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Utilisation and classification of MSWI bottom ash in Denmark

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Danish Waste Solutions ApS

Danish Waste Solutions ApS is a small independent consulting company offering expert services within the management of waste and resources with particular emphasis on environmental aspects.

Our work is based on technical, applied science and R&D results coupled with up-to-date-knowledge of the technical and regulatory development.

We are three partners, all of whom have many years of experience with consultancy and management and performance of R&D projects for industry, waste management companies and public authorities.

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Outline

- Context and regulatory framework
- Comparison of Danish leaching criteria with Swedish guidance values for utilisation
- Content and leaching properties of Danish MSWI BA from 1998 to 2016 (including trends)
- Classification of Danish MSWI BA
- Conclusions

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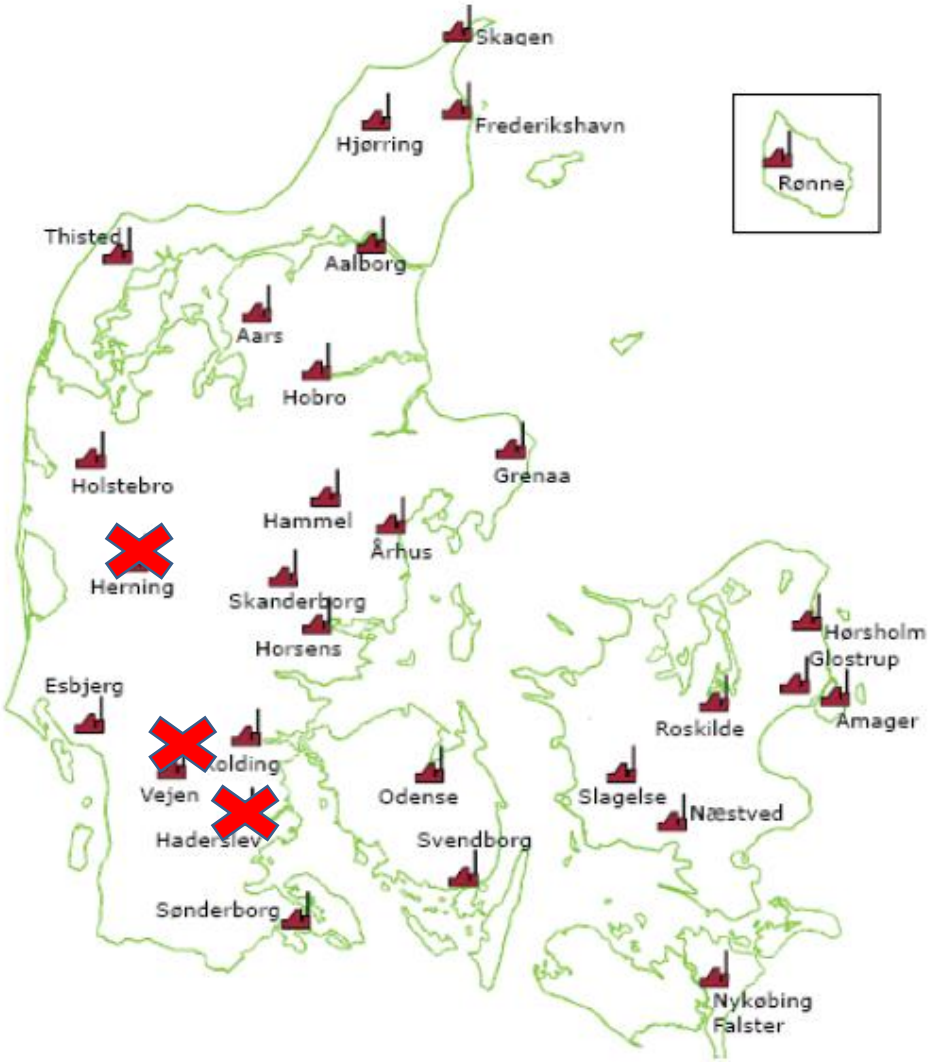
26 MSW incinerators in Denmark (2015)



Denmark 2015

Waste incinerated: 3.6 mio t

BA produced: ~ 0.61 mio t

Almost all utilised

Population: 5.68 mio

Area: 43,000 km^2

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Danish Staturory Order No. 1672 of 15 Dec. 2016 on utilisation of residual waste materials, soil and sorted, unpolluted C&D waste

MSWI BA

Batch leaching test EN 12457-1 (L/S = 2 l/kg) – criteria in table

TOC < 3 % (w/w)

Minimum distance to drinking water wells: 30 m

Placement above maximum groundwater level

Category 1 not applicable to MSWI bottom ash (restrictions on content)

Leaching limit values

Substance	Category 1+2	Categori 3
	mg/kg	mg/kg
Chloride	3000	6000
Sulphate	4000	8000
Na	2000	3000
As	0.016	0.1
Ba	0.6	8
Cd	0.004	0.08
Cr	0.02	1
Cu	0.09	4
Hg	0.0002	0.002
Ni	0.02	0.14
Pb	0.02	0.2
Se	0.02	0.06
Zn	0.2	3

Category 2: Roads, paths, squares, noice reduction barriers, 0.3 to 4 m layer, cover required to prevent contact

Category 3: Roads and paths, foundations (max 1 m), cover to reduce infiltration to max. 10 % of the precipitation (roads)

> Category 3: Permission may be granted based on a specific risk assessment under the Environmental Protection Act

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Application of MSWI BA in Denmark

Limited information available on amounts

Main uses of the mineral part (after removal of metals):

As Category 3:

- Road construction (as sub-base)
- Foundations and fill under floors

With special permission (based on risk assessment):

- Noice reduction barriers, embankments

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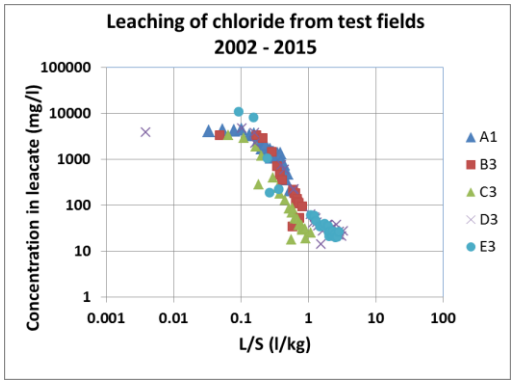
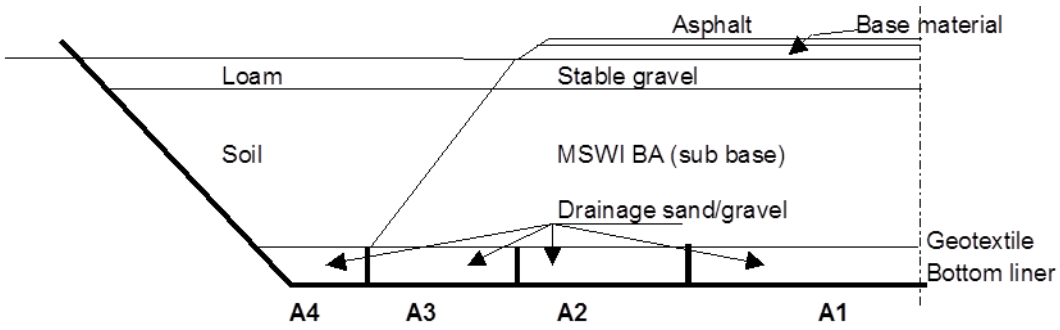
Full scale assessment of the environmental implications of the use of IBA as subbase in road construction

Demonstration sites for IBA use in road construction 2002 – 2019

Client: Danish incinerators (DAFONET)





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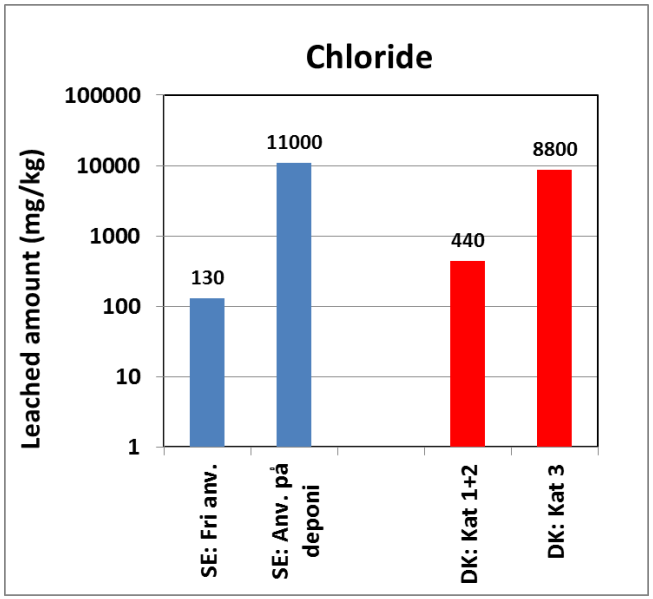
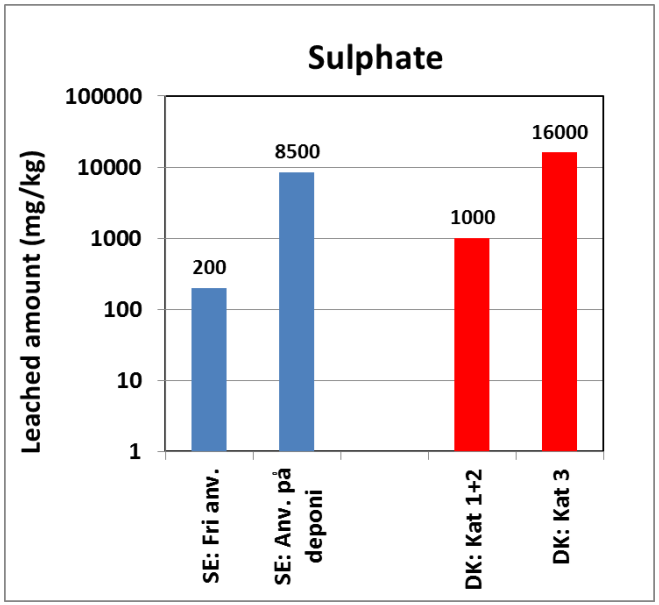
Comparison of SE guidelines with DK criteria at L/S = 10 l/kg

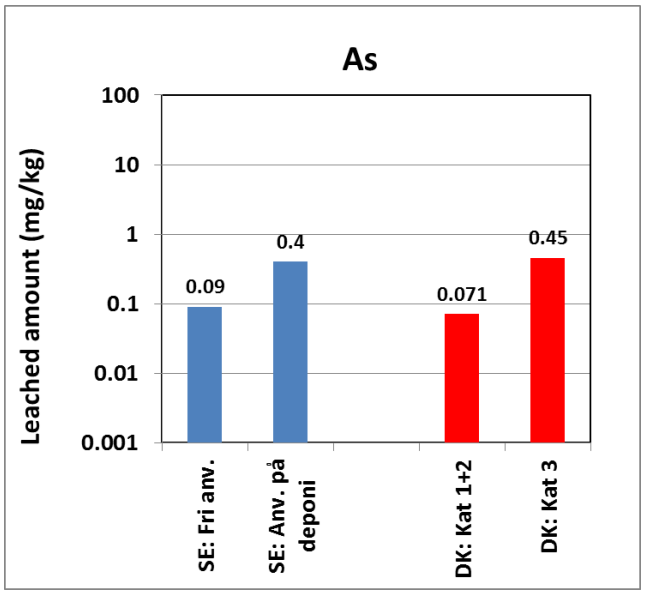
The Danish leaching criteria have been recalculated from L/S = 2 l/kg to L/S = 10 l/kg assuming that the concentration of a substance in the eluate from a batch or column test can be expressed as an exponential function of L/S by means of a substance-specific constant, κ.

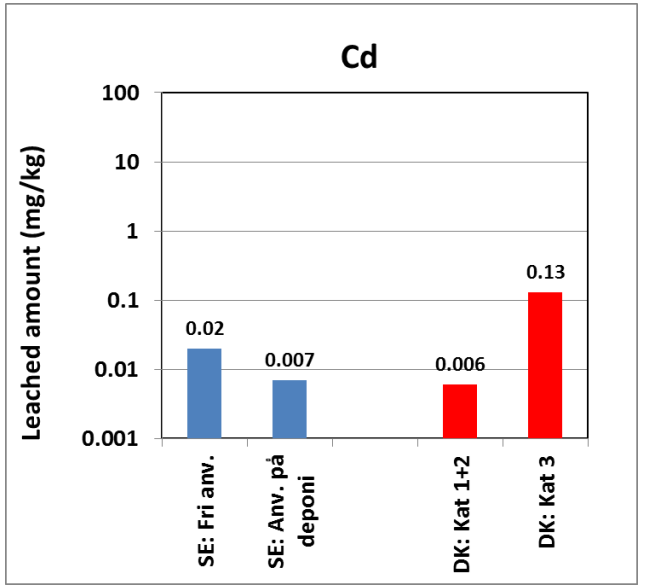
$$C(L/S) = C_0 \times e^{-(L/S)\kappa}$$

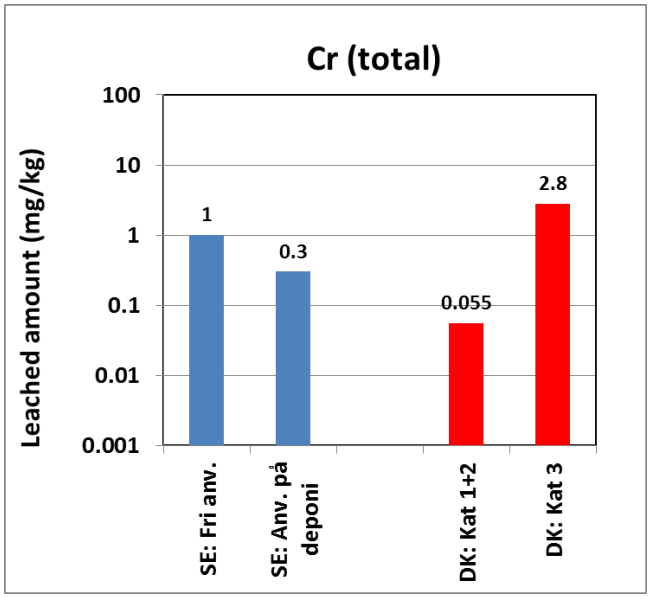


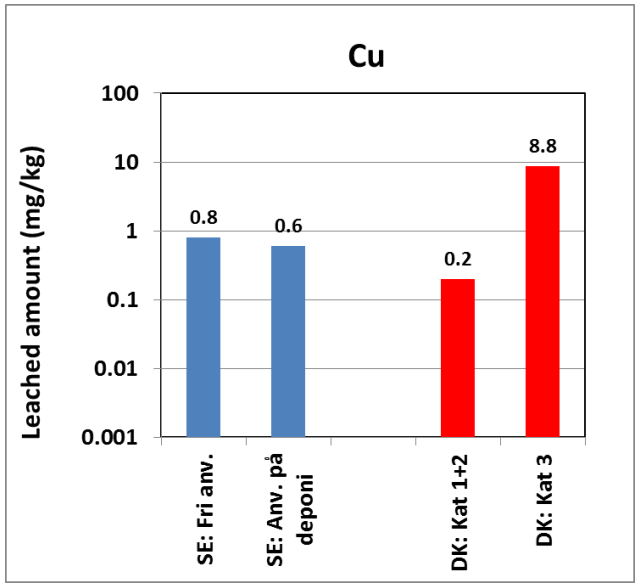


Comparison of SE guidelines with DK criteria both at L/S 0 10 l/kg

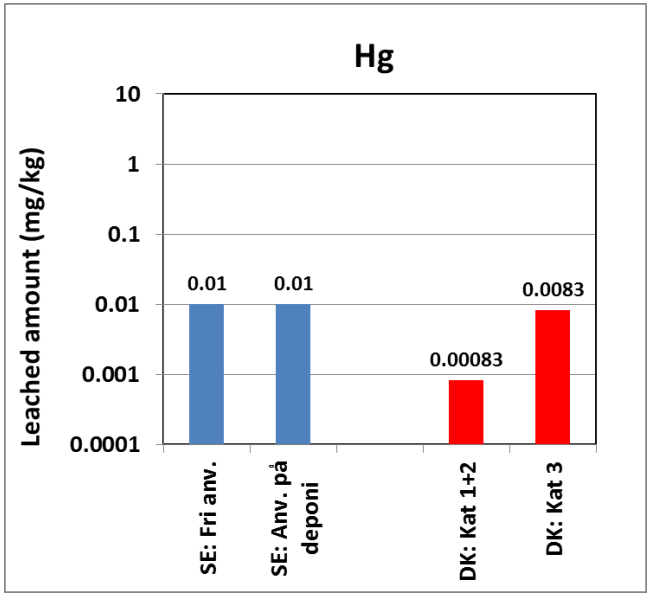


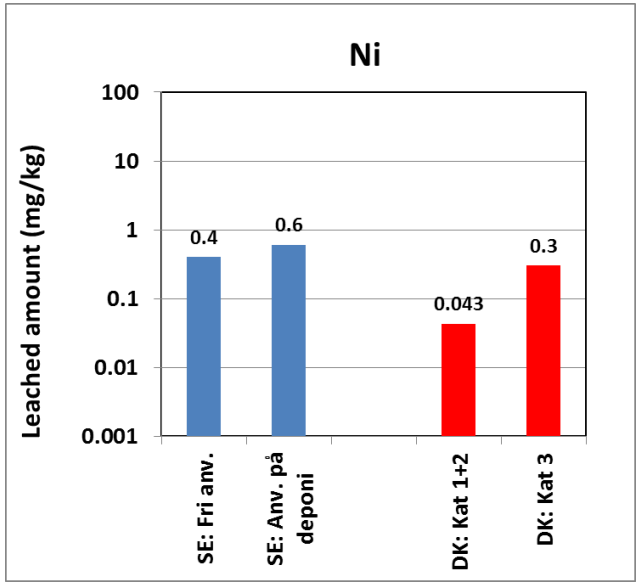


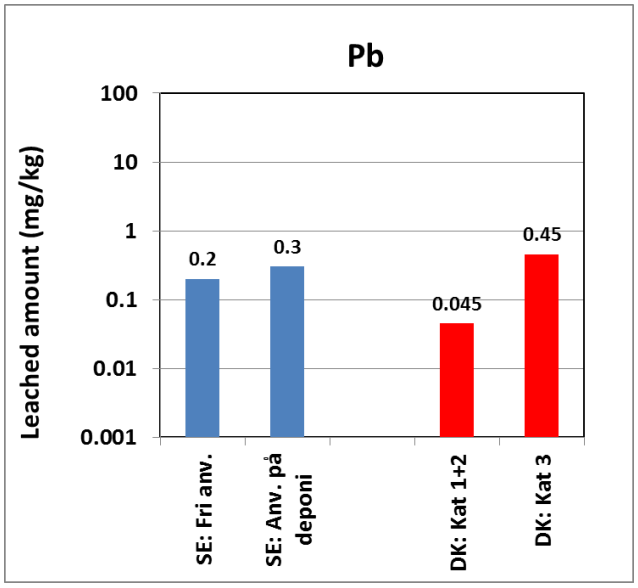


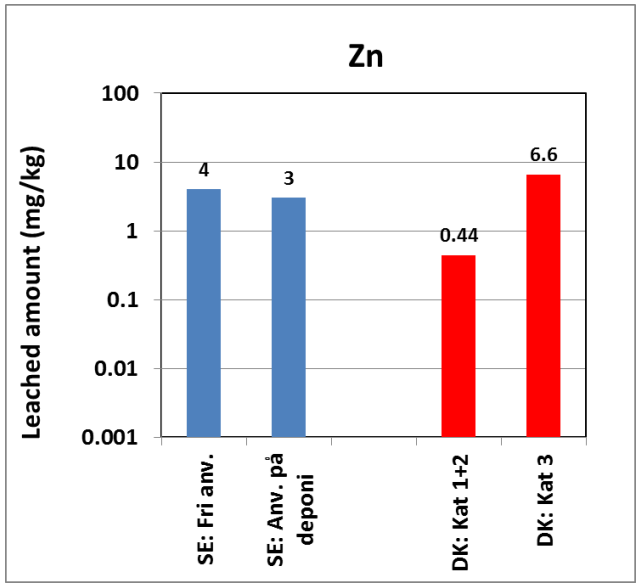


Comparison of SE guidelines with DK criteria both at L/S 0 10 l/kg









Quality monitoring data on content and leaching of substances from 4 Danish incinerators treating approx. 45 % of the waste incinerated in Denmark

MSW incinerator	Period of sampling	No of samples
A	2000 - 2016	372
B	1998 - 2016	249
C	2000 - 2016	118
D	2001 - 2016	185

BA storage time varies from 0 to 7 months with 1 to 3 months dominating

Sampling: Per 5000 tonnes – combination of 50 subsamples from heap or automated sampler from moving stream

Content determined after digestion with 7 M HNO_3 at 120 °C (comparable to aqua regia digestion)

Leaching determined at L/S = 2 l/kg (EN 12457-1)

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All samples: Content of metals/metalloids, S, TOC and LOI

Green: < limit value Cat. 1 Red: > limit value Cat. 1

Parameter	Unit	1st percentile	10th percentile	Median	90th percentile	99th percentile	N
Ag	mg/kg	0.84	2.1	3.2	6.2	19	63
As*	mg/kg	8.3	12	19	25	45	902
Cd*	mg/kg	0.88	1.5	2.7	6.5	20	906
Cr*	mg/kg	57	80	105	140	220	901
Cu*	mg/kg	1200	1600	2500	4400	8400	901
Hg*	mg/kg	0.01	0.017	0.042	0.13	0.39	414
Mo	mg/kg	4.5	6.0	8.3	12	17	393
Ni*	mg/kg	51	66	97	160	370	902
Pb*	mg/kg	320	504	830	1600	3400	905
Sb	mg/kg	3.4	6.1	34	47	76	384
Total S	mg/kg	2794	3700	5300	7600	10000	448
Zn*	mg/kg	1600	2100	3000	4300	6606	898
TOC*	%	0.30	0.50	0.90	1.5	2.7	630

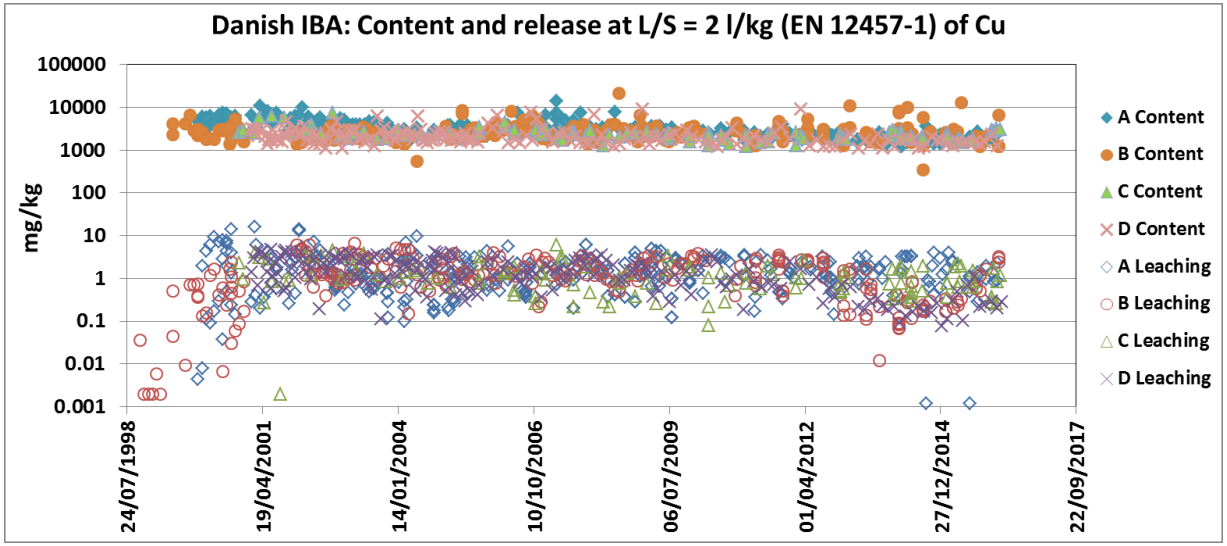
*: Regulated for Cat. 1, but not for Cat. 2 and Cat. 3

All samples: Leaching of substances at L/S = 2 l/kg

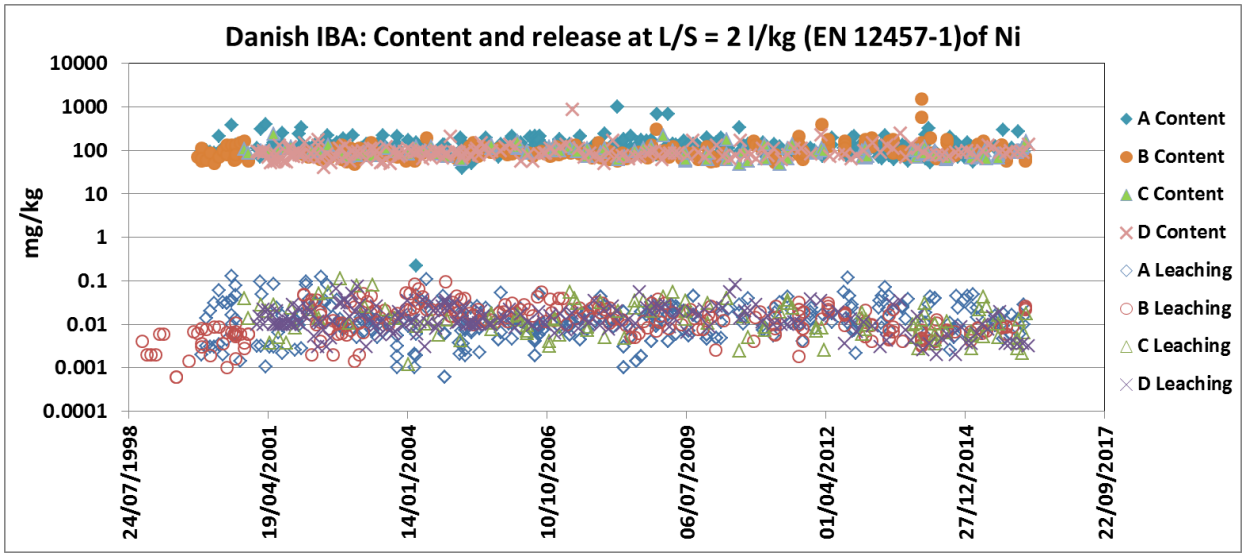
Red exceeds Category 1+2

Para-meter	Unit	10th percentile	Median	90th percentile	N	Cat 2	Cat 3
pH	-	9.4	10.5	11.4	918		
As	mg/kg	0.0022	0.0064	0.014	906	0.016	0.1
Ba	mg/kg	0.044	0.10	0.22	472	0.6	8
Cd	mg/kg	0.0001	0.0004	0.0020	918	0.004	0.08
Cr	mg/kg	0.0094	0.048	0.26	917	0.02	1
Cu	mg/kg	0.24	1.2	3.4	917	0.09	4
Hg	mg/kg	0.000035	0.00012	0.00040	468	0.0002	0.002
Na	mg/kg	740	1360	2200	917	2000	3000
Ni	mg/kg	0.0038	0.011	0.034	917	0.02	0.14
Pb	mg/kg	0.001	0.0052	0.032	918	0.02	0.2
Sb	mg/kg	0.032	0.058	0.098	251		
Se	mg/kg	0.0052	0.012	0.029	448	0.02	0.06
Zn	mg/kg	0.009	0.020	0.11	918	0.2	3
Cl^-	mg/kg	780	1760	3000	917	3000	6000
SO_4^{2-}	mg/kg	532	1540	3800	917	4000	8000

Content and release: 1998 - 2016



917 samples



917 samples

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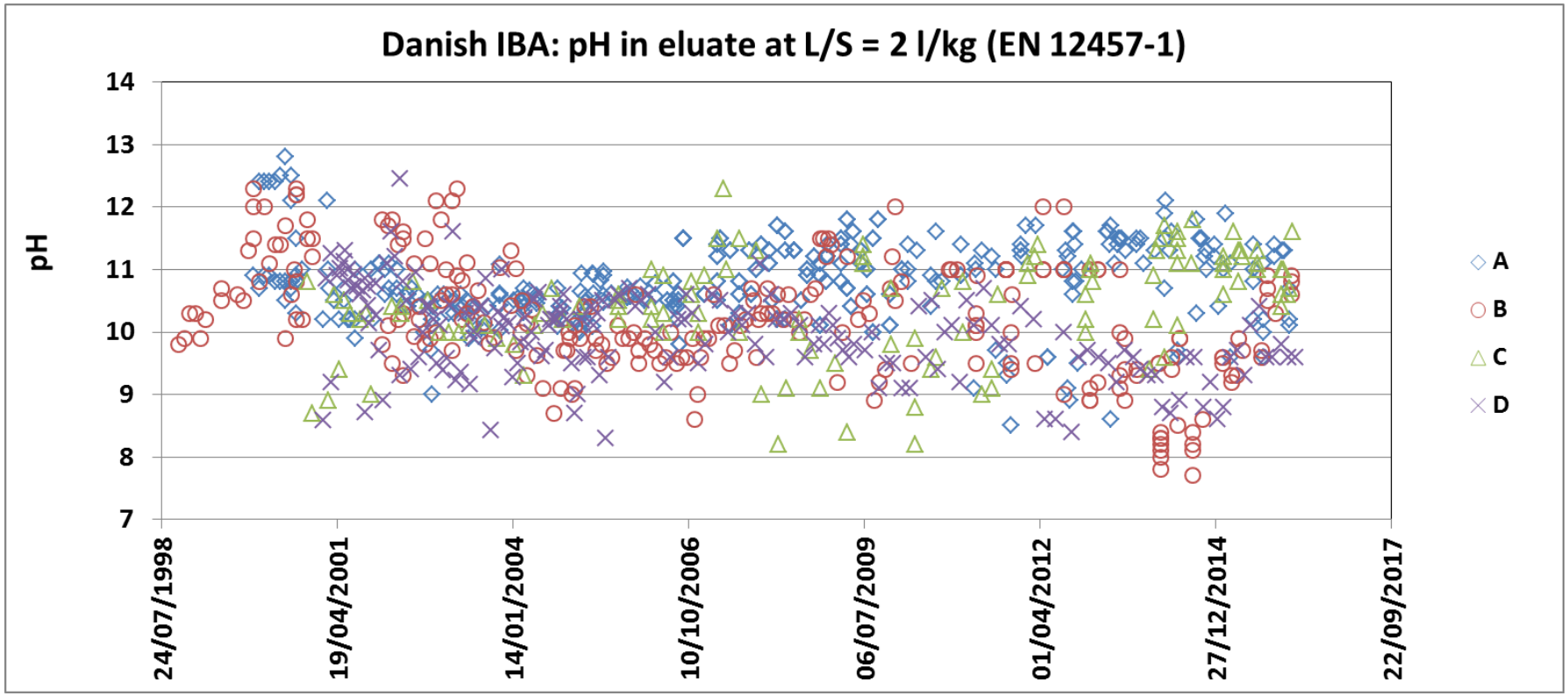
pH in eluates: 1998 - 2016



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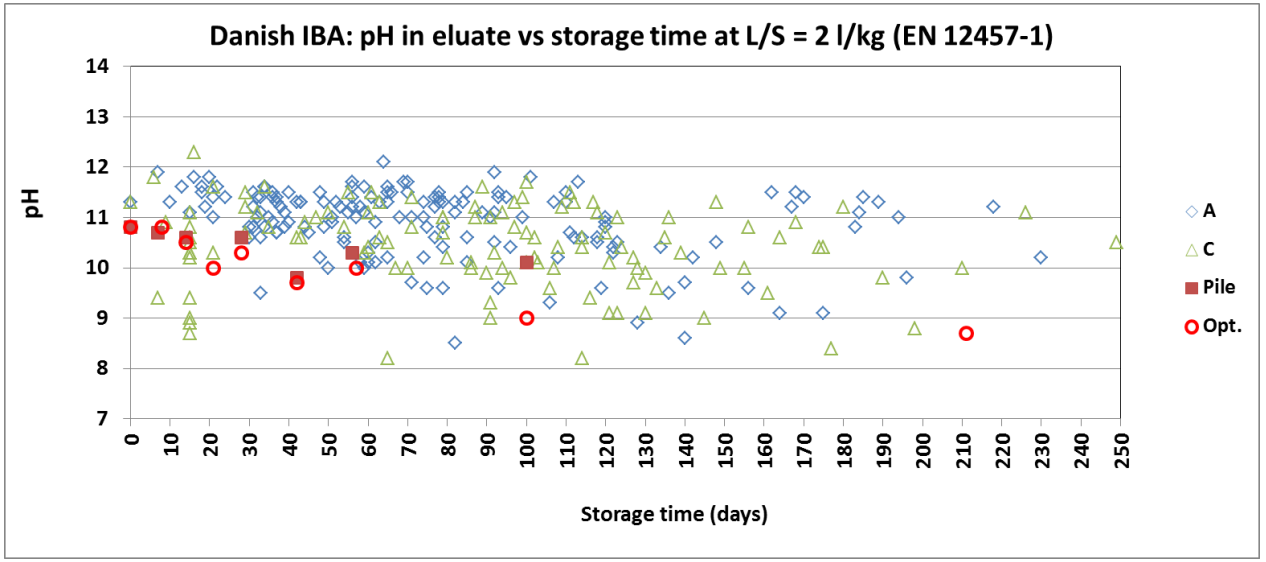
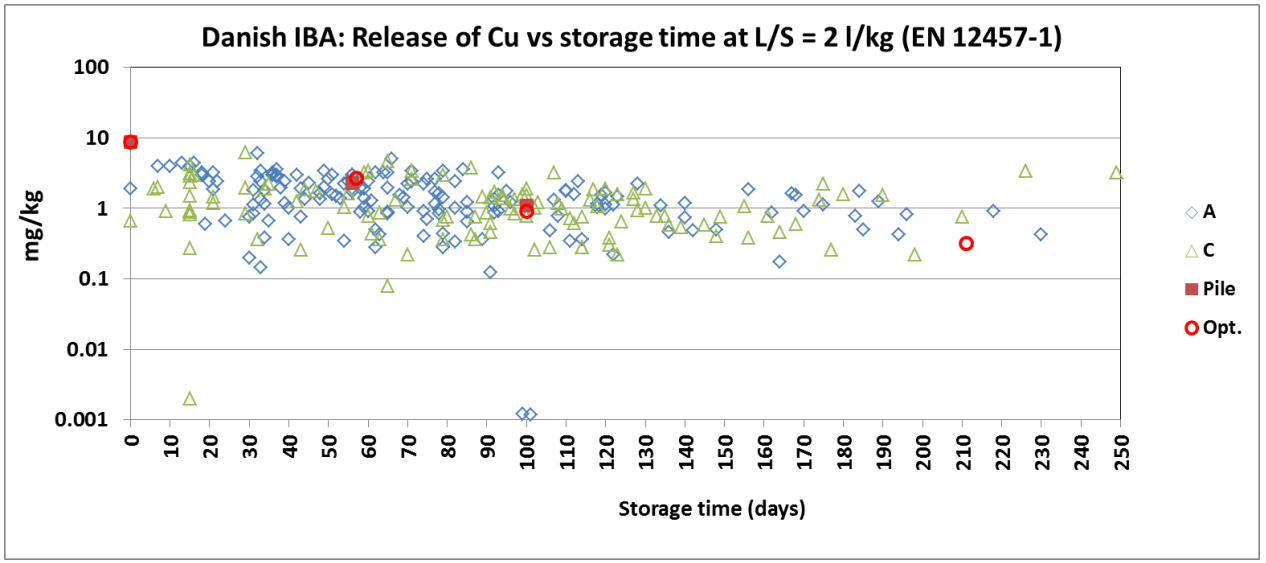
pH and Cu in eluates vs. storage time





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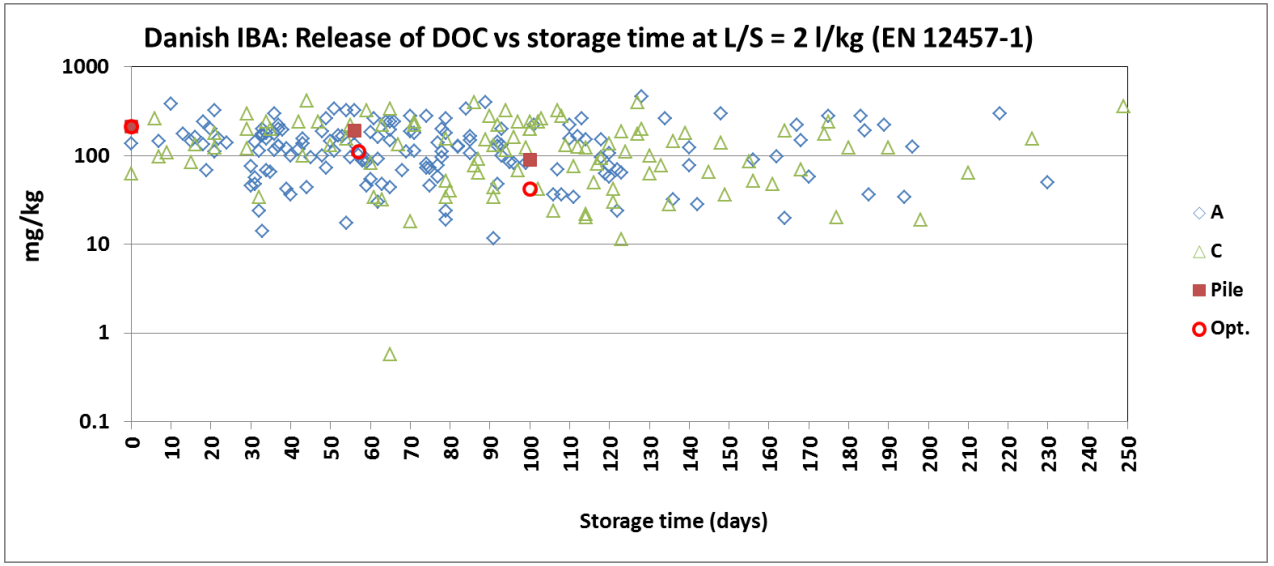
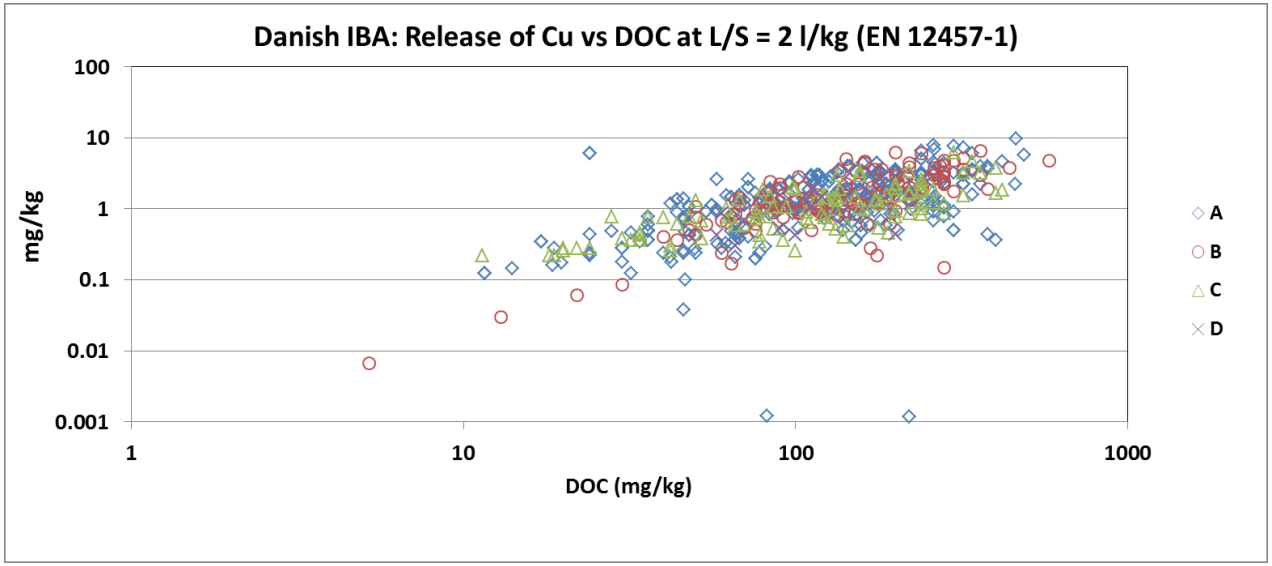
DOC in eluates vs storage time
Cu vs DOC





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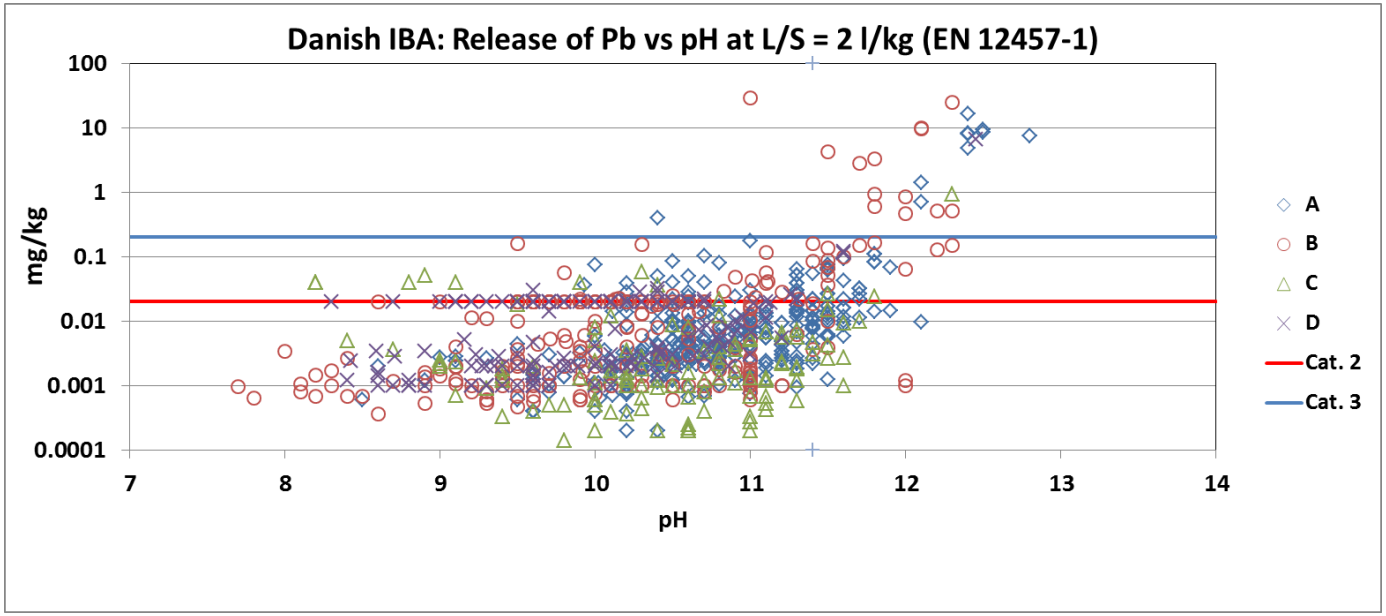
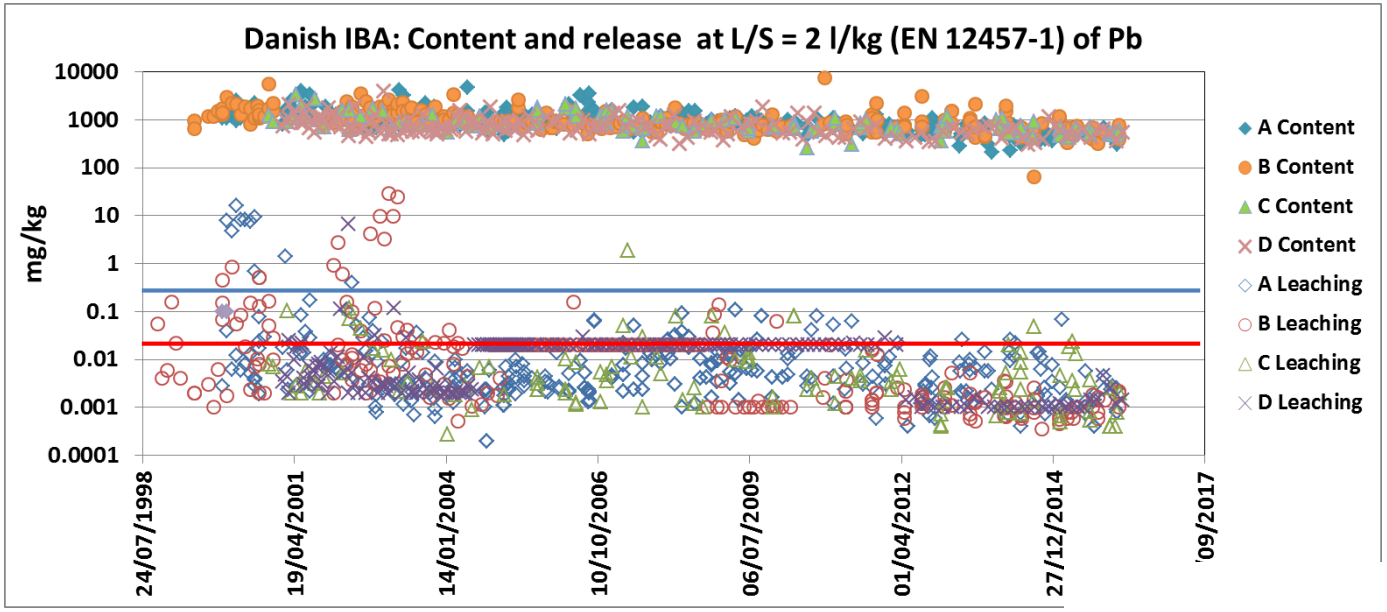

Danish IBA: Release of Pb vs pH at L/S = 2 l/kg (EN 12457-1)
mg/kg
100
10
1
0.1
0.01
0.001
0.0001
7
8
9
10
11
12
13
14
pH
A
B
C
D
Cat. 2
Cat. 3


Danish IBA: Content and release at L/S = 2 l/kg (EN 12457-1) of Pb
mg/kg
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
24/07/1998
19/04/2001
14/01/2004
10/10/2006
06/07/2009
01/04/2012
27/12/2014
'09/2017
A Content
B Content
C Content
D Content
A Leaching
B Leaching
C Leaching
D Leaching

Trends with time: Content (median values)
Comparison of two periods

Para-meter	1998 - 2009		2010 - 2016		Change
	Median (mg/kg)	N	Median (mg/kg)	N	%
As	19	614	16	288	-16
Cd	2.7	618	2.9	288	+7.4
Cr	110	614	100	288	-9.0
Cu	2800	614	2100	288	-24
Hg	0.055	148	0.04	266	-27
Mo	8.9	240	7.1	153	-20
Ni	97	614	98	288	+1
Pb	960	617	610	288	-36
Sb	35	231	32	153	-8.6
Zn	2900	610	3300	288	+14
TOC	10000	343	8000	287	-20

Trends with time: Leaching at L/S = 2 l/kg (median values)

Para-meter	1998 - 2009		2010 - 2016		Change
	Median (mg/kg)	N	Median (mg/kg)	N	%
As	0.0068	619	0.0062	287	-8.8
Ba	0.113	206	0.098	266	-13
Cd	0.00071	630	0.0002	288	-71
Cr	0.054	629	0.031	288	-43
Cu	1.38	629	0.86	288	-38
Hg	0.0001	203	0.0002	265	+100
Mo	0.54	194	0.52	72	-2.9
Na	1300	629	1590	288	+22
Ni	0.012	629	0.010	288	-19
Pb	0.0087	630	0.0019	288	-78
Sb	0.066	179	0.048	72	-27
Se	0.02	183	0.0094	265	-53
Zn	0.02	630	0.024	288	+20
Chloride	1660	629	1930	288	+16
Sulphate	1480	629	1830	288	+24
TOC	134	414	112	153	-16

Classification of MSWI BA in Denmark

The Danish EPA has issued a guidance document on waste classification which is very useful*, particularly if you know exactly which substances (species) the waste contains*. The guideline does not (yet) include the latest HP14 rules (Council Regulation (EU) 2017/997) – which becomes effective from 5 July 2018.

In DK, classification of waste as hazardous or non-harzardous is the responsibility of the individual municipalities.

So far, the HP14 classification by means of ecotoxicity testning has not been considered in DK.

For the time being, MSWI BA is still for all intents and purposes considered non-hazardous and treated as such.

In 2016, the Danish EPA considered the EU Commission's assessment that 14 % of the MSWI BA would be classified as hazardous waste in accordance with the new HP14 rules a low estimate.

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HP14 - There are two options: Chemical assessment or ecotox testing?

- **Neither the EU Guideline nor the DK EPA Guidance provide any guidance on speciation or ecotox testing. Some EU MS (in particular France and Germany) are proposing test batteries consisting of 6 different ecotox tests.**

- **For MSWI BA, chemical speciation will almost certainly require assistance from leaching tests, e.g. a pH-stat leaching test (at L/S = 10 l/kg) where results can be used directly or indirectly (speciation modelling) to include or exclude certain species or to quantify species.**

- **Since ecotox testing is already based on risk rather than truly intrinsic properties (some of the tests are carried out on eluates from a batch leaching test at L/S = 10 l/kg), a similar approach should be possible for the chemical assessment. This is supported by an ECHA guideline on the CLP which states that in order for metals to exhibit an ecotoxicological effect or become a threat to the environment, they must first become dissolved in an aqueous phase.**

A stepwise procedure for classification of MSWI BA in line with the new regulation from 2015/2017, developed by DanWS and ECN

Initial step: Check for POPs

Step 1: General screening	Step 2: "Worst case"-assessment	Step 3: Expert assessment/speciation
HP1: Explosive **HP2:** Oxidising **HP3**: Flammable **HP9:** Infectious **HP12:** Release of an acute toxic gas **HP15:** Yilding another substance	**HP5:** STOT/Aspiration toxicity **HP6:** Acute toxicity **HP11:** Mutagenic **HP13:** Sensitising	**HP4:** Irritant (summation) **HP7:** Carcinogenic **HP8:** Corrosive (summation) **HP10:** Toxic for reproduction **HP14: Ecotoxic (summation)**

Experience shows that the classification of MSWI BA often depends on HP14 and speciation of Cu, Ni, Pb or Zn

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Classification according to HP14

A waste is hazardous according to HP14, if:

c(H420) ≥ 0.1 %, or

∑c(H400) ≥ 25 % (cut-off = 0.1 %), or

100 x ∑c(H410) + 10 x ∑c(H411) + ∑c(H412) ≥ 25 % (cut-off = 0.1 % for H410 and 1 % for H411 or H412), or

∑c(H410) + ∑c(H411) + ∑c(H412) + ∑c(H413) ≥ 25 % (cut-off = 0.1 % for H410 and cut-off = 1 % for H411, H412 og H413)

Description of the hazard statement codes included in HP14	
H400	Aquatic acute 1
H410	Aquatic chronic 1
H411	Aquatic chronic 2
H412	Aquatic chronic 3
H413	Aquatic chronic 4
H420	Ozone depleting (not relevant to MSWI BA)

A general uncertainties which are also relevant for MSWI BA

It is not specified in the EU Commission Regulations nor the EU Commission guidelines which digestion method should be used prior to chemical analysis for content of inorganic subtances. Both a partial digestion method (aqua regia) and a total digestion method (aqua regia + hydrofluoric acid) are referenced. The former does not fully digest silicate based minerals, which is relevant for MSWI.

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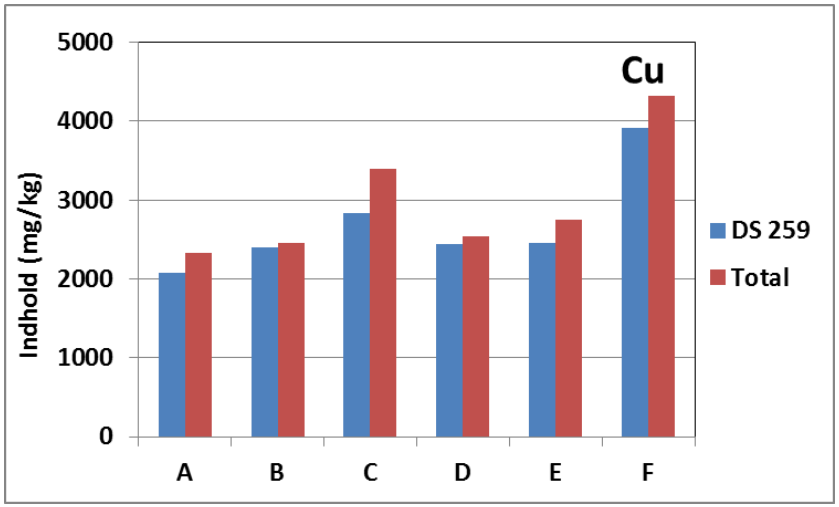
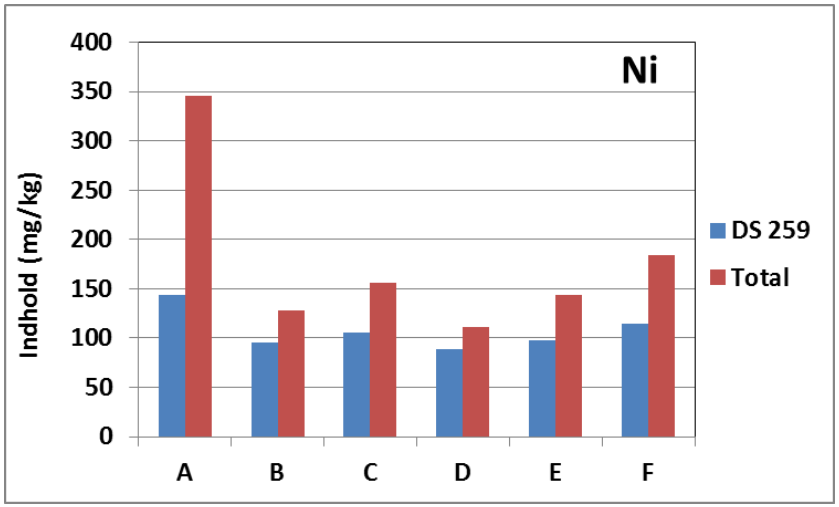
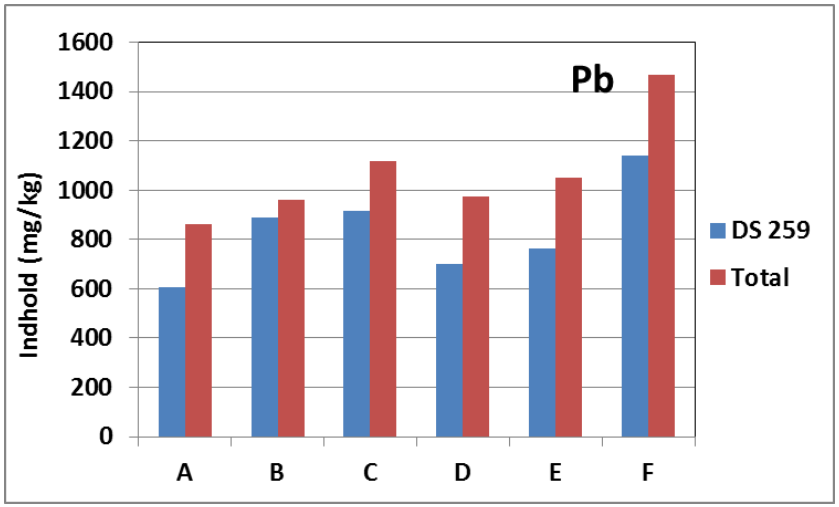
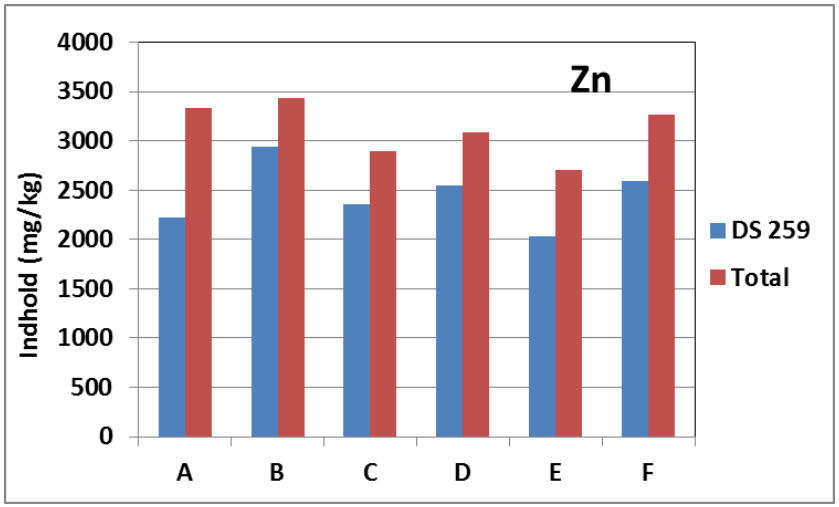
The rules allow both partial and total digestion prior to analysis of the content of inorganic subtances









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What are the consequences of MSWI being classified as hazardous waste?

- **Classification as hazardous waste will mean the MSWI BA cannot be utilised according to Statutory Order No. 1672/2016. It will most likely also have an impact on the handling and transport of the BA.**

- **Since the classification as hazardous waste in not directly related to the risk posed on the quality of groundwater and surface water by BA when it is used e.g. for road construction, it would not influence the environmental protection if the Statutory Order is changed to allow the use BA classified as hazardous waste. Restrictions and requriements that will prevent adverse impacts on groundwater and surface water regardless of the classification are already in place.**

- **Generally, it is perhaps more the consequences of a classification as hazardous waste on other legislation than the classification itself that requires attention. Waste is often declared hazardous without reference to HPs and haz codes it is based upon, thus creating largely unnecessary problems for solutions that may otherwise be sensible.**

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Conclusions

- **Statutory Order No. 1672/2016 regulates the use of MSWI BA for construction works by means of leaching criteria.**
- **Most of the Danish BA belongs to Category 3.**
- **Even though the leaching of DK BA is tested at L/S = 2 l/kg and SE BA is tested at L/S = 10 l/kg, it is possible to compare the DK criteria to the SE guidance values.**
- **Based on chemical analyses and leaching test results from 45% of the MSWI BA produced in DK from 1998 to 2016 (approx. 900 samples), developments and trends with time are quite clear for several substances.**
- **DK has not yet implemented waste classification according to HP14.**
- **A stepwise waste classification procedure for IBA is used by DanWS.**
- **Some issues in the classification rules that can cause uncertainty are pointed out.**
- **If a substantial part of the MSWI BA is classified as hazardous, circular economy could still be saved by appropriate changes in other legislation.**

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Thank you for your attention!

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