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Characterization of char produced by pyrolysis and activation of wastewater sludge

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Adsorbents: a possible valorisation route?

Traditional disposal routes

- Spreading on agricultural land
- Incineration
- Landfill, discharge into water bodies

Alternative valorisation routes are to be found!

Sludge-derived adsorbents for wastewater contaminants:

- Dyes: Methylene blue, Reactive Red, Acid Yellow
- Metals: Copper, Iron, Lead
- Phenolics: Methylphenol, Bisphenol-A, Bromophenol
- Phosphorus and Phosphates

recent review papers on the topic (Hadi P. at al., 2015 and Devi P., 2017)



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Drying and pyrolysis of wastewater sludge

AquaCreen



→ System currently operating at Odense wastewater treatment plan , VandcenterSyd (<u>https://www.vandcenter.dk/viden/spildev/and</u>)



Char composition





Proximate composition







Char thermogravimetric analysis





 N_2 atmosphere: loss of carbon fraction ($\approx 16 \text{ wt\%}$) visible after about 45 minutes. Afterwards the mass reduction progressed, leaving a residual mass of 80.5 wt%.

Air atmosphere: oxidation at 900°C left a residual mass 75.5 wt%, meaning that part of the inorganics left the sample in the gas phase.

Steam activation of sludge char





Steam activation (60 minutes)

- \approx 10 g of char activated in thermo-gravimetric reactor
- \approx 1 kg/h steam flow
- Activation temperatures: 650 700 750 800 900°C

Surface characterization – N₂ adsorption 77 K



BET surface area



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Surface characterization – N₂ adsorption 77 K



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ICP-OES analysis of inorganic fraction



- **Cd** and **Cu** concentrations resulted above the thresholds indicated in the Danish legislation relative to waste materials for agricultural purposes (Fødevareministeriet, 2018).
- The concentration of Cd and other elements (S, Zn, Pb, Al) decreased with increasing activation temperature



Conclusions

- The analyzed sewage sludge char is rich in ashes and contains only about 16% of carbon
- Physical activation with steam is only partially effective in increasing the surface area and porosity of the char
- Activation temperatures above 750°C result in significant degradation of the surface
- With increasing activation temperature, some inorganic species (Zn, Pb, Al, Cd and S) are vaporized and leave the solid sample

... and future work

- Adsorption experiments using dyes and...?
- Use of chemical activation (e.g KOH addition) for further improvement of surface area and porosity

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- THE ENVIRONMENTAL TECHNOLOGY DEVELOPMENT AND DEMONSTRATION PROGRAMME





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> Thank you!



References



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Vand Center Syd WWTP - Odense







ICP-OES analysis of inorganic fraction

									Perio	odic Ta	able								
Group	1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period																			
1	1																		2
	н																		He
	1.008																		4.0026
2	2 3	4												5	6	7	8	9	10
	Li	Be												В	C	N	0	F	Ne
	6.94	9.0122												10.81	12.011	14.007	15.999	18.998	20.18
3	11	12												13	14	15	16	17	18
	Na	Mg												Al	Si	Р	S	CI	Ar
	22.99	24.305												26.982	28.085	30.974	32.06	35.45	39.948
4	19	20		21	22	23	24	25	26	27	28	29	30	31	. 32	33	34	35	36
	к	Ca		Sc	Ti	V	Cr	Mn	Fe	Со	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
	39.098	40.078		44.956	47.867	50.942	51.996	54.938	55.845	58.933	58.693	63.546	65.38	69.723	72.63	74.922	78.96	79.904	83.798
5	5 37	38		39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
	Rb	Sr		Y	Zr	Nb	Мо	Тс	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
	85.468	87.62		88.906	91.224	92.906	95.96	[97.91]	101.07	102.91	106.42	107.87	112.41	114.82	118.71	121.76	127.6	126.9	131.29
6	55	56	*	71	72	73	74	75	76	77	78	79	80	81	. 82	83	84	85	86
	Cs	Ba		Lu	Hf	Та	w	Re	Os	Ir	Pt	Au	Hg	тΙ	Pb	Bi	Ро	At	Rn
	132.91	137.33		174.97	178.49	180.95	183.84	186.21	190.23	192.22	195.08	196.97	200.59	204.38	207.2	208.98	[208.98]	[209.99]	[222.02]
7	7 87	88	**	103	104	105	106	107	108	109	110	111	. 112	113	114	115	116	117	118
	Fr	Ra		Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	FI	Uup	Lv	Uus	Uuo
	[223.02]	[226.03]		[262.11]	[265.12]	[268.13]	[271.13]	[270]	[277.15]	[276.15]	[281.16]	[280.16]	[285.17]	[284.18]	[289.19]	[288.19]	[293]	[294]	[294]
*Lanthan	oids		*	57	58	59	60	61	62	63	64	65	66	67	68	69	70		
				La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Но	Er	Tm	Yb		
				138.91	140.12	140.91	144.24	[144.91]	150.36	151.96	157.25	158.93	162.5	164.93	167.26	168.93	173.05		
**Actino	Actinoids		**	89	90	91	92	93	94	95	96	97	98	99	100	101	102		
				Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No		
				[227.03]	232.04	231.04	238.03	[237.05]	[244.06]	[243.06]	[247.07]	[247.07]	[251.08]	[252.08]	[257.10]	[258.10]	[259.10]		

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