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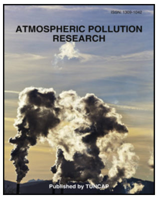

Determination of PCDD/Fs and dl-PCBs in ash and particle samples generated by an incineration plant for hospital and industrial waste in Northern of Algeria

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1. Introduction

In recent years, Algeria has experienced significant urban, economic and industrial development, and has encountered environmental issues regarding the waste management generated by such activities. Among the waste produced, hospital and industrial wastes are strictly regulated by policymakers. The elimination process of these wastes, including hazardous by-products, requires the use of specific treatment techniques. Incineration is presented as an appropriate method for disposal of such substances and Algerian authorities has made this waste management process a priority (Kehila, 2014; Makhoukh, 2004). The destruction of industrial by-products by incineration reduces by 80 percent the weight and volume of the original waste, depending upon the composition of the raw materials burned (Chen et al., 2008a,b). The energy produced during the burning of waste entails the production of water steam, then generating electricity through a turbine and an electrical alternator (Yan et al., 2006). However, waste incineration also generates combustion gases and incineration ashes (Sabbas et al., 2003). Incineration flue gases may emit acidic compounds, fine particulates, heavy metals and trace toxic organic components such as polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polychlorinated biphenyls (PCBs), including dioxin-like PCBs (dl-PCBs), classified as Persistent Organic Pollutants (POPs) and listed in the Stockholm Convention (R.F.I, 2001). The presence of POPs in flue gas emission is affected by the original composition of the waste burned, the incineration conditions and the type of furnace used.

The complex nature of PCDD/Fs and PCBs mixtures found in biotic and abiotic samples complicates the risk evaluation for humans. For this purpose, the concept of toxic equivalent factors (TEFs) has been developed and introduced to facilitate risk assessment and regulatory control of exposure to these mixtures (Safe, 1990). The congener 2,3,7,8-tetrachlorodibenzo-*p*-dioxins (2,3,7,8-TCDD) is the most toxic congener and is given a TEF value of one. Other congeners have TEFs that are fractions of one, reflecting their various toxicities in relation to 2,3,7,8-TCDD.

TEFs are reassessed frequently as our knowledge of them progresses (van den Berg et al., 1998, 2006). The total 2,3,7,8-TCDD toxic equivalent concentration (TEQ), which characterizes the dioxin-like toxicity of a sample, is obtained using the TEQ formula assuming dose additivity (van den Berg et al., 1998). The TEQ levels measured in flue gas and ashes are generally expressed in international toxic equivalents (I-TEQ) for PCDD/Fs while WHO-TEQ are used to express dl-PCBs content.

Currently, very few data exists on emissions of PCDD/Fs and dl-PCBs in Algeria. Only one scientific publication reported sub-pg TEQ m^{-3} levels of PCDD/Fs and dl-PCBs analyzed in ambient air from urban and industrial areas (from 249 to 923 fg TEQ m^{-3}) and in the flue gas of the industrial waste incinerator where level of 268 pq TEQ m^{-3} was found (Moussaoui et al., 2012). Conducting inventories in developing countries is an essential step in implementing an international legally binding instrument on POPs. PCDD/Fs emission inventories have been carried out worldwide on a variety of substances (Quaβ et al., 2000, 2004). For instance, concentration in gaseous emissions have been reported in China (0.019–0.201 ng I-TEQ Nm^{-3}, Chen et al., 2008a,b), Colombia (1–30.3 ng I-TEQ Nm^{-3} Aristizàbal et al., 2007), Portugal (9 -71 ng I-TEQ Nm^{-3}, Ferraz et al., 2003), Poland and Korean (9.7–32 ng I-TEQ Nm^{-3}, 5.86 ng I-TEQ Nm^{-3}, Grochowalski, 1998) and in Korean. Regarding fly ashes, levels were in Taiwan (780–2860 ng TEQ kg^{-1}, Chang et al., 2011), China (140–2680 ng TEQ kg^{-1}, Chen et al., 2008a,b), Japan (3500–6500 ng TEQ kg^{-1}), Colombia (8500–68000 ng I-TEQ/g) (Aristizàbal et al., 2007), Korea (130–2100 ng TEQ kg^{-1}Yun et al., 2013), 1.2 g TEQ/year in Morocco (UNDP, 2005) and 0.05–1.4 g TEQ/year in Egypt (NIPPOP, 2005). However, in Algeria, no data are available regarding the levels of PCDD/Fs and dl-PCBs found in incinerator ashes yet. This report is a first step towards filling the gap on existing POPs inventories for Algeria. Monitoring the PCDD/Fs and dl-PCBs in ashes is of primary importance in this country because unacceptable common practices consist in directly depositing them into

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landfill sites that could affect the environment negatively.

In this report, initial findings on the PCDD/Fs and dl-PCBs 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. Only a few findings are available for emissions from these types of wastes. 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 PCDDs/Fs and dl-PCBs in incinerator generated ash and particle samples emissions, and comment on the technology of incinerator process and flue gas treatment.

2. Material and methods

2.1. 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 gas 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 exceed 700 000 kcal 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 a maximum of 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 during 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.

To removal of pollutants generated by the kiln, a so-called "wet" treatment system is placed downstream of the post combustion. This system makes it possible to capture wet dust by wetting in a turbulent medium, acids (HCl, HF, SO_2) in the wet phase by neutralization by means of 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 4500 $m^3 h^{-1}$ 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 annual average flue gas content analyzed using a HORIBA PG250 analyzer (purchased from Horiba France) for the various incinerated waste is 6–13.4% Vol for O_2, from 2 to 15 ppm for 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.

2.2. Sampling protocols

2.2.1. Incineration ash

After cooling the ash with water to about 50–60 °C, thirty kilograms (kg) of ash mixture are collected, from ash containers at the incinerator facility, for each campaign of incineration. The samples are taken according to the method of the quartering: the elementary catches are grouped, mixed and then divided into 4 parts. Two opposite quarters are eliminated; the remaining 2 quarters are mixed again. This process is repeated until the amount of 8 kg is obtained. Out of these, an aliquot of 100 g is taken and stored in umber glass vials with a capacity of 100 ml (purchased from HTDS - France), for laboratory analysis after homogenization. The samples collected were labeled by notations Ci in Table 1 (i = 1 to 6, respectively).

2.2.2. Particle samples

To sample of the stack gases, particles were collected downstream to air pollutant control device using an isokinetic sampler system (purchased from clean Air Europe, France). The temperature of the gases in the stack during sampling was between 70 and 80 °C.

A schematic of the particle sampling system is shown in Fig. 2. This sampling system was recommended by US EPA Method 0023A (1996). 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 on quartz filters of 80 mm in diameter (purchased from HTDS - France). The collected filters are labeled by notation Fi (i = 1 to 5) and stored with the same conditions as incineration ash in high quality glass boxes. Sampling volume is 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 transfer to the laboratory.

2.3. Chemicals

Nonane Puriss analytical reagent grade, standard for gas chromatography was purchased from Fluka (Steinheim, Germany). Sodium

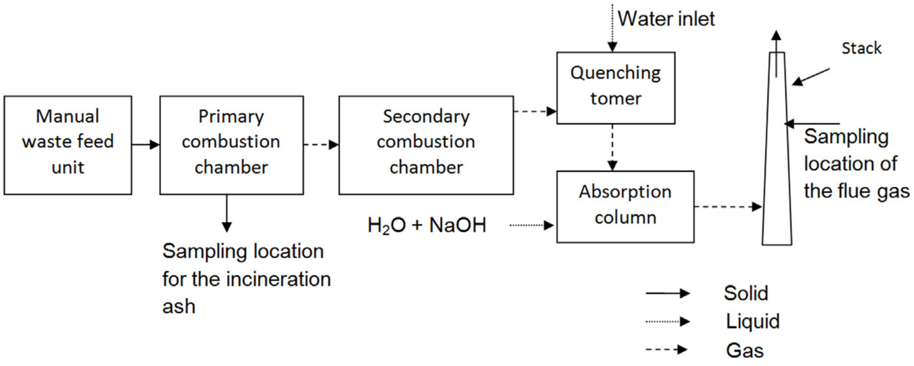

Fig. 1. Schematic of process of incineration system.