

## MODELING AND SIMULATION OF THE SCRUBBING UNIT WASTE INCINERATION PLANT

ANA-MARIA CORMOS<sup>1</sup>, CALIN CORMOS<sup>1</sup>, ANTON FRIEDL<sup>2</sup>,  
SERBAN AGACHI<sup>1</sup>

<sup>1</sup> Babes – Bolyai University, Faculty of Chemistry and Chemical Engineering, 11 Arany Janos Street,  
RO-400028, Cluj-Napoca, Romania, Tel: +40264593833, Fax: +40264590818,  
E-mail: cani@chem.ubbcluj.ro, cormos@chem.ubbcluj.ro, sagachi@chem.ubbcluj.ro

<sup>2</sup> Vienna University of Technology, Institute of Chemical Engineering, Fuel Technology and  
Environmental Technology, Getreidemarkt 9/159, 1060 Vienna, Austria, Tel: +43158801/15920,  
Fax: +43158801/15999, E-mail: afriedl@mail.zserv.tuwine.ac.at

**ABSTRACT.** In many incineration processes, especially in waste incineration plants, the resulting flue gas contains acid components such as sulfur dioxide (SO<sub>2</sub>) and hydrogen chloride (HCl) that have to be removed to meet environmental standards.

A scrubbing with alkaline solution (sodium hydroxide or calcium hydroxide) is used as absorption liquor to reduce the content of HCl and SO<sub>2</sub> of the flue gas coming from waste incineration plants.

The absorption process is done in two absorption columns. In the first column the hydrochloric acid (HCl) content of flue gas is reduced at pH value of 1. Second absorption column uses a pH of 8 to reduce sulfur dioxide (SO<sub>2</sub>). Simulation of the Scrubbing Unit Waste Incineration Plant was done using ChemCAD software package.

The evolutions of the process parameters were studied during the scrubbing process. The model and the simulation results proved to be a reliable tool for analyzing the process of removing HCl and SO<sub>2</sub> from gaseous emissions coming from waste incineration plants.

### 1. INTRODUCTION

Because of the passage of the Clean Air Act Amendments in 1990, many industrial processes must reduce acid gases emissions. In many incineration processes, especially in waste incineration, the resulting flue gas contains acid components such as sulfur dioxide (SO<sub>2</sub>), hydrogen chloride (HCl), hydrogen fluoride (HF), sulfur trioxide (SO<sub>3</sub>) and nitrous oxides (NO<sub>x</sub>) that have to be removed to meet environmental standards.

In order to meet legal limits, it is necessary to reduce the content of acid components (especially HCl and SO<sub>2</sub>) of the flue gas coming from waste incineration plants.

The removal of the toxic acid gases is performed through reactions with alkaline sorbents (sodium hydroxide or calcium hydroxide) in wet, semi-dry, and dry processes [1, 2].

Flue gas cleaning is normally done in several steps. Dust and particulates are removed first in cyclones, filters or electrostatic precipitators. Gaseous pollutants such as hydrochloric acid (HCl) or sulfur dioxide (SO<sub>2</sub>) are removed in spray towers, scrubbers, where the gas is sprayed counter-current with a liquid.

A typical effect in scrubbing processes is the variations of scrubber liquid pH when the control system fails to respond in an appropriate way, variations that affect the absorption of pollutants from the flue gas. Scrubber liquid pH is thus an important aspect in flue gas cleaning.

## 2. MODELING AND SIMULATION OF THE SCRUBBING PROCESS

A scrubbing process with alkaline solution (calcium hydroxide) is used as absorption liquor to reduce the content of hydrochloric acid (HCl), hydrofluoric acid (HF) and sulfur dioxide (SO<sub>2</sub>) from gaseous emissions coming from waste incineration plants. The absorption process of acid gases is done in two columns.

In the first scrubbing unit, the saturated flue gas is contacted with calcium hydroxide solution at sour conditions (pH~1). In this column, the neutralization processes of hydrochloric acid and hydrofluoric acid take place. Hydrochloric acid (HCl) and hydrofluoric acid (HF) are removed in the shape of its ions, respectively the corresponding calcium salts.

In the second scrubbing unit at pH~8, sulfur dioxide (SO<sub>2</sub>) from waste gases is removed. In this absorption column, sulfur dioxide is neutralized forming calcium sulfite and calcium bisulfite.

Both scrubbers are supplied with pump-around (in order to use efficiently the absorption liquor). The flow ratio waste water 1: recycled is 0.9:0.1 for the first scrubber and flow ratio waste water 2: recycled is 0.9:0.1 for the second scrubber (see figure 1).

The acid gas components from waste gaseous emissions coming from incineration plant are absorbed in the alkaline calcium hydroxide solution to form salts according to the following chemical reactions:



The temperature, pressure, composition and mass flow of flue gas coming from waste incineration plants are presented in the table 1 [3].

**Table 1.**

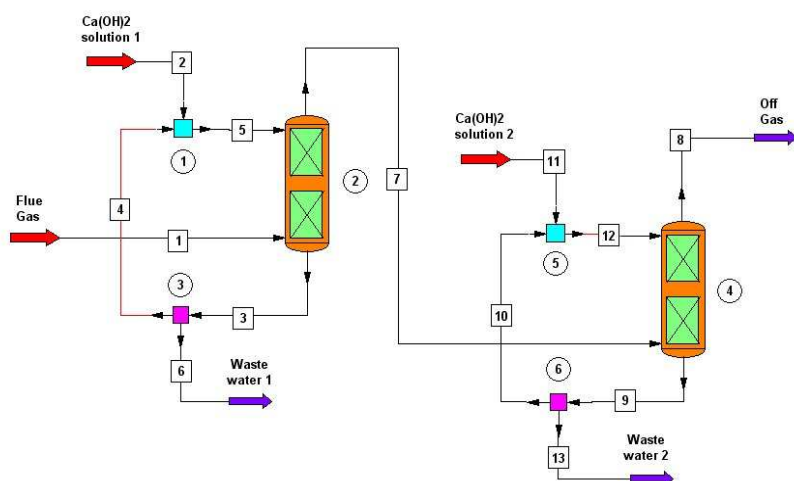
The composition of flue gas

Temperature	[°C]	52
Pressure	[atm]	1
CO <sub>2</sub>	[wt%]	14.4894
CO	[wt%]	0.0033
O <sub>2</sub>	[wt%]	8.7586
N <sub>2</sub>	[wt%]	70.0324
H <sub>2</sub> O	[wt%]	6.7484
SO <sub>2</sub>	[wt%]	0.1247
SO <sub>3</sub>	[wt%]	0.0002
NO <sub>2</sub>	[wt%]	0.0416
HCl	[wt%]	0.0696
HF	[wt%]	0.0017
Flow	[kg/h]	120816.3

## SIMULATION OF THE SCRUBBING UNIT WASTE INCINERATION PLANT USING CHEMCAD

The modeling and simulation of the scrubbing unit waste incineration plant were done using ChemCAD (version 5.1.3) software package. As thermodynamic option used for simulation of the plant, the electrolyte package was used [4].

The main window of the application for wet flue gas purification using calcium hydroxide as absorption liquor is presented in the figure 1.



**Figure 1.** Simulation of wet flue gas purification using ChemCAD

For simulation the scrubbing unit waste incineration plant, the parameters presented in the table 2 were used [2, 3].

**Table 2.**

Parameters of the model		
Column	1	2
Component removed	HCl	SO <sub>2</sub>
Scrubbing - Liquor	10 wt% Ca(OH) <sub>2</sub>	
pH	1	8
No. of stage	2	4
Top pressure	1 atm	1 atm
Legal Limits	15 mg/Nm <sup>3</sup>	100 mg/Nm <sup>3</sup>

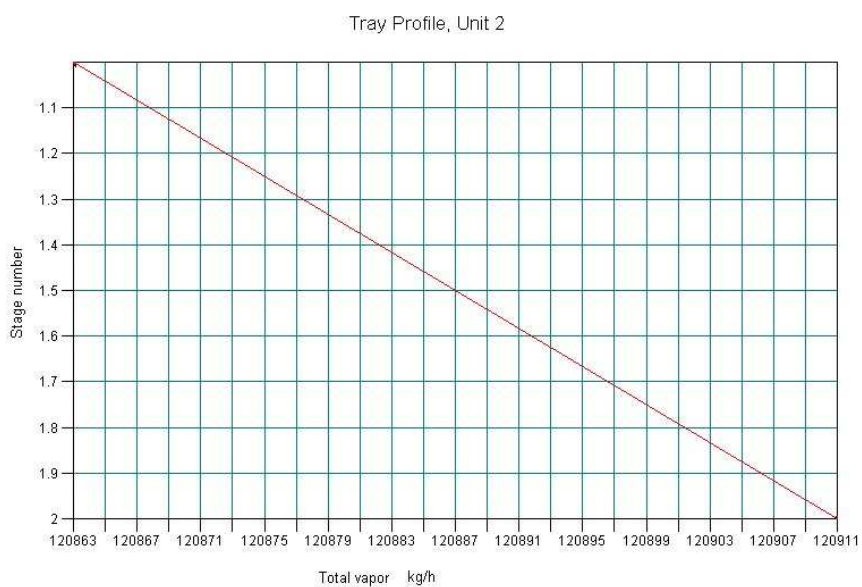
\*) calculated as Cl<sup>-</sup>

### 3. RESULTS AND DISCUSSIONS

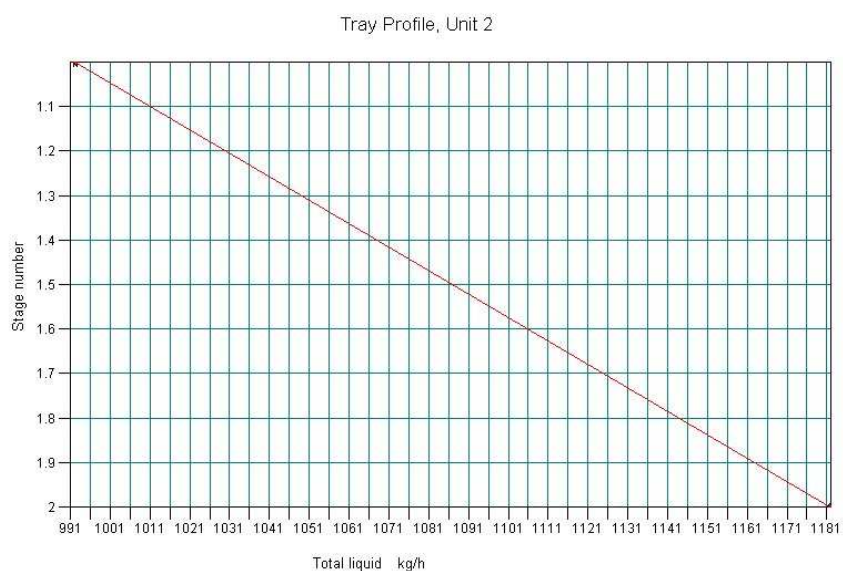
The scrubbing unit waste incineration plant was modeled and simulated using process data presented above. In the both columns, the total vapor flow decrease because of the absorption of acid gas components (hydrochloric acid, hydrofluoric acid and sulfur dioxide) in the alkaline solution (calcium hydroxide).

In the first absorption column, the hydrochloric acid and hydrofluoric acid content of flue gas is reduced at pH value of 1, and in the second absorption column the sulfur dioxide is reduced at pH value of 8.

The variation of total vapor flow, total liquid flow and hydrogen chloride flow for the first column are presented in the figures 2, 3 and 4.

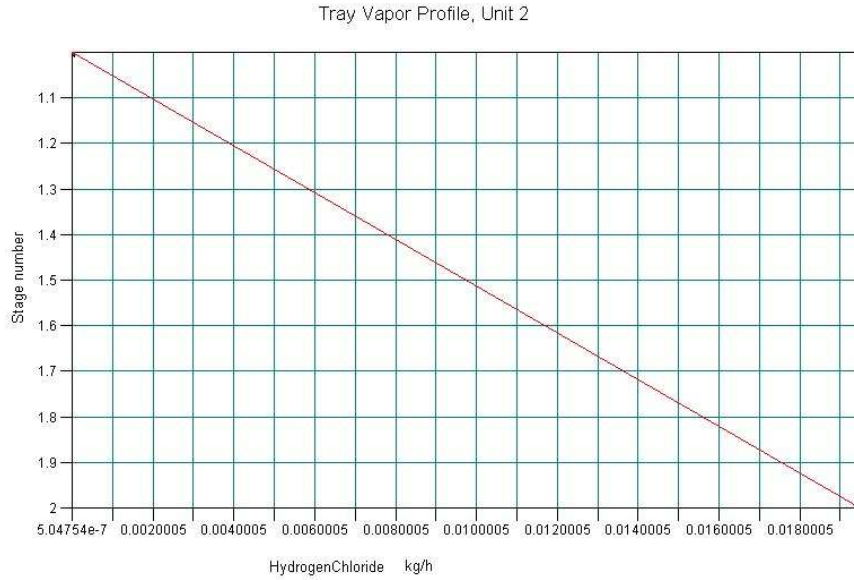


**Figure 2.** Variation of the total vapor flow for the first absorption column



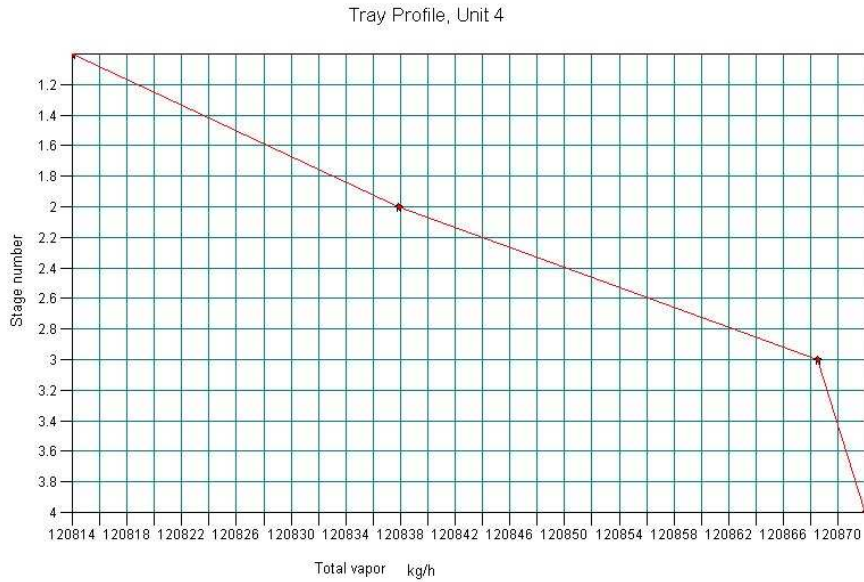
**Figure 3.** Variation of the total liquid flow for the first absorption column

SIMULATION OF THE SCRUBBING UNIT WASTE INCINERATION PLANT USING CHEMCAD

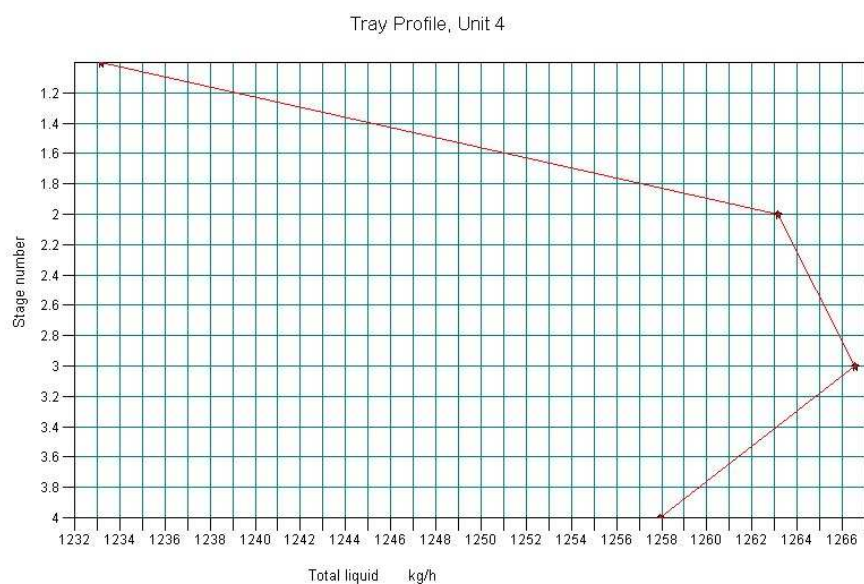


**Figure 4.** Variation of the hydrogen chloride flow for the first absorption column

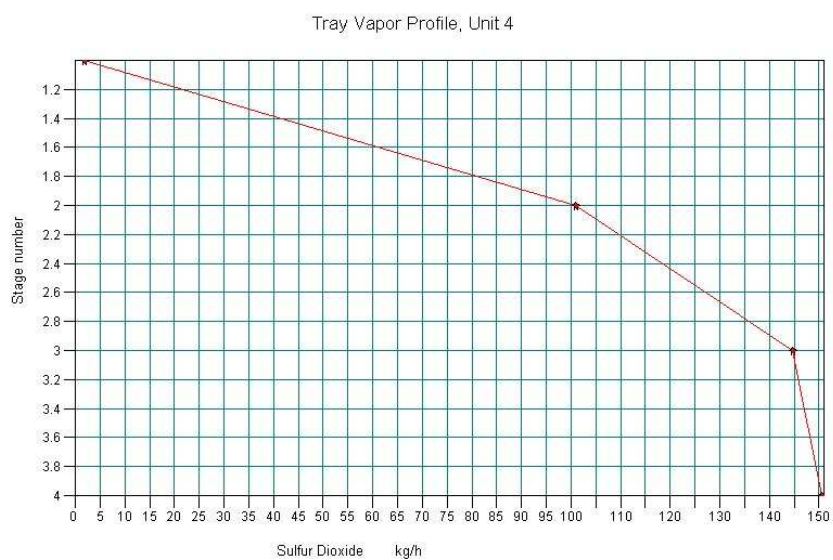
The variation of total vapor flow, total liquid flow and sulfur dioxide flow for the second column are presented in the figures 5, 6 and 7.



**Figure 5.** Variation of the total vapor flow for the second absorption column



**Figure 6.** Variation of the total liquid flow for the second absorption column



**Figure 7.** Variation of the sulfur dioxide flow for the second absorption column

The results obtained from simulation using ChemCAD show that the hydrochloric acid and sulfur dioxide content of the flue gas coming from waste incineration plants was reduced in order to meet the legal limits.

## SIMULATION OF THE SCRUBBING UNIT WASTE INCINERATION PLANT USING CHEMCAD

The hydrogen chloride and sulfur dioxide content of the off gas is  $1.8243 \times 10^{-10}$  [wt%] and respective 0.0016 [wt%]. The calcium hydroxide solution consumption is 825 kg/h for the first absorption column and 1100 kg/h for the second absorption column.

The simulation results and real plant operation data [3] for output gas flows from the first and second columns are presented in the table 3.

**Table 3.**  
The composition of output gas flow from first and second scrubbing unit

Parameter	Unit	Output first column (flow 7)	Output second column (flow 8)	Real plant data (plant emissions)
CO <sub>2</sub>	[wt%]	14.4685	14.4733	14.5
CO	[wt%]	0.0033	0.0033	0.0032
O <sub>2</sub>	[wt%]	8.9868	8.9863	8.4
N <sub>2</sub>	[wt%]	69.9314	69.9552	70.58
H <sub>2</sub> O	[wt%]	6.453	6.5453	6.5
SO <sub>2</sub>	[wt%]	0.1242	0.0016	0.002
SO <sub>3</sub>	[wt%]	0.0001	0.0001	0.0001
NO <sub>2</sub>	[wt%]	0.0355	0.0344	0.0066
HCl	[wt%]	$1.8257 \times 10^{-10}$	$1.8243 \times 10^{-10}$	0.000375
HF	[wt%]	0.0002	$0.4025 \times 10^{-8}$	0.000016
Flow	[kg/h]	120863.2	120227.5	120000

The output liquid flows coming from the first and the second absorption columns (flows 3 and 9 from the figure 1) have the following pH values: 1.02 for the first column and 8.76 for the second column (in a real plant pH values are 1 and 8). The calcium hydroxide consumption resulted by simulation is 192 kg/h, compared with 190 kg/h in a real plant [3].

Modeling and simulation of the scrubbing unit waste incineration plant using ChemCAD, certifies a good pollutants removal at low calcium hydroxide consumption.

#### 4. CONCLUSIONS

Modeling and simulation of the scrubbing unit waste incineration plant was done using ChemCAD software package (version 5.1.3).

The absorption process of acid components (HCl, SO<sub>2</sub>, HF) coming from incineration plant was done using calcium hydroxide solution (10 % mass percent) in two absorption columns. The first absorption column is used to reduce hydrochloric acid (HCl) and hydrofluoric acid (HF) from flue gas at pH value of 1. The second absorption column is used to reduce sulfur dioxide (SO<sub>2</sub>) from flue at pH value of 8.

The evolutions of the process parameters (liquid and gaseous flows, composition of the flue gas) were studied during the process. The simulation results were compared with real plant operation data in order to validate the application developed for the absorption process.

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The mathematical model and the simulation results, using ChemCAD proved to be a reliable tool for analyzing the process of removing hydrochloric acid (HCl) and sulfur dioxide (SO<sub>2</sub>) from gaseous emissions coming from waste incineration plants.

## REFERENCES

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