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Heavy metals in flue gas emission and ash generated by an incineration plant for hospital and industrial waste in Northern of Algeria

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ABSTRACT/RESUME

Abstract :*Metal elements in ash and flue gas emission samples, generated by an incineration plant of clinical and industrial waste, were investigated at the sole incineration waste plant currently operating in Northern Algeria. We studied the incineration of several types of waste like wastewater treatment plant sludge, expired pharmaceuticals and clinical waste. For each of them, we collected samples of flue gas particulates and ashes after incineration. The characterization of the metal elements associated with the ash and flue gas particulates was carried out by X-Ray Fluorescence analysis (XRF). Flue gas results indicated that the emission concentrations of the regulated metal elements, expressed in mg Nm-3, were in the range of 0.0004 – 0.4090 for Sb+As+Pb+Cr+Co+Cu+Mn+Ni+V+Sn and 0.0005 to 0.1540 for the total of Cd+Ti, while for the regulated toxic metal elements in ash related to the recovery, maturation or storage of solid incineration residues; expressed in percentage, average levels reported were respectively 0, 0.003, 0.0001 and 0.001 for Hg, Pb, Cd and As. The results showed that the contribution of the metal elements analyzed was relatively low for all the matrices analyzed. To confirm the influence of the presence of chlorine in the waste on the concentrations of the metallic elements in the gaseous emissions, a characterization of chlorine and others chemical components as C,Si,K elements in flue gas particles was performed using SEM-EDX.*

I. Introduction

One of the most difficult environmental problems in Algeria is the management of hazardous industrial waste [1]. In Algeria, the activity of waste treatment in general, and hazardous and special hazardous waste is not very developed [2-3]. The lack of interest in this activity is consequential to the national industrial culture, which places greater emphasis on manufacturing than on waste disposal. The persistence of this situation, which tends to neglect waste management, is not without danger for groundwater, the environment and public health[2-3]. Currently, Algeria is consideredas the largest producer of toxic industrial waste in the Maghreb[4]. The quantities generated annually are estimatedto325,000 T for Algeria, 118,900 T for Morocco and 135,525 T for Tunisia. On the other hand, the quantities stored, which are pending elimination,are around 2,500,000 T [4-5]. For other wastes, such as hospital waste, annual quantities are in the order of 40 200 Ts[3].According to the National Program for the Elimination of Special Waste established in 2001by the Algerian Ministry of Environment, the proposed solutions for the disposal of these wastes are currently either storage, export or incineration [2]. Of these, incineration appears to be the most appropriate method for the reduction of certain hazardous wastes. In the last few years, the Algerian authorities have made waste management process a priority[4]. However, it is accepted that the incineration of waste leads to the

formation of various toxic pollutants [6-10]. Among the pollutants that can be generated are the heavy metals contained in the solid residues and atmospheric releases generated after the combustion of waste [11].

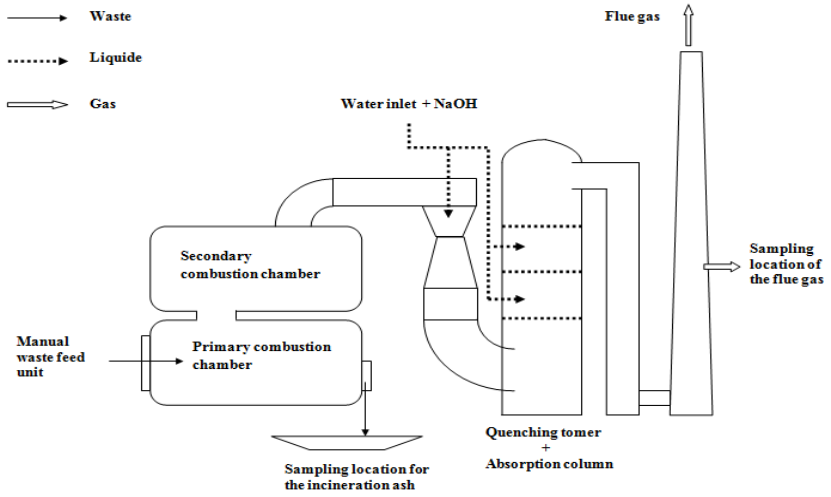

Figure 1.*Schematic of incineration systems*

The term heavy metal refers to antimony (Sb), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se), tellurium (Te), thallium (Tl), tin (Sn), as well as their compounds, while manganese (Mn) and zinc (Zn) are often included [12]. The presence of these metallic elements in the natural environment causes problems, on the human health and the environment, because of their toxicity. In Algeria, only heavy metals in atmospheric and industrial effluents are regulated [13]. Regarding solid discharges, and in particular, those resulting from incineration, no regulations are available. Concentrations of heavy metals in waste fractions vary significantly depending on the composition and source of waste. Several studies on the heavy metal levels generated by the incineration activity have shown that the emission factors for As, Cd, Cr, Cu, Hg, Ni, Se et Zn sont de 0.59, 0.44, 1.56, 1.3, 1,79, 2.06, 5.52, 1,11 et 2.33 mg/GJ [12,14-15]. However, in Algeria, no data are available regarding the levels of heavy metals found in flue gas and incinerator ashes yet. This report is a first step towards filling the gap on existing heavy metals inventories for Algeria. Monitoring the heavy metals in ashes is of primary importance in this country because unacceptable common practices consist in directly depositing them into landfill sites that could affect the environment negatively. In this report, initial findings on the heavy metals composition in the particle samples and ashes released by Algerian incineration plants are presented. The samples were collected from emissions generated by the sole incineration plant of clinical and industrial wastes currently active in the North of Algeria. The plant studied here has four static type ovens each equipped with a wet scrubber with neutralization of acid gases as an air pollutant control device (APCD). We discuss the relationship between the compositions and concentrations of the heavy metals in an incinerator generated ash and particle samples emissions, and comment on the technology of incinerator process and flue gas treatment.

II. Materials and methods

II.1.Description of sampling sites and incineration facility

Samples of gas particles and ashes collected for this study came from an incineration plant of clinical and industrial waste located in the city of Boumerdes – the center region of Northern of Algeria (36° 43 ′29″ North 3° 36′ 55″ East).

The incineration plant has four identical incineration lines; each of these is made up of a static kiln followed by a wet-type smoke gas treatment system (Fig. 1). The static furnace consists of a main combustion chamber equipped with two fuel oil burners delivering a total power of 750 kWmax, which serve to ignite the waste, to ensure combustion and maintain the temperature of the fireplace (850 °C −1200 °C) and to power a primary air fan with a maximum flow rate of 3000 m^3 h^{-1}. The oven is equipped with a waste loading door and a lower hatch for manually collecting incineration residues after cooling down with water. The optimal heat capacity of the furnace does not exceed750 000kcal h^{-1}. Given the characteristics of the various wastes that can be incinerated, the maximum hourly operating capacity, according to the lower heating value of the waste (LHV) can reach to 300 kg h^{-1} (LHV 3500 kcal kg^{-1}) and a minimum of 186 kg h^{-1} (LHV 5500 kcal kg^{-1}). The gases formed during the incineration of wastes in the main combustion chamber pass through a post combustion chamber (secondary combustion chamber) in order to re-burnt, in excess air at

1200°C for 2 s, the unburned wastes and the odors contained in the fumes. The combustion chamber is equipped with a gas burner with a power of 340 kWmax and a secondary air fan with a maximum flow of 1000 m^3 h^{-1}. This room is also equipped with a hatch of visit to ensure the cleaning of it, if necessary. The removal of pollutants generated by the kiln, a so-called "wet" treatment system is placed at downstream of the post combustion. This system makes possible to capture wet dust by wetting in a turbulent medium, acids (HCl, HF, SO_2) in the wet phase by neutralization using a strong base reagent (NaOH), and some heavy metals in the wet phase by washing of water with a neutralization reagent. The flue gas scrubber is sized to process a gas flow rate of 2080 Nm^3 h^{-1} by spraying with water at 1200 l h^{-1} with a smoke outlet rate of 4500m^3 h^{-1} at a dew point temperature of 80 °C (Efficiency on dust: 90% on particles at 5 µm). The scrubber consists of a spray section, a venturi for washing and deducting, a tray absorption column and defusing system. The annualaverage flue gas content analyzed usinga HORIBA PG250 analyzer(purchased from Horiba France) for the various incinerated waste is 6-13.4% Vol for O_2, 2 to 15 ppmfor the CO, 80–145 ppm for NOx and 5-20 ppm for SO_2. The exiting purge water passes through a water treatment system before being discharged or recycled.

II.2sampling protocols

II.2 .1 Incineration ash

After cooling the ash with water to about 50-60 °C, 30 kg of ash mixture was collected from ash containers at the incinerator facility, for eachcampagne of incineration. The samples were takenaccording to the method of the quartering: the elementary catches were grouped, mixed and then divided into 4 parts. Two quarters were eliminated; the remaining 2 were mixed again. This process was repeated until the amount reduced to 8 kg. After that, an approximate quantity of 100 g was taken and stored in brown glass vials having 100 ml capacity (purchased from HTDS - France); for laboratory analysis after homogenization. The samples collected were labeled by Ci notations as shown in Table 1 (i=1 to 10, respectively).

II.2 .2 Flue gas

The sampling of particulate matter contained in flue gases was performed at the stack of the air pollution control device using an isokinetic sampling system (purchased from clean Air Europe, France). The temperature of the gases in the stack during sampling was between 70-80 °C. A schematic of the particle sampling system is shown in Figure .2. This sampling system was recommended by US EPA Method 0023A [16]. The device used in this study for particle sampling consists of a glass tube and a filter holder (Pyrex) heated and maintained at a temperature of 120/130 °C. All parts are made of glass. The gas particles carried by the incineration fumes are trapped in quartz filters having 80 mm diameter (purchased from HTDS - France). The collected filters were labeled by Fi notation (i=1 to 5) and stored with the same conditions as incineration ash in high quality glass boxes. Sampling volume was approximately 1-2 Nm^3. After each sampling event, the system was rinsed with toluene and acetone, respectively. All samples (particles and ashes) were stored without exposure to light at 4 °C in the field until transferred to the laboratory.

Table 1. *Type of waste incinerated*

i	1	2	3	4	5	6	7	8	9	10
Waste	Metformine (Tablets in a blister)	Dictoma (drug)	Sargenor (drug)	sewage sludge	dry ink sludge	various expired drugs	Victoza (Drugs in injectable form)	Klavox (Drugs in solid form)	Waste clinicals	Drug in the form of syrup

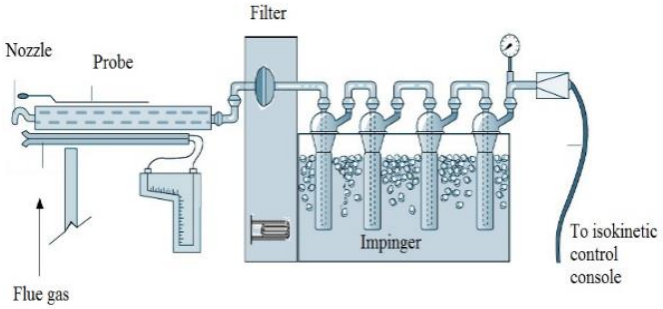

Figure 2. *Schematic of system for particles sampling from flue gas.*

II.2.3. Analysis protocol

II.2.3.1. XRF analysis

To characterize the heavy metals in the solid residues, 50 g of the ashes collected were ground, homogenized and then placed in sample holder. Regarding the particle characterization, blank and loaded filters were cut to the size of 31 mm diameter. The quantitative analysis of As, Ni, Pb, Hg, Cr, Cd, Mo, Zr, Sr, U, Rb,Th, Se, Au, Zn, W, Cu, Co, Fe, Mn, V, Ti, Sc, Ca, K, S, Ba, Cs, Te, Sb, Sn, Ag and Pd in all samples, was performed using the Thermo Scientific XRF analyzer (NITON XL3t) with the highest power (50kV) x-ray tubes (purchased from HTDS - France).

The detection limits of the XL3t XRF analyzer are specified following the United States Environmental Protection Agency (US EPA) protocol of 99.7% confidence level [17]. The Individual limits of detection (LODs) improve as a function of the square root of the count test time.

For the particle samples, field blanks were taken with each series of samples and processedin the same manner as the samples. The concentration of the targeted compounds in the blanks corresponded to less than 10% of the concentrations found among the air samples.

The concentrations of the duplicates obtained in the co-located sites were in good agreement with each other (less than 20%). The recoveries for target heavy metals were between 92% and 109%. The LODs were: 7.13 ng m^{-3} for Pb; 5.51 ng m^{-3} for As; 23.11 ng m^{-3} for Ni; 12.09 ng m^{-3} for Cd; 12.41 ng m^{-3} for Cr; 13.86 ng m^{-3} for Cu; 50.46 ng m^{-3} for Mn; 2.20 ng m^{-3} for Sr; 13.25 ng m^{-3} for Sc and 72.74 ng m^{-3} for Fe.

II.2.3.2. SEM-EDX analysis

The samples of ash and particle were examined by a scanning electron microscopy (JSM-6380 LA) to investigate its microstructure and morphology. The scanning electron microscopy (SEM) was coupled with energy dispersive X-ray analysis (EDX e LINK ISIS with the ZAF-4 measurement program), enabling to determine elemental concentrations in selected spots and areas. The samples were prepared by pressing a tape (Scotch Ruban Adhesive) attached to an aluminum plate onto the filter surface covered with particles. Then samples were coated with carbon (Agar SEM Carbon Coater) to make the sample surfaces conductive. The SEM-EDX was operated at an accelerating voltage of 20 kV, a low vacuum (60 Pa), a spot between 4 and 5, and a counting time of the X-ray spectrum of 15 s. The relative elemental weight percentages (normalized to 100%) were calculated using ZAF^{-4} corrections for the following elements: C, O, Na, Al, Si, Cl, and K.

III. Results and Discussion

III. 1 Toxic metal elements concentrations in ash incineration

The composition of the heavy metals present in the incineration ashes is given in table 2. The results found clearly show the presence of the main toxic metal elements regulated for the recovery, maturation or storage of solid residues (Machefers); such as Hg, Pb, Cd and As. The total average of the four elements recorded in the incineration ashes is 0.0036% with a maximum of 0.018% and aminimum of 0%. The average percentages measured for Hg, Pb, Cd and As are 0, 0.0025, 0.0001 and 0.001% respectively. These values are below the levels required by the regulations and may be valuedif the other parameters (unburnt, solubility, $SO4^{2-}$ and TOCs) will be met (Table 3).In addition to these heavy metals, other toxic metal elements, such as Sb + Cr + Co + Cu + Mn + Ni + V + Sn + Ti, were detected in the solid residues collected from the various incinerated products. The highest average grades for these elements were 0.98 and 2.5%. These maximum values measured respectively corresponded to the ashes of incineration of the expired pharmaceutical products and sludge from urban wastewater treatment plants. The high concentrations detected are mainly due to the initial composition of the waste which probably contained these metallic elements [18-20]. Different studies have shown the presence of heavy metals in the sludge of wastewater stations. The analysis of the metallic trace elements of urban wastewater treatment plant sludge of Baraki (Algiers) showed the presence of several metallic elements such as Cd (7 ppm), Cr (70 ppm), Pb (43.4 ppm), Zn (2240 ppm), Hg (1.36 ppm), Cu (510 ppm) and Mn (256 ppm) [21-24]. For expired pharmaceutical waste, the presence of high levels of metallic elements analyzed, studies have shown that the main sources of the latter are due to the heavy metal levels contained in drugs and packaging of plastics, paper, cardboard and glass [25-26]. The comparison of the average metal elements Pb (0.35%), As (0.03%), Hg (0.0001%), Zn (1.173%), Cu (0.788%), Ni (0.425%), Mn (0.142%), Cr (0.126%), Sn (0.05%) and Cd (0.008) found in the solid waste of industrial waste from eight incinerators (46 analysis in total) [27], showed that these are well below those recorded in this study. In general, the results showed that the characteristics of solid incineration residues are specific for each type of incinerated product. In the latter, other metallic elements have been found which are generally derived from the combustion of fuel oil, such as V (0.01%), Ca (14.43%), Mn (0.209%), S (0.608%), Fe (7.33%), Si (4.43%) and radioactive metals such as Th (0.0005%) which are at higher or lower levels than the regulated elements. These results are in agreement with studies carried out on the characterization of heavy metals in fly ash from fuel oil combustion [28-30].

Table 2. *Metallic elements content measured in ash incineration (%)*

	Ash										
Metalelements	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Average**
Mo	0.001	0.001	0.002	0.001	0	0.001	0.001	0	0.001	0	0.001
Zr	0.009	0.013	0.008	0.011	0	0.006	0.015	0.03	0.045	0.002	0.013
Sr	0.016	0.009	0.046	0.069	0.003	0.024	0.018	0.06	0.053	0.01	0.031
U	0	0	0	0	0	0	0	0	0	0	0
Rb	0	0.007	0.006	0.006	0	0.003	0.002	0	0.002	0	0.003
Th	0	0.001	0	0	0	0.001	0.001	0	0.001	0	0.001
Pb	0	0.001	0	0.017	0	0.002	0.004	0	0.001	0	0.003
Au	0	0	0	0	0	0	0	0	0	0	0
Se	0	0	0	0	0	0.001	0	0	0	0	0.0001
As	0.001	0	0.001	0.001	0	0.002	0.001	0	0.002	0.001	0.001
Hg	0	0	0	0	0	0	0	0	0	0	0
Zn	0.062	0.404	0.146	0.89	0.001	0.736	0.101	0.01	0.104	0.009	0.246
W	0	0.005	0	0	0	0.006	0	0	0.003	0	0.001
Cu	0.012	0.009	0.01	0.017	0	0.063	0.013	0.02	0.007	0	0.015
Ni	0	0	0	0.004	0	0.005	0.013	0	0.003	31.355	0.003
Co	0.107	0	0	0	0	0	0	0	0	0.024	0.011
Fe	34.061	0.514	0.456	2.32	0.014	1.937	1.081	0.53	1.056	0	7.332
Mn	0.038	0.005	0.008	0.063	0	1.675	0.177	0.06	0.035	0.024	0.208
Cr	0	0	0	0.001	0	0	0.015	0	0.002	0	0.002
V	0.024	0.008	0.003	0.005	0	0.008	0.011	0	0.011	0.026	0.010
Ti	6.927	1.848	0.285	0.207	0	2.242	1.372	0.21	1.252	7.738	2.208
Sc	0.016	0.017	0.02	0.017	0.029	0	0.022	0	0	0	0.012
Ca	11.874	10.343	5.051	13.347	12.42	21.35	10.29	30.7	15.011	13.856	14.426
K	0.163	1.737	8.405	0.982	0.064	0.662	0.265	0.69	1.447	0.116	1.452
S	0.469	0.138	0.218	0.839	0.196	2.615	0.671	0.32	0.478	0.135	0.607
Ba	0.018	0	0	0.038	0	0.07	0	0	0.017	0	0.014
Cs	0	0	0	0.002	0	0.003	0	0	0	0	0.0005
Te	0	0	0	0.003	0	0.004	0	0	0	0	0.0007
Sb	0	0	0	0.002	0	0.004	0	0	0	0	0.0006
Sn	0.003	0	0	0.001	0	0.008	0.002	0	0.001	0	0.0015
Cd	0	0	0	0	0	0.001	0	0	0	0	0.0001
Ag	0.002	0	0	0.001	0	0.001	0.002	0	0	0	0.0006
Pd	0	0	0	0	0	0	0	0	0	0	0
Si	6.2513	6.1289	2.003	7.8437	0.073	3.125	2.915	8.84	6.0471	1.0776	4.430
Cl	0.483	0.3898	0.382	0.0606	0.253	3.745	6.481	0.06	0.5317	0.1245	1.251
Total (%)	**53.803**	**15.06**	**14.67**	**18.844**	**12.73**	**31.43**	**14.08**	**32.7**	**19.532**	**53.296**	**26.606**

Table 3. *Potential of release of the metals contained in the slag (mg kg^{-1})*

	Unburned	Soluble	Hg	Pb	Cd	As	Cr^{+6}	SO_4^{2-}	COT
Recoverable	<5%	<5%	<0.2	<10	<1	<2	<1.5	<10 000	<1 500

Maturable	<5%	<10%	<0.4	<50	<2	<4	<3	<15 000	<2 000
Storable	>5%	>10%	>0.5	>50	>2	>4	>3	>15 000	>2 000

Table 4. *Concentration of particles and heavy metals emitted for each waste incinerated (mg Nm-^{3} dry to 11% O2)*

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**ED***
Dust	26.7	30.6	29.5	17.2	3.3	20.3	25.0	1.6	6.8	116.4	10
Sb+As+Pb+Cr +Co +Cu+Mn+Ni+ V+Sn	0,0105	0.0590	0.0013	0.0415	0.0230	0.0004	0.0740	0.4090	0.4313	0.1439	0.5
Hg	-	-	-	-	-	-	-	-	-	-	0.05
Cd+Ti	0.1540	-	-	-	-	-	0.0005	0.0026	0.0025	-	0.05

***European Decree 20/09/02**

III. 2 Toxic metal elements concentrations in flue gas particles

The sampling of the dust emissions of the different waste incinerated (1 to 10) at the incineration stations have given results that meet the limits set by the Algerian regulations[13]. The values obtained ranged from 1.6 to 116.4 mg Nm^{-3} (Table 4). The levels found are due to the fact that the installed treatment system (wet treatment) is very effective for dust removal. Also the maintenance of the high temperature at the post-combustion (> 1000 °C) minimizes the unburnt rate and consequently the dust concentrations at the exit of the furnace [10].The results found are comparable to other studies carried out at the incineration plants. These are slightly higher than those found in some European Municipal waste incineration plants (MSWI) Plants (0.1-10 mg Nm^{-3}) [31-35].This excess is explained by the regulatory restrictions of each country because in European countries, the regulation for atmospheric emissions (dust: 10 mg Nm^{-3}) is stricter than in Algeria (50 mg Nm^{-3}). Also, the release limits are relative to the capacity of the facility. Studies on the particle size distribution in the combustion gases from municipal solid waste incineration have shown that fine particles account for about 70% of coarse particles [36] with varying contents between 1.51 and 14.81 mg Nm^{-3}. Considering these rates, it can be said that the fine particles leaving the chimneys of the incinerators studied for the various incinerated waste varied between 2.68 and 93.12 mg Nm^{-3} with an average of 22.2 mg Nm^{-3} which is close to that found by Chang et al. [36].

The analysis of the toxic metallic elements contained in the dust by the incineration of the various wastes (Table 5) showed the presence of the majority of the regulated heavy metals Hg, Cd, Ti, Sb, As, Pb, Cr, Co, Cu, Mn, Ni , V and Sn. The total concentrations of heavy metals detected ranged from 1.41 to 0.086%. The highest levels were for pharmaceutical waste such as Dictomma (1.41%), Sergore (1.39%) followed by hospital waste (0.87%). These high levels are due to the composition of metal elements of the waste. For example, for the waste studied, we found high levels of Zn, which was probably the major element in the chemical composition of the various waste incinerated. This element can be found either in the package or the medication itself. The comparison of the measured contents compared to the European decree of 20/09/02 [37] showed that the total concentration of metals (Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V + Sn) measured is below the fixed limit of 0.5 mg Nm^{-3}.

The levels closest to this limit correspond to the pharmaceutical waste such as Dictomma and Segore. The analysis also revealed the absence of Hg and exceeding the limit of 0.05 mg Nm^{-3} for the Cd + Ti elements, concerning the liquid pharmaceutical product in the form of syrup. The value of the total concentration of metals (Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V + Sn) measured during this study is close to the mean values measured (0.0051-0.014 mg Nm^{-3}) in some European Municipal waste incineration plants (MSWI) Plants [31-34]. The same concentration was observed for the elements that were at the origin of fuel oil combustion and found in atmospheric emissions at higher or lower average contents, such as V (0.002%) and Ca (0.1728%), Mn (0.0322%), S (0.9878%), Fe (0.1386%), Si (46.15%) and Th (0.0026%) [38-40].The majority ofelements found in the particles collected from the different incinerated wastes were generally Zn, Cu, Pb and Cr. The distribution profile in these metal elements in hospital waste particles and the various pharmaceutical lapses that are most commonly incinerated are in the order of Zn> Cu> Cr>Pb and Cu> Zn>Pb> Cr. These profiles are similar to those found in atmospheric emissions of heavy metals in France [25] and by Chang et al., 2000[36].

III. 3 Characterization of chlorine and others chemical components in flue gas particles by SEM-EDX

For the characterization and study of particle morphology in gaseous releases, filters 2 and 6 were chosen. Figs. 3 and 5 show the images of the particles obtained by SEM for a resolution of less

than 1µm. For the two filters studied, the images show that the particles collected on the filters mainly contain aggregates and separate particles with irregular (mineral) and spherical shapes, emitted by the combustion processes of variable sizes [41-42]. Figs. 3 (b) and 5 (b) show a zoom on the marked areas of a rectangle in Figure 3 and 5 (a). In Figure 3 (b), there are many spherical particles of different sizes. For Figure 5 (b), we also noticed the abundance of the spherical shape compared to the irregular shape. The EDX spectra of the F6 and F9 filters are respectively shown in Figs. 4 and 6. The analysis of the different particulate morphologies and aggregates confirms the presence of various elements such as: C; O; Na; Si; Cl and K. Table 6 shows the quantitative composition of elements in different particles collected in the filters. As shown in Table 6 and 7, C is the major component present in the dusts collected during the incineration of the clinical and drug wastes. C-rich particles are mainly resulting from the poor combustion of waste.

Table 5. *Contents of metallic elements in the dust collected from different waste after incineration (% mass)*

	Filters										
Metalelements	1	2	3	4	5	6	7	8	9	10	**Average**
Mo	0.003	0.005	0.005	0.004	0.003	0.003	0.003	0.002	0.002	0	0.003
Zr	0.002	0	0	0.002	0.02	0.002	0.002	0.002	0.002	0	0.0032
Sr	0.001	0.001	0.001	0.001	0.01	0.001	0.001	0.001	0.001	0.003	0.0021
U	0	0	0	0	0	0	0.001	0	0	0	0.0001
Rb	0	0.079	0.078	0.005	0.011	0.001	0.001	0.002	0.003	0.001	0.0181
Th	0	0.011	0.012	0	0.002	0	0.001	0	0	0	0.0026
Pb	0	0.015	0.014	0.065	0.003	0.002	0.003	0.004	0.004	0	0.011
Au	0	0.008	0.007	0	0.001	0	0	0	0	0	0.0016
Se	0	0.001	0.001	0	0.001	0	0	0	0	0	0.0003
As	0	0.006	0.006	0.02	0.002	0.001	0.003	0.002	0.002	0	0.0042
Hg	0	0	0	0	0	0	0	0	0	0	0
Zn	0.011	1.307	1.295	0.318	0.009	0.075	0.097	0.041	0.828	0.006	0.3987
W	0.002	0.043	0.04	0	0.2	0.031	0.028	0.029	0.035	0	0.0408
Cu	0.002	0.055	0.054	0.015	0.012	0.02	0.019	0.016	0.018	0	0.0211
Ni	0.002	0.006	0.006	0	0	0	0	0	0	0	0.0014
Co	0.24	0	0	0	0	0	0	0	0	0	0.024
Fe	0.759	0.123	0.121	0.037	0.036	0.028	0.219	0.03	0.03	0.003	0.1386
Mn	0.284	0.008	0	0	0	0	0.03	0	0	0	0.0322
Cr	0	0.011	0.011	0.011	0.01	0.011	0.011	0.012	0.01	0	0.0087
V	0	0.001	0.001	0.002	0.002	0.003	0.003	0.003	0.002	0.003	0.002
Ti	0	0.008	0.009	0.003	0	0	0	0	0	0.132	0.0152
Sc	0	0.009	0.01	0.003	0.001	0.001	0.001	0.001	0.002	0.011	0.0039
Ca	0	0.215	0.213	0.202	0.126	0.163	0.128	0.2	0.099	0.382	0.1728
K	0	2.717	2.73	1.17	0.594	1.134	0.075	0.729	4.51	0.897	1.4556
S	0	1.188	1.177	1.786	3.418	0.685	0.038	0.28	0.791	0.516	0.9879
Ba	0	0	0	0	0	0	0	0	0	0	0
Cs	0	0	0	0	0	0	0	0	0	0	0
Sb	0	0	0	0	0	0	0	0	0	0	0
Sn	0	0	0	0	0	0	0	0	0	0	0
Cd	0	0	0	0	0	0	0	0	0	0	0
Ag	0	0.106	0.109	0	0	0	0	0	0	0	0.0215

Pd	0	0	0	0	0	0	0	0	0	0	0
Si	65.682	42.090	4.262	55.520	1.779	43.812	98.13	86.411	34.475	29.414	46.157
Cl	28.763	58.894	59.15	8.088	20.8639	36.369	0.089	5.735	30.678	2.935	25.157
Total	**1.306**	**5.923**	**5.900**	**3.644**	**4.461**	**2.161**	**0.664**	**1.354**	**6.339**	**1.954**	**3.371**

The weight percentages of the C in the filters 6 and 9 are 77.46% and 86.76% respectively. However, regarding the other elements, low percentages were detected (Table 6 and 7). The presence of the high percentage of C in both filters could be attributed to the ratio of C in the clinical and drug wastes and the combustion parameters in the oven. Despite the washing and neutralization of the acid gases by the flue gas treatment system installed, traces of chlorine were detected in the particles collected on the filters studied. The concentration of Clwas found in both filters varied from 0.3 to 6.44%. The presence of carbon and chlorine in combustion particles probably implies the presence of dioxin and furan particles in the combustion waste [10]. On the other hand, the presence of chlorine in the waste promotes the volatilization of heavy metals. These metals present in the incineration waste are not removed by the incineration process but are distributed in ash residues and flue gases. This distribution of heavy metals in the various incineration residues is a function of the physico-chemical characteristics of the metallic elements and the chemical composition of the incinerated waste [43-44]. Studies have shown that the distribution and transfer mechanisms of heavy metals in different effluents are controlled by thermodynamics, combustion parameters in the furnace (temperature, redox condition) as well as the presence of chlorides in the waste [45-49]. It was also reported that some of the metal elements remain in the slag in the form of oxides but in the gases and dust, they will be in the form of more volatile chlorides to condense and redeposit itself [50-53]. This research is in perfect agreement with the results found in our study where they showed the presence of metallic elements in the particles collected but the presence of a high percentage of chlorine does not imply the presence of high levels of heavy metals.

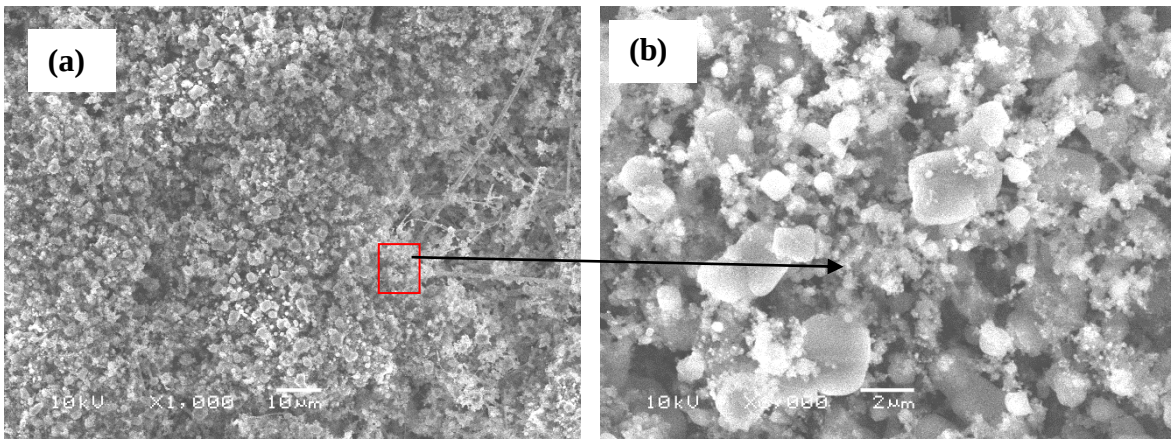

***Figure* 3.** *SEM images of the particles flue gas from waste drugs*

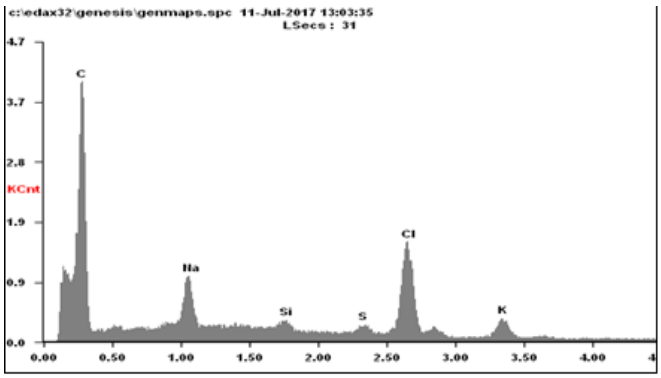

Figure 4. *EDX spectra of the particles flue gas of waste drugs*

Table 6.*Quantitative estimates of the elemental composition of the particles flue gas of waste drugs (F6)*

Element	C(K)	Na(K)	Si(K)	S(K)	Cl(K)	K(K)
wt(%)	86.76	4.09	0.79	0.57	6.44	1.36

K is the electronic layer

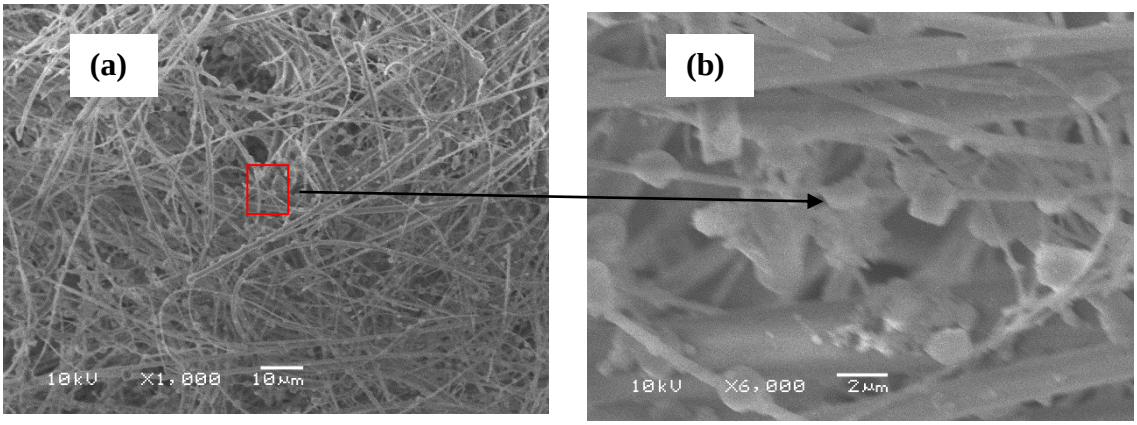

Figure 5. *SEM images of the particles flue gas from waste clinical*

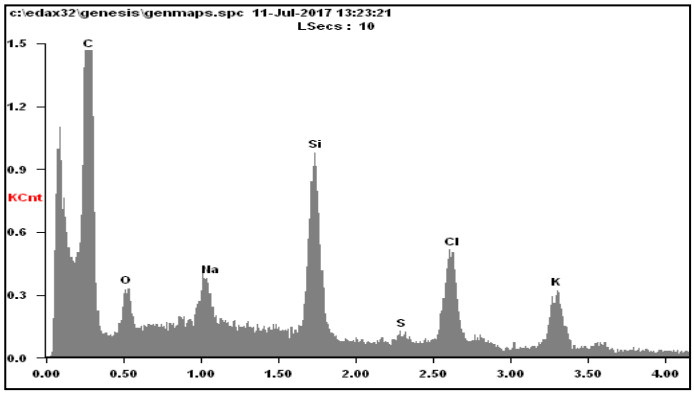

Figure 6. *EDX spectra of the particles flue gas of waste clinical*

Table 7. *Quantitative estimates of the elemental composition of the particles flue gas of waste clinical (F9)*

Element	C(K)	O(K)	Na(K)	Si(K)	S(K)	Cl(K)	K(K)
Wt(%)	77.46	8.85	2.75	0.79	5.08	0.30	2.39

K is the electronic layer

IV. Conclusion

Heavy metal elements in different ash and flue gas emission generated by the incineration of different waste from Algeria, other than classical Municipal Solid Waste Incinerator (MSWI), are investigated in this work for the first time. The results indicate that the metal elements concentrations in gas and ash samples from different types of incineration processes are dominated by relatively high levels when the drug and clinical wastes are burnt. The main reason is related to the heterogeneity of raw and the composition in metal elements of waste incinerated compared to the other type of waste analyzed in this study. In general, we found that levels detected for the samples collected are lowerthan the regulated values and do not represent any environmental issue. Only few data are reported in this non-financially supported study and it definitely would require confirmation at a larger scale in the case where ashes, for example, are going to be the subject of valuation. However, it gives a first report about the metal elements levels found in air and ash samples associated with the management policy of waste incineration in Algeria.

V. References

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