Environmentally friendly use of non coal ashes - research and use in Sweden

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Claes Ribbing

SVENSKA ENERGIASKOR AB

www.energiaskor.se

www.askprogrammet.com

Svenska EnergiAskor AB

is owned by 12 energy companies are working as trade organsation for

" Environmentally friendly uses of non coal ashes"

Are supporting the "Ash program" of Värmeforsk

(The Thermal Engineering Research Institute of Sweden)

The Vision of the Ash Program

- Combustion residues are resources in a sustainable society

Strategy

- **Ashes shall be useful resources**
- **Balance between**
  - **Non –toxic nature and waste hierarchy**
    - **Swedish EPA 2003: Utility shall be given priority when the risk for health and environment is low**
- **Practical research with scientific base**
  - Universities, research centers consultants
    - Technique, Environmental chemistry,
    - Good examples, Long term trials
- **A broad funding and management**
  - Authorities: Energy, EPA, Geo technique, Road
  - Producers Energy, Paper industry
  - Consultants, Research funder, Boiler producer, University
- **Information**

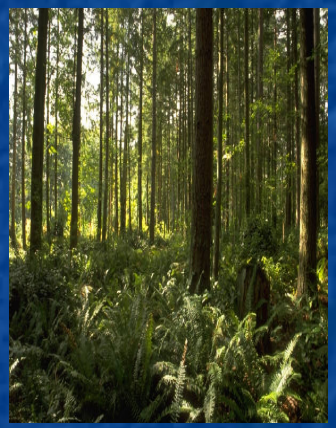
Research program

Environmentally friendly uses of none coal ashes

1 m€/year since 2002. 40 companies and authorities

The Thermal Enginiering Research Institute of Sweden

Forestry



- Recycling

When outtake of energy

- Growth

Environment

- Criterias
- Law
- Test methods
- Quality control

Geotechnigue

- Roads
- Surfaces
- Concrete
- Mining

Landfilling.

- Dense layers
- Stabilization
- Covering Mine Tailings

Ashes shall be used as resources

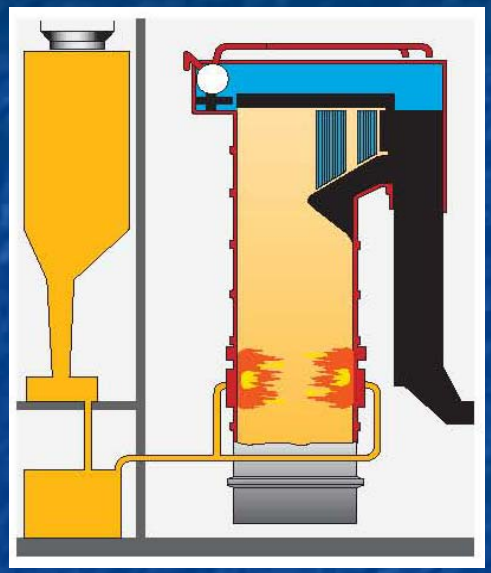
- **Ashes shall be used where the benefits are as high as possible**
  - **This demands competition between many uses**
  - **Benefits stand for both environmental benefits as well as economical benefits.**

Ash content in different fuels

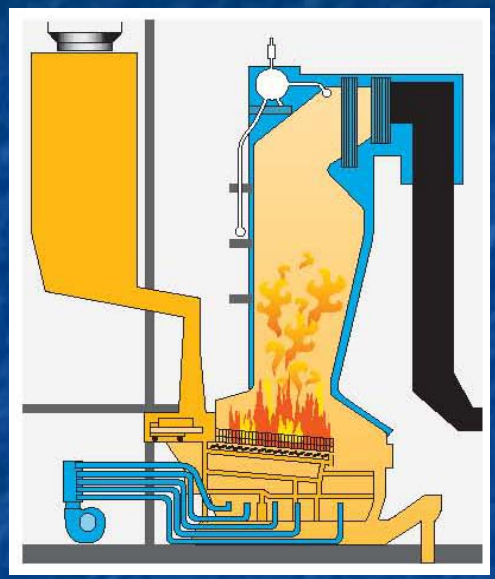
- 25% in municipal wastes
- 5% in peat (can be much more)
- 10-50% in sludge from paper industry
- 2-4% in bark, needles and branches
- 0,3-0,5% in pure wood

Boilers

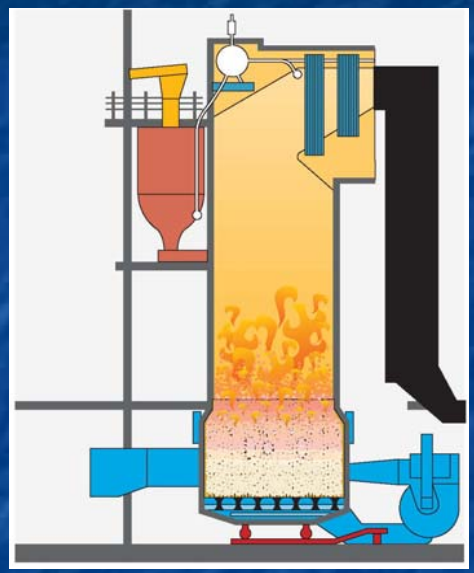
(the Pictures show rebuilt boilers at Söderenergi)



Powder cumbustion
Peat, pellets
≈ 1 200 °C
Fly ashes dominate



Grate boiler
Incinerators and
Smaller boilers less
than 100 MW
All fuels as bark,
Industrial Wastes etc
1 100 °C
Bottom ashes dominate



Fluidised bed. All
fuels as wood
chips, peat
≈ 850 °C
Often equal
amount
fly/bottom ashes
low NOx

Production of ashes in Sweden 2006

ton dry weight

Grate Bioilers	**Bottom ash**	**Fly ash**	**tot**
Waste	454 000	96 000	550 000
Solid bio fuel	110 000	20 000	130 000
Co-cumbustion (inc peat)	42 000	28 000	70 000
Boilers for pulverised fuels			
Coal/peat	7 000	24 000	31 000
Peat/woodchips,pellets	18 000	31 000	49 000
Fluid bed biolers CFB, BFB.			
Waste	45 000	57 000	102 000
Solid biofuel	46 000	92 000	138 000
Co-cumbustion	75 000	160 000	133 000
Total:	800 000	500 000	**1 300 000**

Problem: Many small producers, different qualities

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EnergiAskor AB

Use of ashes in Sweden 2006

- Roads etc 200 kton
- Forestry, Arable land 35 kton
- Backfillning cavities 50 kton
- Construction on landfills 650 kton
- Others 175 kton
- Total 1 milj ton
- Production 1,3 milj ton TS

- Construction on landfills will more or less disappear within 10-15 years

Recycling of ashes to forests

Logging residues will increasingly be used for production of energy.

Harvesting whole trees will increase removal of (mineral) nutrients,
exceeding the long term capacity of the soil... Especially in SW Sweden, where the problems are acid rain and a small buffering capacity of the soil

Recycling of/fertilizing with ashes to forests

- **Returns P, K, Ca, Mg, Zn to the forests**
- **Increases the growth rate on organic soils and minerogenic soils with low C/N quota**
- **No or less release of climate gases on dithced peat solis**

(new and unexpected)

- **Lowers the acidification of the soils and water streams**

Test surfaces on ditched peat soil with without ash fertilizing.

Ashes to the forests

The ashes must be treated before recycling:
Matured/self hardened, crushed and sieved (as in the picture)
or pelletized
so that the pH and/or the osmotic pressure will not be too high
and that the particle sizes are suitable for spreading

Hillevi Ericsson Swedish Forest Agency 2006

		B	Cu	Zn	As	Pb	Cd	Cr	Hg	Ni	V
	Limit today	500	400	7000	30	300	30	100	3	70	70
	New limit??	800						150		175	
pine wood	*n*	*24*	*67*	*67*	*14*	*19*	*65*	*32*	*14*	*30*	*14*
	median value	342	313	2928	15	24	68	100	2	59	1
	85th percentile	540	437	4305	15	133	90	144	2	170	2
spruce wood	*n*	*45*	*93*	*93*	*28*	*57*	*54*	*34*	*28*	*41*	*28*
	median value	456	257	3920	12	39	22	29	2	39	2
	85th percentile	595	422	5200	32	99	39	110	4	84	4
pine bark	*n*	*53*	*65*	*65*	*12*	*65*	*65*	*62*	*12*	*55*	*12*
	median value	337	127	1707	2	21	23	19	1	17	3
	85th percentile	422	163	2448	3	37	33	26	2	47	8
spruce bark	*n*	*90*	*110*	*110*	*21*	*74*	*68*	*68*	*20*	*71*	*21*
	median value	408	113	4851	2	29	10	13	1	37	5
	85th percentile	495	157	5983	3	59	22	22	2	71	10
pine branch	*n*	*56*	*68*	*70*	*13*	*68*	*68*	*62*	*12*	*56*	*12*
	median value	615	276	3615	3	81	27	47	1	15	14
	85th percentile	774	382	5397	4	139	38	69	2	39	20
spruce branch	*n*	*58*	*78*	*78*	*21*	*74*	*74*	*71*	*20*	*71*	*21*
	median value	371	177	5210	5	216	7	42	2	20	35
	85th percentile	434	220	6663	5	311	13	65	3	76	44

Ashes to Forests

as to the recommendations from the Swedish Forest Agency

Maximum mg/kg dry weight

B	800
Cu	400
Zn	7000
As	30
Pb	300
Cd	30
Cr	100
Hg	3
Ni	70
V	70
PAH	low

Minimum g/kg dry weight

Ca	125
Mg	15
K	30
P	7
Zn	0,5

Dense layers of ashes and digested sewage sludges

when closure of landfills

- **FSA = 50/50 dry wt fly ashes/sludge**
- **It is dense: 10^{-9}m/s**
- **It has an OK shear strength 30kPa**
- **It is long lasting: the biological and chemical degrading are very very slow**

(High pH, Salts, Low perculation)

Dense layer trails at Dragmossen

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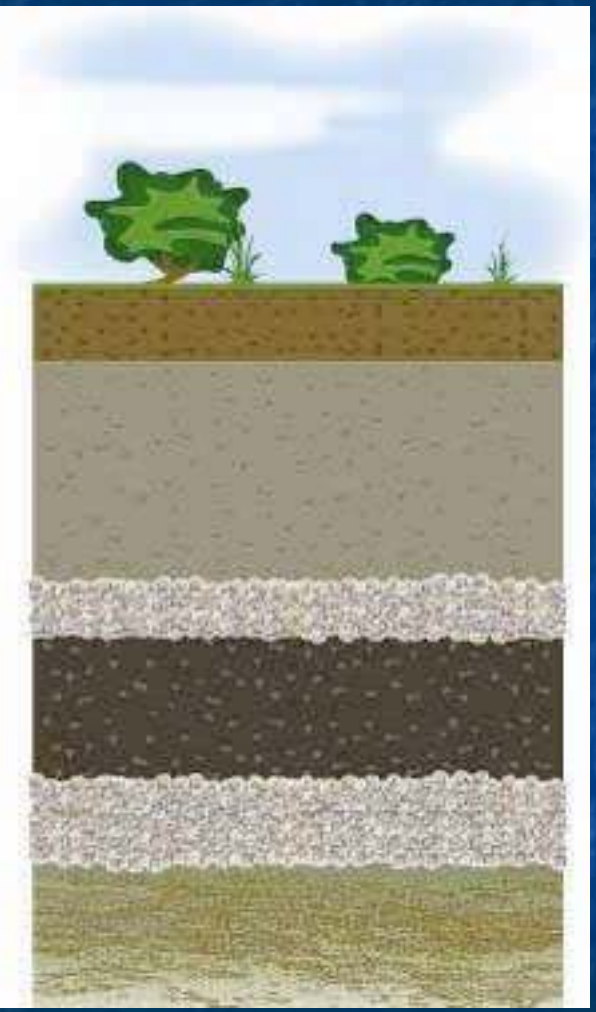
The Tveta method

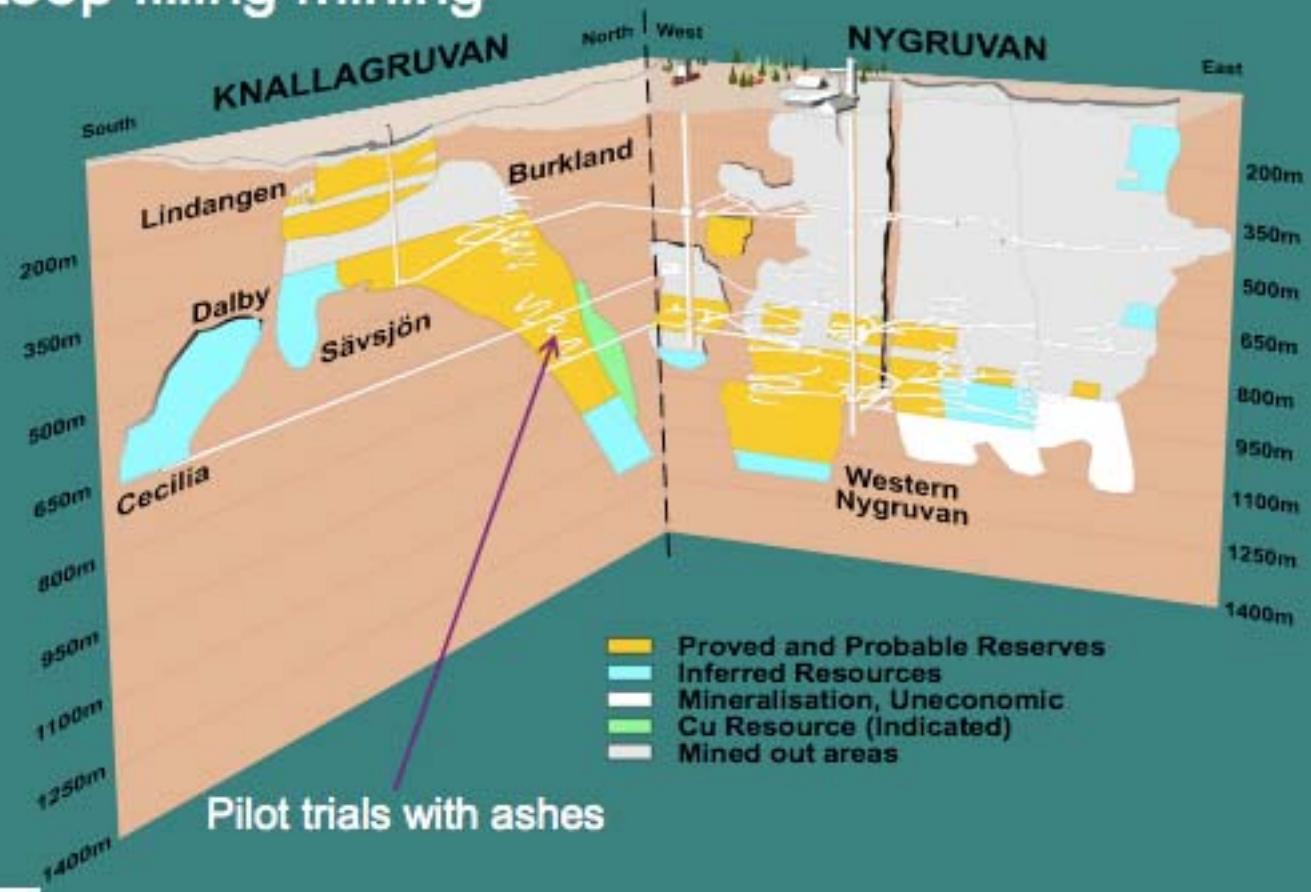


- After a lot of research work
- At the Tveta Landfill they use wastes and specially ashes in all layers
- The drainage layer with very coarse MSWI bottom ashes
- The dense layer with fly ashes and clay or only fly ashes of good quality

Layer composition for the landfill cover system

Replacing Portland cement

Even non-coal ashes give similar reactions like cement. It can replace at least 50% of the Portland cement in stoop filling mining

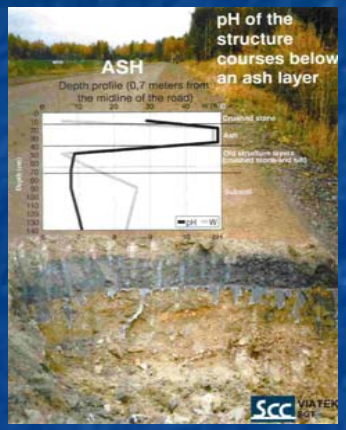


Zink mine – tailings and cement are pumped into the cavities

Ashes in concrete

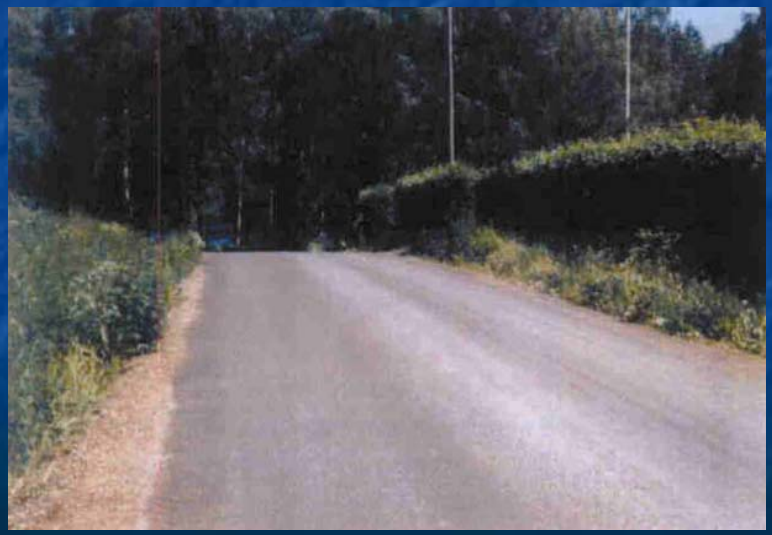
- Bio fly ashes cant satisfy EN 1450
  - That suits only fly ashes from SiO_2-rich coals
- In concrete, fly ashes are a good filler and can replace some Portland cement
- Clorides (0,1% Cl) are a problem, they corrode the armouring-iron.
- Low quality concretes are preferred markets.

Fly ash gives frost resistant and stiff roads

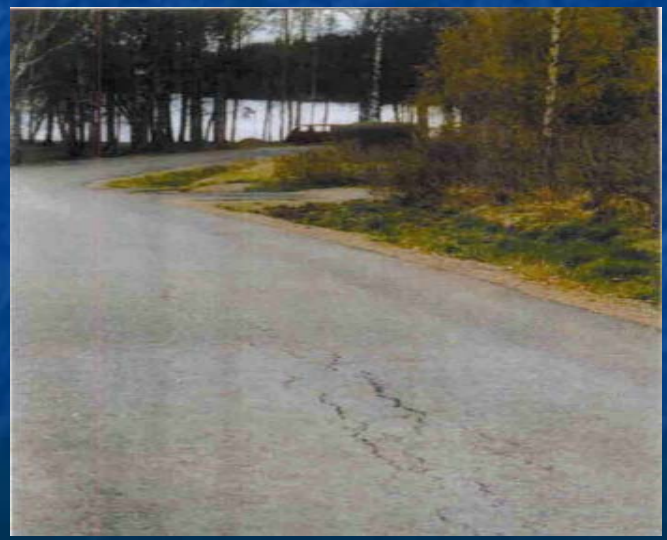


Pentti Lahtinens thesis shows that

Fly ashes gives frost resistant and stiff roads.
Much lesser material <1/4
Much lesser maintenance
No impact on the environment
Mo should be critical- but wasn´t



Road with fly ash 7 years after renovation
The ash hold 5% portland cement and fibersludge



Reference road traditionally renovated
Cracks after 1 year

Mainroad 90

- Bio fly ashes in the upper part of the terrace
- The road became stiffer than without fly ashes
- Better in the lane going southwards due to heavy timber traffic that made a better packing.
- **Analyses can´t discover any hazardous impact on the environment**

Constructions with peat/wood fly ashes
blended with 30-50% gravel

- **This plant for recycling of domestic wastes – is a light weight construction of fly ashes on clay soil**

Fly ashes have transformed this former bad farmroad to a very good road

Constructions with bottom ashes

Very low impact of the environment

MSWI slag road is examined after 18 years of use. Very interesting scientific reports from this road

Lightweight motorway construction with roster bottom ash from coal-firing

Ashes shall be tested with functional test methods as the triaxial method

.

Covering Mine Tailings

Gillervattnet tailing pond at Boliden

A layer of fly ash between layers of municipal sludge prevents oxygen from reaching the sulphuric tailings. We are looking for plants that will give an “eternal” protecting top layer.

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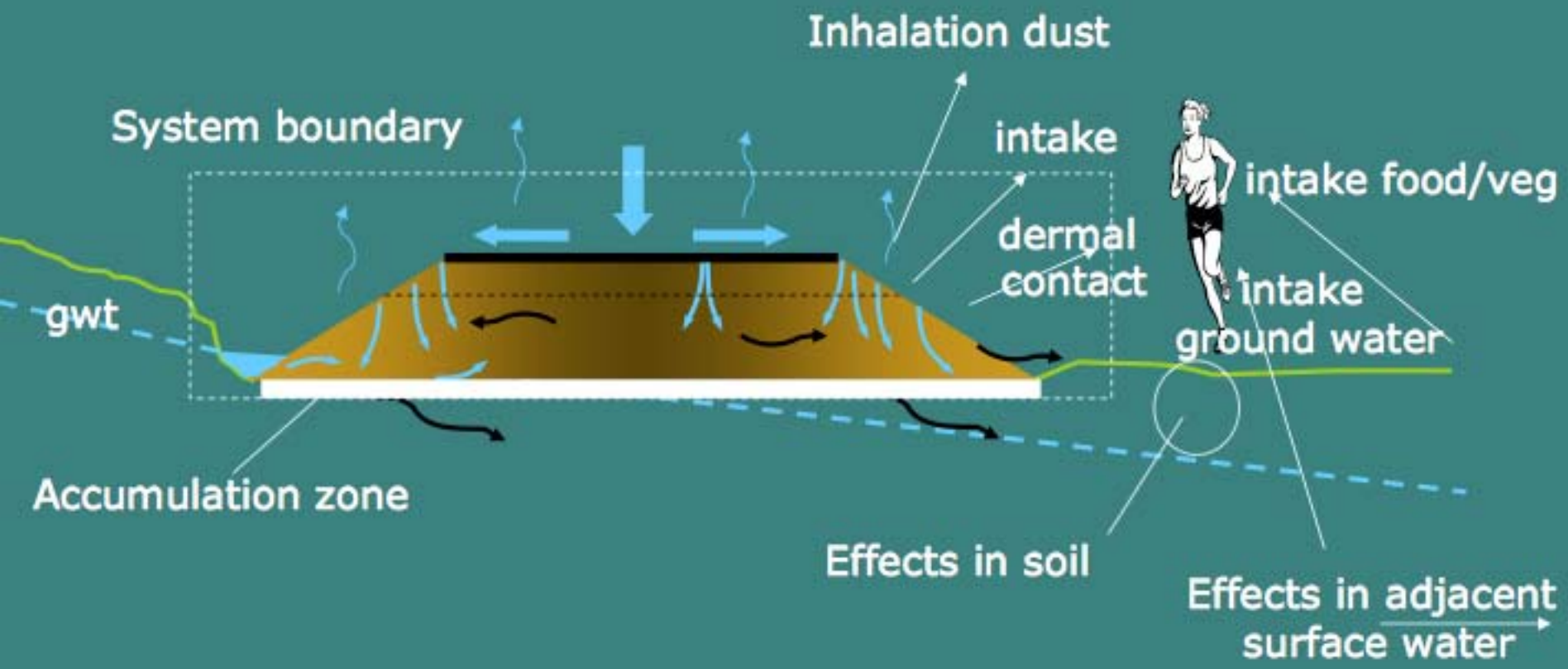
Covering Mine Tailings

Low Risk calculation model for ashes in roads



Q4-238 Environmental guidelines for reuse of ash in civil engineering applications (Bendz et al. 2006)

Low Risk oral intake

- 1/100 000 to get damaged
  - To get cancer (not to die of it)
  - For one individual in the most exposed group
  - That leads to very very improbable scenarios
    - In this case most critical is a person who
    - have vegetables 20 m from the road,
    - he badly washes them and
    - Most of his intake of vegetables cames from them
    - there is a lot of dust from building, repairing and demolition of the road and for
    - gravel roads dusting from part of the ashes during 64 years

Low risk Leaching

- Leaching calculated according to the TAC model for landfills, is not critical for the local risk for ashes. But
- Regional risk, i.e, many roads with ashes in a watersystem leads to more stringent limits– a report will come in a few weeks – (some ashes might require extended knowledge about the long term leaching)
- Another new report with lower limits for low risk will come within a few weeks

Low risk leaving a road

- The scenario is that the road is left in open with the ash at the surface and a person
- walks on it 40 windy days a year
- inhales a lot of dust
- has oral intake
- eats 1 kg/y of plants that has taken up a lot of metals

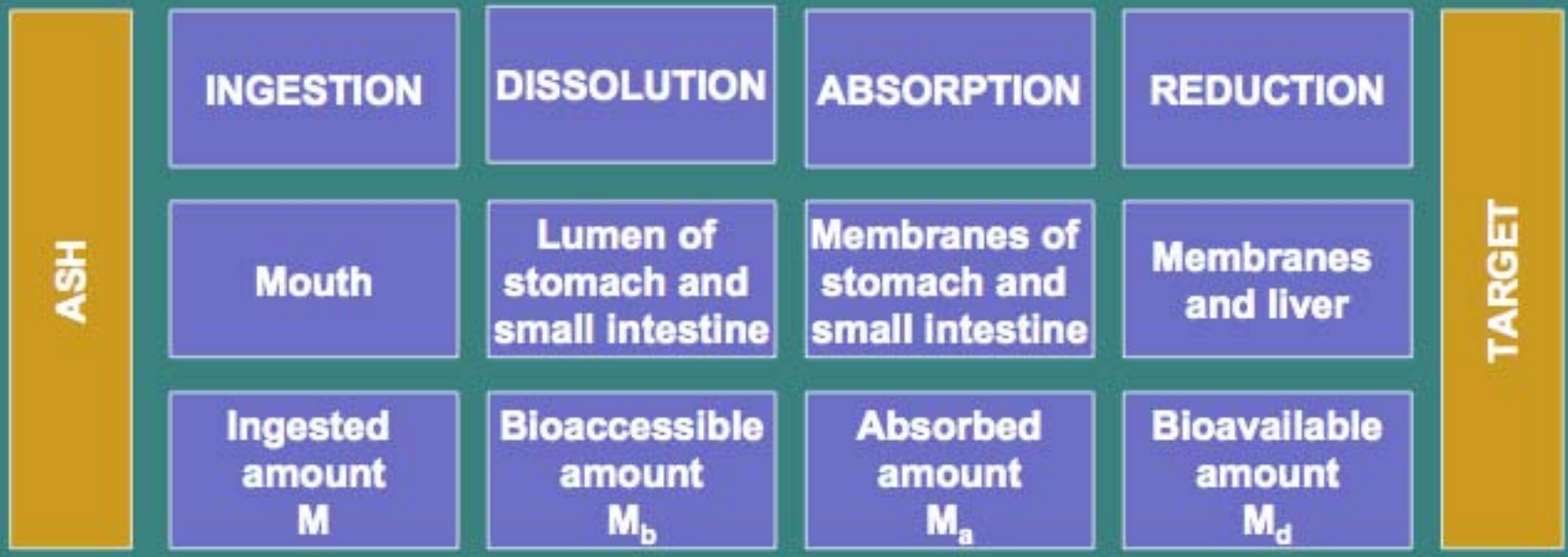
Max contents

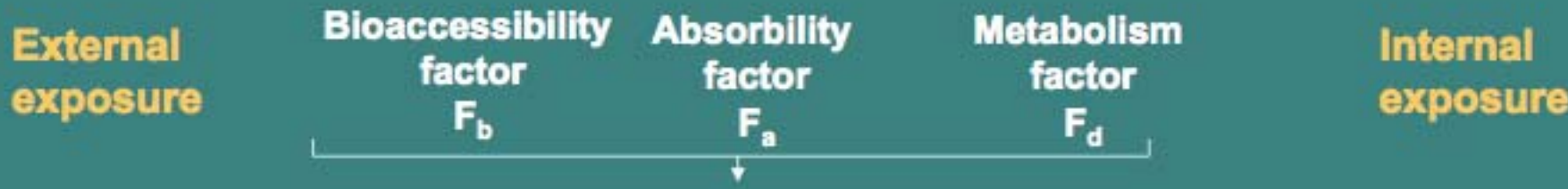
	Pb	Cd	Hg	Zn	As
90% of Swedish Morain free use?	20	0,2	0,1	120	10
Ashes to forests	300	30	3	7 000	30
Low risk gravel roads	2 700	520	150	25 000	110
Low risk leaving ashes at the surface exposure 40 days/y	1 500	60	60	> 5%	15

Low risk. In vitro trials

- As the scenarios etc are so unlikely to happen , we have calculated that we can use the total limit for the hazardous elements.
- I.e. for oral intake we have suggested that 100% goes into the blood and pass the liver and the cell membranes into the cell etc
- To verify that we have made conservative calculations SGI have made in vitro tests to look at the first step; that is what is leachable in solutions like the mouth , stomach and intestines

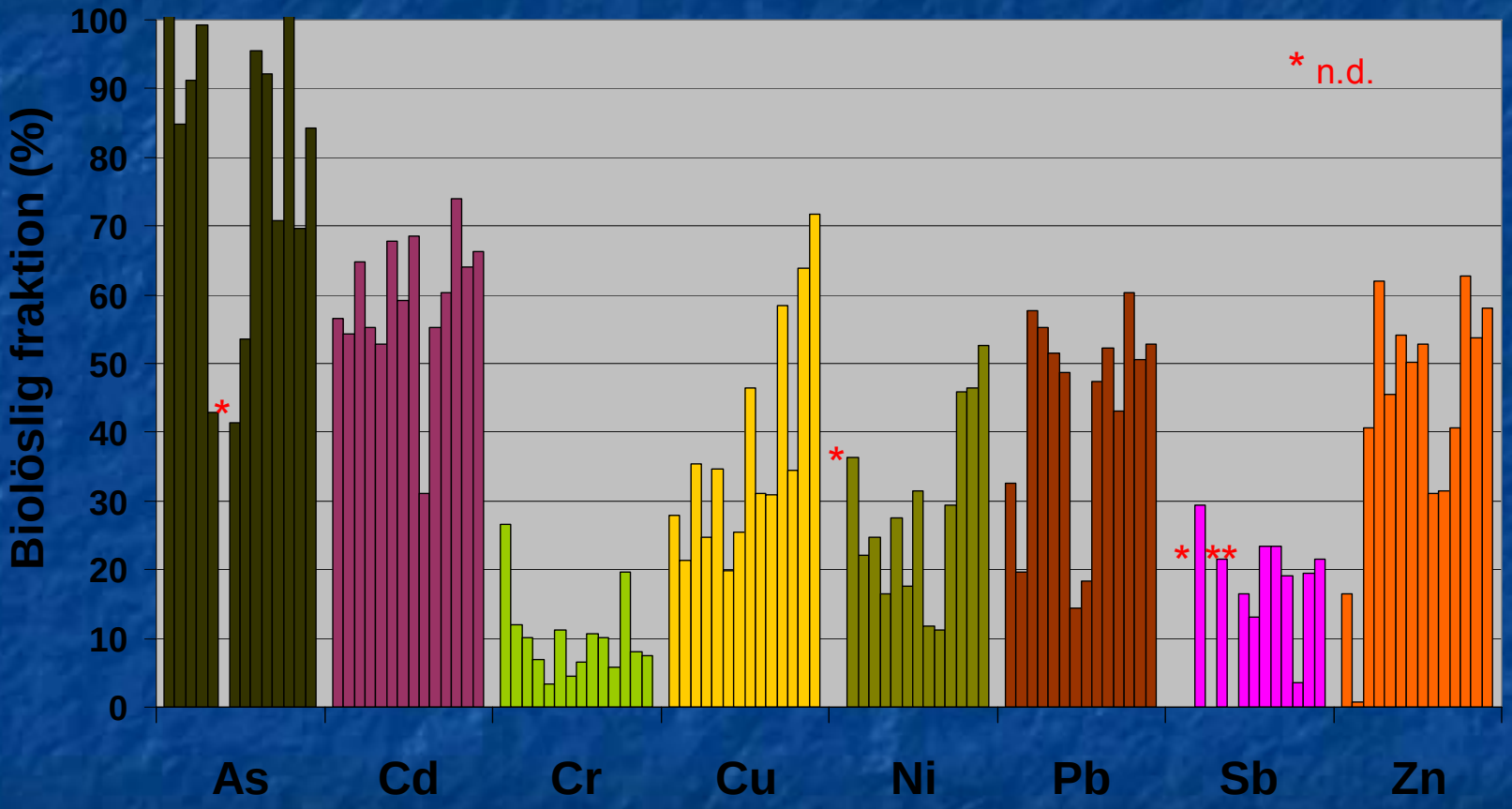
Definition of Bioavailability





Oral bioavailability: $F_{bad} = F_b \times F_a \times F_d$

In vitro trials with ashes F_b



How to comply with the hazardous waste directive?

- Necessary to identify reference substances
- Known properties with regard to health and environment
- Should represent realistic form for the element in question
- Should represent actual substances in a conservative manner

How to comply with the hazardous waste directive? Continued

- A special methodology has been developed on commission by
- Branch organisations for heat generation and waste management
- (Swedish Thermal Engineering Research Institute, Ash Programme and
- Swedish Association of Waste Management – RVF)
- The Swedish Environmental Protection Agency (EPA) (with support
- from the Swedish Chemicals Inspectorate)
- The methodology has been applied to > 30 plants
- The Swedish EPA disagrees with the criteria for ecotoxicity in the methodology
- "So we must
  - Look at how zinc occurs in the ashes
  - develop a method for ecotoxic studies with ashes

H-14 ecotox

- 3 reports strongly indicates that zinc is in the form of silicates or ferrite and little as $Zn(OH)_2$ in wetterd ashes (more in MSWI fly ashes)
- Tests for ecotoxicity must be and has been done on brack water organisms: Algea Shrimp, Fish embryo and Bacteria.
- At L/S 10 all ashes but for old MSWI-bottom ash was at least somewhat ecotoxic.
- But most of it depended on Ca^{2+} and K^{+}!!!

  (New and unexpected)
- The work will be continued by ITM and SGI

Organic poison in ashes

- LOI shows not only unburned but also chemical bonded water for wetted ashes.
- TOC (total organic carbon) shows total oxidize able carbon
- Most of TOC in ashes are mineralogical coal
- Very little is organic poisons
- The total TOC is not connected with the amount of organic poisons
- PAH's in fuels are destroyed, PAH's in residues originate in imperfect combustion and the concentration can be high
- For modern incinerators the total amount of dioxins are lower in the fly ashes than in the incoming household wastes

Luckily the nature is more robust to impurities than our models show

- Quotation from the Danish environmental consult Sten Stensdøe on a coffee break at a workshop about landfills in Helsinki 071029
- Cornelis Aart Meyles Holland/Iceland agreed referring to experiences from old bad landfills in Holland
- Evidence to the point may also be had from “The Environmental history of the Falun Mine”
  - (a nice book but based on scientific results)
  - 600 years of environmental disaster with SO2, Cu, Pb, Cd and Zn has a very little impact on the biosphere of today
- Our test results that indicate lower metal contents around the ash parts of the roads
- It is natural as life always has thrived close to volcanoes

Non toxic nature

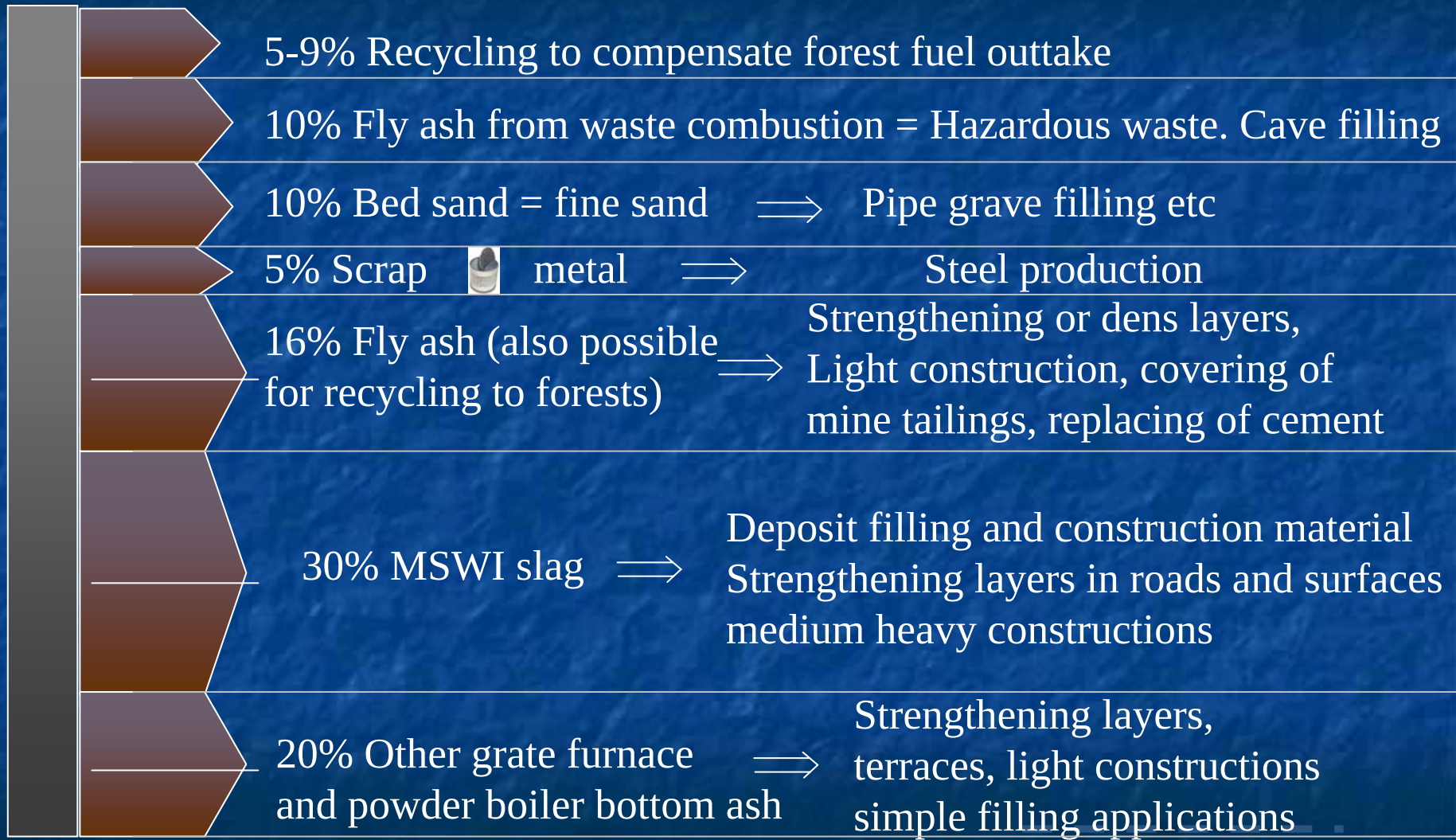
- Poison is a question of dose
- You can get a non toxic nature to higher levels than the background
- Taking too many precautions is not environmentally friendly
- It's in conflict with other environmental aims
- It costs a lot of resources
- It gives new risks often by traffic
- A risk in the traffic is often much higher than a conservatively calculated health and environmental risk
- It increases land filling
- It is not according to the waste hierarchy

Usefulness shall be given priority when the risk for health and environment is low

- As risks always are calculated in a conservative way it gives a good balance between
- Poison free nature and
- The waste hierarchy
- It gives possibilities to get
- ***Ashes used as resources in a sustainable society***

What can non coal ashes be used for?

1,5 milj tons in Sweden 2008



5-9% Recycling to compensate forest fuel outtake

10% Fly ash from waste combustion = Hazardous waste. Cave filling

10% Bed sand = fine sand ⟹ Pipe grave filling etc

5% Scrap metal ⟹ Steel production

16% Fly ash (also possible for recycling to forests) ⟹ Strengthening or dens layers, Light construction, covering of mine tailings, replacing of cement

30% MSWI slag ⟹ Deposit filling and construction material Strengthening layers in roads and surfaces medium heavy constructions

20% Other grate furnace and powder boiler bottom ash ⟹ Strengthening layers, terraces, light constructions simple filling applications

Claus Ribbing, Sensual
EnergiAskor AB

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Thanks for your attention

Questions?