

An ecotoxicological approach for hazard identification of energy ash

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Major aim of projects



“The overall aim of the this work has been to develop a scientifically well-founded basis for the choice of leaching methodology and ecotoxicological testing primarily for classification of ash materials according to H-14, but to some extent also for risk assessment.”

Hazard classification of waste

WASTE FRAMEWORK DIRECTIVE

- **H-14 (Ecotoxic):** *“waste which presents or may present immediate or delayed risks to the environment”.*
- Waste and hazardous waste should be classified in accordance with the **List of waste (LoW)**.
-  **Mirror entries** denote waste with the potential to be either hazardous or non-hazardous depending on their composition and concentrations of hazardous substances.
- Classification of waste should follow **Regulation (EC) No 1272/2008 on the classification, labelling and packaging of substances and mixtures (CLP)**.

Designing study

ASPECTS TO CONSIDER FOR ASH ELUATES

- **Leaching tests**
 - Choice of pH, particle size and L/S?
 - Choice of test?
 - Compatible with subsequent ecotoxicity tests?

- **Ecotoxicity tests - species/endpoints**
 - Terrstrial vs aquatic toxicity tests?
 - Acute vs chronic?
 - Freshwater vs marine species?

Major research questions



1. Is it scientifically justifiable to extrapolate measurements of elements in solid material or eluates to actual ecotoxicity effects?
2. Which are the problematic elements causing the toxic responses observed in aquatic organisms exposed to ash eluates?

Projects



- 1. An ecotoxicological approach for hazard identification of energy ash** (*Waste Management* 31(2), 342-352, 2011).
- 2. Improved understanding of key elements governing the toxicity of ash eluates** (*Ms in prep.*).
3. Influence of leaching conditions (pH, L/S ratio, particle size) for ecotoxicological classification (H14) of ash (*Ms in prep.*).
- 4. Use of MSIWI bottom ash in constructions – Long-term ecotoxicological risks to the environment** (*Ms in prep.*).

Each project also available as reports within Värmeforsk (Thermal Engineering Research Association) and Avfall Sverige (Swedish Waste Management). See *end of presentation*.

Materials & Methods

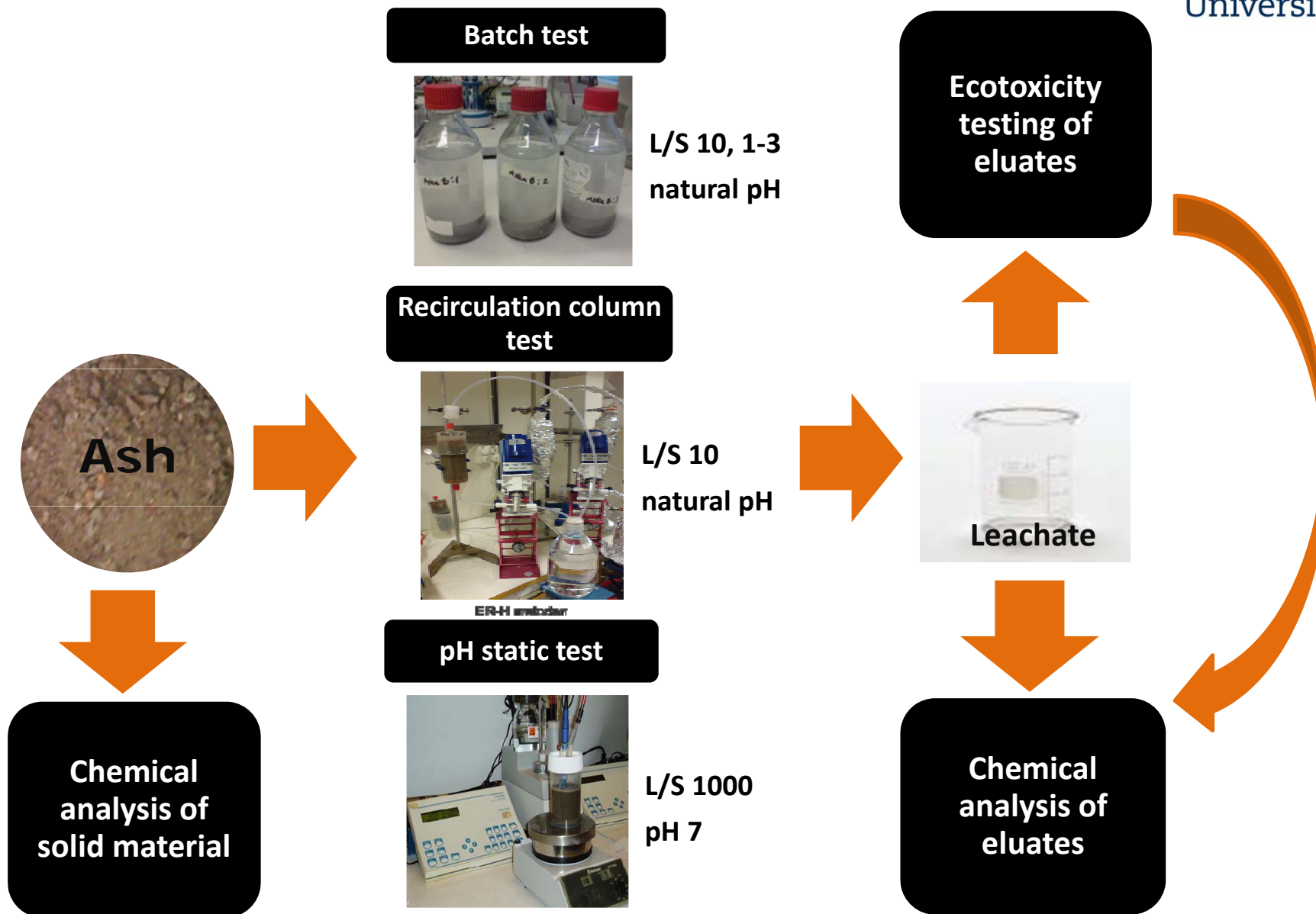
THE STUDIED MATERIALS



Code	Type	Origin	Fuel type	Age	Leaching test	Ecotox tests
A	Bottom ash	Högdalen	Municipal waste	ca 3 m	Column L/S 10	Full battery
B	Stabil. fly ash	Högdalen	Municipal waste	ca 1 y	Column + batch L/S 10	Full battery
C	Fresh fly ash	Högdalen	Municipal waste	Fresh	Batch L/S 10	Full battery
D	Fly ash	Telge Återvinning	Industrial waste	> 3 y	Column L/S 10	Full battery
E	Mix. Fly/bottom	Telge Återvinning	Industrial waste	> 4 y	Column L/S 10	Full battery
F	Fly ash	Brista	Bio fuel	< 1 m	Column L/S 10	Full battery
G	Bottom ash	Linköping	Municipal waste	> 15 y	Column L/S 10	Full battery
H	Fly ash	Uppsala	Peat	Fresh/ Aged	Batch L/S 10	Algae + acute & subchronic crustacea
I	Bottom ash	Uppsala	Municipal/ industrial waste	3-6 m	Batch L/S 10 + pH-stat L/S 1000, pH 7	Algae + acute & subchronic crustacea
J	Bottom ash	Linköping	Municipal waste	ca 5 y	Batch L/S 1-3	Subchronic crustacea

Material & Methods

OVERVIEW OF TEST PROCEDURE



Study 1

METHODOLOGY

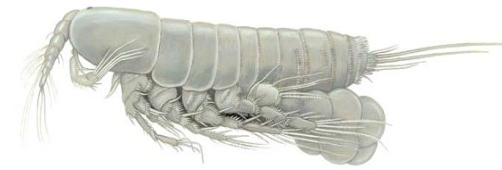
- Chemical analysis of solid materials and eluates of ash A-G.
- Eluates prepared by column and/or batch test methods
- Ecotoxicological testing using test battery of species.



Bacterium (*Vibrio fischeri*)
Microtox

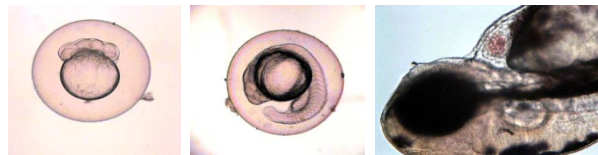


Alga (*P. subcapitata*)
Growth inhibition, 72h



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Crustacean (*Nitocra spinipes*)
Acute toxicity, 96h
Subchronic toxicity 7 days



1h 24h 48h

Fish (*Danio rerio*)
Embryo toxicity, 144 h

Study 1

MAIN RESULTS (1/2)

Ash eluate	Bacterium <i>EC</i> ₅₀	Alga <i>EC</i> ₅₀ (95%CI)	Crustacea (acute) <i>LC</i> ₅₀ (95%CI)	Crustacea (subch.) <i>NOEC</i>	Fish embryo <i>NOEC</i>
A (column)	>90.0	>80	121 (93-200)	8	3.2
B (column)	>90.0	>20	38 (24-43)	8	13
B (batch)	>90.0	>20	40 (---)^a	<1.3	13
C (batch)	12.5-25.0	3.0 (2.6-3.4)	22 (19-25)	1.3	0.78
D (column)	>90.0	11(9.3-12)	16 (13-19)	0.5	>10
E (column)	>90.0	>80	78 (71-86)	20	>50
F (column)	>90.0	59 (49-72)	21 (19-24)	3.2	25
G (column)	>90.0	95 (87-108)	>100	>50	nm

Study 1

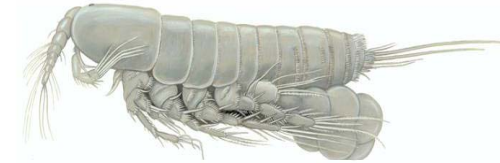
MAIN RESULTS (2/2)

- Test sensitivity may differ between ash materials, a **battery of tests combined with chemical analysis** crucial for avoiding miss-classification.
- Based on acute toxicity data for *Nitocra spinipes*, six elements identified as **potentially responsible** for the toxicity of the eluates: **K, Ca, Al, Pb, Zn and Cu**.
- **Weak correspondence** between classification based on analytical determination of elements in **solid material** and actual **ecotoxicity of eluates**.

Study 2

METHODOLOGY

- Further evaluation of pinpointed elements using the crustacean subchronic test.
- Calculating Hazard Quotients (HQs) based on acute and subchronic data.



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HQ > 1 indicates toxicity

Study 2

MAIN RESULTS – REFINED HQs



Ash B_c

HQ

Ash B_b

HQ

Ash E

HQ

	acute	subchronic	acute	subchronic	acute	subchronic
Zn	0.003	0.03	0.004	0.03	0.008	0.04
Cu	0.002	0.06	0.003	0.06	0.005	0.09
K	1.3	1.6	1.4	0.8	1.0	1.5
Ca	1.2	0.9	1.2	0.5	0.6	0.7
Al	0.03	1.2	0.03	0.2	0.06	2.8
Pb	0.0003	0.002	0.00009	0.001	0.06	0.2

(LC50=38%, NOEC=8% eluate) (LC50=40%, NOEC=<1.3%eluate) (LC50=78%, NOEC=20% eluate)

Study 4

METHODOLOGY



- Focus on **risk assessment** of aged bottom ash (ash J).
- Sequential batch leaching at **low L/S: 1-3 L/kg**.
- Analytical determination of elements in eluates.
- **Freely available fractions** of elements.
- Eluates tested with crustacean **subchronic test**.
- Calculating **HQs** based on subchronic data.

Study 4

MAIN RESULTS



Element	Effect level <i>NOEC (mg/l)</i>	HQ highest tested conc. (40.5%)		
		<i>L/S1</i>	<i>L/S 2</i>	<i>L/S 3</i>
Al	0.09	0.90	0.88	0.94
Ca	160	1.10	1.09	1.10
K	35	1.62	0.51	0.08
Cu	0.06	0.54	0.34	0.27
Pb	0.27	0.00	0.00	0.00
Zn	0.24	0.05	0.05	0.04
		↑ Significant toxicity of eluate!	<i>No toxicity</i>	<i>No toxicity</i>

Major research questions

CONCLUSIONS

1. Is it scientifically justifiable to extrapolate measurements of elements in solid material or eluates to actual ecotoxicity effects?

No!

2. Which are the problematic elements causing the toxic responses observed in aquatic organisms exposed to ash eluates?

K, Ca and Al, whereas Cu, Zn and Pb less problematic

Thanks for your attention!



...and thanks to:

- Värmeforsk
- Avfall Sverige
- Svenska Energiaskor
- SYSAV
- Telge Energi
- SÖRAB
- Naturvårdsverket
- FORTUM

Swedish reports



- **AS 2008:16.** *Metodik för klassificering av H14-kriteriet i Avfallsförordningen – Förslag till biotestbatteri för klassificering av farligt avfall – Ekotoxikologisk testning med bakterie, alg, kräftdjur och fiskembryo.* Stiernström S, Hemström K, Wik O, Bengtsson B-E, Breitholtz M.
- **AS U2009:23.** *Uppföljning till projektet "Metodik för klassificering av H14-kriteriet i Avfallsförordningen.* Stiernström S, Hemström K, Wik O, Bengtsson B-E, Breitholtz M.
- **Värmeforsk, Miljöriktig användning av askor No 1092.** 2009. *Metodik för klassificering av H14-kriteriet i Avfallsförordningen.* Stiernström S, Hemström K, Wik O, Carlsson G, Breitholtz M.
- **NV 2011.** *Förslag till biotestbaserade gränsvärden för klassning av avfall som ekotoxiskt enligt avfallsförordningen.* Breitholtz M, Bengtsson B-E, Wik O, Hemström K
http://www.naturvardsverket.se/upload/10_Forskning/2011/klassning_avfall.pdf.
- **Värmeforsk, Miljöriktig användning av askor No 1197.** 2011. *Inverkan av laktestförhållanden, samt antagonistiska och ekotoxiska effekter av makroelement vid avfallsklassificering av askor.* Wik O, Breitholtz M, Hemström K, Linde M, Stiernström S
- **Värmeforsk, Miljöriktig användning av askor No 1208.** 2012. *Askor – Långsiktiga ekotoxikologiska miljörisker.* Breitholtz M, Linde M, Enell A, Wik O