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Bottom ash treatment at the site of producing plant for reutilization

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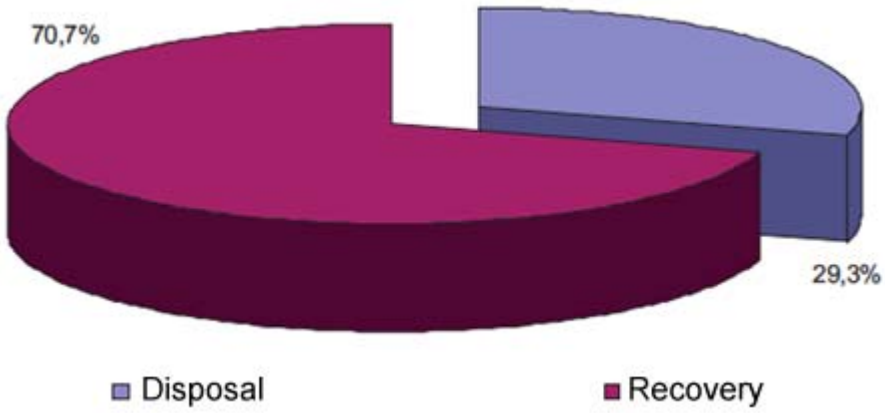
Summary

- Bottom ashes
- Accelerated carbonation
- Experimental set-up and results
- Industrial scale hypothesis
- Costs
- Conclusions

Bottom ashes

- Solid residues from waste combustion
- 15-25% in mass of incinerated waste
- Non-hazardous waste (Waste European Catalogue)
- 16 million of t/y of BA (2009) in Europe (CEWEP)
- 1,200,000 t/y in Italy
- 58,000 t/y in Tuscany



da ENEA-Federambiente - Rapporto sul recupero energetico da rifiuti urbani in Italia – 3° edizione – marzo 2012

Bottom ash

- Landfilling (non-hazardous / inert landfills)
- Reuse - without any treatment or acceptance test for the **production of cement**, bricks and expanded clay

- Reuse - for road construction or environmental restorations if leaching test results comply with limits,

Metal	Limits for reuse*	Limits for landfill of inert waste**	units
Lead	50	50	µg/l
Barium	1	2	mg/l
Zinc	3	0,4	mg/l
Nickel	10	40	µg/l
Vanadium	250	-	µg/l
Molybdenum	-	0,05	mg/l
Chromium	50	50	µg/l
Copper	0,05	0,2	mg/l
Antimony	-	0,006	mg/l
Beryllium	10	-	µg/l
Cobalt	250	-	µg/l
Arsenic	50	50	µg/l
Cadmium	5	4	µg/l
Selenium	10	10	µg/l
Mercury	1	1	µg/l

Leaching tests must be performed according to the UNI 10802 and methods reported in UNI EN 12457-2,

*Ministerial Decree dated 05/04/2006
** Ministerial Decree dated 27/09/2010

Accelerated carbonation

- Accelerated carbonation

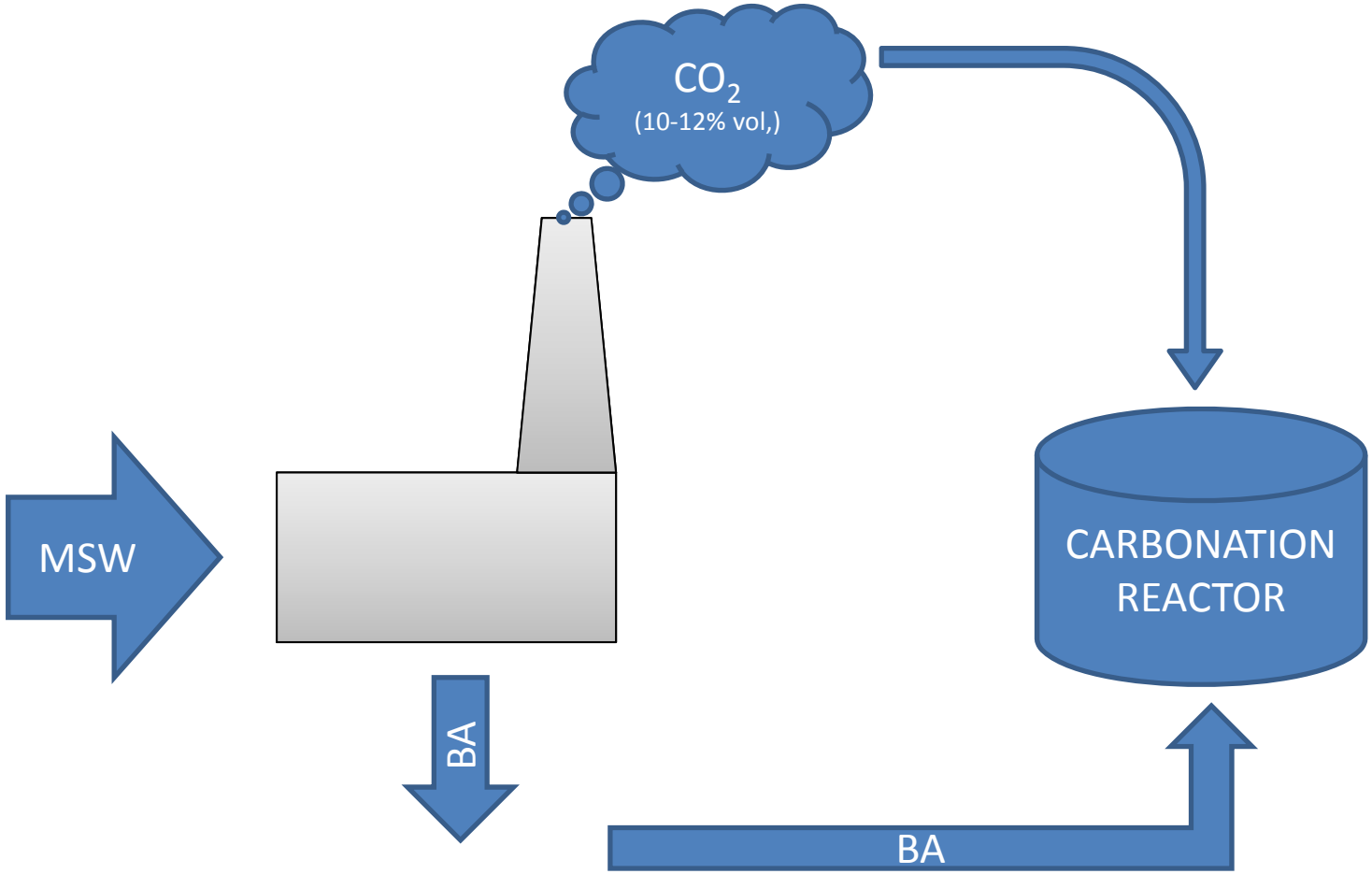
$$Ca(OH)_{2(aq)} + CO_{2(aq)} \rightarrow CaCO_{3(s)} + H_2O_{(l)}$$

- Improves the metals leaching behavior
- Indirect carbonation route: the alkaline metals are first extracted from the silicate matrix and then precipitated as carbonate
- Direct carbonation route: the reaction occurs either in the aqueous phase or at the **gas-solid interface**

Pure CO_2 stream (expensive)

Industrial point source CO_2 emissions

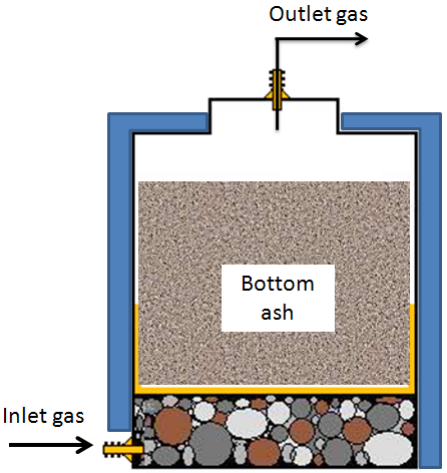
Accelerated carbonation



- **Experimental investigations**
- **Technical and economic analysis**

Experimental set-up

BA from a MSW grid incinerator



Gas mixer

10% vol, CO_2
90% vol, N_2

T P

Flowmeter

20 Nl/h

4 $Nm^3/(h \cdot t)$

T

5 kg_{BA}
Reactor

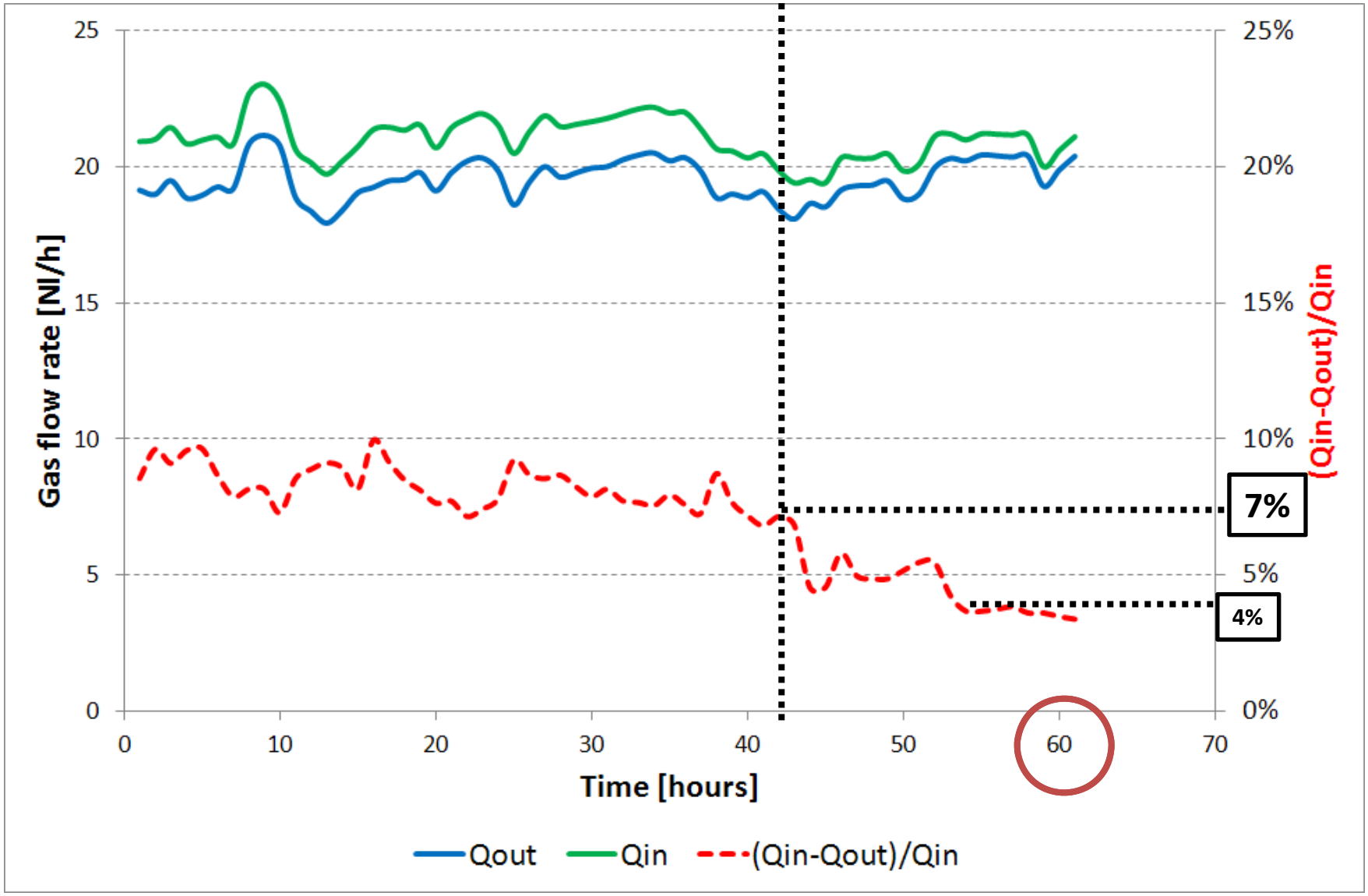
Metals leaching before/after

T P

Flowmeter

$$CO_{2.captured} = \frac{(V_{in.t} - V_{out.t})}{V_m} \cdot M_{CO2}$$

Experimental results

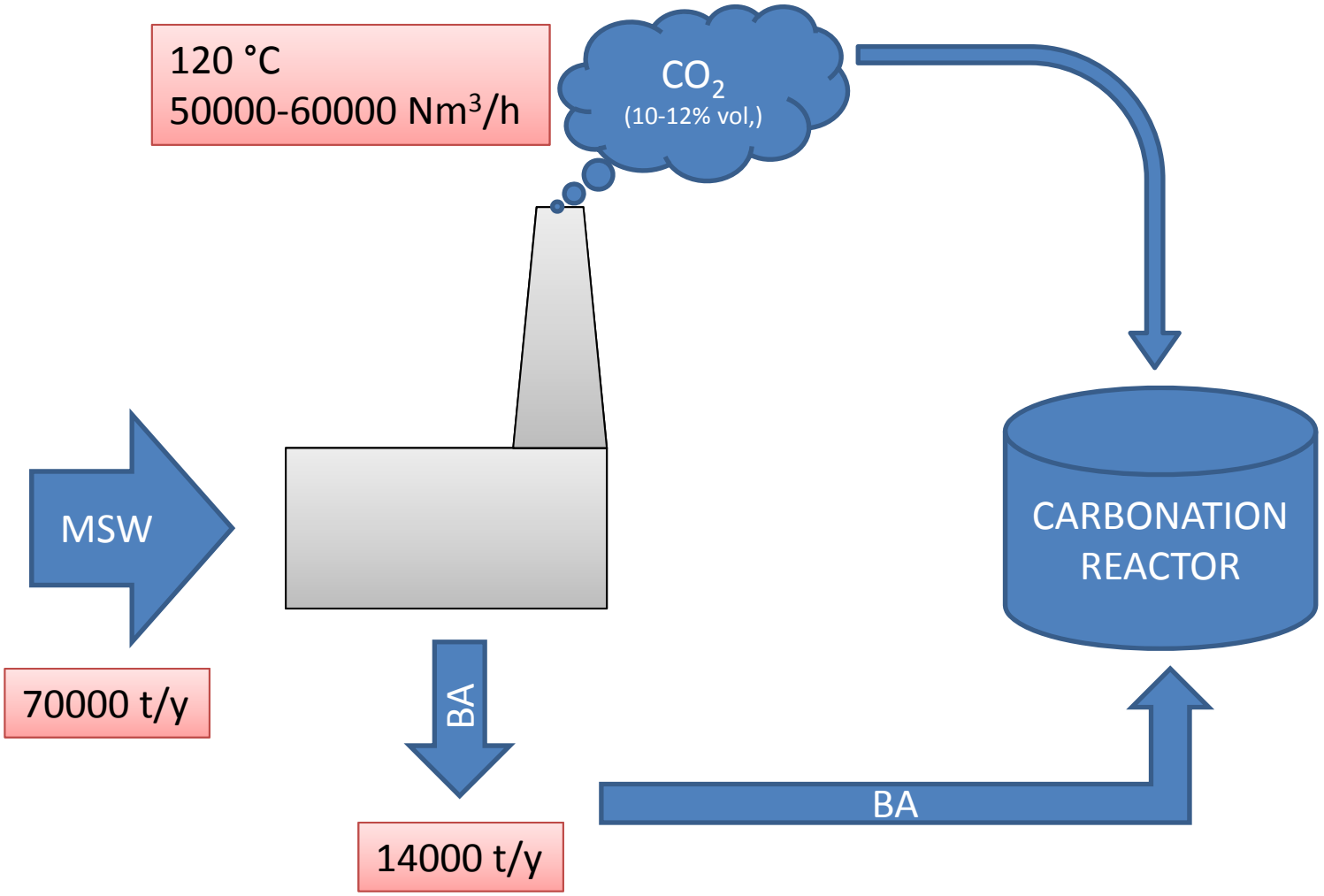


Vin [Nl]	Vout [Nl]	V_{CO2cap} [Nl]	m_{CO2cap} [g_{CO2}]	Specific uptake [g_{CO2}/kg_{BA}]
1283	1192	91	179	36

Experimental results

Metal	Limits for reuse	Limits for landfill of inert waste	Non-processed BA	Processed BA	units
Lead	50	50	14955	5	µg/l
Barium	1	2	1,923	0,105	mg/l
Zinc	3	0,4	0,377	0,003	mg/l
Nickel	10	40	2	3	µg/l
Vanadium	250	-	<1	6	µg/l
Molybdenum	-	0,05	0,018	0,028	mg/l
Chromium	50	50	8	17	µg/l
Copper	0,05	0,2	0,769	0,871	mg/l
Antimony	-	0,006	0,004	0,109	mg/l
Beryllium	10	-	<1	<1	µg/l
Cobalt	250	-	<1	<1	µg/l
Arsenic	50	50	<1	<1	µg/l
Cadmium	5	4	<1	<1	µg/l
Selenium	10	10	<1	<1	µg/l
Mercury	1	1	<0,1	<0,1	µg/l

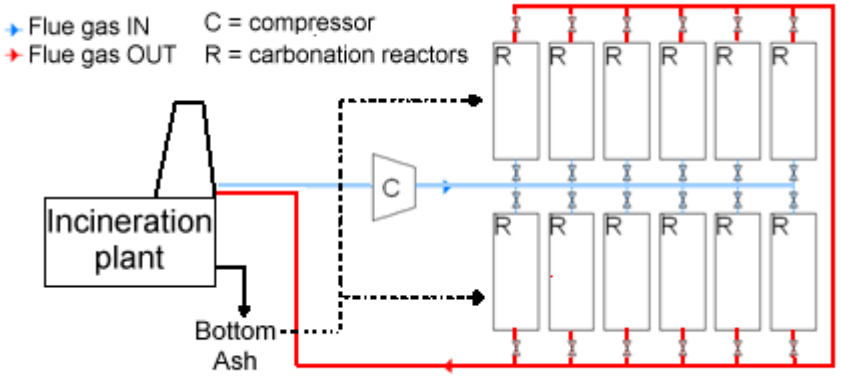
Industrial scale plant



Industrial scale plant

CARBONATION REACTOR

25 m^3
(6,5 m x 2,5 m x 2,65 m)
→ 20,5 m^3
→ BA density 1,67 t/m^3
→ 34 t → layer thickness = 1,4 m



Different duration of the treatment:
4 – 6 – 9 days

$$n_{active} = \frac{m_{BA,day}}{m_{container}} \cdot t$$

$$n = n_{active} + 1$$

Industrial scale plant

t	day	4,00	6,00	9,00
$m_{BA,day}$	t/day	45,00	45,00	45,00
$m_{container}$	t	34,03	34,03	34,03
n_{active}		6,00	8,00	12,00
n		7,00	9,00	13,00
Q_{spec}	$Nm^3/(h \cdot t_{BA})$	4,00	4,00	4,00
$Q_{fluegas}$	Nm^3/h	720	1080	1620
BA in each container	t	30,00	33,75	33,75
BA layer thickness	m	1,11	1,25	1,25
Pressure loss	mbar	100	113	113

$$Q_{fluegas} = m_{BA,day} \cdot t \cdot Q_{spec} \qquad Q_{spec} = 4 \frac{Nm^3}{h \cdot t}$$

Specific pressure drop = 0,9 mbar/cm

Investment cost

- container systems
- compressor
- piping
- truck

340000 € x 10 containers (+20%)

172500 €

Container system	326,869,00	381,893,00	482,028,00
Truck	172,500,00	172,500,00	172,500,00
Piping	6,400,00	7600,00	10510,00
Compressor	2,592,00	3,309,00	4,262,00
Total investment	508,361,00	565,302,00	669,300,00

O&M costs

Maintenance = 3,5% of total investment costs;
2 persons - 50000 Euro/year each;
diesel specific consumption of the truck =30 l/h, 4 hours per day of operation , 1,6 Euro/l;
electricity 0,17 Euro/kWh;
leachate 23 Euro/m^3 ,

	4 days	6 days	9 days
Annual amortization	57,901,00	64,387,00	76,232,00
Maintenance	17,793,00	19,786,00	23,426,00
Personnel	100,000,00	100,000,00	100,000,00
Diesel	59,904,00	59,904,00	59,904,00
Electricity	9,165,00	13,748,00	20,622,00
Leachate treatment	14,946,00	22,419,00	33,629,00
Total annual cost	259,709	280,244	313,813
Specific treatment cost [Euro/t_{BA}]	18,55	20,02	22,42

Final costs

ST	4 days	6 days	9 days
0%	88,55	90,02	92,42
10%	82,55	84,02	86,42
20%	76,55	78,02	80,42
30%	70,55	72,02	74,42
40%	64,55	66,02	68,42
50%	58,55	60,02	62,42
60%	52,55	54,02	56,42
70%	46,55	48,02	50,42
80%	40,55	42,02	44,42
90%	34,55	36,02	38,42
100%	28,55	30,02	32,42

$$FC = TC + ST \cdot C_{inert} + (1 - ST) \cdot C_{non-hazardous}$$

10 €/t

70 €/t

TC = treatment cost
ST= successful treatment (%)

Final costs

4 days

	S										
ST	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
0%	88,55	88,55	88,55	88,55	88,55	88,55	88,55	88,55	88,55	88,55	88,55
10%	82,55	82,42	82,29	82,16	82,03	81,90	81,77	81,64	81,51	81,38	81,25
20%	76,55	76,29	76,03	75,77	75,51	75,25	74,99	74,73	74,47	74,21	73,95
30%	70,55	70,16	69,77	69,38	68,99	68,60	68,21	67,82	67,43	67,04	66,65
40%	64,55	64,03	63,51	62,99	62,47	61,95	61,43	60,91	60,39	59,87	59,35
50%	58,55	57,90	57,25	56,60	55,95	55,30	54,65	54,00	53,35	52,70	52,05
60%	52,55	51,77	50,99	50,21	49,43	48,65	47,87	47,09	46,31	45,53	44,75
70%	46,55	45,64	44,73	43,82	42,91	42,00	41,09	40,18	39,27	38,36	37,45
80%	40,55	39,51	38,47	37,43	36,39	35,35	34,31	33,27	32,23	31,19	30,15
90%	34,55	33,38	32,21	31,04	29,87	28,70	27,53	26,36	25,19	24,02	22,85
100%	28,55	27,25	25,95	24,65	23,35	22,05	20,75	19,45	18,15	16,85	15,55

$$C = TC + (ST - ST \cdot S) \cdot C_{inert} + (1 - ST) \cdot C_{non-hazardous} - ST \cdot S \cdot C_{sold}$$

10 €/t

70 €/t

3 €/t

TC = treatment cost
ST= successful treatment (%)
S = sold (%)

Conclusions

- Accelerated carbonation to improve BA metal leaching potential,
- Possibly change the classification of bottom ashes from non-hazardous waste to waste suitable for disposal in landfills for inert waste or for the reuse in construction works,
- Flue gases from waste incineration plant as an alternative source of CO_2
- Preliminarily laboratory investigations: some criticisms with copper and the antimony
- Preliminary sizing of the process at industrial scale (70000 t_{MSW}/y → 14000 t_{BA}/y)
- Specific cost of treatment: 19 - 22 Euro/t_{BA},
- The economic benefit even if the process is not always successful in reducing the leaching of some metals below the imposed thresholds,
- Additional investigation at laboratory level and pilot plant level, in order to check: size influence, influence of real flue gases in the interaction with bottom ashes