Evaluation of the Incineration Conditions Effects on Gas Emissions by Using a Simulation Software

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Abstract: Waste problem is a very important for rapidly developing country such as Turkey. Paralleling with increasing of life level and changing of consuming habits, waste quantity has increased but on country base an effective waste management system has not been performed yet. On this content, incineration is subjected to environmentally and economically criticism in the waste management system that should be performed regionally. Experimental study, related with this process, is difficult and has various risks. For that reason, generally it was studied on mathematical models relevant with optimum combustion conditions. In recent years, especially it was focused on simulation studies and was developed various optimization techniques. In this study, licensed CYCOM 2004 simulation software, developed through using mass and energy balances for solid and gas phases, was used for stationary kiln and effects of design and operation conditions on gas emissions were investigated.

Key words: CYCOM 2004, gas emissions, incineration, solid waste, simulation.

1 Introduction

There are two important parameters for the design and engineering of an incineration; completely decomposition of the waste and not to exceed the regulation limits for hazardous components in flue gas. These parameters can be achieved through adequate flow regime for the system and therefore controlling of time, temperature and turbulence. Generally, it was studied on mathematical models related to optimum combustion conditions until now because of difficulties and various risks of experimental studies on incinerators. But, in recent years, various optimization techniques were developed through an increasing numbers of studies which are comprised to simulation and experimental results.

Most of the literature studies have been focused on the applications related with design and simulation of incineration systems especially TDW 1.0, PHOENICS, ASPEN PLUS and also CYCOM. PHOENICS was used for researching of consistency between isothermal and non-isothermal models in incinerator [1] while the effects of various waste types on incineration efficiency were examined in TDW software [2]. Furthermore, an integrated model including basic units of incinerators, postcombustion chamber for a rotary kiln incinerator and air pollution control devices was developed in ASPEN PLUS software [3]. Likewise, not only a dynamic modeling of a waste incinerator that would be a stationary, a rotary or a grate kiln can be performed but also economical analysis of the system can be examined by using licensed CYCOM 2004, the software was used for this study [4].

CYCOM 2004 software is a tool used for design and simulation of incinerators, air pollution control devices and heat recovery systems.

CYCOM 2004 uses a design-simulation procedure as different from other simulation systems and provides designs of the equipments which are presented in the flow chart and determination of gas emissions and amount of recovered energy.

This software consists basic equipments (incinerators and postcombustion chambers) and optional equipments (air pollution control devices and heat recovery units) (Fig. 1).

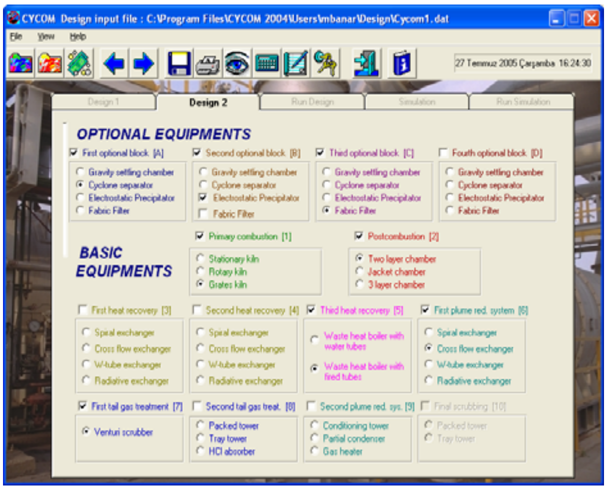


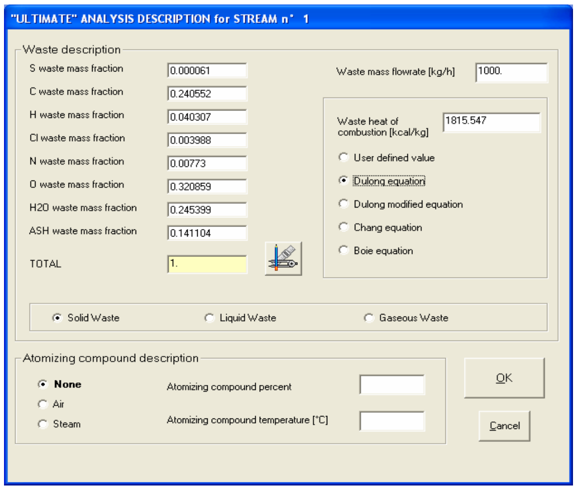
Figure 1 Equipments in CYCOM 2004

2 Simulation Studies with CYCOM 2004

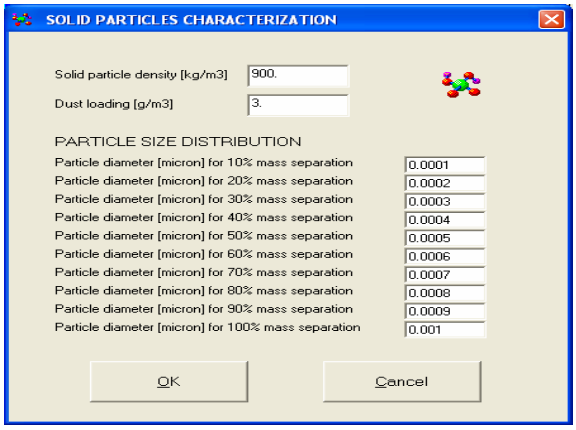
In this study it was aimed that to investigate the effects of design and operation conditions on gas emissions. For that aim, designs for different temperatures in stationary kiln by using CYCOM 2004 were carried out and simulation results were evaluated basing on gas emissions [5].

Ultimate analysis and humidity values of the solid waste used for running of the CYCOM 2004 were normalized and are given in Fig.2(a). Also, distribution of the waste particulate size data is shown in Fig.2(b). Heating value of waste was calculated according to Dulong equation by software. Mass flow rate of waste was assumed as 1000 kg per hour.

Designs for a stationary kiln in different temperatures (600, 700, 800, 900 and 1000 °C) by using the waste composition given in Fig.2(a) were carried out. The flow chart of processes and the sample image of program for 600°C are given in Fig. 3 and 4, respectively. Properties of a laboratory scale incinerator such as refractor conductivity and insulator thickness and conductivity were also used in these designs.



(a)



(b)

Figure 2 (a) Waste composition; (b) Distribution of waste particulate size

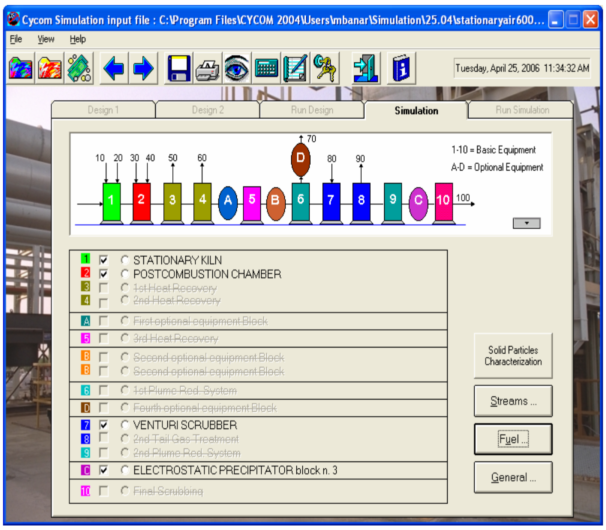


Figure 3 The flow chart of processes

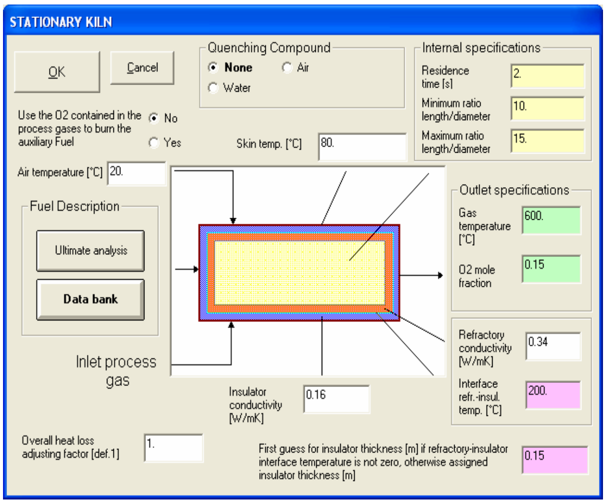


Figure 4 Sample image of program for the kiln operated in 600°C

Furthermore, postcombustion chambers which had different oxygen mole fractions based on operation temperature of kilns and operated in 1200°C were added to the systems and sample image of program for 600°C is shown in Fig. 5. Also, sample image of program for 600°C of venturi scrubber and electrostatic precipitator that had same design parameters for all temperatures are given in Fig. 6 and 7, respectively.

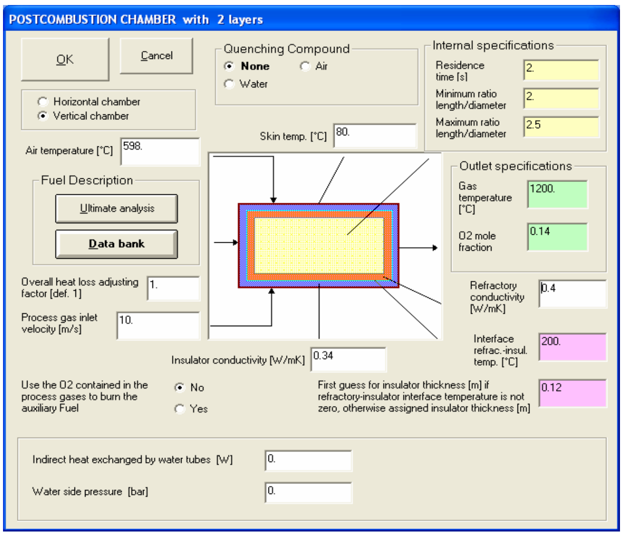


Figure 5 Sample image of program for postcombustion chamber of the kiln operated in 600°C

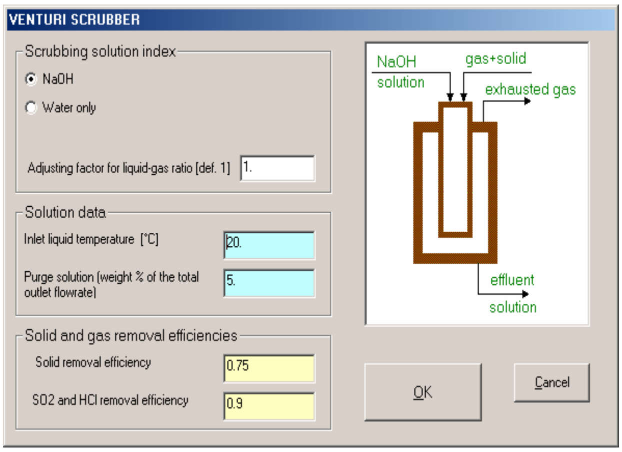


Figure 6 Venturi scrubber

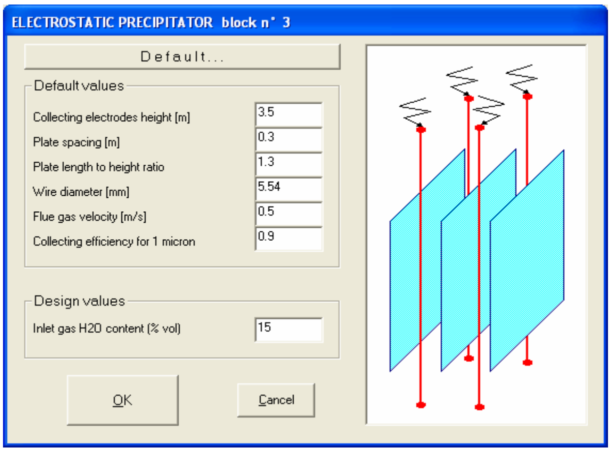


Figure 7 Electrostatic precipitator

3 Results

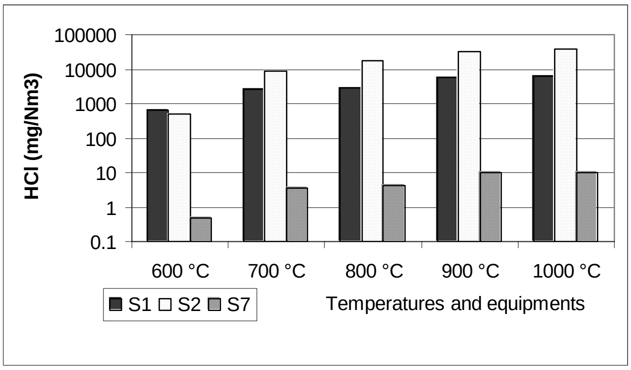
According to these design data, simulation results are given in Table 1 and comparisons of gas emissions for different temperatures are shown in Fig. 8 (a, b, c, d, e).

Minimum value of SO_2 and HCl emissions is obtained in outflow of the venturi scrubber for 600˚C. These emissions were increased in outflow of postcombustion chambers for all temperatures except 600˚C. And also, it was seen an increasing on the total dust emissions in outflow of postcombustion chambers but 99% of dust removal efficiency was obtained after electrostatic precipitator. It's so difficult to make an interpretation for NO_2 emissions since their unstable struvture.

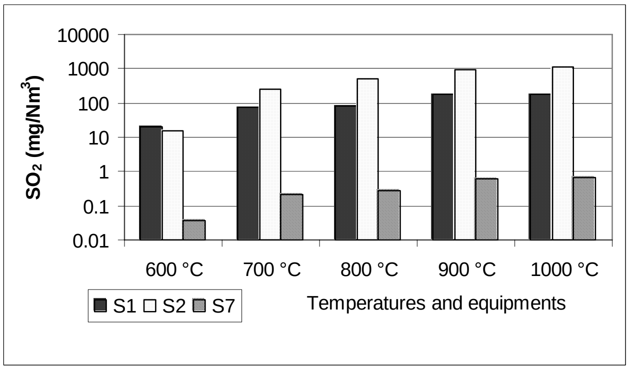
Total dust, HCl, Cl^- and SO_2 results were comprised to the limit values that are given by Air Quality Control Regulation in Turkey (AQCR) (1986) and Directive 89/369/EEC on Air Pollution from New and Municipal Waste Incineration Plants and values are given in Table 2.

Table 1 Simulation results

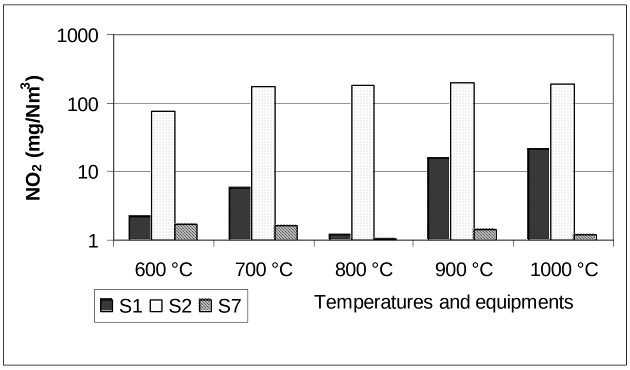
Temperature (°C) / Parameters	600	700	800	900	1000
STATIONARY KILN					
Mass flow rate (kg/h)	1000	1000	1000	1000	1000
Net heating value of waste (kcal/kg)	1815.55	1815.55	1815.55	1815.55	1815.55
Air flow rate (kg/h)	19851	9418	9501	6285	6495
Fuel flow rate (kg/h)	120	12	41	4	30
Total flue gas flow rate (kg/h)	20830	10289	10402	7148	7384
Kiln temperature (°C)	599	699	799	899	999
Unburned waste flow rate (kg/h)	0	0	0	0	0
Heat losses (kW)	58	45	52	48	55
Outlet process stream heat flow (kW)	3670	2203	2599	2074	2424
Internal chamber length (m)	20	16	17	15	16
Internal chamber diameter (m)	1.35	1.11	1.15	1.05	1.09
Refractor thickness (m)	0.26	0.31	0.38	0.43	0.49
Insulator thickness (m)	0.04	0.04	0.05	0.05	0.06
POSTCOMBUSTION CHAMBER					
Inlet gas temperature (°C)	599	699	799	899	999
Outlet gas temperature (°C)	1199	1199	1199	1199	1199
Heat losses (kW)	182	66	52	42	40
Outlet process stream heat flow (kW)	53625	8715	5628	3693	3382
Internal chamber length (m)	13.80	6.67	5.56	4.81	4.66
Internal chamber diameter (m)	5.52	3.18	2.79	2.41	2.33
Diameter of outlet throat (m)	2.76	1.59	1.39	1.20	1.17
Refractor thickness (m)	0.77	0.69	0.67	0.65	0.64
Insulator thickness (m)	0.08	0.07	0.07	0.07	0.07
VENTURI SCRUBBER					
Inlet gas temperature (°C)	1199	1199	1199	1199	1199
Outlet gas temperature (°C)	65	67	68	69	70
NaOH consumption (kg/h)	4.4	4.4	4.5	4.5	4.5
Absorbed HCl (kg/h)	3.9	3.9	3.9	3.9	3.9
Absorbed SO_2 (kg/h)	0.1	0.1	0.1	0.1	0.1
Cross-sectional area of venturi throat (m^2)	0.90	0.14	0.09	0.06	0.05
Active height (m)	0.4	0.4	0.4	0.4	0.4
Loading tube diameter (m)	2.0	0.8	0.6	0.5	0.5
Column diameter (m)	5.8	2.3	1.9	1.5	1.4
ELECTROSTATIC PRECIPITATOR					
Inlet dust loading (g/m^3)	2.15	2.15	2.15	2.14	2.14
Outlet dust loading (mg/m^3)	7.5	6.3	6.1	5.1	1.2
Total collecting area (m^2)	2985	491	368	209	234
Collecting electrodes height (m)	3.9	3.9	3.9	3.2	4.8
Collecting electrodes length (m)	5.2	5.2	5.2	4.1	6.2
Number of gas passages	73	12	9	8	4



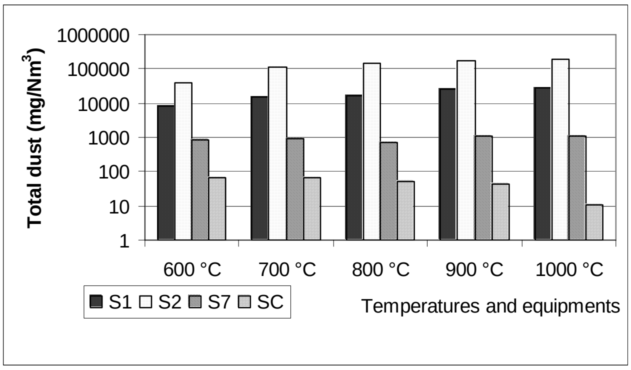
(a)HCl emissions



(b) SO_2 emissions



(c) NO_2 emissions



(d) Total dust emissions

Figure 8 Comparison of the gas emissions from process stages for different temperatures

S1: Outflow of stationary kiln;

S2: Outflow of postcombustion chamber;

S7: Outflow of venturi scrubber;

SC: Outflow of electrostatic precipitator

Table 2 Comparison of simulation results with legal status

Simulation results		Parameter (mg/Nm^3)				
		Total dust		HCl and Cl^- compounds		SO_2
		AQCR	89/369/EEC	AQCR* (Cl^- compounds)	89/369/EEC (HCl)	89/369/EEC
		100	30	100	50	300
Reference condition: 0 °C, 1 atm and %11 O_2 correction						
600 ˚C	Kiln	8052.8		654.74	672.02	20.03
	Postcombustion	40581.3		489.42	503.21	14.88
	Venturi scrubber	823.9		0.45	0.49	0.04
	Electrostatic precipitator	64.9		0.45	0.49	0.04
700 ˚C	Kiln	14889.7		2444.87	2511.31	74.79
	Postcombustion	114696.8		8645.47	8889.00	263.80
	Venturi scrubber	951.15		3.30	3.40	0.22
	Electrostatic precipitator	64.96		3.30	3.40	0.22
800 ˚C	Kiln	16845.44		2729.26	2806.14	83.53
	Postcombustion	145184.10		171075.41	17659.23	527.50
	Venturi scrubber	717.96		3.95	4.06	0.27
	Electrostatic precipitator	52.73		3.95	4.06	0.27
900 ˚C	Kiln	24357.90		5728.58	5889.95	175.29
	Postcombustion	173535.96		31629.66	32520.64	966.02
	Venturi scrubber	1103.89		9.41	9.67	0.62
	Electrostatic precipitator	44.12		9.41	9.67	0.62
1000 ˚C	Kiln	26591.25		6042.34	6211.70	184.84
	Postcombustion	187108.23		37470.08	38525.58	1147.60
	Venturi scrubber	1052.84		9.88	10.16	0.64
	Electrostatic precipitator	10.40		9.88	10.16	0.64

* Air Quality Control Regulation in Turkey

4 Conclusion

In this study, it was seen that an incinerator without a postcombustion and air control devices would have very significant risks in gas emissions. For that reason, a postcombustion operated at 1200˚C providing complete combustion and for HCl, SO_2 and dust removing a venturi scrubber and an electrostatic precipitator were used, respectively.

According to comparisons with legal regulations it was noticed that legal limit values could be only achieved by using these units.

It was thought that to do an economical analysis of the process for future would be a complimentary study.

As a conclusion, design of an incineration process is so difficult since a lot of parameters affect its performance and it needs to be very careful.

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