Project Neptune

End-user workshop, January 2009, Ghent, Belgium

Sewage Sludge Treatment by Ultrahigh-Temperature Pyrolysis

Natalija Miladinovic, Eawag, Switzerland
Pyromex, Eawag, Switzerland
Florence Boyer-Souchet, Henrik Fred Larsen, DTU, IPU, Denmark

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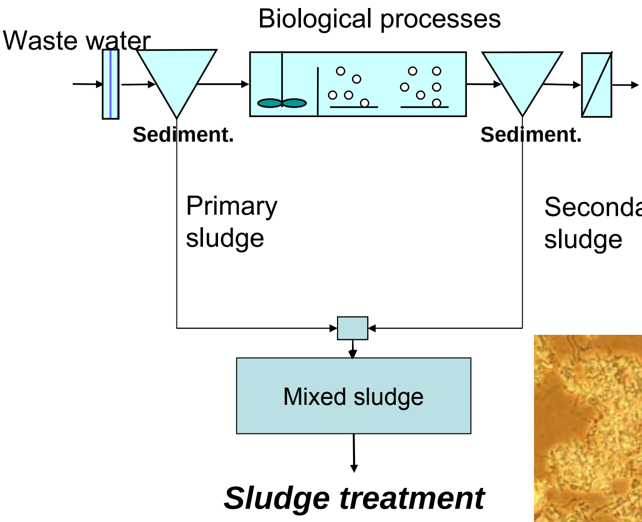
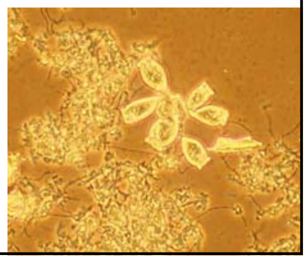
Content

- Sewage sludge and sludge treatment
- Pyrolysis process; potential for P removal
- LCA results; comparison with incineration

Sludge line in WWTP



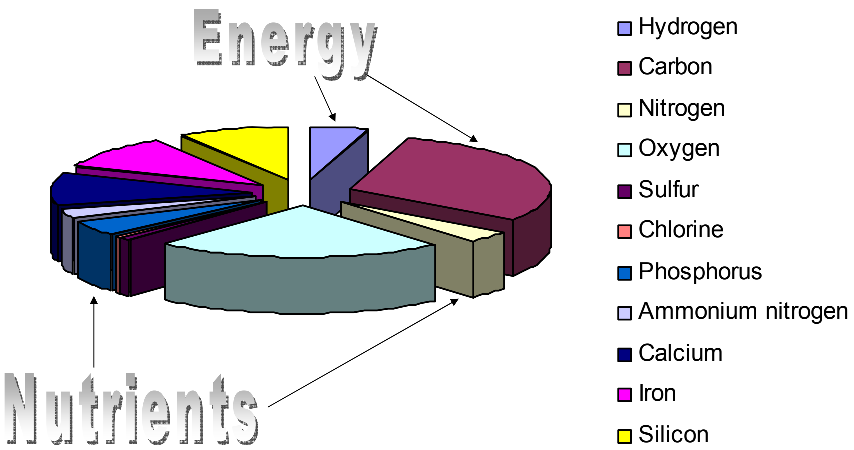


Sludge treatment

- Dewatering and drying
- Stabilization and disinfection (to stop biological processes as well as to reduce pathogens and volume of material)
  - Anaerobic digestion
  - Aerobic digestion
  - Composting
  - Long time storage
  - Lime or nitrite treatment
  - Pasteurization

Sludge composition (stabilized sewage sludge)

Nutrient	Nutrients in WW vs. fertilizer consumption %
Nitrogen	12% - 19%
Phosphorus	8% - 21%
Potassium	11% - 24%



Sludge composition (stabilized sewage sludge), cont.

- Heavy metals
- Organic contaminants

Polynuclear aromatic hydrocarbons (PAH)	Herbicide residues
Polychlorinated biphenyls (PCB)	Organo-tin compounds
Polychlorinated terphenyls	Phthalate esters
Phenol	Petroleum hydrocarbons
Chlorinated hydrocarbon solvents and phenols	Surfactants
Organochlorine insecticides	Aromatic amines
Organophosphorus compounds	

- Pathogens

Sludge disposal and recycling

- ~~Ocean dumping~~ 1980's
- ~~Land filling~~ ? In Switzerland since 2000, in Sweeden since 2005
- ~~Agriculture~~ ? Switzerland, Sweeden, The Netherlands...
- Incineration
- Other methods

Novel sludge inertisation processes - reuse of sludge and of its resources

- Super Critical Water Oxidation (SCWO)
  - T=374°C; P=22Mpa
- Wet Oxidation
  - T=250-300°C; P=6-10Mpa
- Sludge Gasification
  - T=850°C
- Ultra High Temperature Pyrolysis
  - T=1200-1400°C

<u>The final result should be</u>:

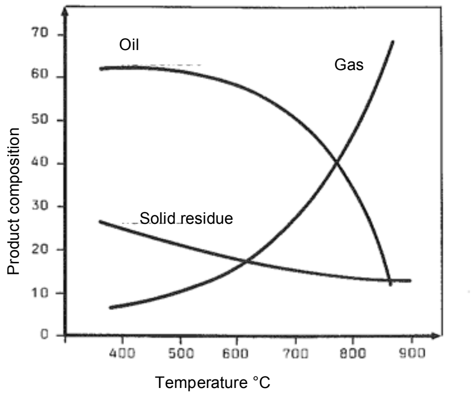
▪Reduced sludge volume

▪Elimination or fixation of pollutants

▪Recovery of nutrients

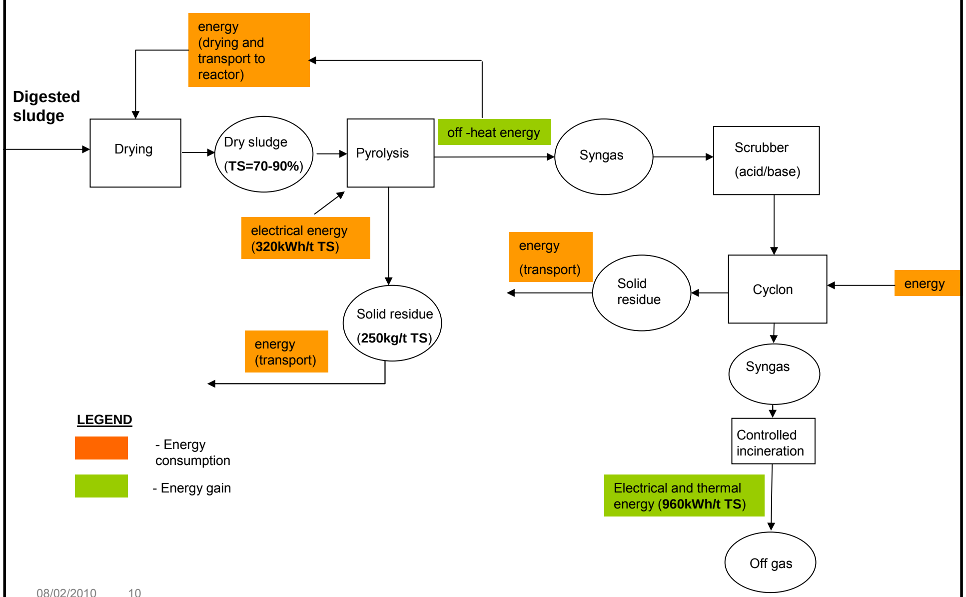
▪Recovery of energy (not only in form of heat

High Temperature Pyrolysis (>1’000°C)



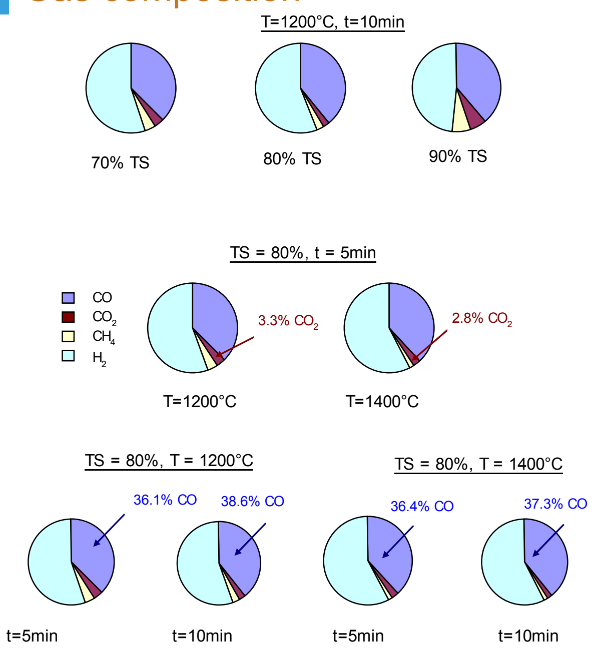
- Only two phases in product
- Gas is free of tar so that cleaning is avoided
- Organic micropollutants are completely destroyed

High temperature pyrolysis



High temperature Pyrolysis, pilot plant Munich

Gas composition



Solid product

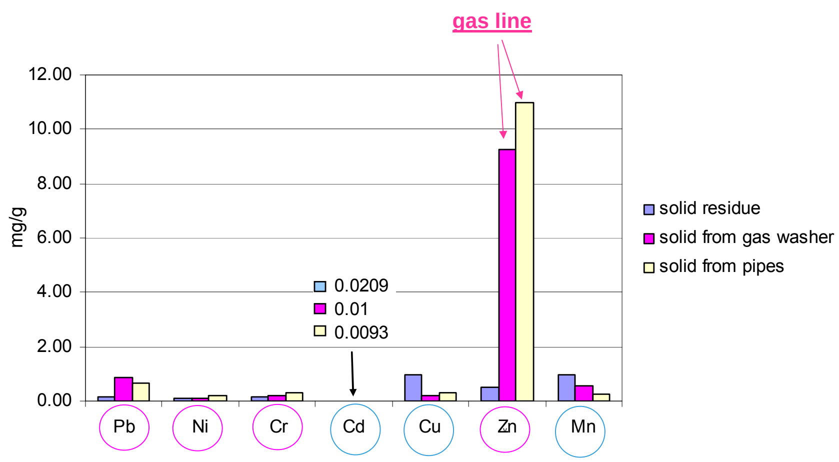
- The amount of produced solid residue (and consequently the gas) is strongly dependent on process temperature and reaction time.

- TS reduction:

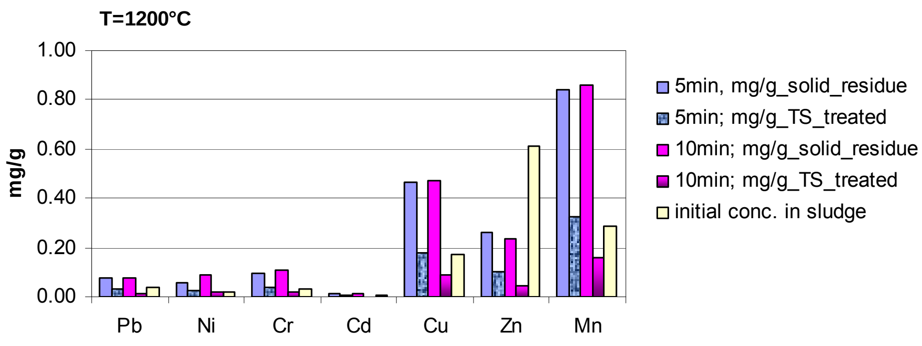
T \ t	5min	10min
1200°C	62%	81%
1400°C	76%	87%

- Beside the amount which leaves the reactor (82% of total solid residue) smaller part of the solids (16%) could be collected from the gas washing tank as well as from the gas cooling pipes (2%).

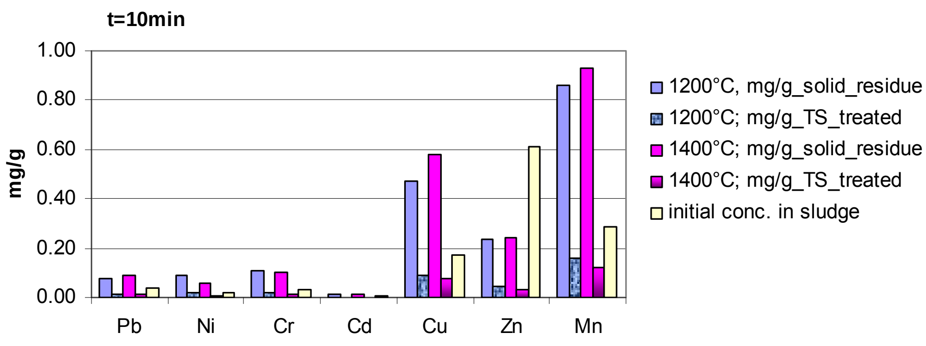
Heavy metals distribution among solid products (90% TS, T=1200°C, t=10min)



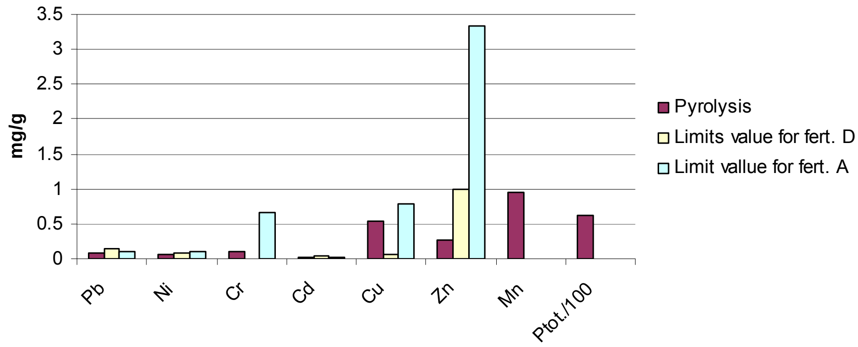
Results, solid residue (80%TS)



Results, solid residue; cont. (80% TS)



Heavy metals content – comparison with EU limits[1)] for fertilizers



1) Adam et al., (2007) Materials Transactions, 48 (12): 3056-3061

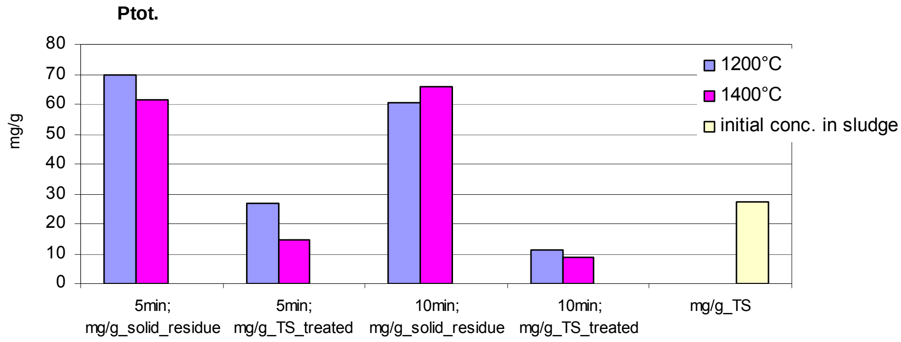
Heavy metals leaching from the solid residue (80% TS)

- 1g sample was placed in the closed flask and shaken with 20ml of deionisied water for 5 days. After filtration the heavy metals concentration was measured.

T	*time*	*Pb*	*Ni*	*Cr*	*Cd*	*Cu*	*Zn*	*Mn*
1200°C	***5 min***	0.63%	0.15%	0.10%	0.13%	0.04%	0.02%	0.00%
	10 min	1.42%	0.19%	0.13%	0.65%	0.08%	0.05%	0.00%
1400°C	***5 min***	0.77%	0.16%	0.09%	0.16%	0.04%	0.03%	0.01%
	10 min	0.73%	0.19%	0.10%	0.14%	0.04%	0.03%	0.01%

- Neither the temperature nor the residence time influenced the stability of the heavy metals in the solid residue.

Potential for phosphorus recovery



Phosphorus bioavailability, 1g in 20ml of 2% citric acid

	5min		*10min*		
	init.conc.in res. (mg/g	*% leached*	*init.conc.in res. (mg/g)*	*% leached*	*init.conc.in sl. (mg/g)*
T					
1200°C	69.9	12.6%	60.6	9.9%	27.4
1400°C	61.4	11.9%	65.6	11.8%	

Conclusion:

A shorter residence time gives a slightly better phosphorus bioavailability with a higher P fraction remaining in the inert residue.

	Ptot. init. (mg/g)	*Percentage leached*
Incineration ash	58-90	0.07%-0.12%
Wet Oxydation solid residue	81.1	8.9%
Pyrolysis (TS80%, 1200°C, 10min)	60.6	9.9%
Gasification in Balingen	58.6	16.5%

Basic data for the pyrolysis process (full scale plant)

Pyrolysis process	
Capacity:	7000tTS/year
TS :	70-90%
Electricity consumption:	320kWh/tonTS
Oxygen consumption:	none
Solid mineral out:	250kg/tonTS
Gas out (to the atmosphere)	none
Operato and maintenance:	4men/year
Primary energy gain:	960kWh/tonTS
Investment costs:	9milion € (for 25ton/d unit)
Personal costs	200'000€/year

LCA: Characterization of Pyrolysis scenario

- Sludge composition from European average on WWTP, 4% TS

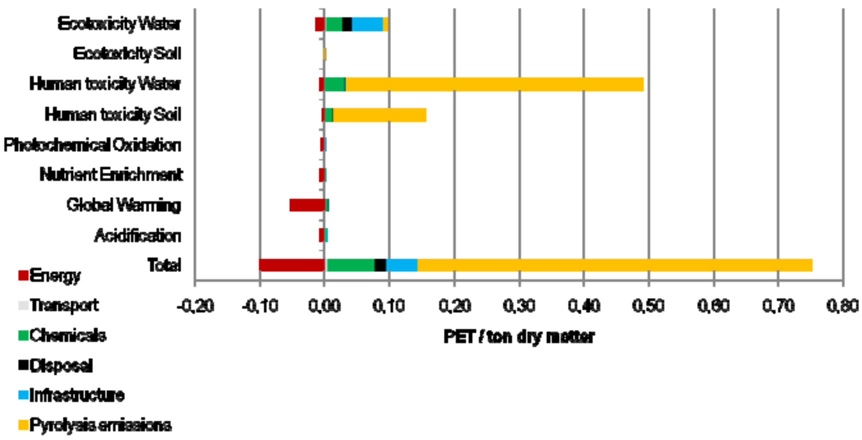
Scoping (included):

- Emissions of heavy metals to air -> *Cd, Cr, Cu, Hg, Ni, Pb, Zn*
- Infrastructure
- Disposal of solid residues
- Chemicals (for off-gas treatment; assumed identical to on-site incineration)
- Transport
- Energy consumption / production

		kWh / ton DM
Energy production	As electricity	+ 960 (theoretical yield)
	As heat	+ 2 200 (theoretical yield)
Energy consumption	As electricity	-340
	As heat	- 1 510
Energy balance		**+ 1 310**

LCA: Impact profile; Pyrolysis - heat drying

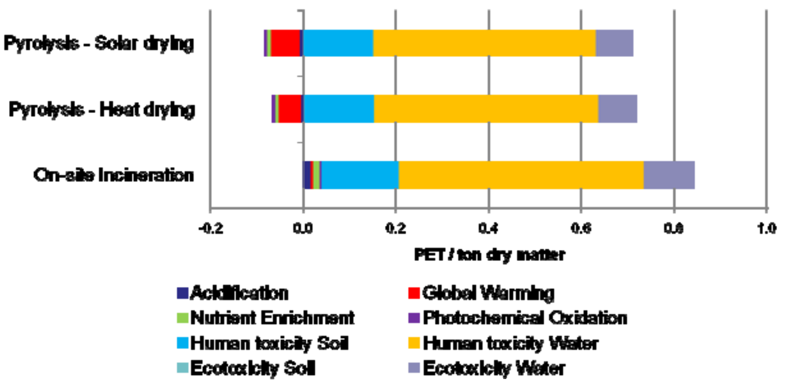
(Normalized and weighted impacts, PET. Weighting factors =1 for all impact categories).



Total (net) = 0,65

The impact of "pyrolysis emissions" is dominated by mercury air emissions

LCA: Comparison of impact profiles; Pyrolysis and on-site incineration



Total (net): Incineration = 0,84 PET/ton DM

Pyrolysis – heat drying = 0,65 PET/ton DM

Pyrolysis – solar drying = 0,63PET/ton DM

Conclusions

- High temperature allows for avoiding oily phase as a product; only solids (free of organics) and gas leave the reactor.
- Gas is free of tar and expensive cleaning is avoided.
- Solid product has low content of heavy metals and there is a possibility for phosphorus recycling.
- Present heavy metals are well immobilized, which contributes to overall process sustainability.
- LCA studies indicate that high temperature pyrolysis (HTP) might be more environmental sustainable than on-site incineration due to apparent lower mercury air emissions and a better energy balance
- However, the sustainability assessment is highly sensitive to the actual heavy metal emissions and the energy balance used for HTP is based on theoretical yield

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Acknowledgment

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