Bottom ash treatment at the site of producing plant for reutilization

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Abstract

Bottom ashes are the solid residues remaining in the furnace after solid waste incineration, mainly consisting of unburnable materials. They are classified as industrial non-hazardous waste from the European Waste Catalogue. The final disposal or reuse of BA is strictly linked to the potential release of constituent contaminants into theenvironment. In this study we considered the possibility of improving the quality of bottom ashes, by accelerated carbonation, in order to make them suitable for disposal in landfills for inert waste or for the reuse in construction works. In particular, we evaluated the possibility of using the flue gases from waste incineration plant as an alternativesource of carbon dioxide for use in the controlled accelerated carbonationof the BA produced by the incineration plant itself.The process was preliminarilyinvestigated at laboratory scale and then evaluated from an economic point of view, estimating the specific cost for the treatment, which ranged from 19 to 22 Euro per t of processed BA.

Keywords: accelerated carbonation, metal leaching, reuse, inert waste, incineration, alkaline residues.

Introduction

Bottom ashes (BA) are the solid residues remaining in the furnace after solid waste incineration, mainly consisting of unburnable, i.e. inert, materials (Figure 1). They are classified as industrial non-hazardous waste from the European Waste Catalogue. Talking about municipal solid waste (MSW) incineration, the produced BA is about 15-25% in mass of the incinerated waste, according to its content of inert [1-3].

The Confederation of European Waste-to-Energy Plants (CEWEP) reports that about 16 million of t of BA were produced in 2009 in Europe [4]. About 1.200.000 t of BA are produced annually in Italy from MSW incineration, while the overall amount of BA produced annually by the MSW incineration plants located in the Tuscany region is about 58.000 t [5].

The final disposal or reuse of BA is strictly linked to the potential release of constituent contaminants into the environment. With reference to Italy, the most common fate of BA is disposal in landfills for non-hazardous waste, even if in other European countries the reuse option is more commonly diffused.

According to the Decree of the Environmental Ministry dated 05/04/2006, in Italy BA may be reused: i) without any treatment or acceptance test for the production of cement, bricks and expanded clay; ii) for road construction or environmental restorations if leaching test results comply with limits reported in the following in Table 2. Leaching tests must be performed according to the UNI 10802 and methods reported in UNIEN 12457-2.

According to the Decreeof the Environmental Ministry dated 27/09/2010, complying with EU directives, the criteria of waste acceptance in different types of landfills are defined (i.e. landfills for inert, non-hazardous or hazardous waste). In particular, waste can be accepted in landfills for inert waste if the results of leaching tests, executed according to the UNI 10802, comply with the limits reported in Table 2.

One possibility of processing this type of waste, for making it suitable for use in civil engineering applications or for safer final disposal to landfills, is applying stabilization by accelerated carbonation, with the aim of producing a chemically stable material with improved leaching behavior [6-10].

Accelerated carbonation may be applied following the indirect route - by which the alkaline metals are first extracted from the silicate matrix and then precipitated as carbonate – or the direct carbonation route, by which the reaction occurs either in the aqueous phase or at the gas-solid interface. In this latter case, predominantly, a high purity carbon dioxide gas is used, which is expensive to produce and buy. An alternative supply of lower purity carbon dioxide can be obtained from industrial point source emissions.

In this study we evaluated the possibility of using the flue gases from waste incineration plant as an alternative source of carbon dioxide for use in the controlled accelerated carbonation of the BA produced by the incineration plant itself. The volumetric content of CO_2 in the flue gases of incinerators is about 10-12% [11].

The process was preliminarily investigated at laboratory scale by setting up a process for realizing the direct contact between the BA and the simulated incineration flue gas in a fixed bed reactor. Then a first draft of process sizing at industrial scale was performed, with the aim of evaluating the cost of the treatment.

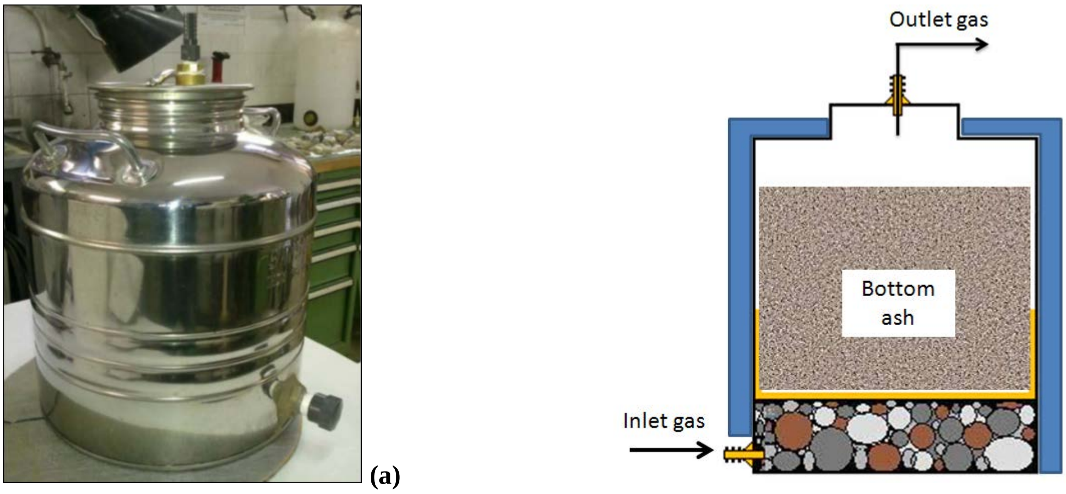
Fig. 1.Bottom ashes.

2. Materials and methods

2.1. Experimental facility

The experimental facility mainly consists of the BA fixed bed reactor and the measuring systems.

The BA fixed bed reactor is realized by a 15 l stainless steel cylindrical container (diameter 28 cm; height 35 cm) (Fig. 2 (a)). The reactor can be opened from the top, by means of a cover, for loading and unloading the BA. The gas flows into the filter bed from the bottom to the top. The ashes rest on a gravel layer covered by a geotextile fabric, which retains the small particles and allows the passage of the gas (Fig. 2 (b)). For external thermal insulation, an insulating adhesive material, provided in rolls, was used.



(a) (b)

Fig. 2.Fixed bed reactor: a) external view without the insulation cover, b) schematic of the internal arrangement.

Input and output gas flow rates to/from the BA fixed bed reactor are measured by means of CKD-small size flow sensors FSM2-NVF010-S063, able to measure in the range 0-1000 ml/min with accuracy of +/- 3% f.s. and repeatability < +/- 1% f.s..

The differential pressure of the input and output gas streams to/from the reactor is measured by a differential piezoresistive pressure transducer (Delta Ohm-HD 408T) able to work in the range from -100 to +100 mbar relative to the atmospheric pressure with accuracy of +/- 0,5% f.s. at 20°C.

Atmospheric pressure is measured by means of a barometric pressure transducer (Delta Ohm HD 9908 BARO) able to work in the range from 700 to 1100 mbar, with accuracy of +/- 0,5 mbar at 20°C and resolution 1 mbar.

The inlet/outlet gas temperature and the temperature inside the reactor are measured by electronic thermometers, produced by Hanna Instruments (HI 98501 - Checktemp C), able to measure in the range da -50 a +150°C with precision of +/- 0,3 °C and resolution 0,1 °C.

The gas flow rate, pressure and temperature are measured at sampling rate of 1 khz, the average of the measured values is registered in a discontinuous manner (every second). The measurement instruments are controlled by a programmable automation controller NI-USB 6008 National Instruments with 8 analog inputs (12-bit, 10 kS/s); 2 analog outputs (12 bit, 150 S/s); 12 I/O digital; 1 counter 32 bit; programming software Labview 10.0.

Besides, the experimental facility is equipped with a gas mixing device (Witt MG 100-3MEEEx), able to produce CO_2/N_2 gas mixtures of different compositions. The device allows setting the desired volumetric concentration for 5 % steps with an accuracy of ±2 % abs.

2.2. Materials

The BA used in the experiments originated from a MSW incinerator located in central Italy equipped with a grid furnace and fed by pre-treated waste. The pre-treatment of the MSW consists of bag opening and waste shredding, followed by size separation by a rotating drum, magnetic metals removal and secondary shredding. The BA are discharged at the bottom of the furnace in a water channel.

CO_2 and N_2 were provided in gas cylinders with a purity of, respectively, N_2Lev.5 purity 99,999 % and CO_2Lev.6 purity 99,9999 % .

2.3. Experimental tests

The incineration flue gas composition was simulated preparing a mixture of CO_2 and N_2, using the gas mixing device.The CO_2 volumetric content was assumed at 10%. N_2 does not react with BA, thus the difference between the inlet and outlet flow represents the CO_2 subtracted by the carbonation reaction.

The amount of captured CO_2 can be estimated from the difference between the entering and the exiting volume of gas, at a given time of the experiment, since the captured gas is only CO_2, by using equation 2:

$$\boldsymbol{CO_{2,captured} = \frac{(V_{in,t} - V_{out,t})}{V_m} \cdot M_{CO2}} \qquad \textbf{(1)}$$

where $V_{in,t}$ is the volume of gas flowed in in at time t (expressed in Nm^3); $V_{out,t}$ is the volume of gas processed flowed out at time t (expressed in Nm^3); V_m is the volume of a kmol of ideal gas at normal condition (equal to 22,414 Nm^3/kmol); M_{CO2} is the CO_2 molar weight (equal to 44 kg/kmol).

The appropriate amount of BA was loaded in the reactor after manual sorting of large metal particles. The amount of BA placed in the reactor is 5 kg, while the inlet flow rate was set at 20 Nl/h, realizing a specific flow rate equal to 4 Nl/(kg·h), as a first approach value, which was found as appropriate from previous studies concerned with different types of applications [12].

BA samples were analyzed before and after the treatment with respect to the leaching behavior of metals and results were compared with limits for reutilization and landfill for inert waste, as set by the Italian regulation cited before.

The results are here reported for one experimental test. At the time of writing additional tests are ongoing in order to collect a larger basis of data.

3. Results

Figure 3 shows the trends of the inlet and outlet gas flow rate to and from the BA fixed bed reactor, together with the percent difference between the inlet and outlet flow.

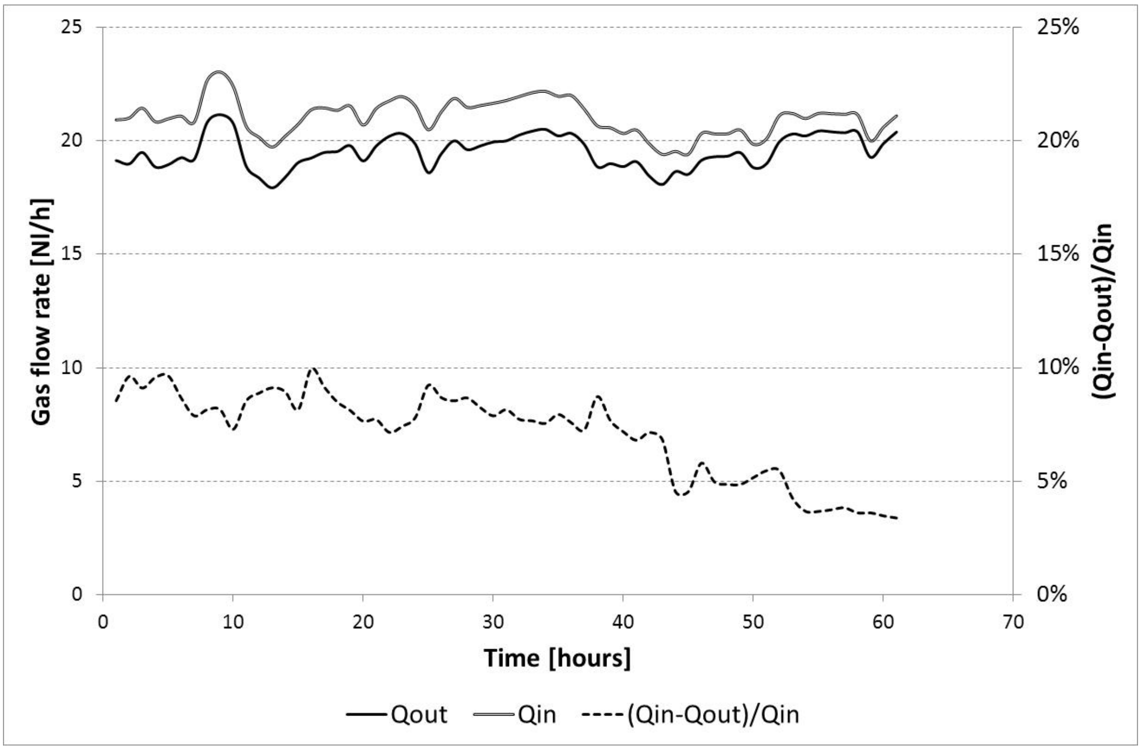


Fig. 3. Trends of the gas flow entering and exiting to/from the BA reactor and their percent difference.

As it can be noticed from Figure 3, the CO_2 in the inlet flow is captured by the BA, thus the gas exiting flow is always lower than the entering one. For more than two thirds of the test duration, the percent difference between the inlet and outlet flow is higher than 7%, i.e. more than 7% of the inlet CO_2 is captured. In the last part of the test the percent difference starts to decrease at values lower than 5%, showing that the BA carbonation ability is depleting. When the percent difference remained below 4% for few hours, it was decided to stop the test. The overall time duration of the test was about 60 hours.

The volume of the gas entered and exited to/from the BA reactor at the end of the test is reported in Table 1, together with the calculated amount of captured CO_2 and the specific BA uptake. Table 2 reports the results of the leaching tests carried out for the BA before and after their treatment.

Table 1.Final values of entering and exiting gas volume and calculated captured CO_2.

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

Table 2.Results of leaching tests for samples of BA before and after the carbonation treatment, compared with regulation limits for reuse and disposal in landfills for inert waste.

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

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

The results show that the carbonated BA have a lower leaching for lead, barium and zinc. The lead leaching is substantially improved, being reduced to values lower than the limits for reuse or inert landfills. The initial value of barium was acceptable for inert landfilling, but higher than the limit for reuse: after carbonation also this second limit is complied. The zinc content already complied with both limits for reuse or inert landfilling even before the carbonation process.

Reduction in leaching of lead (lowering of about two orders of magnitude) and zinc (lowering of about one order of magnitude) thanks to BA carbonation treatment is extensively reported in the scientific literature [9,10,13-15]. Similarly, barium leaching reduction after BA carbonation is reported by several authors [8,9,16].

On the other side, the carbonated BA show an increase in the leaching of: nickel, vanadium, chromium, molybdenum, antimony and copper.

However, concerning nickel, vanadium, chromium and molybdenum both the non-carbonated and carbonated BA present leaching metal concentrations lower than limits for reuse or inert landfills.

Antimony leaching value was below inert landfill limit (no limits for reuse), but it increased over such limit after the carbonation process. This increasing behavior is in agreement with what reported by other authors [8].

Copper leaching concentrations were above the limits for reuse and inert landfill even before carbonation process and further worsen after carbonation process. Such worsening is in agreement with other results [9],reporting that copper is generally the only metal that is not reduced below reuse limits.

For the other metals (beryllium, cobalt, arsenic, cadmium, selenium and mercury) the leaching concentration was below the detection limit for both the carbonated and non-carbonated samples and in any case far below the inert landfill or reuse limits.

In summary, it is possible to state that the carbonation processes had: i) positive effect on lead and barium decreasing the leaching concentration below the reuse/inert landfills limits; ii) negative effect on copper and antimony, increasing the leaching concentrations which did not comply with the considered limits. As a matter of fact, iii) before carbonation process the BA presented leaching concentrations not suitable for inert landfills/reuse for lead, barium and copper; iv) after the carbonation process the BA showed leaching concentrations suitable for reuse except for copper (antimony is not regulated) and suitable for inert landfill except for copper and antimony.

4. Industrial scale plant sizing and economic evaluation

Even if the results of the single test performed until now –additional tests are ongoing at the time of writing - posed some criticisms about the possibility of changing the classification of BA from non-hazardous waste to inert waste or recoverable waste, a preliminary assessment of the process from the economic point of view was performed. The preliminary results obtained from the experimental set-up were used for carrying out a draft sizing of the process on industrial scale in order to further estimate the treatment cost.

The reference incineration plant was assumed to burn about 70.000 t/y of MSWproducing about 14.000 t/y of BA, as the 20% in mass of entering waste. It is assumed to extract part of the exhausted gases flow rate at the stack and convey them through the BA carbonation reactor. Exhausted gas temperature at the stack is about 120 °C, however, during the path to the reactor the gases cool down and it is possible to assume that the temperature will be not far from the ambient one, as in the experimental tests. Overall exhausts flow rate is around 50.000-60.000Nm^3/h.

It was assumed to run the BA treatment plant for 312 days per year, 24 hours per day, thus the amount of BA to be processed each day is about 45 t/day.

Concerning the carbonation reactor, it was assumed to use a reactor technology that was originally proposed for the composting or the aerobic biostabilization of biodegradable waste, based on the use of containers (Fig. 4(a)). The system is, indeed, already equipped with an air insufflation system – in our case substituted by flue gases insufflation system - and a leachate collection system due to its original function. This technology offers substantial advantages, mainly related to the modularity of the treatment, which makes it suitable for different plant sizes, and to the simplification of the movement operations, since each container can be moved by a truck. In this way, the empty container is brought by the truck in the loading area where BA are loaded by a conveyor belt by the top of the container. The container, containing exhausted BA, can be unloaded by the truck in the appropriate storing area (Fig. 4(b)).

(a) (b)

Fig. 4. Container system: a) view of the modular system, b) truck operation.(Le Coccinelle ® Entsorga - http://www.entsorga.it)

Each container has a volume of about 25 m^3 (length 6,5 m, width 2,5 m, height 2,65 m). We considered here to use only 20,5m^3 of the available volume, to account for the higher specific weight of BA with respect to biodegradable waste. Thus assuming a specific weight of 1,67 t/m^3 for the BA, each contain can host about 34 t of BA, with a BA layer thickness of about 1,4 m.

The key parameter for the plant sizing is the duration of the treatment. We assumed different time durations for the process, 4, 6 and 9 days, in general higher than the time reached during the experimental test in laboratory (i.e. 60 hours). In each case, the number of necessary containers (n_{active}) is calculated according to the following equation (2) and rounding the result to the upper integer number:

$$n_{active} = \frac{m_{BA,day}}{m_{container}} \cdot t \tag{2}$$

Where $m_{BA,day}$ is the amount of BA to be fed to the treatment daily, in t; $m_{container}$ is the maximum amount of BA which can be hosted by one container, int; t is the process duration, in day.

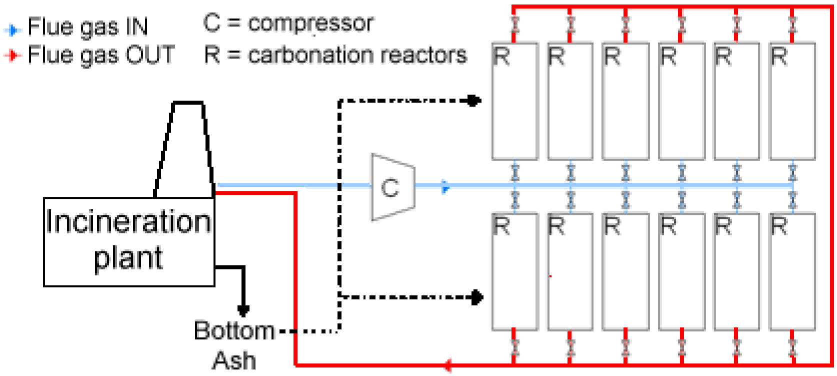


Fig. 5. Simplified layout of the BA treatment plant (case: process time = 9 days).

The actual number of containers (n) is calculated considering one additional container in each case, for allowing and facilitating the daily unloading/loading operations.

Considering to supply the flue gases from the incinerator stack with a specific flow rate (Q_{spec}) of 4 $Nm^3/(h \cdot t_{BA})$, the flow rate to feed the reactors can be calculated from equation (3):

$$Q_{fluegas} = m_{BA,day} \cdot t \cdot Q_{spec} \tag{3}$$

Table 3 summarizes the calculation for the three cases of process duration, reporting also the thickness of the BA layer in each reactor, which is useful to estimate the pressure losses encountered by the exhausts passing through the BA bed, knowing, from laboratory observation, that the specific pressure loss is about 0,9 mbar/cm.

Table 3.Calculation of container number, exhaust flow arte and BA thickness for the three cases of process duration.

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	720,00	1.080,00	1.620,00
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

Investment cost for the plant, can be estimated considering the simplified layout of the plant as reported in Fig. 5, and including the expenses for the container systems, the compressor, to feed the reactors, the necessary piping from the stack base to the reactors and the truck for containers movement. Basic costs for a 10 containers system and one truck were supplied by Entsorga Italia s.p.a. and are equal to 340.000 and 172.500 respectively. An extra cost of 20% was assumed for the reactors for their adaptation to the different use with respect to the original purpose.The cost for the different systems, characterized by different number of containers was scaled through the use of equation (4) on the basis of the container number:

$$\boldsymbol{C_2 = C_1 \cdot 0.1 + C_1 \cdot 0.9 \left(\frac{n_2}{n_1}\right)^{0.7}} \qquad (4)$$

where, C_1 is the investment cost for 10 containers, n_1 is equal to 10, n_2 is the actual number of used containers and C_2 is the calculated investment cost.

Similarly, compressor cost was estimated knowing that a 15 kW compressor, processing 1.500 Nm^3/h supplying 210 mbar pressure increase, which can be suitable for our purpose, costs about 4.060 Euro, and upscaling or downscaling this cost by eq. 3, on the basis of the flow rate.Additionally piping cost, including installation, was estimated considering appropriate diameter size for the different cases and assuming a given length.

The initial rows of Table 4 summarize the estimated investment cost for the three possibilities of process time. Capital annual amortization (K) was calculated from total investment (C), assuming 6% interest rate (r) and 10 years investment time (n), using eq. 5:

$$\boldsymbol{K = C \cdot (1+r)^n \cdot \frac{r}{(1+r)^n - 1}} \qquad (5)$$

Maintenance cost were assumed to be 3,5% of total investment costs. The work of two persons with specific cost of 50.000 Euro/year each, was assumed. The cost for diesel consumption was estimated considering a specific consumption of the truck equal to 30 l/h, 4 hours per day of operation and a specific cost of 1,6 Euro/l. The cost for electricity consumption of the compressor was estimated considering scaled powers, on the basis of the exhausts flow rate, and electricity specific cost of 0,17 Euro/kWh. Additionally, the cost for the further treatment of leachate, originated from the exhausts humidity, was accounted for, assuming 15% in volume of water in the exhausts and a specific cost of treatment equal to 23 Euro/m^3 of leachate. The second part of Table 4 summarizes the estimated O&M costs.

From the total annual cost, dividing by the total annual amount of processed BA (i.e. 14.000 t), it is possible to calculate the specific treatment cost for a unit of mass of BA, as reported in the last raw of Table 4.

Table 4.Summary of investment and O&M costs (Euro). The last row reports the calculated specific treatment cost.

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**
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**

5. Discussion

As anticipated BA are generally disposed in landfills for non-hazardous waste at a specific cost of about 70 Euro/t, at least with reference to Italian market.

With reference to the prosed process, after the carbonation, the BA may be disposed in a landfill for inert waste or reused in construction works, if the metal leaching accomplishes the limits highlighted before (assuming that also criticism about copper and antimony can be resolved).

In the first case - disposal in landfills for inert waste - the additional cost for the disposal needs to be added to the treatment cost and it was assumed equal to 10 Euro/t. However, it may happen that the treatment is not always successful (the leaching of some metals exceeds the regulation limits) and the BA, even if treated, must be disposed in landfills for non-hazardous waste. Table 5 shows how the percentage of successful treatment (ST) influences the final cost (FC) of treatment and disposal, calculated according to eq. 6:

$$\boldsymbol{FC = TC + ST \cdot C_{inert} + (1 - ST) \cdot C_{non-hazardous}} \qquad (6)$$

whereC_{inert} is the disposal cost in landfills for inert waste and $C_{non\text{-}hazardous}$ is the disposal cost in landfills for non-hazardous waste.

The final cost – i.e. treatment cost plus disposal – is lower than the direct disposal cost of un-treated BA, if the percentage of success of the carbonation process is higher than 40%.

Table 5. Influence of the percentage of successful treatment on the final cost, in Euro/tBA, for the three cases of process time.

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

In alternative, the processed BA may be suitable for reuse. In this case it was assumed that they can be sold at 3 Euro/t. However, also in this case, it may happen that the treatment is not always successful in complaining the reuse limits and the BA must be disposed in landfills for inert waste or, if even the limits for inert waste are not respected, in landfills for non-hazardous waste. Table 6 shows how both the percentage of successful treatment - i.e. BA that can be disposed in landfills for inert waste - and the percentage of sold BA (S) influence the final cost (FC) of treatment and disposal, calculated according to eq. 7:

$$FC = TC + (ST - ST \cdot S) \cdot C_{inert} + (1 - ST) \cdot C_{non-hazardous} - ST \cdot S \cdot C_{sold} \qquad (7)$$

whereC$_{sold}$ is the specific cost at which BA are sold for reuse.

In this case, the final cost – i.e. treatment cost plus disposal less selling costs – is lower than the direct disposal cost of un-treated BA, if the percentage of success of the carbonation process is higher than 30%.

Table 6. Influence of the percentage of successful treatment and the percentage of sold BA on the final cost, in Euro/tBA, for the case process time = 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

6. Conclusion

In this study we proposed to process bottom ashes by accelerated carbonation in order to improve their environmental quality in term of metal leaching potential. The aim was to 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. In particular, we evaluated the possibility of using the flue gases from waste incineration plant as an alternative source of carbon dioxide for use in the controlled accelerated carbonation of the BA produced by the incineration plant itself. The process was preliminarily investigated at laboratory scale, highlighting some criticisms in the possibility of reducing the copper and the antimony leaching below the regulation limits. However, additional laboratory test are on-going at the time of writing in order to collect more information about this behavior. Further we performed a preliminary sizing of the process at industrial scale in order to estimate the specific cost of treatment which ranged from 19 to 22 Euro/t. The economic benefit of applying the proposed treatment, with respect to bottom ashes disposal in landfills for non-hazardous waste, is reached even if the process is not always successful in reducing the leaching of some metals below the imposed thresholds. Additional investigation of this type of process are necessary at laboratory level, but also at pilot plant level, in order to check the influence of real flue gases in the interaction with bottom ashes.

Acknowledgment

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