Workshop on Sludge management in the Danube Region for a greener EU
10 June 2021

Mitigation of hazardous substances in sewage sludge: SLUDGEFFECT project

EU GREEN WEEK 2021 PARTNER EVENT

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ZERO POLLUTION #EUGreenWeek
for healthier people and planet

DANUBE REGION strategy Water Quality
ICPDR IKSD International Commission for the Protection of the Danube River Internationale Kommission zum Schutz der Donau
IAWD DANUBE WATER PROGRAM Smart policies, strong utilities, sustainable services
INTERNATIONAL SAVA RIVER BASIN COMMISSION

Short bio

From Fredericton, New Brunswick, Canada

Education:
PhD. Environmental Chemistry, 2008, ETHZ, Switzerland

Work
2008-present NGI, Oslo (Senior Expert)
2018-present NTNU, Trondheim (Professor II)

Research Interests regarding Sludge
Focussed on environmental risks of chemicals, and how such risks can be best managed. *I am a researcher, and do not represent the Norwegian government, a WWTP or technology start-up*.

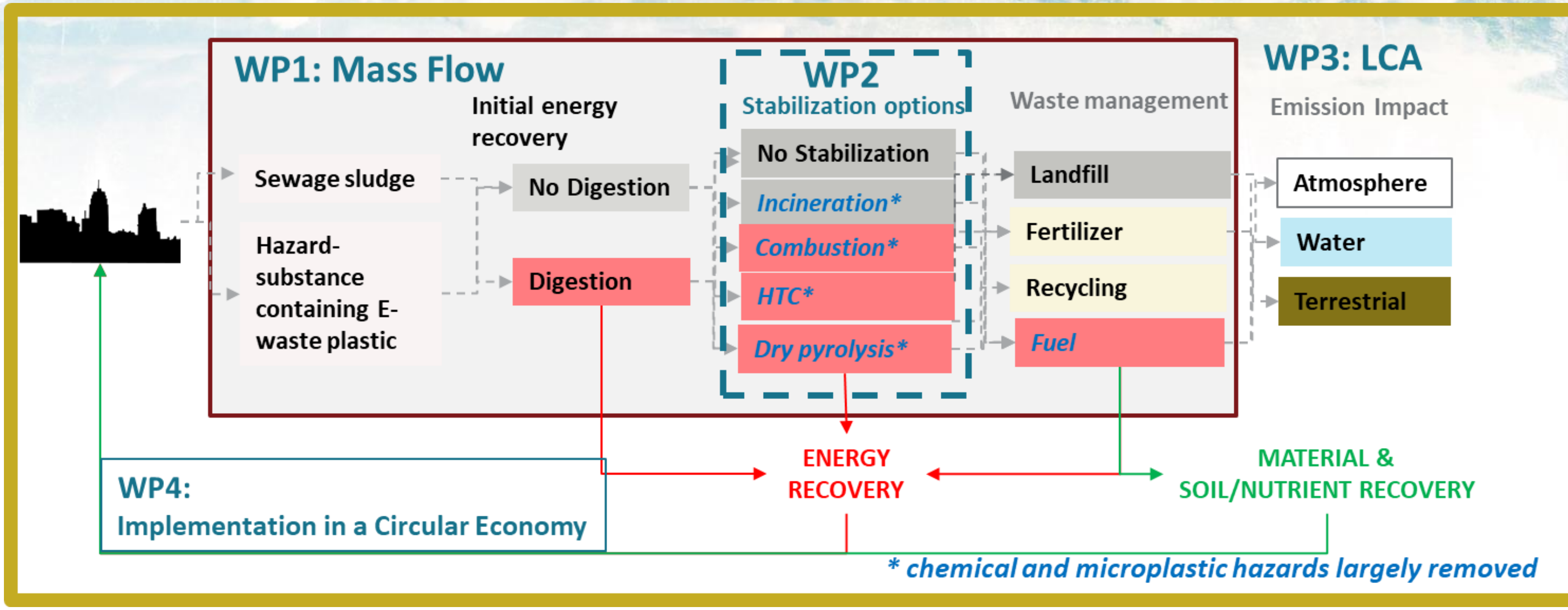
Sludge management in Norway compared to the EU

Figure	Norway (2018)	EU-27 (2019)
Population	5.3 million	447.7 million
Total sludge produced	118 kton (22 kg/capita)	8300 kton (19 kg/capita)
% used for biogas production	24%	??
% agriculture/soil	**82%**	**50%**
% incinerated	**1%**	**28%**
% landfilled (+ other)	5% (+ 12%)	18% (+4%)

No tributaries to the Danube currently known

Sources: SSB Norway,
Collivignarelli et al., 2019
Preliminary SLUDGEFFECT results (biogas)

SLUDGEFFECT Project



Life cycle effects from removing hazardous substances in sludge and plastic through thermal treatment.

Years: 2020-2024

The Research Council of Norway

Funding : SLUDGEFFECT: The Research Council of Norway, Project No. 302371

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Overview of thermal treatment recycling technology categories

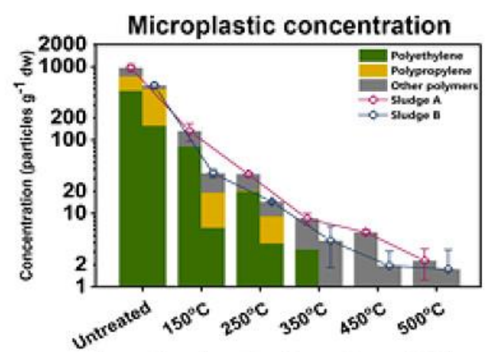
Thermal treatment category	Description	Recycling Negatives ☹	Recycling Positives ☺
Monovalent Incineration	Dedicated sewage sludge incinerators	Carbon is lost, ash and flue gas management, air emissions*	energy recycling, P can be extracted (struvite)
Co-combustion	Combusting sludge with e.g. coal, municipal waste, cement kilns	Carbon is lost, fertilizer is lost, air emissions,* ash management unless cement	energy recycling, cement raw material
Wet-pyrolysis/ gasification	Heating wet sludge with no oxygen	Fertilizer is lost, ash and flue gas management, air emissions	efficient for energy recapture (e.g. syngas & liquid fuel)
Dry-pyrolysis	Heating dry sludge with no oxygen	Heavy metals concentrate in fertilizer, air emissions	C-sequestration, fuel, bioavailable P concentrates

* Incinerators and co-combusters (also pyrolyzers?) need to fulfill air emission regulations, such as Directive 2010/75/EU and Directive 2001/80/EC

Further reading:
https://www.umweltbundesamt.de/en/publikationen/technical-guide-on-the-treatment-recycling-0
https://www.eureau.org/resources/news/545-key-to-a-circular-future

Contaminants and thermal treatment (to research)

Contaminant	Reaction to sludge incineration/pyrolsis	Ref
PAHs / dioxins	Formed to a varying degrees. High temperature and long times tends to give less PAHs/dioxins, low temperature processes (e.g. gasification) tend to produce more. Often strongly sorbed to chars/soots (limited bioavailability).	Hale et al. ES&T 2012
Heavy metals	Some lost to flue gas, remainder is enriched in the ash/char. Bioavailability tends to decrease though treatment dependant (incineration -> insoluble oxides, pyrolysis increases pH to insoluble oxidation states)	Kahn et al. ES&T 2012
Microplastics	Converted to volatiles (e.g. monomers) or mineralized by 500 ˚C given enough time (more efficient at higher temp)	Ni et al. ES&T lett. 2021
PFAS	Converted to volatiles or mineralized to CO_2/chars by 600 ˚C given enough time (more efficient at higher temp)	Simon & Kaminsky (1998)
Other organic contaminants	Converted to volatiles (e.g. monomers) or mineralized by 500 ˚C given enough time (more efficient at higher temp)	SLUDGEFFECT



Ni et al. ES&T lett. 2021

Growth of Thermal Recycling of Sludge

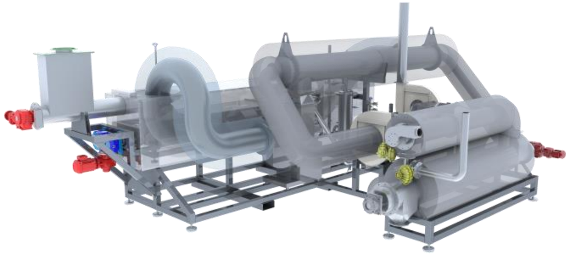
Mono-incineration and co-combustion: increasing in many countries, especially regions that do not apply sludge directly to agriculture/land (e.g. Germany targeting 70% monoinceration)

Wet pyrolysis/gasification: rarely applied to sludge beyond pilot scale
Dry pyrolysis: rarely applied to sludge, but this becoming an active area of innovation, e.g. companies selling and installing sludge pyrolysers.

Pyreg, Germany

VOW/ETIA-Biogreen, Norway/France*

AquaGreen, Denmark*

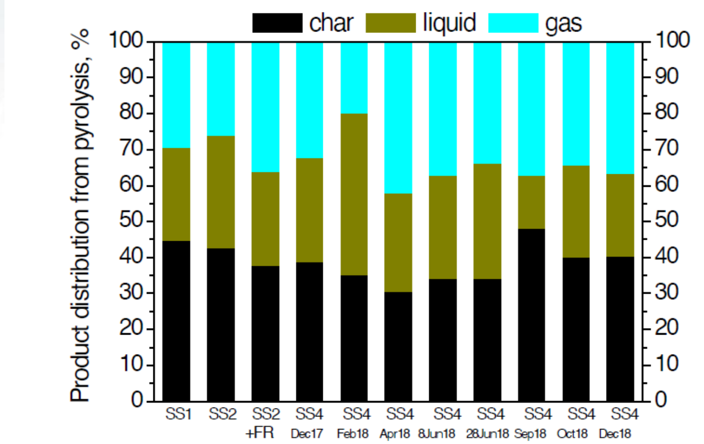


Vow/Lindum – Microwave assisted pyrolysis, Norway*

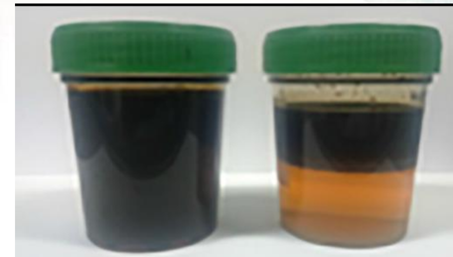
* Tested in SUDGEFFECT

Variation in fertilizer from dry pyrolysis

Sludge biochar fertilizer (30-50%)



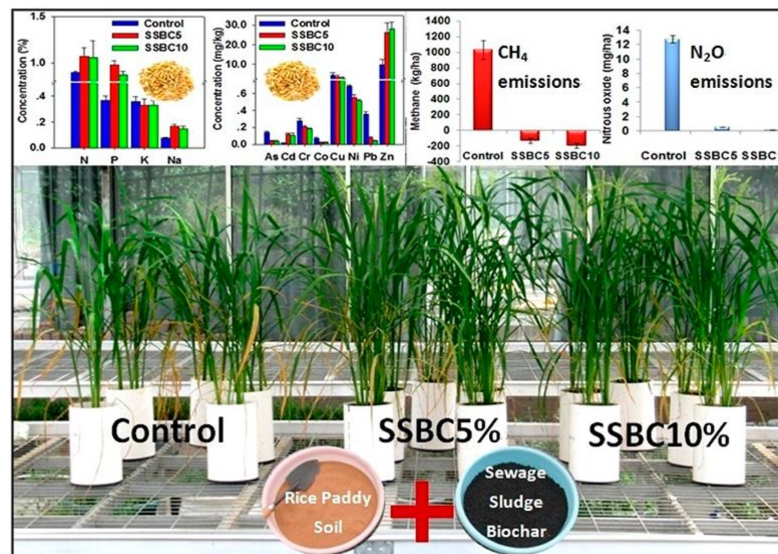
Kwapinska, M., Agar, D. A., Bonsall, B., & Leahy, J. J. (2020) Valorisation of Composted Organic Fines and Sewage Sludge Using Pyrolysis (OF-PYR). (2016-RE-MS-7). Irish EPA Research Report



Pyrolysis condensates (complex) (20-40%), best for producing energy on-site, e.g. providing heat to pyrolyzer/co-incineration

Total phosphorous - Total phosphorous is retained (enriched) in sludge chars more than gas and condensates (on average doubles in concentration).

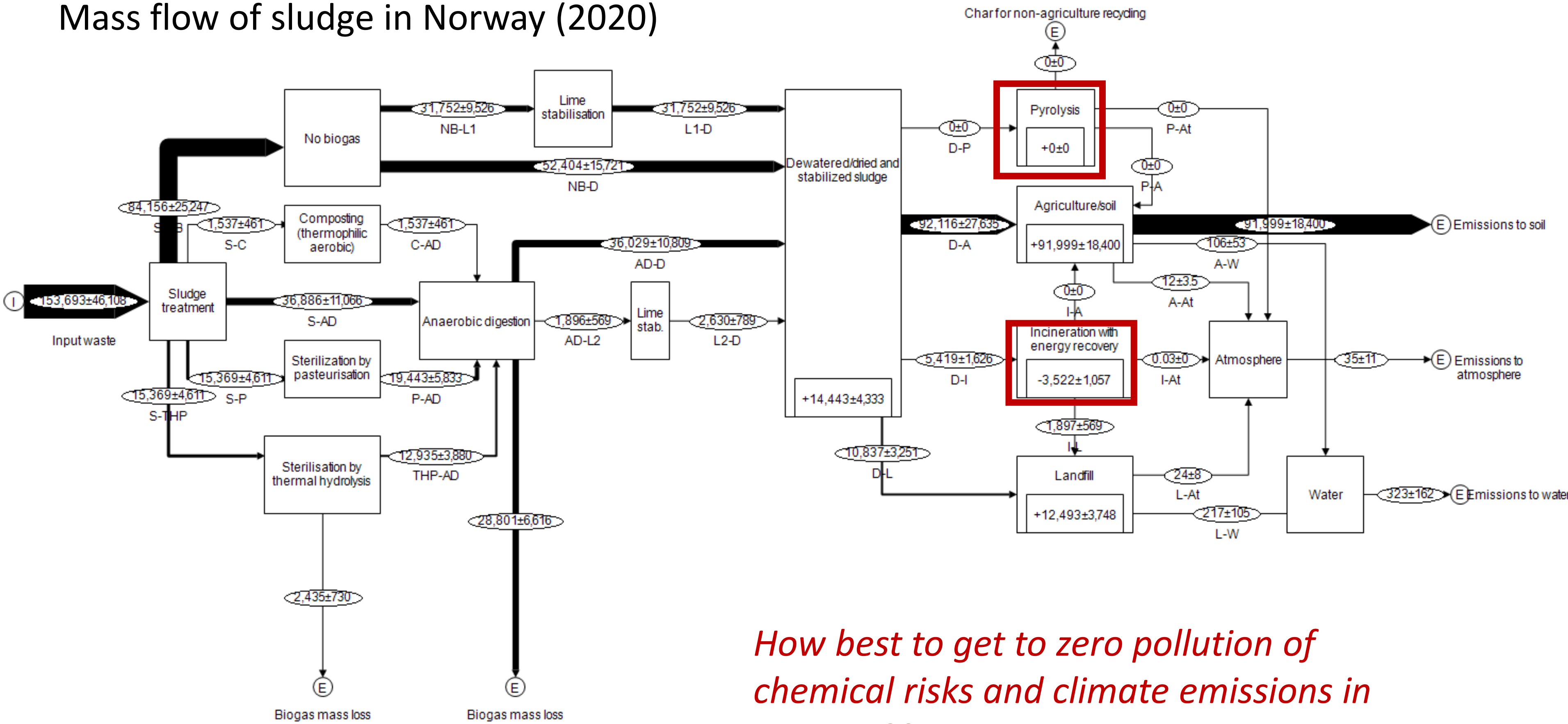
Bioavailable phosphorous – are variable from different (preliminary reports), some pilots and most lab scale studies show this doubles increasing soil fertility, also due to other properties of char (e.g. alkalinity, water retention) (e.g. Khan et al- ES&T 2012)



Khan et al- ES&T 2012

SLUDGEFFECT goal – predicting impacts (chemical risk and LCA) if Norway switched to more thermal treatments.

Mass flow of sludge in Norway (2020)



How best to get to zero pollution of chemical risks and climate emissions in Norway??

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H. Knutsen, preliminary SLUDGEFFECT results

Different views on the future of thermal treatments of sludge

Negative

Commission

JRC SCIENCE FOR POLICY REPORT

Technical proposals for selected new fertilising materials under the Fertilising Products Regulation (Regulation (EU) 2019/1009)

Process and quality criteria, and assessment of environmental and market impacts for precipitated phosphate salts & derivates, thermal oxidation materials & derivates and pyrolysis & gasification materials

Huygens D, Saveyn HGM, Tonini D, Eder P, Delgado Sancho L

2019

Positive

3.2.6.4 Life Cycle Impact Assessment

Barry, Devon J., "Pyrolysis as an Economical and Ecological Treatment Option for Solid Anaerobic Digestate and Municipal Sewage Sludge" (2018).

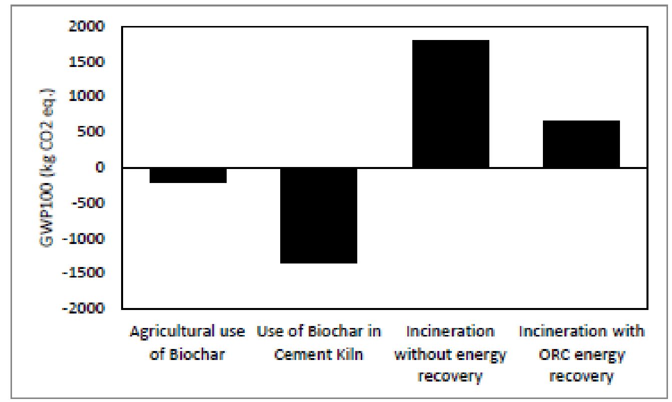

Figure 3.25: LCA Global Warming Potential Results

- JRC recommends mono-incineration and nutrient extraction (fertilizer regulation)
- *Precautionary principle*: unknown chemical hazards- do not use sludge for fertilizer, pyrolyzed or otherwise

- Incineration worse than pyrolysis from an LCA perspective
- Dry pyrolysis is carbon negative in agriculture
- Sewage sludge biochar for co-combustioni in cement kilns is even more carbon negative

The way forward for sludge management in a circular economy

The best solution is local, and depends on contaminants in the sludge, need for phosphorous, climate mitigation targets and goals towards zero pollution. New thermal technologies can have a role. Recommendations inspired by EurEau (2021) are:

1. **Control at source** (prevent pollution from entering sludge, e.g. PFAS restriction) *is the most important part* of sludge management (see: REVAQ system in Sweden)
2. **Biosolids have a role, as do pyrolyzed biosolids**, for agriculture and land reclamation in a climate mitigating way (particularly if chemical risks are low)
3. **Risk assessment for chemicals is important**
4. **Incineration / co-combustion is best option in many cases**: if chemical risks are unacceptable, phosphorous not needed locally, land application not feasible, etc.
5. **Innovation** towards zero pollution should not be hindered by over-complex/contradicting regulation

- To be explored more in SLUDGEFFECT
- https://www.ngi.no/eng/Projects/SLUDGEFFECT


May 2021

Briefing note

EurEau

Waste water treatment – sludge management

A regulatory framework is needed to support sustainable and resilient sludge management, incorporating a broader scope for risk assessment and strict sludge quality control.

Thank-you!

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