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P-REX

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Hypotheses for evaluation of P recovery processes

Within the P-REX project, different pathways and processes for P recovery from sewage sludge are assessed in their environmental and economic impacts. For this task, the life-cycle perspective is adopted, using the methodology of Life Cycle Assessment (LCA, ISO 14044/44) and Life Cycle Costing (LCC).

For a fair and robust comparison, process data of the different P recovery technologies has to be transferred from pilot or full-scale installations to a defined reference system to overcome potential bias due to site-specific conditions. This reference system is defined as the sludge treatment line of a wastewater treatment plant (WWTP) for 1 Mio inhabitant equivalents, reflecting the annual operation of a typical large-scale WWTP in Germany. The model includes sludge digestion, dewatering, transport, mono-incineration, and ash disposal, and accounts for energy credits from electricity production in CHP plants (from digester gas) and heat/electricity use from incineration (Figure 1). Recovered P fertilizer is accounted via substituting the equivalent production of mineral fertilizer, also taking into account the heavy metals content transferred to agricultural soil with each fertilizer. To reflect all side effects of sludge treatment, treatment of sludge liquor in mainstream WWTP process is also included in the model with a simplified energy calculation based on liquor loads of P and NH_4-N. Dewatered sludge (25% dry matter) is transported to mono-incineration (35 km) where energy content of sludge can be recovered (14% of heating value as electricity, 73% as district heating).

Input raw sludge is defined as mixed sludge from primary and biological stage, according to typical compositions in Germany (Table 1). Concentration of P and other metals (Fe, heavy metals) is adjusted in the model to reflect mean concentrations in incineration ashes from mono-incineration[1] (Table 2). For P recovery from sludge or sludge liquor, PO_4-P concentration in sludge liquor determines the potential P yield of the process and thus process efficiency, also in relation to the required electricity and chemicals. For WWTP with extended biological phosphorus removal (EBPR), a PO_4-P concentration of 200 mg/L PO_4-P is defined in the model. For WWTP with chemical P removal via Fe dosing, a PO_4-P concentration of 10 mg/L PO_4-P is assumed.

Table 1 Composition of digested sludge and liquor in P-REX reference model

Parameter		Digested sludge			Sludge liquor	
		Chem-P	EBPR		Chem-P	EBPR
Volume	[m³/a]	418800	418800	[m³/a]	372500	372500
Dry solids (DS)	[%]	3.0	2.9	[mg/L]	2000	2000
Volatile solids	[% of DS]	54	57			
COD	[g/kg DS]	751	804	[mg/L]	1500	1500
N	[g/kg DS]	82	89	[mg/L]	1000	1000
P	[g/kg DS]	41	43	[mg/L]		
PO4-P in liquor	[mg/L]	10	200	[mg/L]	20	200
Fe	[g/kg DS]	66	20	[mg/L]	0	0
Mg	[g/kg DS]	7	7	[mg/L]	15	15
Cd	[mg/kg DS]	1	1			
Cu	[mg/kg DS]	447	460			
Cr	[mg/kg DS]	66	68			
Ni	[mg/kg DS]	25	26			
Pb	[mg/kg DS]	53	54			
Hg	[mg/kg DS]	0.83	0.85			
Zn	[mg/kg DS]	1043	1072			

[1] Krüger und Adam (2014): Monitoring von Klärschlammmonoverbrennungsaschen hinsichtlich ihrer Zusammensetzung zur Ermittlung ihrer Rohstoffrückgewinnungspotentiale und zur Erstellung von Referenzmaterial für die Überwachungsanalytik, UBA-Bericht 49/2014, German Federal Environmental Agency, Dessau, Germany.

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For the process fact sheets, P recovery yield is related in relation to the total amount of P in sludge (523.5 t/a). Electricity, heat and chemicals demand for each process is then related to the amount of recovered P (kg P). Hence, relative data of each process may differ from other publications, but is here related to the conditions defined in the P-REX reference model.

Table 2 Composition of ash from mono-incineration in P-REX reference model

Parameter		Ash	
		Chem-P	EBPR
Mass	*[t/a]*	551	4889
Dry solids (DS)	*[%]*	100	100
Volatile solids	*[% of DS]*	0	0
N	*[g/kg DS]*	0	0
P	*[g/kg DS]*	95	107
Fe	*[g/kg DS]*	152	51
Mg	*[g/kg DS]*	15	17
Al*	*[g/kg DS]*	50	50
Ca*	*[g/kg DS]*	100	100
Si*	*[g/kg DS]*	100	100
S*	*[g/kg DS]*	10	10
Cd	*[mg/kg DS]*	2.3	2.6
Cu	*[mg/kg DS]*	1024	1156
Cr	*[mg/kg DS]*	152	171
Ni	*[mg/kg DS]*	57	64
Pb	*[mg/kg DS]*	121	137
Hg	*[mg/kg DS]*	0.51	0.57
Zn	*[mg/kg DS]*	2390	2698

*Defined from Krüger and Adam 2014, *estimated*

Process scheme

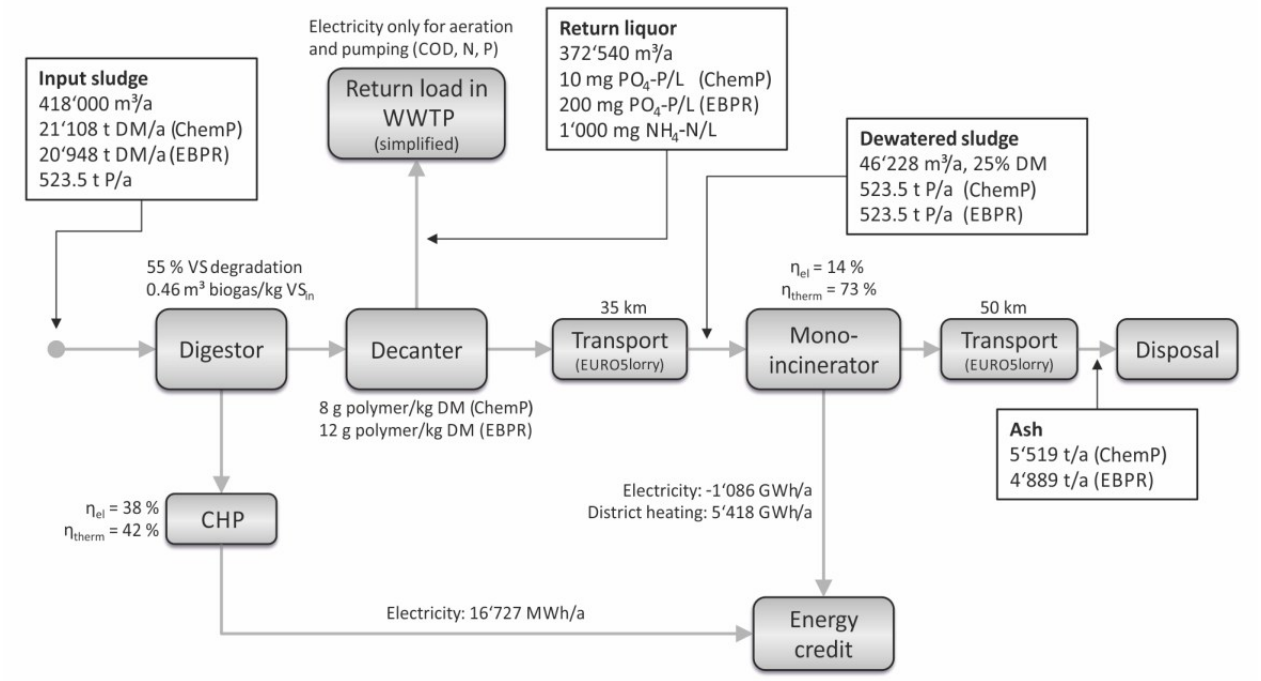

Figure 1 Process scheme for reference model of WWTP sludge line (1 Mio pe)

[1] Krüger und Adam (2014): Monitoring von Klärschlammmonoverbrennungsaschen hinsichtlich ihrer Zusammensetzung zur Ermittlung ihrer Rohstoffrückgewinnungspotentiale und zur Erstellung von Referenzmaterial für die Überwachungsanalytik, UBA-Bericht 49/2014, German Federal Environmental Agency, Dessau, Germany.

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