The Effect of Combustion Parameters on Gas/Solid Emissions in a Laboratory Scale Incinerator

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Abstract: In this study, municipal solid waste (MSW) samples were incinerated at different temperatures (600, 700, 800, 900, 1000 ˚C) and different air feeding rates in a laboratory scale incinerator. SO_2, NO_2 and HCl for outlet emissions and heavy metal analyses for bottom ashes were carried out. The results indicate that the relationship between temperature and SO_2 emissions were strong in 6 L/min at 900 °C. There is no relationship between NO_2 and temperature, because of unstable structure of NO_x. When it was focused the relationship between HCl and temperatures, it was seen that HCl concentration is the highest in 6L/min at 900 °C. Heavy metal concentrations in bottom ash decreased with temperature rising while air feeding rate was increased. Finally, the results were statistically evaluated by use of SPSS 10.0 program.

Key words: Bottom ash, gas emissions, heavy metals, incineration, solid waste, SPSS

1 Introduction

Incineration technique, commonly used in many industrialized countries, can be applied to sterilize the waste and reduce the volume of material requiring final disposal [1]. However, incineration can substantially reduce the volume of solid wastes incinerated and kill all bacteria, but cannot eliminate any heavy metals at all [2, 3]. Thus, a significant quantity of hazardous pollutants, such as dioxins and furans, HCl, and heavy metals including Cd, Hg, and Pb, has been produced from the incineration of solid wastes (especially healthcare and hazardous wastes).

European Directive (2000/76/EC) on the incineration of waste states that the combustion gas should be raised to a temperature of 850°C for two seconds. If the content of the waste in halogenated organic substances exceed 1% (expressed as chlorine), then the temperature has to be raised to 1100°C while the residence time remains constant at 2 seconds.

In this study MSW samples were incinerated at different temperatures (600, 700, 800, 900, 1000 ˚C) and different air feeding rates in a laboratory scale incinerator. SO_2, NO_2, HCl and heavy metals analysis were carried out for outlet emissions and bottom ashes, respectively. Furthermore, SPSS 10.0 statistical program was used to determine the correlation between temperature and gas emissions and heavy metals.

2 Material and Methods

2.1 Experimental system

The experimental apparatus consisted of a tube furnace and flue gas sampling train (Figure 1). The laboratory scale incinerator made of ASI 310 quality CrNi has a length of 50 cm, 1 m width, and 55 mm inner diameter. Its thermocouple was controlled from three points. Two heads of the incineration tube are flasks. They can be turned down, fixed again easily, and a filter paper is put between them. The heating part of the incineration tube is isolated with ceramic wool. The combustion air was supplied with an air compressor at 3, 6 and 9 L/min and room temperature under 1 atm. The sampling train is composed of five impingers connector in a series. Adopting the modified USEPA method 5 (MM5 method), the first impinger is empty, the second filled with a solution of 0,1 N NaOH, the third filled with solution of absorbing reagent, the fourth filled with solution of 1% H_2O_2 and the last with silica jel. The combustion temperatures were controlled at 600, 700, 800, 900 ºC and 1000 ºC [4].

Figure 1 Laboratory scale tube incinerator

2.2 Sample preparation

In this study, MSW samples were prepared according to following composition: plastic 6.9 %, glass 8.4 %, metal 2.1 %, liquid beverage carton 0.15 %, paper 12.45 %, ash 5 %, food waste 65%. 10 g samples were burned out in laboratory scale incinerator using different temperatures (600-700-800-900-1000 ºC).

2.3 Gas emission analyses

SO_2, NO_2 and HCl were determined by H_2O_2, Saltzman and mercury nitrate method, respectively.

2.4 Heavy metal analyses

Heavy metals (Cd, Cr, Cu, Ni, Pb) in bottom ash were analyzed by atomic absorption spectrometry (Varian mark flame photometer) after acidic digestion based on the analytical method of DIN-38414-S4. Bottom ashes were digested with 28 ml HCl: HNO_3 mixture at 3:1 by volume for 24 h.

2.5 Statistical evaluation

Gas emissions (SO_2, NO_2, HCl,) and heavy metal (Cd, Cr, Cu, Ni, Pb) analysis results were evaluated by SPSS 10.0 program. Multi-variate Pearson analysis was subsequently performed to indicate the possible relationships between temperatures and gas emissions and heavy metals for different air flow rates (3 L/min, 6 L/min and 9 L/min). In this study, if Pearson correlation coefficient is 0.5 or greater than 0.5, we considered that there are good correlation between two parameters and these results are evaluated according to this value. Also, we looked that smaller than 0.05 and 0.01 of significant coefficient [5].

3 Results

In this study, the relationship between temperature-gas emissions and temperature-heavy metal concentrations at different air feeding rates was examined.

Temperature effects on SO_2, NO_2, HCl and heavy metal analysis results are given in Fig. 2, 3, 4 and 5, respectively.

The relationship between temperature and SO_2 emissions were strong in 6 L/min at 900 °C. But, SO_2 concentration decreased when air feeding rate was increased only at 600 °C. There is no relationship between NO_2 and temperature, because of unstable structure of NO_x. Exclusively, when air feeding rate was rised NO_2 concentrations were decreased. HCl is another important component in incinerator emissions. It was seen that relationship between HCl and temperatures, its concentrations highest in 6L/min at 900 °C. Furthermore, when air feeding rate was increased, HCl concentration decreased at 600, 700, 800 and 1000 °C.

Heavy metal concentrations in bottom ash decreased with temperature rising while air feeding rate was increased.

Statistical evaluation of analysis results is given in Table 1. Most noteworthy is the good correlation found between the following parameters.

1. Temperature and Cr, Cu and Cd for 6 L/min; Cr and Cd for 9 L/min.
2. SO_2 and HCl for 6 L/min; NO_2 for 9L/min.
3. Cr and Cd for 3 L/min, 6 L/min and 9 L/min.
4. Ni and Cu for 3 L/min.

Also, correlation between Cr-Cd and Ni-Cu-Cd parameters are in direct proportion for all air feeding rates.

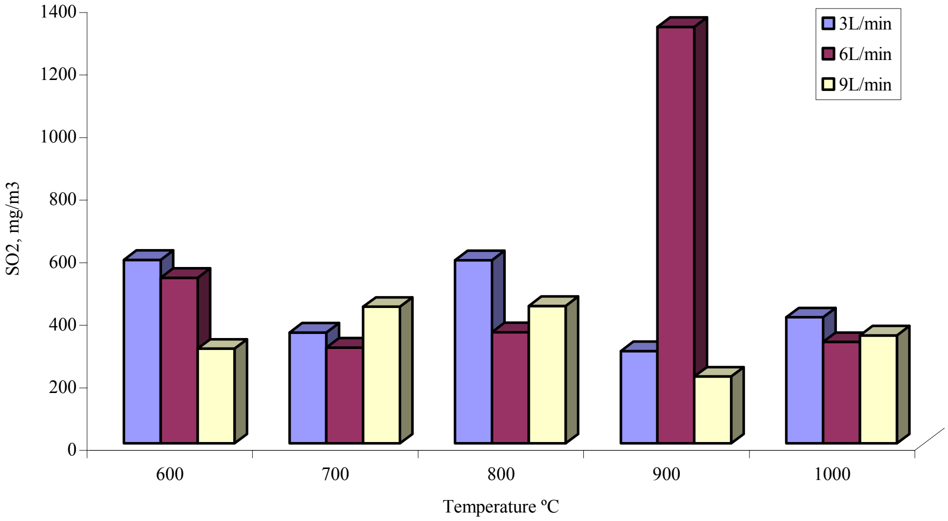


Figure 2 Relationship between temperature and SO_2 emissions

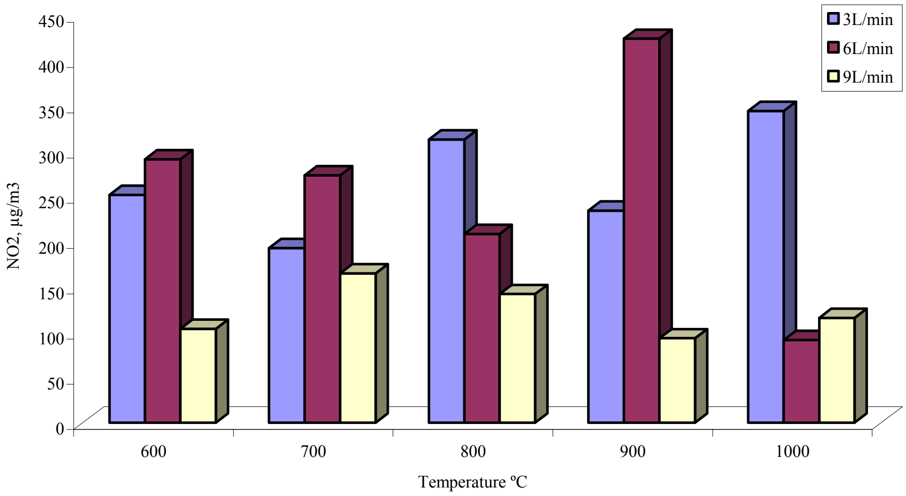


Figure 3 Relationship between temperature and NO_2 emissions

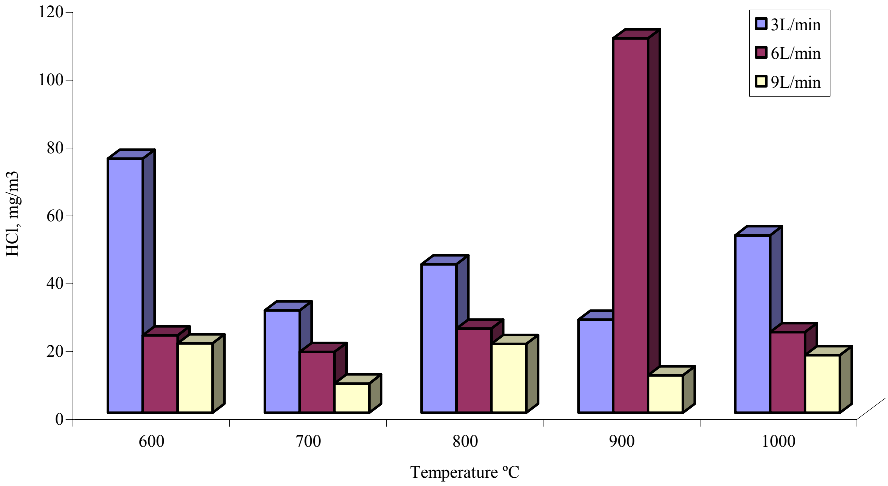
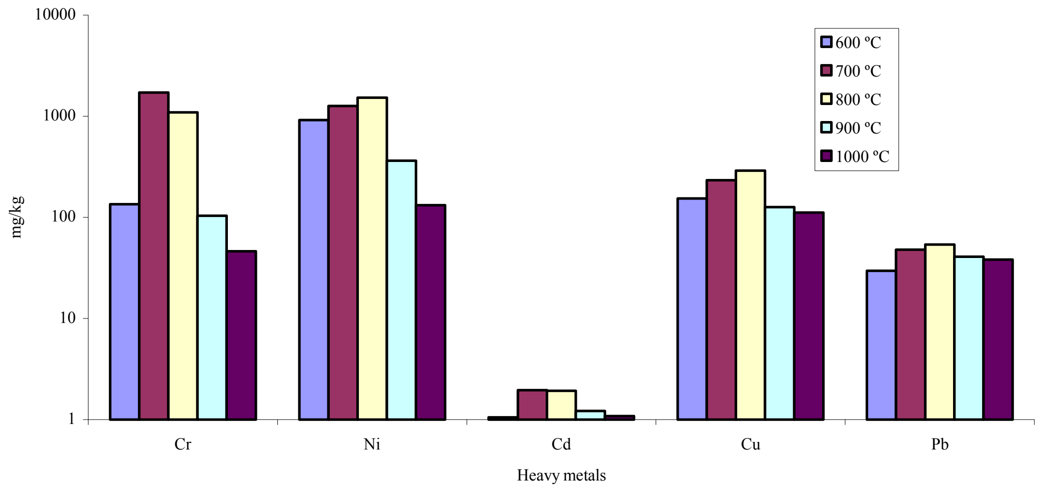
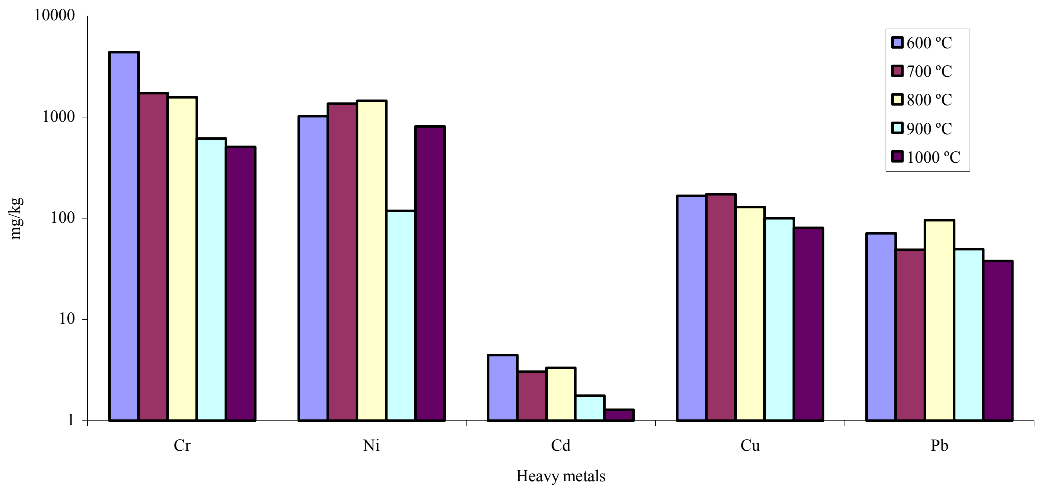


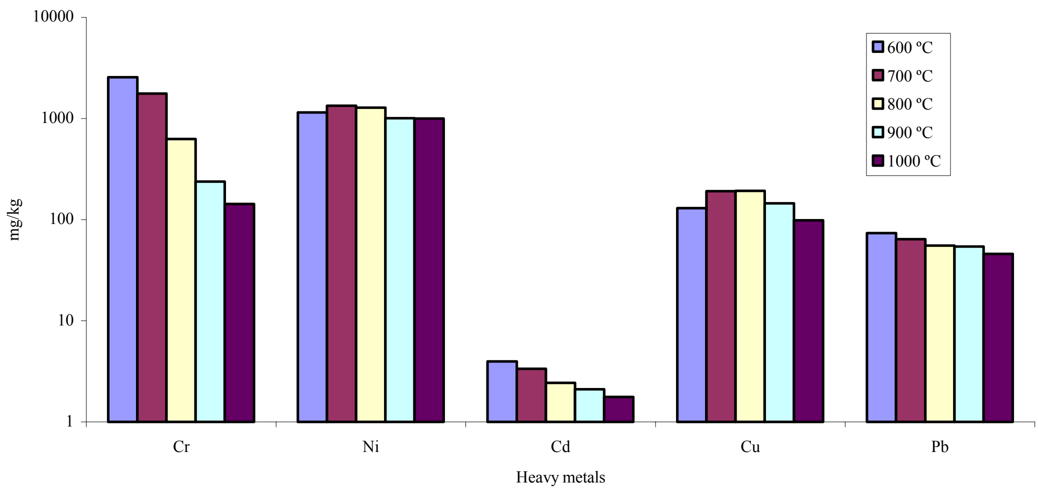
Figure 4 Relationship between temperature and HCl emissions



(a)



(b)



(c)

Figure 5 Relationship between temperature and heavy metals in bottom ash at different air feeding rates a) 3 L/min b) 6 L/min c) 9 L/min

Table 1 (a) Statistical evaluation for 3L/min

	Temperature	SO_2	NO_2	HCl	Cr	Pb	Ni	Cu	Cd
Temperature	1.000								
SO_2	-.502	1.000							
NO_2	.491	.437	1.000						
HCl	-.282	.151	.056	1.000					
Cr	.377	-.280	.224	-.639	1.000				
Pb	-.431	.296	-.205	-.685	.523	1.000			
Ni	.663	-.089	.528	-.775	.796	.358	1.000		
Cu	.581	-.184	.287	**-.915***	.772	.477	**.960****	1.000	
Cd	.235	-.097	.174	-.796	**.952***	.730	.823	.844	1.000

(b) Statistical evaluation for 6L/min

	Temperature	SO_2	NO_2	HCl	Cr	Pb	Ni	Cu	Cd
Temperature	1,000								
SO_2	.224	1.000							
NO_2	-.307	.827	1.000						
HCl	.349	**.970****	.748	1.000					
Cr	**.895***	-.103	-.635	.032	1.000				
Pb	-.378	.156	.518	.027	-.687	1.000			
Ni	.492	.447	.079	.328	.359	.048	1.000		
Cu	**.960****	.478	-.038	.571	.758	-.236	.600	1.000	
Cd	**.950***	.001	-.513	.087	**.921***	-.362	.573	.864	1.000

(c) Statistical evaluation for 9L/min

	Temperature	SO_2	NO_2	HCl	Cr	Pb	Ni	Cu	Cd
Temperature	1.000								
SO_2	-.229	1.000							
NO_2	-.385	**.934***	1.000						
HCl	-.134	.096	-.182	1.000					
Cr	**.953***	-.424	-.587	-.085	1.000				
Pb	-.332	,535	.723	-.320	-.586	1.000			
Ni	.639	-.323	-.363	.003	.500	.190	1.000		
Cu	.427	.017	.087	-.271	.189	.623	.871	1.000	
Cd	**.981****	-.364	-.513	-.146	**.993****	-.486	.552	.286	1.000

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

4 Conclusion

In this study, incineration process that is criticized especially in terms of gas emissions and heavy metals in bottom ash was discussed.

Experimental incineration studies are very complicated and difficult, since there are a lot of parameters affect this kind of system. Therefore, it wasn't obtained strong and consistent correlations between experimental results in this study. Finally, it is thought that to do more experimental studies which will consider other important parameters such as time, waste composition and turbulence for future works.

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