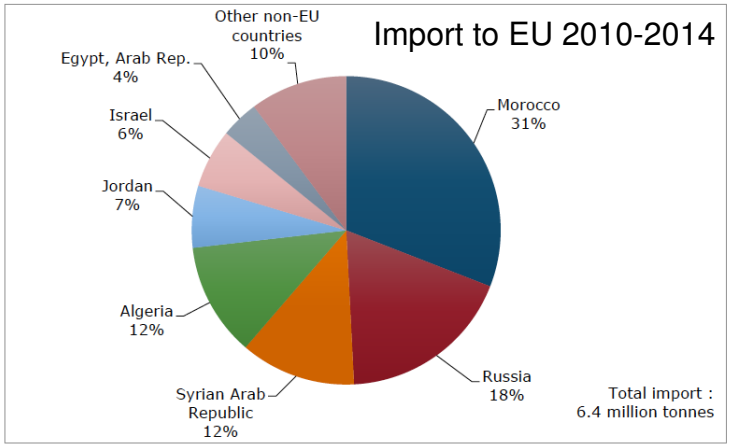
P

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

DEATH

P

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

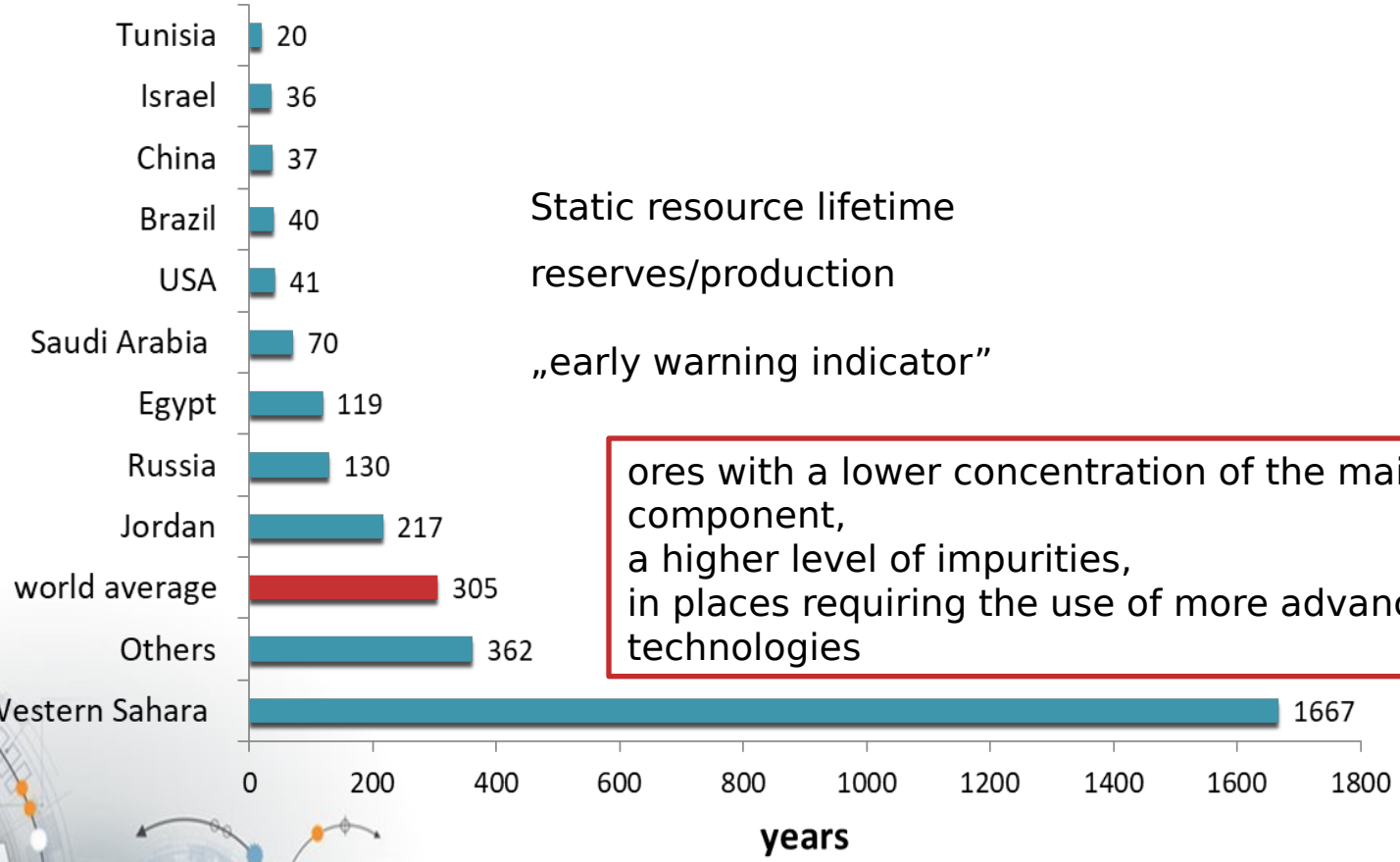


Materials	Criticality of the material in 2017		Demand forecast			Supply forecast		
	Yes	No	5 years	10 years	20 years	5 years	10 years	20 years
Phosphate rock	x		+	+	++	+	+	0

2017 CRMs (27)			
Antimony	Fluorspar	LREEs	Phosphorus
Baryte	Gallium	Magnesium	Scandium
Beryllium	Germanium	Natural graphite	Silicon metal
Bismuth	Hafnium	Natural rubber	Tantalum
Borate	Helium	Niobium	Tungsten
Cobalt	HREEs	PGMs	Vanadium
Coking coal	Indium	Phosphate rock	

Study on the review of the list of critical raw materials, EU Commission, 2017

PHOSPHATE INDUSTRY - Non-renewable resources as an input material



Static resource lifetime

reserves/production

„early warning indicator”

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

D. A. Vaccari, M. Mew, R. W. Scholz, i F.-W. Wellmer, „Exploration: What reserves and resources?”, Springer, 2014, p. 129–151

PHOSPHATE INDUSTRY – POLISH CASE

WASTE

Group 06: **2** 149.7 thousand tons

total mass on landfills till 2013:

112 806.4 thousand tons

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%

PHOSPHATE ROCK

949 000 tons

308 000 tons P_2O_5

from Algiers , Egypt and Syria

ELEMENTAL PHOSPHORUS

25 000 tons from Kazachstan

technical (phosphoric) acid

fertilizer ammonium phosphate (MAP, DAP)

forage calcium phosphate,

sodium phosphates,

triple superphosphate,

phosphorus oxide technical,

technical phosphorus sulphide,

phosphorus chloride technical

Ch. W. Police S.A.,

19.07 mln tons

waste during 2004-2010

National Statistical Office, 2014.
Waste catalog, 29.12.2014, Dz. U. poz 1923.

PHOSPHATE INDUSTRY – SUSTAINABLE SOLUTIONS

Environmentally friendly solutions includes:

Improvement of the phosphorus balance in waste streams

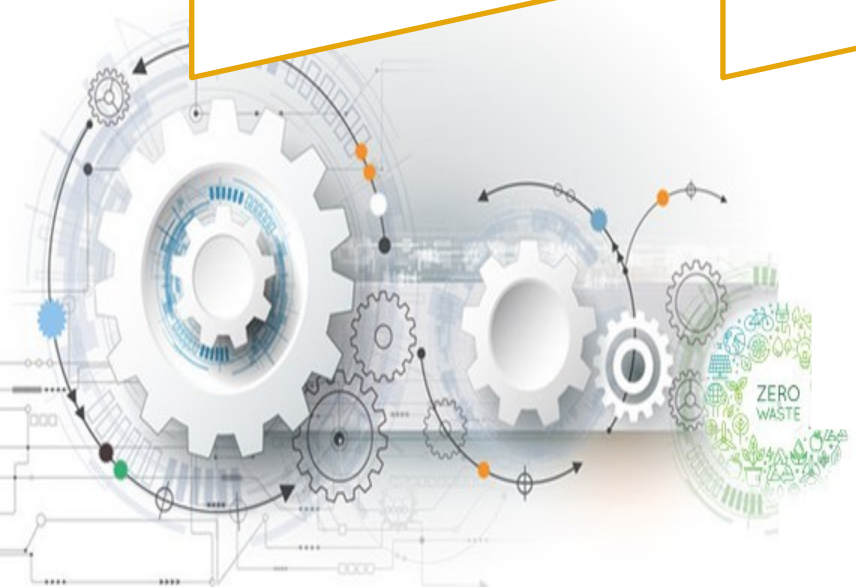
Feedstock flow release and replacement

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

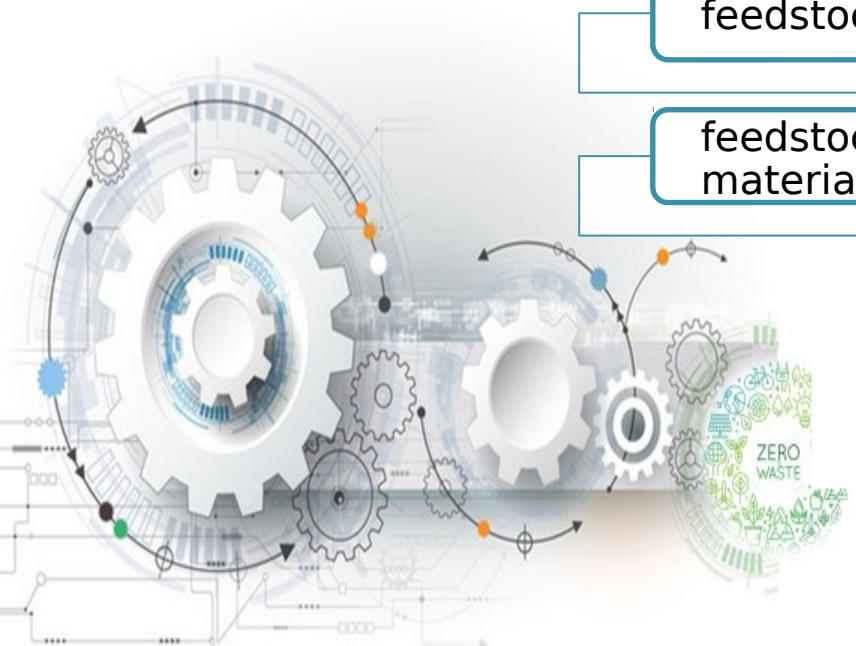


PHOSPHATE INDUSTRY – SUSTAINABLE SOLUTIONS

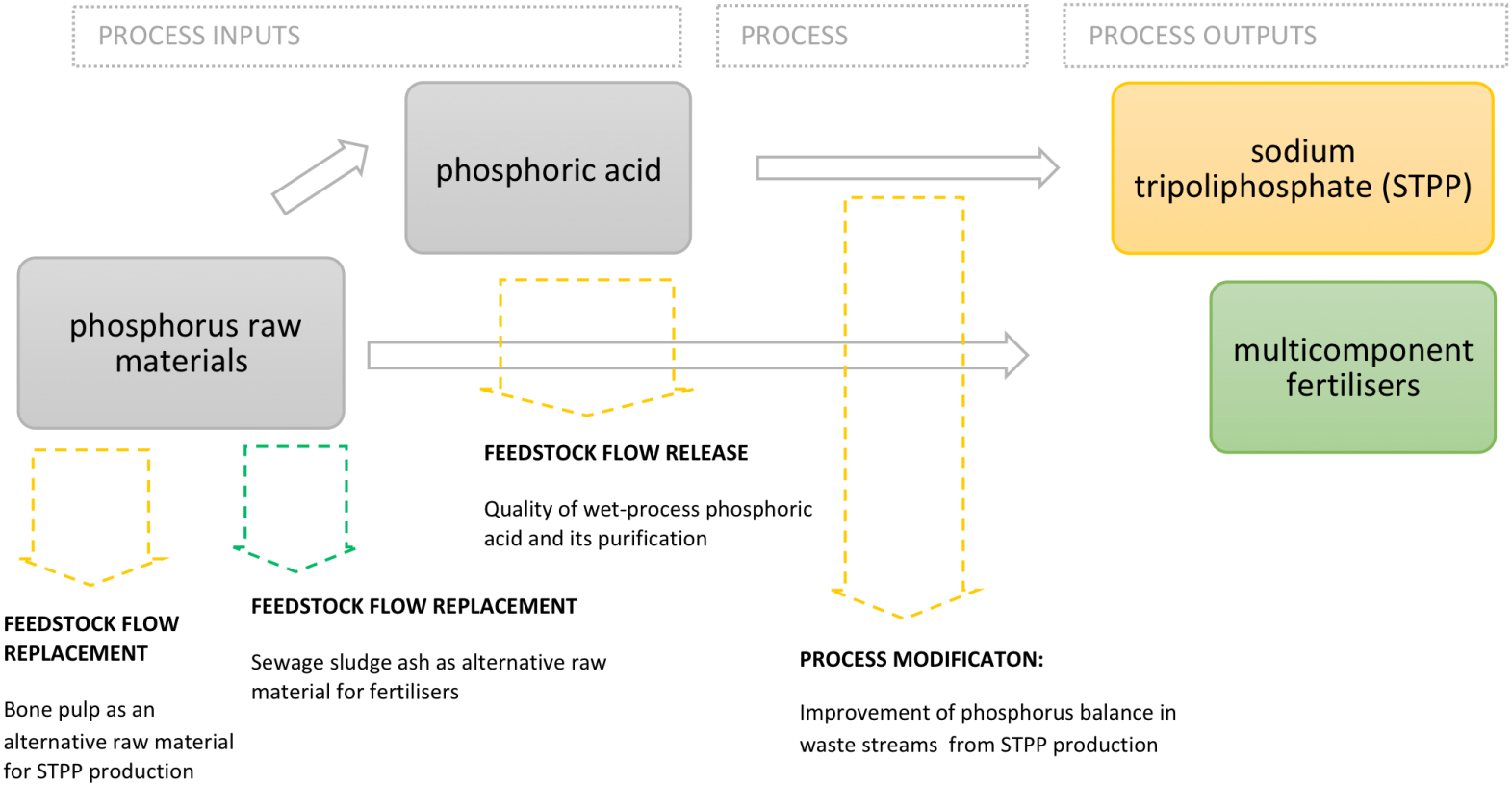
Environmental technologies introduce a constant improvement on processes, products and services through the protection of raw materials.

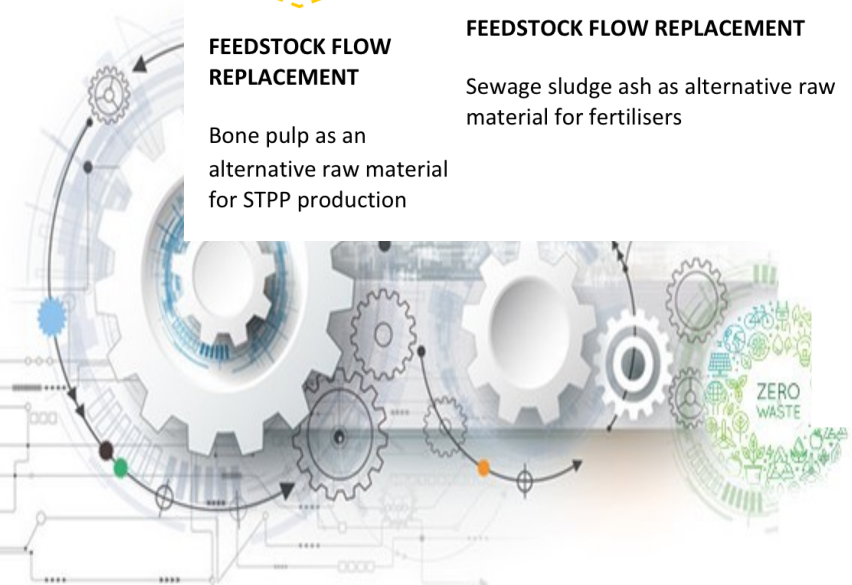
STRATEGIES FOR RAW MATERIALS

- the limitation of feedstock flow (decreased exploitation),
- feedstock flow release (quality, longer exploitation),
- feedstock flow recycling (re-use)
- feedstock flow replacement (renewable materials)



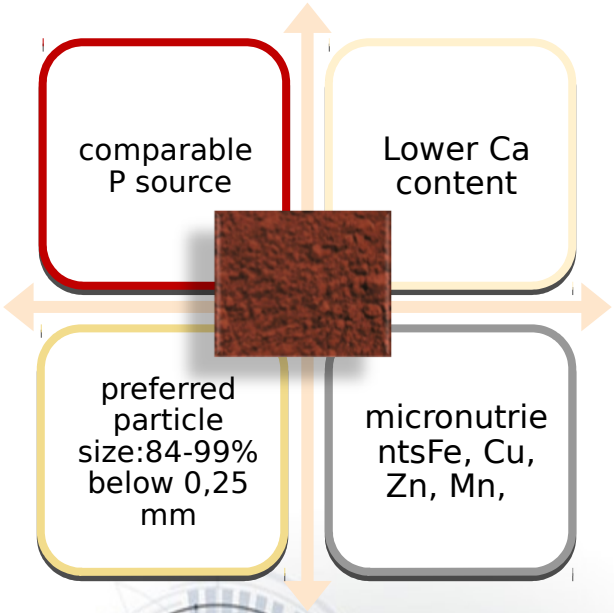
CLEANER INNOVATIONS IN THE PRODUCTION OF PHOSPHATE SALTS

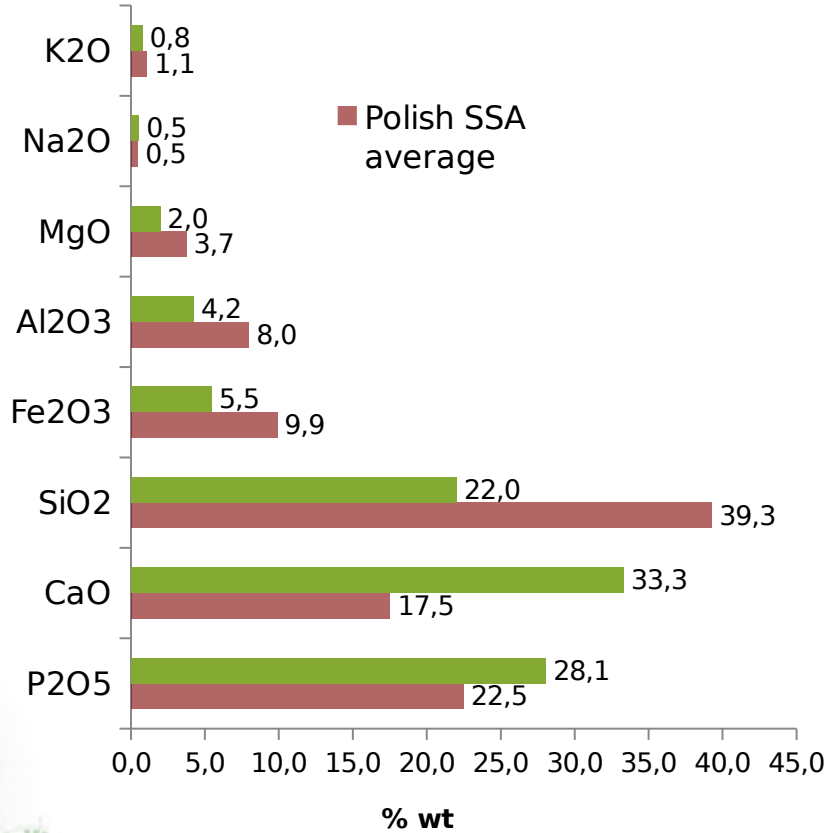


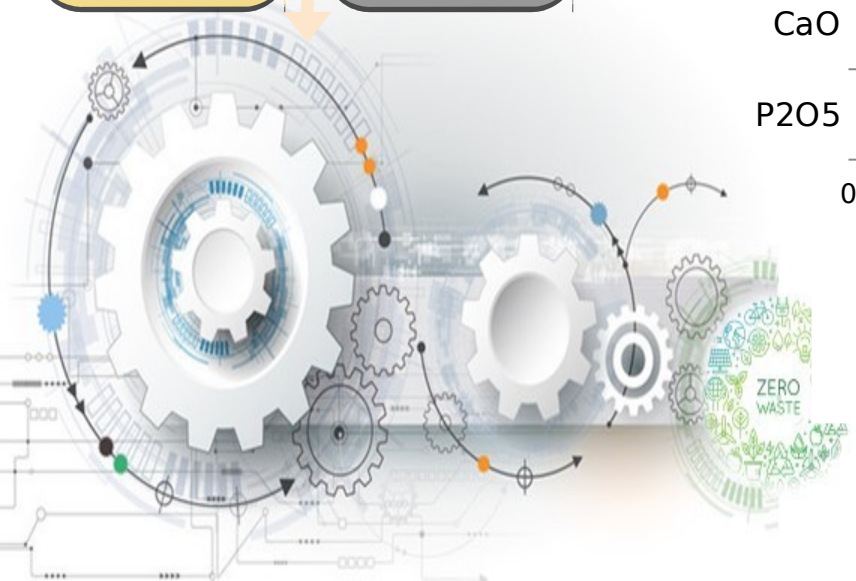


feedstock flow replacement (renewable materials)

SEWAGE SLUDGE ASH VS PHOSPHATE ROCK







K. Gorazda, B. Tarko, Z. Wzorek , H. Kominko, A.K. Nowak, J. Kulczycka, A. Henclik, M. Smol, „Fertilisers production from ashes after sewage sludge combustion -strategy towards sustainable development“, Environmental Research, 2017, 154(2017), s.171-180.

feedstock flow replacement (renewable materials)

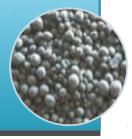
wych

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.

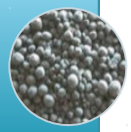
- total annual capacity of existing installations

170 620 Mg d.s of sewage sludge



- the actual annual potential of mono-combustion

100 000 Mg d.s of sewage sludge



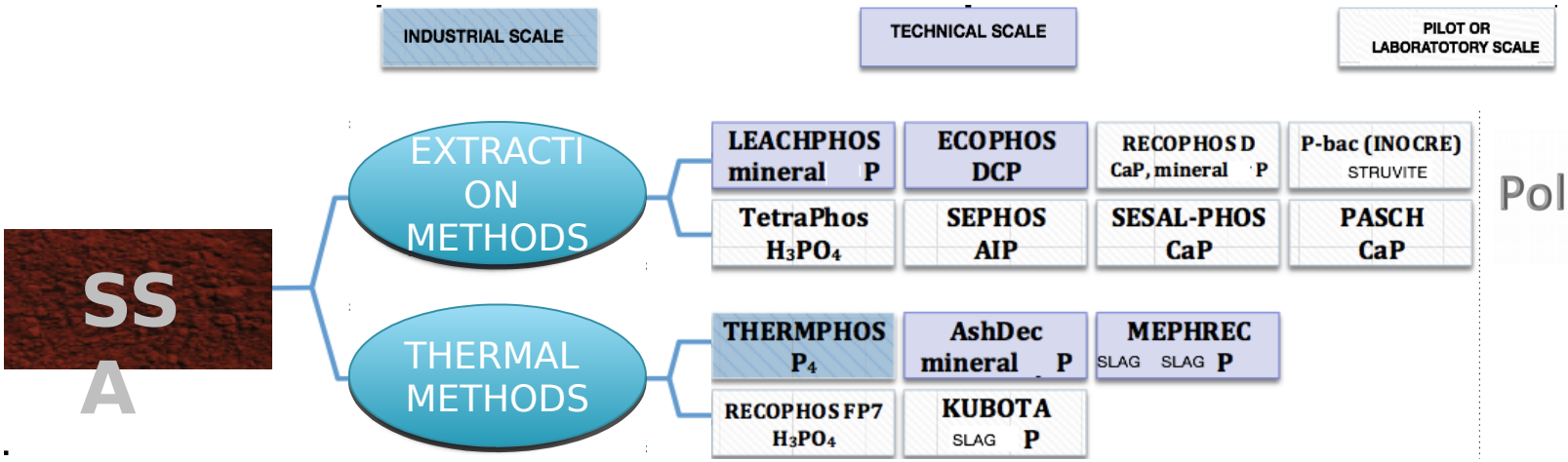
- The amount of ash produced in Poland

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,
K. Gorazda, Z. Wzorek, A.K. Nowak, B. Tarko,“ Odzysk fosforu z popiołów ze spalenia osadów ściekowych- analiza potencjału surowcowego“, Gospodarka odpadami komunalnymi, Tom IX, Komitet Chemii Analitycznej PAN, 2013, Wydawnictwo Politechniki Łódzkiej,

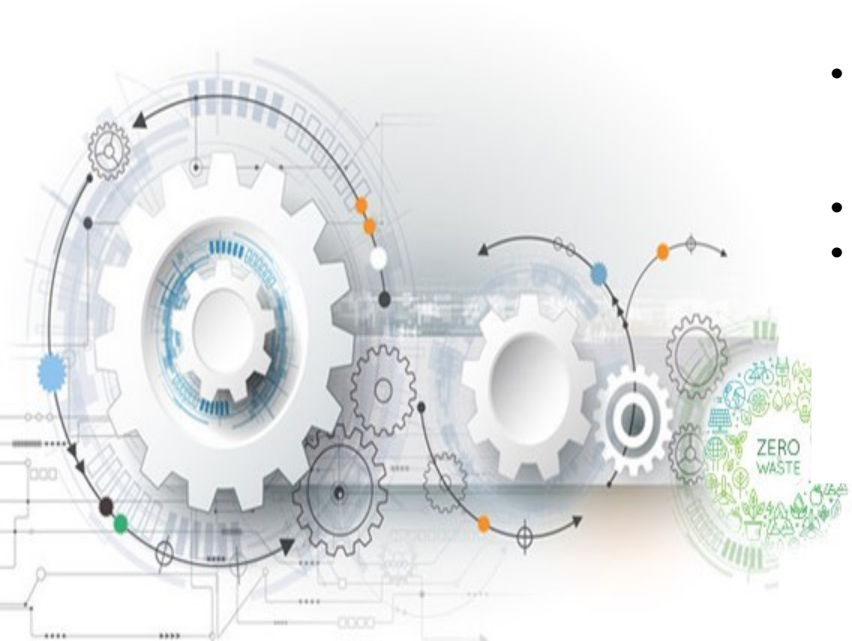
feedstock flow replacement (renewable materials)



PolFerAsh

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



K. Gorazda, Z. Wzorek, A. K. Nowak, B. Tarko, J. Kulczycka, A. Henclik, Phosphorus cycle- possibilities for its rebuilding, 2013, Acta Biochimica Polonica , 60(4), s.725-730.

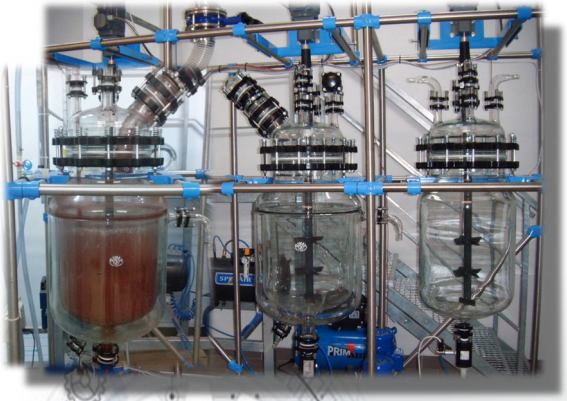
feedstock flow replacement (renewable materials)

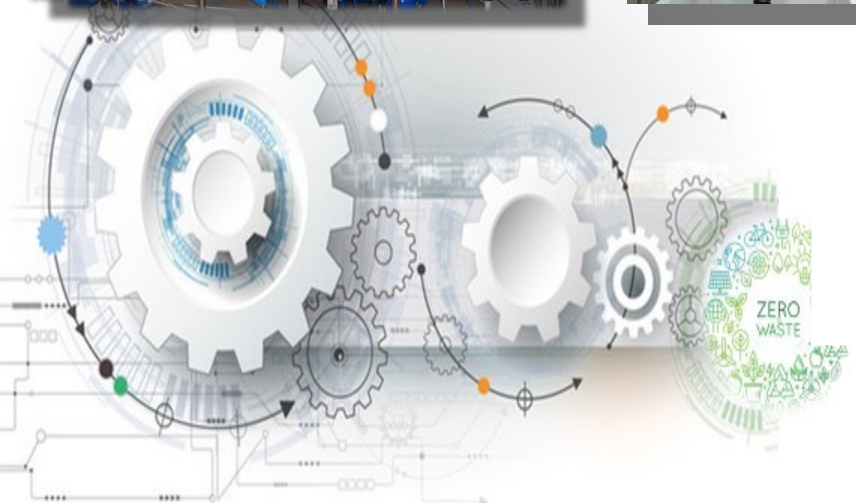
important factors:

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

TRL 5

Extraction *Neutralisation* *Filtration* *Granulation*





Gorazda, K., Jodko, M., Kowalski, Z., Wzorek, Z. (2010) PL Patent No. 207630 B1,

Gorazda, K., Jodko, M., Kowalski, Z., Wzorek, Z. (2012) PL Patent No. 210459 B1

feedstock flow replacement (renewable materials)

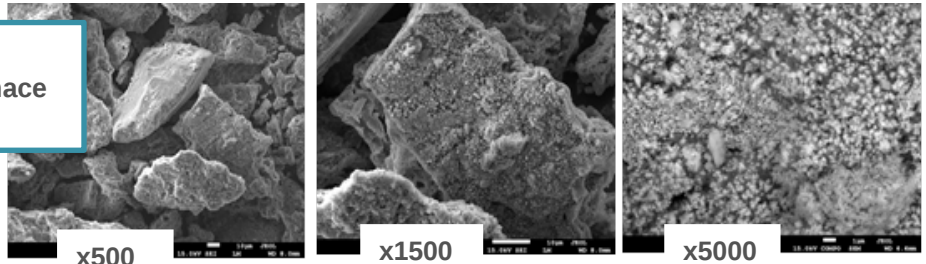
The application of a grate furnace for the incineration of sewage sludge reduces the utilization of ash in extraction processes

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

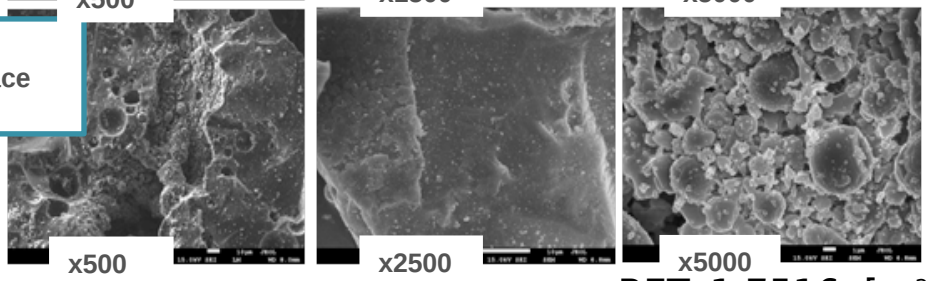
Plant Location	Combusted Sewage sludge [t d.s./d]	Combustion Technology	Temperature
Kielce	19	fluidal	850-900°C
Szczecin	40	grate	850-1000°C

BET: 5.1767 [m²/g]

SSA A
Fluidal furnace



SSA B
Grate furnace



BET: 1,7516 [m²/g]

ASH	Leaching agent	P recovery rate [%]
SSA A	H_3PO_4	93.66
SSA B	H_3PO_4	**29.60**
SSA A	HNO_3	90.14
SSA B	HNO_3	62.03

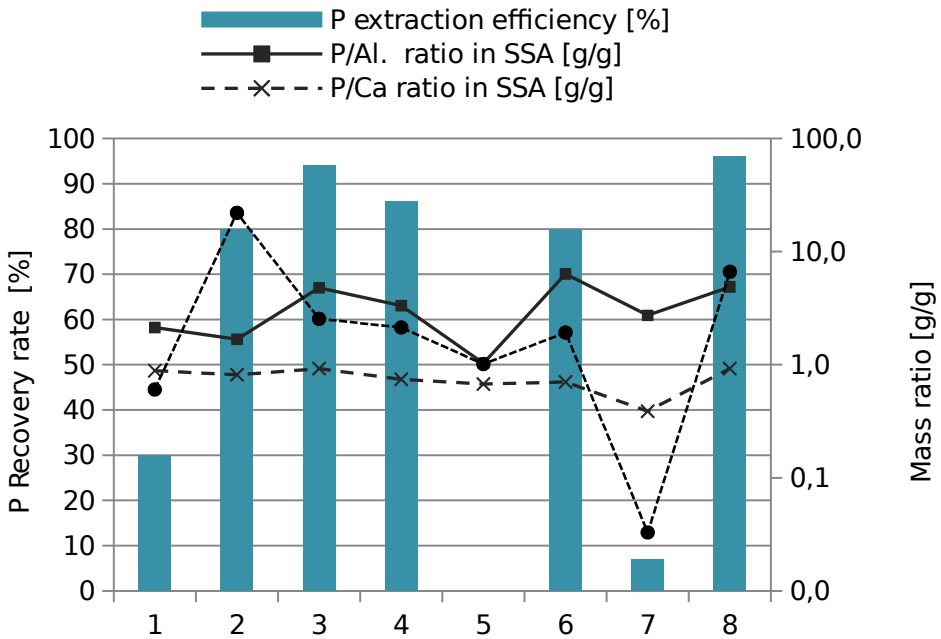
K. Gorazda, Z. Wzorek, A.K. Nowak, B. Tarko, J. Kulczycka, A. Henclik, „Phosphorus recovery from sewage sludge ash“, Proceedings 5th International Conference on Engineering for Waste and Biomas Valorisation, 25-28.08.2014, Rio De Janerio, Brazylia

feedstock flow replacement (renewable materials)

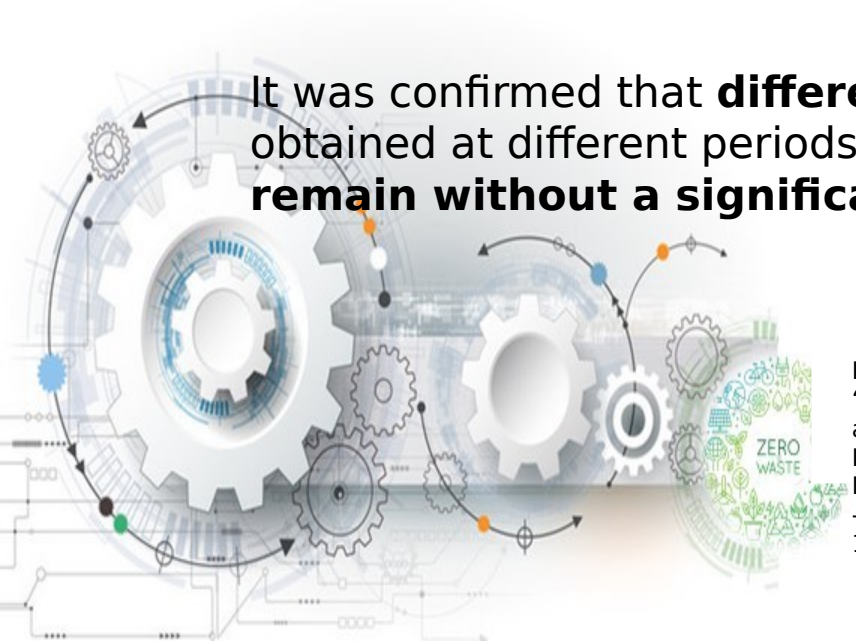
high content of Al in ash reduces its utilization in extraction processes

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

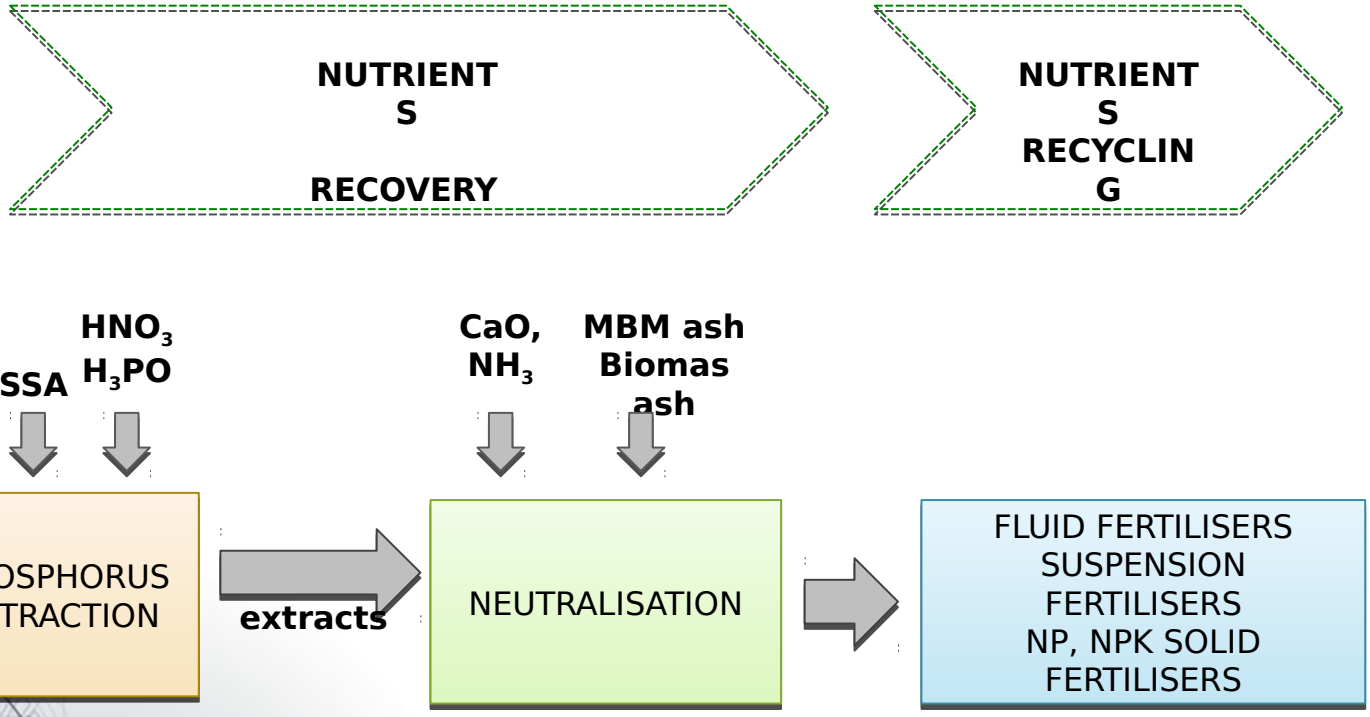


It was confirmed that **differences in the composition of ashes** obtained at different periods of sewage treatment plant operation **remain without a significant impact** on the extraction parameters



K. Gorazda, B. Tarko, Z. Wzorek, A.K. Nowak, J. Kulczycka, A. Henclik, "Characteristic of wet method of phosphorus recovery from polish sewage sludge ash with nitric acid", 2016, Open Chemistry, 14, s.37-45.
K. Gorazda, B. Tarko, Z. Wzorek , H. Kominko, A.K. Nowak, J. Kulczycka, A. Henclik, M. Smol, „Fertilisers production from ashes after sewage sludge combustion -strategy towards sustainable development", Environmental Research, 2017, 154(2017), s.171-180.

feedstock flow replacement (renewable materials)



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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

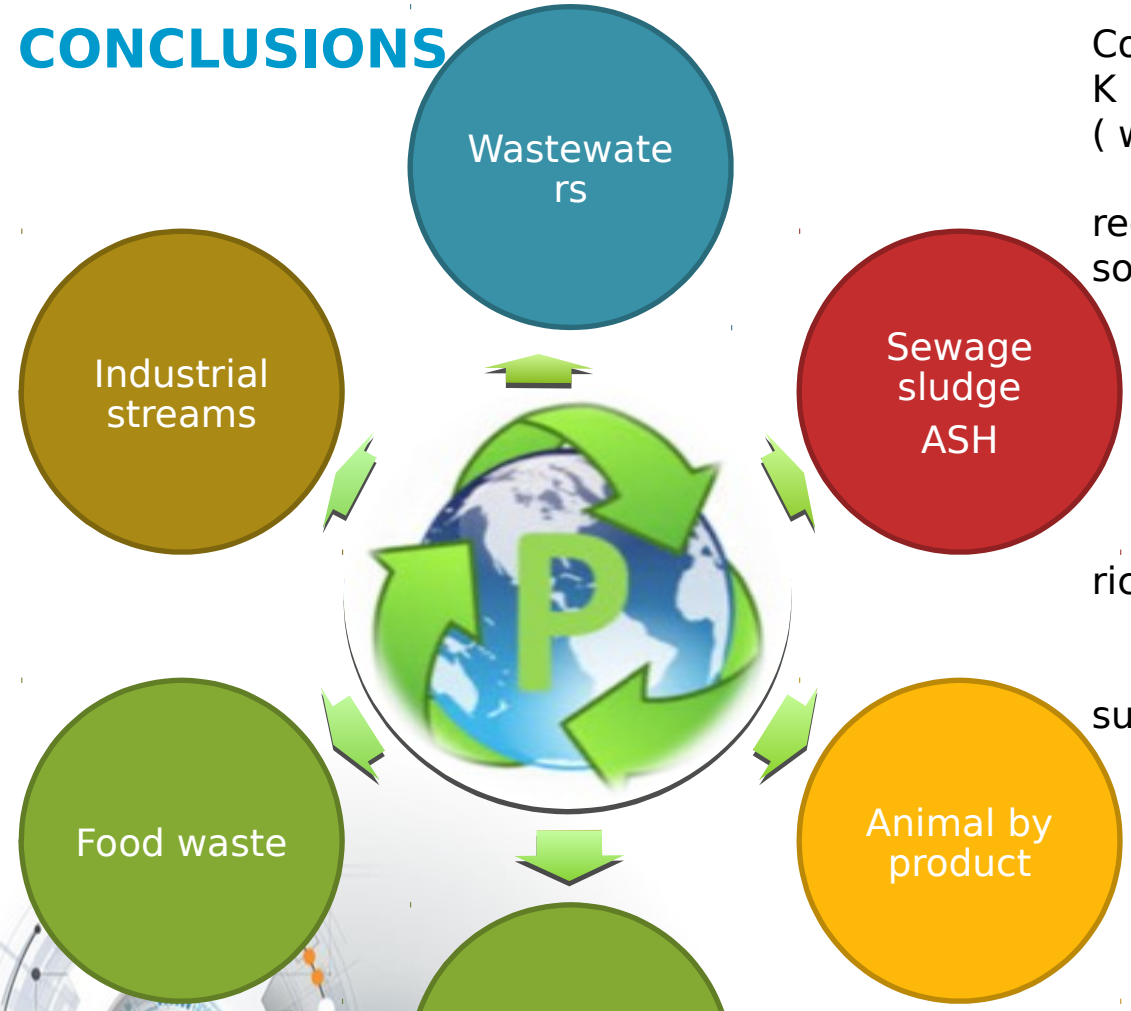
- recovery of the critical element - phosphorus from waste with a yield above 80%,

- 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%**

Huygens;, D., Saveyn;, H., D.Tonini;, ;, P.E., Sancho, L.D.: Pre-final STRUBIAS Report, DRAFT STRUBIAS recovery rules and market study for precipitated phosphate salts & derivates, thermal, oxidation materials & derivates and pyrolysis & gasification materials in view of their possible inclusion as Component Material Categories in the Revised Fertiliser Regulation. In. Circular Economy and Industrial Leadership Unit, Directorate B - Growth and Innovation, Joint Research Centre - European Commission, (2018)