

Preliminary studies of the purification properties of the bottom ash from incineration of hospital waste for bleaching a synthetic discharge from the textile industry

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Abstract

Yearly the incineration of healthcare wastes (HW) generates large tonnages of bottom ash. Due to their constitutions and particle size distribution, these complex and heterogeneous materials are in the form of an ashy, grayish, friable and heterogeneous magma which is not very fragrant and contains many metal waste (Eguilles syringes, blades, etc.), incombustible mineral residues (glass, plastic, ceramic bottle, etc.) and unbridled resulting from the imperfect combustion of certain constituents. These materials have also adequate mechanical properties for use as a substitute material in the field of road and civil engineering.

Bottom Ash (BA) from incineration of HW cannot be disposed off aleatory in landfills due to their composition. However their valorization would be worth considering from the economical and environmental points of view. Therefore they have been tested as discoloring agents in the textile industry which is known to use toxic important quantities of synthetic colorants that pollute its rejected wastewaters. This may also provide an important source of treated water that may be reused.

Encouraging results have been obtained concerning the dye removal capacity such as Gentian Violet, used in the textile industry; which has reached 98.82% for a contact time of one minute, an L / S ratio: 0.3 ml mg⁻¹, a stirring speed of 850 rpm, a Temperature of 20 ± 5 °C. However this bleaching ability could not be achieved for the different BA tested and collected from five different health centers.

Keywords: Waste Incineration, Bottom Ash, Revaluation, Bleaching, Textile Industry.

I. Introduction

In Algeria, one of the major ways of eliminating waste generated by health care activities (HW)) is incineration [1]. This treatment method produces large tonnages of thermal residues since the bottom ash accounts for 22.59% of incinerated waste, an approximate production of 4500 kg/year in the considered hospital which is one of Constantine city (Algeria) hospitals with a care managing capacity of about 140 patients.

Faced with the growth of the HW and increasing severe environmental regulations, the recovery of these granular materials remains a real challenge.

The bottom ash (BA) materials have been used in various civil engineering industrial applications, mainly road engineering [2-5], but their uses are still limited because they are highly reactive and evolve over time chemically and mineralogically.

The characterization of this type of thermal residue has been the subject of numerous studies but they have been oriented towards the upgrading of BA as a raw material for use in road engineering [6, 7].

The upgrading of the BA for the discoloration of the rejected wastes requires a minimum of characterization before its contact with the effluent.

The characterization of the BA was performed to determine the particle size, the chemical compound, leaching composition and the mass loss in contact with water.

The study of the bleaching properties of BA was carried out on three dyes, namely Gentian Violet ($C_{25}H_{30}ClN_3$), Cuprofixe Gray and Cibacron Green ($C_{60}H_{29}Cl_3N_{16}NiO_{21}S, 6Na$). A comparative study between the bleaching capacities of different varieties of BA from five health care centers in the city of Constantine was performed.

II. Analytical procedures and bottom ash characterization

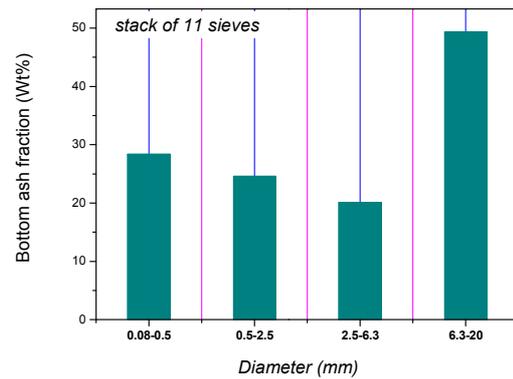
A. Particle size analysis

The granulometric curve is a fundamental element of the classification of solid matrices. The results can be used to predict certain properties of the material such as permeability, compactness or use as filters. This would indicate whether BA can be used in its raw state or should need a preliminary treatment such as crushing and grinding, before its use.

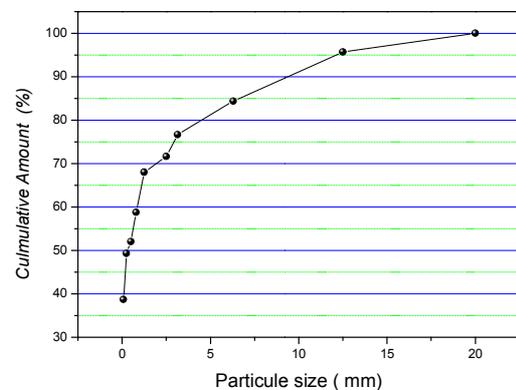
The BA had a well-spread grain size curve between 0.08 and 20 mm, with a hold of 11.32 and 26.05%, respectively. It was therefore a very heterogeneous material, given its content of large and fine particles. In view of the heterogeneity presented by the slag, it was necessary to prepare the sample for the different physical and chemical characterizations. For this the residue was finely crushed and sieved again and all the analyses were carried out on the fraction presenting a particle size less than 0.315 mm.



(a)



(b)



(c)

Figure 1. (a) Photo of the raw state of BA; (b) fractioning of the BA; (c) Particle size distribution curve of BA

B. Chemical characterization

a) Fire loss and moisture content

The fire loss was estimated by determining the mass loss of BA, expressed as a percentage of the dry weight of the initial sample after 04 hours of calcination at 525 ± 25 °C (NF EN 15169). This made it possible to estimate the rate of organic matter present in the BA despite its calcination in the incinerator.

Although the combustion temperature of the incinerator used could reach 1350°C, the fire loss of BA was estimated at 93.59% (% dry weight), indicating that the thermal residue had been badly calcined, so a very large organic fraction exists always in the BA.

On the other hand, the estimated moisture content by quantification of the dried mass at 105 °C up to constant weight (NF P94-050) was only 2%.

b) Elementary analysis

The elemental chemical composition is defined by the nature and the proportion of the chemical

elements contained in the Bottom Ash. Different techniques exist such as X-ray diffraction analysis, solution dissolution by acid attacks (digestion) then analysis by atomic absorption, etc. In the present study, the elemental analysis was carried out by X-ray diffraction for several Bottom Ashes from a variety of health centers (Table .1) of city of Constantine, Algeria.

Table .1 Assignments of the types of studied bottom Ash

Sample notation	Location	Incinerator capacity (kg h ⁻¹)
BA A	EL BIR Hospital (1 st sample)	60
BA B	EL BIR Hospital (2 nd sample)	60
BA C	Psychiatric Hospital	50
BA D	EL KHROUB Hospital	50 à 90
BA E	EL MEHDI surgery	12
BA F	ALI MENDJLI Hospital	35

The X-ray diffraction made it possible to identify the crystalline phases present. It was a qualitative analysis and a similarity in the mineralogical composition of the BA A and B, C and D and that of E and F, was noted.

The highest grades in decreasing order, based on the height of the peaks were:

- **BA A and BA B:** Calcium Carbonate, Lead Oxides, Nickel Oxides, Phosphate Calcium Silicates, Zinc Oxides and Copper Oxides.
- **BA C and BA D:** Calcium carbonate, zinc oxides, nickel oxides, copper oxides, phosphate calcium silicates.
- **BA E and BA F:** Cesium Bromide, Lead Oxide, Silica Chlorite, Aluminum Calcium, Phosphate Bromide, Nickel Oxide, Iron Oxide, Zinc Oxide.

However, the obtained diffractograms were difficult to interpret and only allowed to identify the majority of crystallized compounds. Therefore the mineralogical composition could not be confirmed with this technique. It would rather be interesting to make complementary analyses such as spectrometry emission, atomic absorption, etc.

Calcium carbonate (CaCO₃) was a common component in the majority of the BA, because CaO

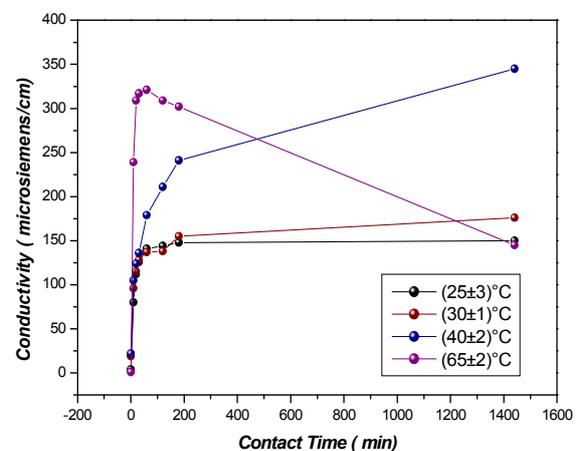
was produced during incineration and then reacted to Ca(OH)₂ during quenching and weathering. Subsequently the Ca(OH)₂ reacted to CaCO₃ during contact with the CO₂ in the air [7].

Another mineral commonly found in high quantities was the silicate products. A clear difference in the amount of silicate products between BA A and C was noted because the latter did undergo a more selective sorting, fully recovering and recycling the glass bottles before incineration.

c) Release of elements (leaching test)

The leaching test was always performed on the BA [8]. It assessed the risk of migration of elements to the natural environment and the need or not to carry out additional treatments in case of recovery technique road. The release of the elements constituting the residue and their solubilities in contact with water were function of temperature and pH.

The interest of this analysis in the case of this study was to evaluate the release of these elements during the depollution stage (in contact with the wastewater having different pH and at different temperatures) and to study the effect of this release on purification efficiencies. Unfortunately the possibility to follow the solubility of each element as a function of the pH was hardly possible, but as even the behavior following the leaching test was carried out by the immediate measurement of the electrical conductivity (Multiline P4 WTW Universal Meter) and that of the pH (pHM 210 standard pH Meter MeterLab) in contact with distilled water and this at different temperatures (the wastewater temperature of the textile industry could reach more than 50°C at the discharge point) (Figure2).



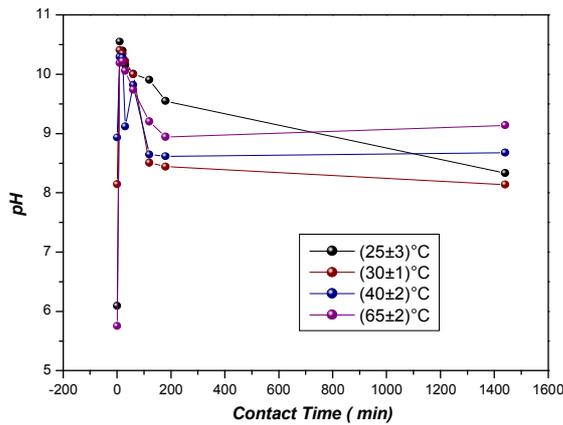


Figure.2. Variation of conductivity and pH as a function of contact time at different temperatures (BA A)

The conductivity test allowed examining two behaviors: the release detected by the variation of the conductivity was dependent on the temperature, where for example for a contact time of 10 min the increase was 16% between 25 ± 3 and 30 ± 1 °C; the conductivity measured the capacity of the water to conduct the current between two electrodes. Most of the dissolved materials in the water were in the form of electrically charged ions. The measurement of the conductivity thus made it possible to appreciate the quantity of dissolved salts in the water and therefore the variation of temperature also influenced the measurement and not only the release, because while increasing the temperature the ions would be more mobile and so would drive more current, so it was not possible to differentiate between the two effects.

The release was dependent on the time of contacting, especially in the first 10 minutes where the increase was between 79 and 99% for the different temperatures. Beyond 30 minutes the effect decreased and the release tended to stop (Figure 2). For temperatures of 40 ± 2 and 65 ± 2 °C, evaporation of the sample influenced the measurement at 1440 min.

When placed in contact with distilled water, the obtained pH varied between 8-10 for the different temperatures and during the contacting process. This confirmed the elemental characterization made where the major constituent in the different BA (A, B, C, D) was calcium carbonates the solubilization of which in water would release the strong bases carbonates inducing the increase of the pH.

The pH tended to decrease with the contact time, due to the equilibrium established between the carbonates and the bicarbonates where after 24 hours (1440 min) all the carbonates were almost converted into bicarbonates (decrease of pH down to a value ≤ 8.3 except for 41 and 67°C experiments where evaporation of the solution was somewhat important). This could be confirmed by the determination of carbonates and bicarbonates in the filtrates recovered after the leaching.

d) Determination of the alkalinity in the filtrates recovered from the leaching test

The alkalinity was measured in the filtrates recovered from the leaching tests (Table 2) after a contact time of two hours. The alkalinity was estimated after the calorimetric determination of the alkalinity (T A), Complete (T A C) in the different leachates [9].

Table.2. Alkalinity of the filtrates after a contact time of 02 hours depending on the temperature (BA A)

Temperature (°C)	TA (meq L ⁻¹)	[HCO ₃ ⁻] = TAC (meq L ⁻¹)
25±3	0	60
30±1	0	70
40±3	0	85
65±2	0	45

This confirmed the hypothesis that the balance between forms of alkalinity tended to move towards the dominance of bicarbonate compared with carbonates.

e) Mass loss

This part presented a synthesis of the effects obtained after contacting the BA with water having pH varying between 4 and 12. In the present study the interest of this analysis was to estimate the lost quantity of BA during the bleaching of colored wastewater at different pH levels (Figure 3). The procedure was as follows: contacting 100 mg of BA A with a water of different pH with constant stirring for one hour, the residual amount of BA was recovered by filtration of the solution, followed by drying of the pellet recovered at 105°C to constant weight. The recovered residue was again quantified by simple weighing (the variation of the pH of the leaching solution was obtained by the addition of chloride acid or the solution of sodium hydroxide).

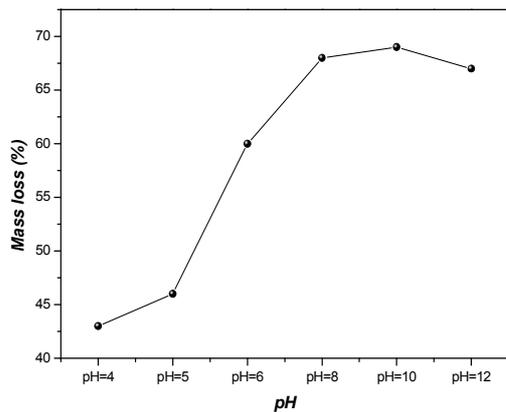


Figure.3. Variation of mass loss at different pH (Bottom Ash A)

The loss of mass in acidic and basic medium was relatively important and was accentuated while increasing the pH reaching a value of 69%. For pH higher than 8, the loss was stable and any excess could be due to the organic fraction (93.59%) still present in the BA.

When using the BA for bleaching synthetic waste water there would be a great loss of material.

III. Bleaching of synthetic solutions

Representative samples of the crushed and sieved materials (<0.315 mm) of the various BA were put batchwise into contact with aqueous solutions containing the various toxic dyes.

The discoloration would be tested for the three considered dyes, Gentian Violet, Cuprofixe Gray and Cibacron Green, which are still used in abundance in the textile industry. A comparative study between the bleaching power of the different BA (A, B, C, D, E, F) was established.

Measures of the residual concentrations of Gentian Violet, Cuprofixe Grey and Cibacron Green dyes after several contact times, were carried out by an UV-Visible dosage at 583, 705, 614 nm, respectively, following also the pH of the filtrates at operating conditions of L/S ratio = 0.3 mL. mg⁻¹, a stirring speed = 850 rpm and a temperature = 20 ± 5°C) (Figure 4).

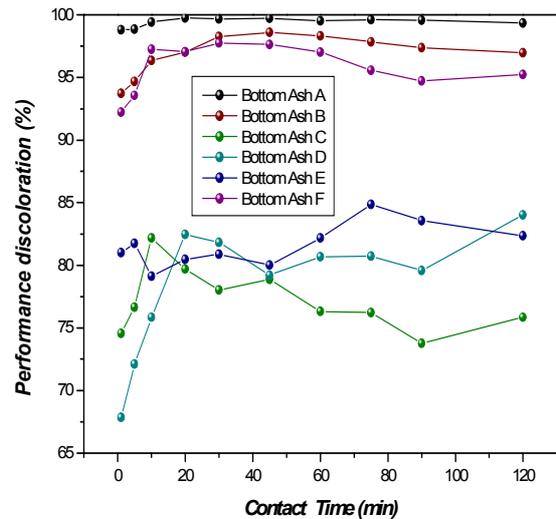


Figure.4. Variation of the performance of Gentian violet discoloration against the contact time

The fading yields were very important for the BA A and B (98.82% and 93.73% respectively after one minute). These thermal residues had a very good discoloration without any specific treatment in comparison with other types materials (such as coal, bentonite clay, etc.) [10].

The bleaching power varied from one type of BA to the other, the fading yields were greater in decreasing order for the BA A, B, F, E, D, C (Figure 4). This was mainly due to the different constitution of one BA to the other where the residues rich in silica derivatives had a greater performance discoloration (BA A, BA B, BA F, BA E), and also to the fluctuations of the pH during the discoloration (Figure 5) which influenced not only the solubility of the elements constituting the BA in the solution but also the chemical reactions which could intervene at the level of the aqueous solutions (reactions of complexation, precipitations, etc.). The mass loss was important in basic pH up to 69% and also with the surface reactions in the BA (adsorption, ion exchange, etc.).

The same experimental procedure was established for the discoloration of a synthetic solution of Cuprofixe Gray and Cibacron Green by the two bottom slates A and B (Figure 6).

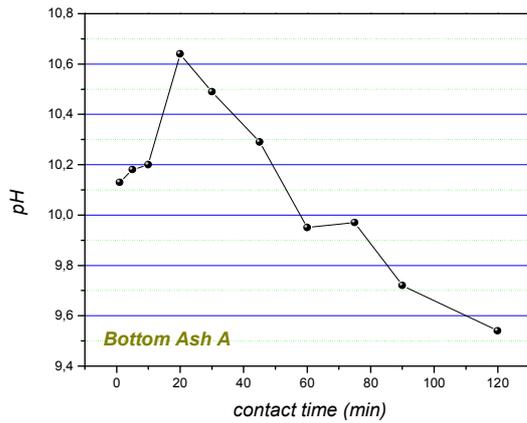


Figure.5.Example of the pH variation during the bleaching of the synthetic solution of Gentian Violet in contact with the BAA as a function of the contact time

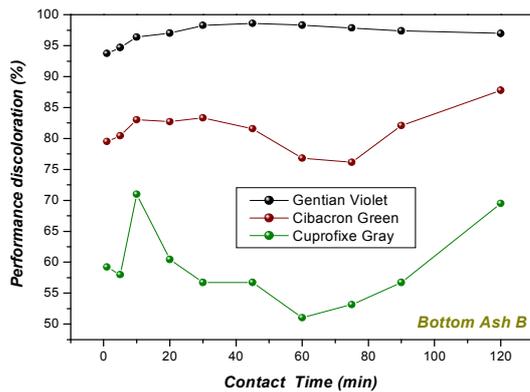
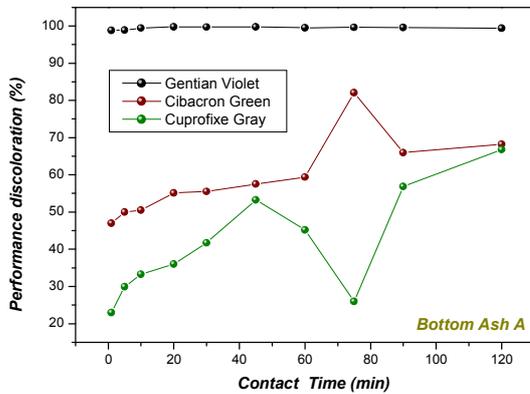


Figure.6. Variation of the fading yield of the three synthetic solutions (Gentian Violet, Cuprofixe Grey and Cibacron Green) by the BA A and BA B as a function of the contact time

The performances of the BA A and B were different with respect to the discoloration of the aqueous Cuprofixe Grey solutions. The BAB had 70.99% more discoloration than the 33.29% BA A

for a contact time of 10 min, despite that the two slags came from the same source. This was due to the affinity of the components of each type of BA with respect to the constitution of the dye and the solubility of the BA constituents which depended on the pH of the mixture, as well as on incineration conditions that changed from every day (a variable incineration temperature at the level of the incinerator influenced the content of the organic load still present in the BA).

Similarly, the behaviors of the BA A and B were different with respect to the discoloration of the aqueous solutions of the Cibacron Green with the BA B exhibiting a better performance of 83.02% compared to the BA A with 50.50% for a contact time of 10 min. This discoloration capacity varied according to the tested dye.

IV. Conclusion

Through the characterization tests carried out in the present study, a better understanding of the properties of the BA was achieved particularly with respect to the influence of the incineration procedure on the final composition, providing a way to predict the slag behavior when it came into contact with wastewater.

The results obtained by the application of the considered physical and chemical methods allowed to draw the following conclusions:

- The BA was a very heterogeneous material that required an important preparation before its upgrading, so the need for a pretreatment such as grinding and crushing, before the incineration step to obtain a less heterogeneous residue.
- The BA had a variable composition which should be mainly mineral but depended on the conditions of incineration and the composition of the incinerated wastes (more selective collection)
- The loss of mass was very important so it was necessary to select a way of the implementation during the depollution to minimize this loss.

The manipulations that had been described and carried out showed that the incineration slag of the HW had a discoloration capacity relatively interesting. These capacities were greatly influenced by the composition of the used BA as well as on the pH obtained from the mixture after contacting.

These results are very promising for the purpose of a real application of depollution of colored wastewater from the textile industry. The idea of combining the "waste/construction material" and the "waste /bleaching material" passages would be very beneficial.

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