Importance of nutrients recovery from circular economy perspective

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Importance of nutrients recovery from circular economy perspective

1. Circular economy and nutrients
2. Overview on nutrient recycling
3. Overview on phosphorus recovering technologies from sewage sludge
4. Trends in sludge processing
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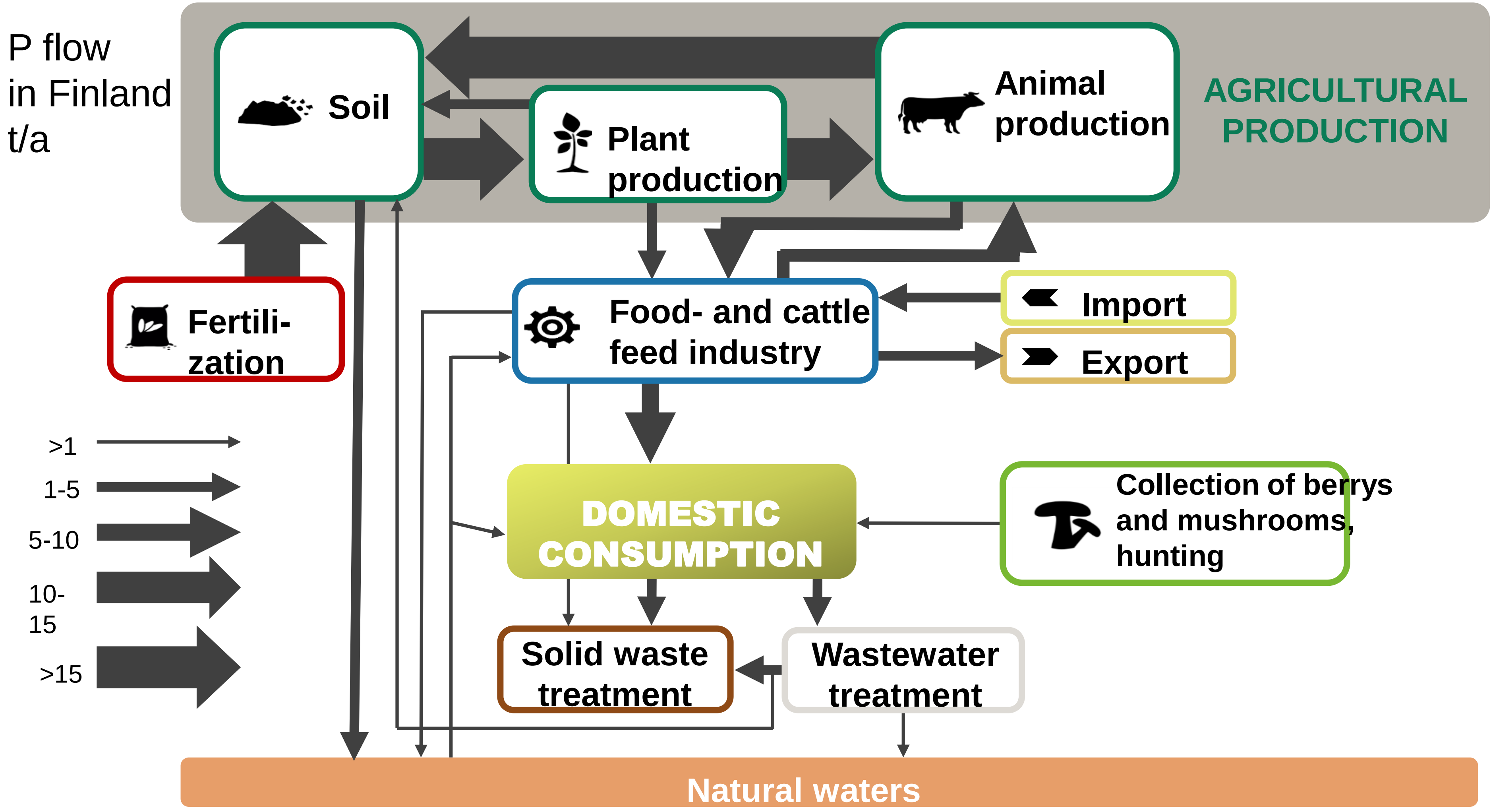
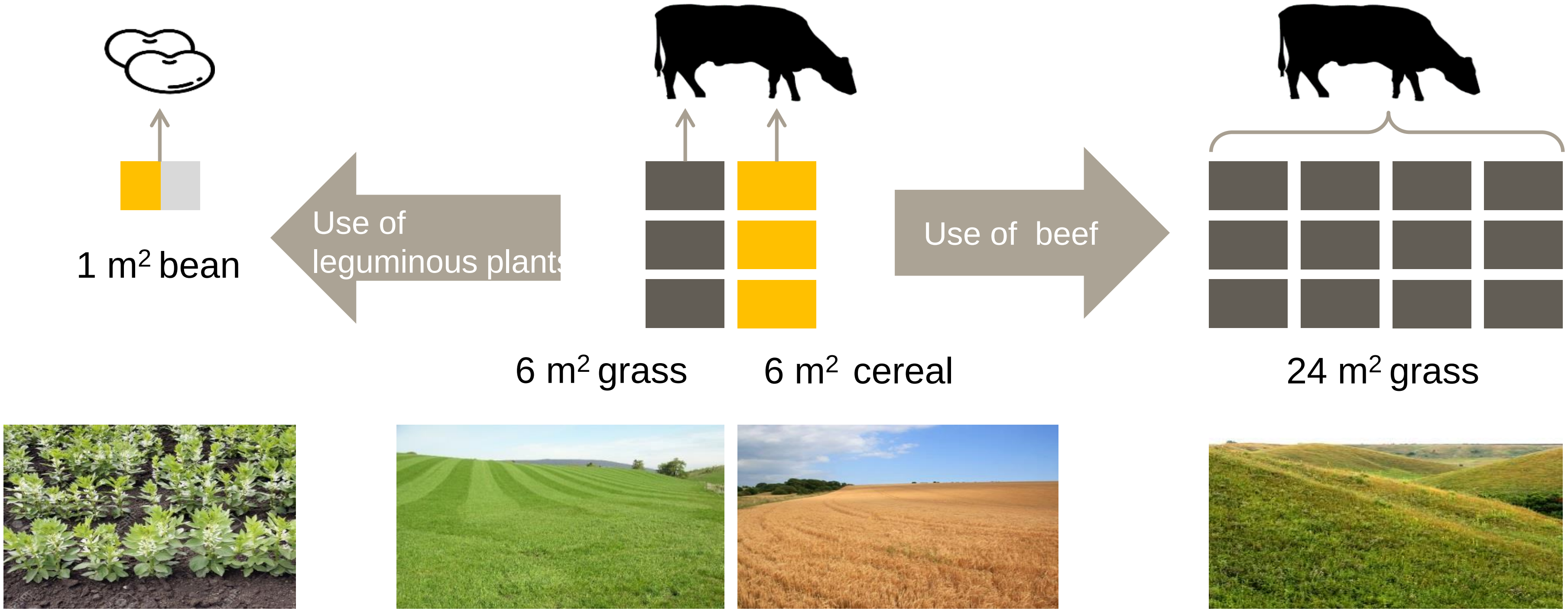
6. Constraints that limit recycling of sewage sludge and agricultural use
7. Sludge treatment and nutrients recovery (ISO/TC 275)
8. Case: Thermal drying of sludge in Finland
9. Conclusions

Circular economy activities

1. Design out waste
    - No waste
2. Build resilience through diversity
    - Resilience is an ability to withstand or adjust to unexpected shocks and diversity refers to having multiple pathways in a system
3. Work toward energy from renewable waste
    - Close the loops in as many areas of production and consumption as possible (renewable energy)
4. Think in systems
    - Understanding the influences, interdependencies, and the different forms of correlations
5. Think in cascades
    - A circular economy model based on nature will include a cascading approach

Esposito, M., Tse, T. and Soufani, K., 2018. Introducing a Circular Economy: New Thinking with New Managerial and Policy Implications. California Management Review. Vol. 60(3) 5-19.


P flow
in Finland
t/a
Soil
Plant
production
Animal
production
AGRICULTURAL
PRODUCTION
Fertili-
zation
Food- and cattle
feed industry
Import
Export
>1
1-5
5-10
10-
15
>15
DOMESTIC
CONSUMPTION
Collection of berrys
and mushrooms,
hunting
Solid waste
treatment
Wastewater
treatment
Natural waters



Nutrient flux can be controlled by substituting beef by leguminous plants, which decreases needed land area. Transfer to pasturage increases need of land area, but decreases concentration of agriculture and decreases erosion risk.

Overview on nutrient recycling

Besides hyginesation, the sludge treatment aims to produce sewage sludge to fertilizer products, which meet the requirements set out in national and international regulations. Both the international legislative framework and its national implementations effect on recycling, processing and use of the nutrients. In addition, many countries have their own national regulations. There are national differences in the implementation of the nitrate directive (EU), fertilizing limits, legislation related to sewage sludge use in agriculture and also legislation related to environmental permits.

Overview on nutrient recycling

Many EU legislations affect nutrient recycling. These regulations are nationally implemented in very different ways, leading to different kinds of solutions and organic fertilizer markets.

Nutrients and inorganics recovered from sewage sludge can also be utilized in industrial processes. Then the industry in case defines the requirements.

Overview on phosphorus recovering technologies

Main challenges in increasing phosphorus recycling are concerns regarding heavy metals, organic pollutants and pathogens that could jeopardize food safety, as well as transport and utilization. The demand and supply also varies regionally. There is no global market for recycled nutrients, which hinders further development of business.

Developing nutrient recovery, especially of phosphorus, reduces dependency on imported nutrients. This would increase agricultural and political stability. In large scale the nutrient recycling industry has a significant role in employment.

Overview on phosphorus recovering technologies

Wet sludge and liquor

Aqueous phase (dissolved P)				Enforced P dissolution	
PEARL struvite	PHOSPAQ struvite	PhosphoGreen struvite	Naskeo struvite	LYSOGEST struvite	Stutgart struvite
AirPrex stuvite	ANPHOS struvite	STRUVIA stuvite	PHORWater struvite	WASSTRIP struvite	Gifhorn struvite/CaP
NuReSys struvite	REPHOS stuvite	NutriTee sturuvite	Ecobalans struvite, NPK	THP (general)	Budenhelm DCP

Sludge and sludge ash

Acidic digestion / leaching		Thermal	
Fert. industry mineral fertilizer	ECOPHOS H_3PO_4 /DCP	MEPHREC P-slag	KUBOTA P-slag
LEACHPHOS P-mineral	RECOPHOS DE MCP	AshDec (Outotec) P-mineral	InduCarb H_3PO_4 / P_4
EDASK H_3PO_4	TetraPhos H_3PO_4	THERMOPHOS (not in use) P_4	PYREG P-mineral

Phosphorus recovery technologies in Europe (pink=pilot/laboratory scale, brown=not in use)

Trends in sludge processing

Mininni et al. (2015) summarize trends in sludge processing in the following:

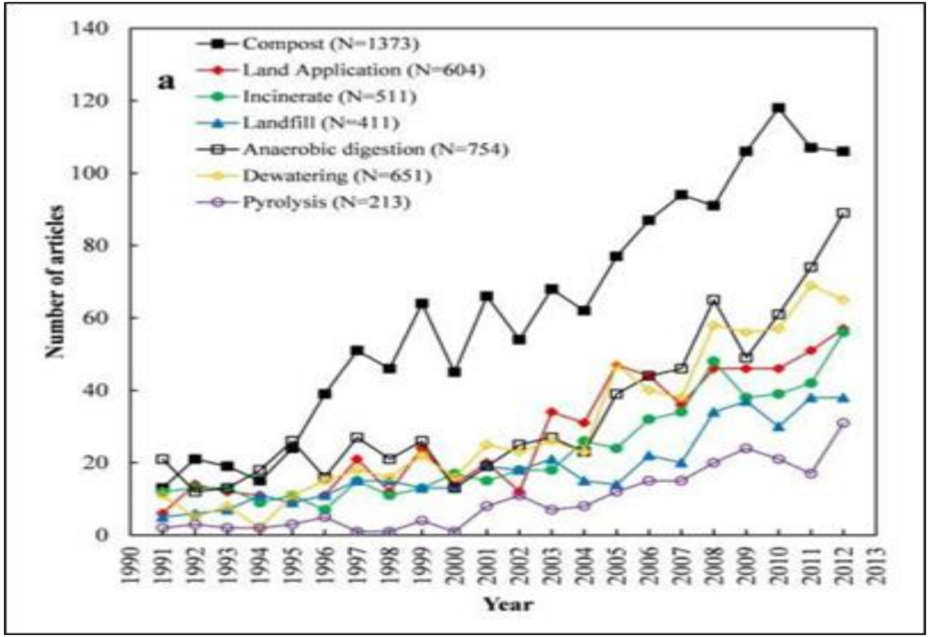
- Methods aiming to minimize sludge production by uncoupling metabolism obtained with alternating conditions of anaerobic famine and aerobic feast. Under these conditions most organics are oxidized and converted into CO_2.
- Methods aiming at preparing sludge for agricultural purposes, so that good biological stabilization is reached and the level of pathogens is acceptable. Methods are quite diverse and Mininni draws attention to thermal treatment before digestion, e.g. Cambi-process.
- Final thermal treatments at high temperatures, which include incineration, wet oxidation (WO) and pyrolysis.
- Off-site solutions for sludge processing, for example composting or co-incineration.

Trends in sludge processing

Inna (2015) examines trends and drivers of phosphorus recovery in a blog of Aquatech. Inna divides methods of phosphorus recovery into three principles:

1. Application of sludge to land is the traditional method of recycling nutrients. However, the concern of heavy metal, organic and pathogenic contaminants has significantly reduced land-spreading. Several EU-countries have banned agricultural usage of sludge. Despite of the shift, Inna predicts sludge usage continue to be one of the main routes of nutrient recovery
2. Recovery of phosphorus as struvite, either from aqueous phase or from sludge, is a potential method to recycle phosphorus.
3. Recovery of phosphorus from sewage ash after incineration has the advantage of removing pathogens and organic pollutants, but challenges regarding heavy metals remain.

Research emphasis on sewage sludge



Research trends of a) disposal and treatment methods: compost, land application, incinerate, landfill, anaerobic digestion, dewatering, pyrolysis

Constraints that limit recycling of sewage sludge and agricultural use

Kirchmann et al. (2016) summarize challenges in agricultural usage of sewage sludge. Even when sludge is hygienic, there are two main challenges:

- nutrients have low plant availability
- water content is high and nutrient content is low

Phosphorus and nitrogen are the most important nutrients in sludge, since potassium, calcium and magnesium are less efficiently removed in wastewater treatment. About 10 % of total nitrogen in sewage sludge is in ammonium nitrogen, which is plant available, but the majority is organically bound. Level on mineralization is important factor in nitrogen availability. Phosphorus’ plant availability is lower than in mineral fertilizers since iron and aluminum compounds are non-soluble.

Constraints that limit recycling of sewage sludge and agricultural use

Kasurinen et al. (2014) conducted a literature study about the occurrence of different organic compounds in the municipal sludge in northern countries, especially in Finland. According to this study especially dioxins (PCDD/F), polychlorinated biphenyls (PCB), dioxin like polychlorinated biphenyls, hexabromocyclododecane (HBCD), polyaromatic hydrocarbons (PAH), polybrominated diphenylethers (PBDE), perfluorooctane sulfonate (PFOS) and some pharmaceuticals and personal care products (triclosan, citralopram, diclofenac) are absorbed quite efficiently to the sludge and further on to the surface layer of the soil. It is concluded that more detailed information on the occurrence of different organic compounds in sludge and their behavior in the waste water treatment plants and sludge processing is still needed.

Constraints that limit recycling of sewage sludge and agricultural use

Fjäder (2016) has studied extensively both the occurrence of harmful substances in wastewater sludge and the accumulation in soil. The study concentrated on dried sludge and sludge after anaerobic digestion, as well as composted sludge. According to this study some hazardous organic compounds are very persistent in the sludge handling processes, and may therefore cause harmful effects when entering the environment. PFAS and PBDE compounds were also found to accumulate in earthworms. The concentrations of triclosan and phatalates in end products that contained sewage sludge, but also in sludge amended soils, were quite high.

ISO/TC 275 Sludge recovery, recycling, treatment and disposal

WG 1 : Terminology

WG 2 : Characterization methods

WG 3 : Digestion

WG 4 : Land application

WG 5 : Thermal process

WG 6 : Thickening & Dewatering

WG 7 : Inorganics & nutrients recovery

ISO/TC 275 Sludge recovery, recycling, treatment and disposal

WG 7 : Inorganics & nutrients recovery

Foreword
Introduction
1 Scope
2 Normative references
3 Terms and definitions
4 Phosphorus recovery
4.1 General
4.2 Struvite recovery from anaerobic digested sludge and/or concentrate
4.3 Hydroxyapatite recovery
4.4 Phosphorus recovery from incineration ash
4.5 Phosphorus recovery from sewage sludge into slag
4.6 Other technologies for phosphorus recovery

ISO/TC 275 Sludge recovery, recycling, treatment and disposal

WG 7 : Inorganics & nutrients recovery (continued)

5 Recovery of other nutrients

5.1 General

5.2 Nitrogen (N)

5.3 Sulphur (S)

5.4 Potassium (K)

6 Recovery of other inorganics

6.1 General

6.2 Metals

Annex A (informative) Sludge composition[1]

Annex B (informative) Case studies

B.1 Phosphorus recovery from centrate ‘Phosnix’

B.2 Struvite recovery from digested sewage sludge

B.3 Phosphorus recovery from centrate using seawater as Mg source

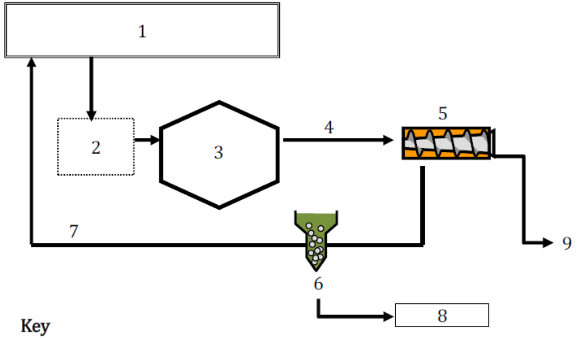
B.4 Phosphorus recovery from filtrate ‘HAP system’

ISO/TC 275 Sludge recovery, recycling, treatment and disposal

WG 7 : Inorganics & nutrients recovery (continued)

Struvite recovery (Japan)

$PO_4^{3-} + NH_4^{+} + Mg^{2+} + 6H_2O \rightarrow MgNH_4PO_4 \cdot 6H_2O$ (Struvite)

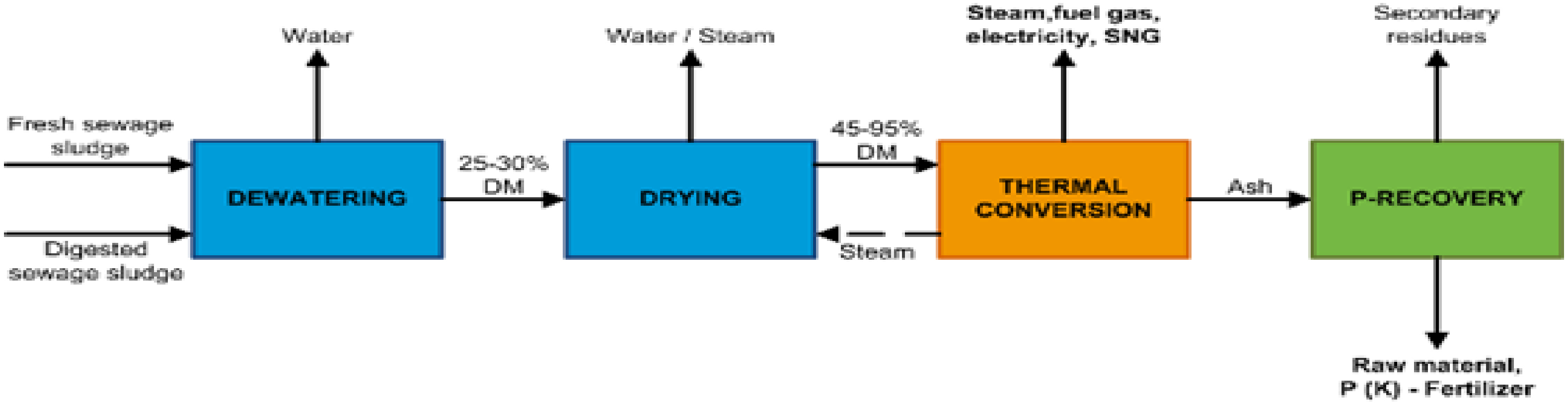


Key
1 water treatment process
2 excess sludge
3 anaerobic digester
4 digested sludge
5 dehydrating facility
6 Phosnix
7 centrate
8 struvite
9 cake

Sludge treatment and nutrients recovery

Treatment method	End product	Processing/ Use	+	-
Anaerobic digestion	Digested sludge (san)	Post processing needed, e.g. composting	Energy production	Not feasible with small amounts
Composting	Composted sludge (san)	Landscaping	Easy and cheap process	No energy nor fertilizer
Chemical treatment	Dried, sanitized sludge	Fertilizer	Sanitized product	Difficult process, chemicals needed in the process
Incineration	Ash	Industrial, landscaping	Small amount of end product	Energy needed
Thermal processing	Dry sludge	Incineration, fertilizer	Dry product, easy to process	Energy needed

Case: Thermal drying of sludge in Finland



Pilot test

Feed rate: 300 – 500 kg/h wet material
DM feedstock: 20 – 27 %
Pressure in loop: 3.5 – 5 bar
Temperatures: 160 – 200 °C

Case: Thermal drying of sludge in Finland

Dried sewage sludge; DM > 90 %

P: remains in end product

N: 7-10 % of total nitrogen of sludge remains as soluble ammonia nitrogen in the sludge phase after thermal treatment

Heating does not noticeably change the total leached quantities of metals (%) (Obrador e al. (2000))

Concluding remarks and discussion

- Regarding circular economy principles, nutrients from manure, bio-waste and sewage sludge should be recovered and reused
- Objective of future wastewater process is to get good quality wastewater, nutrients to be reused safely and no harmful sludge product
- Problems in recycling are technical, economical, harmful substances and also attitudes of producers and consumers
- Development of nutrient recycling needs more research, technical development as well as informing and awareness

Thank you!

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