Journal of Applied Sciences

ISSN 1812-5654

science alert

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 11 (19): 3362-3371, 2011
ISSN 1812-5654 / DOI: 10.3923/jas.2011.3362.3371

Thermo-destruction of Atmospheric Effluents Resulting from Household Wastes Carbonization

[1,3]Kalifa Palm, [3]Serge W. Igo, [3]Inoussa Zongo, [4]N'Wuitcha Kokou,
[1]Alioune Ouedraogo and [2]Belkacem Zeghmati
[1]Universite de Ouagadougou, LCOPA, BP 7021, Ouagadougou, Burkina Faso
[2]Universite de Perpignan, LAMPS-GME, 52 Avenue Paul Alduy, 66860, Perpignan, France
[3]Institut de Recherche en Sciences Appliquees et Technologies (IRSAT),
03 BP 7047 Ouagadougou 03, Burkina Faso
[4]Universite de Lome, Faculte des Sciences, Departement de Physique, BP 1515 Lome, Togo

Abstract: The burning of industrial and agricultural wastes and garbage into ashes brought about significant air pollution characterized by the following gas components: CO, CO_2, CH_4, C_2H_4, H_2O, etc. Among, technologies used to get rid of the components, thermodestruction remained the most efficient one. This study was devoted to thermodestruction modeling in a cylindrical incinerator of gas wastes produced by the combustion of garbage. Dimensionless transfer equations were solved using an implicit numerical scheme, Thomas and Gauss algorithms. Then the analysis of the influence of inlet smoke mass rate on heat and mass transfers was made. Values of the Reynolds number of 500, 1000 and 1750 were considered after a previous study for the values of 750 and 1250. The production of H_2O and CO_2 was even faster when Reynolds number was large during the combustion of effluents of smokes, whereas the thermodestruction was especially faster when the Reynolds number was large. The curves showed that C_2H_4 and CO disappeared completely within 8 sec for Re = 500 and 4 sec for Re = 1750 while for CH_4 the process became inconsiderable within 3.2 sec for Re = 500 and 1.8 sec for Re = 1750. Then, the influence of smoke flow on the evolution of smoke composition over time was analyzed, using an overall chemical kinetic model. The numerical model showed the impact of smokes flow, heat and mass transfers and air excess on the incineration process. It could explain the clean-up of fumes from garbage combustion in an axial entry incinerator; polluting compounds were easily destroyed. Modern incinerators included pollution mitigation equipment such as flue gas cleaning.

Key words: Mass transfers, chemical kinetic, thermodestruction, fumes, garbage

INTRODUCTION

Household waste disposal remains a major problem in cities particularly because of urbanization expansion and the quantity of wastes produced by consumers. Garbage can be recycled in agriculture as a nutrient supply for plants. Thus, Al-Redhaiman *et al*. (2003) showed that when mixed with sandy soil at 1%, 2 or 3, they are a good source of plant nutrients and soil conditioner. Among waste processing techniques, heat treatment is very widespread despite the atmospheric pollution it brings about (Palm, 2008). Indeed, smoke produced by household waste incineration contains several pollutants such as CO, CH, NO, etc. (McKay, 2002; Nammari *et al*., 2004). Thus, a study by Bahillo *et al*. (2004) on the incineration of leather chose waste in Spain shows that 60% of these wastes become smoke made of NO, NO_2, NH_3, SO_2, Cr_2O_2, Cr_2O_3, SiO_2 and carbonaceous gases. The atmospheric emissions of effluents produced by controlled burning of packaging wastes are made up of Hg, Cd, HCl, HF, HBr, NH_3, Ni, Cr, Mn, Cu, Co and Sb which are toxic and harmful to environment (Nammari *et al*., 2004). There are emissions of toxic gases such as NO_x combustion throughout as shown (Mobasheri *et al*., 2009) in a model of a Spark Ignition combustion engine. It is necessary to work on the waste processing technique or the fumes to reduce smoke pollutants. Syamsiro *et al*. (2011) has also shown a CO emission with a loss of mass during pod Husk indonesian experimental combustion. which means that the heat and mass transfers always accompany the process of combustion. This helps to fight against environmental pollution. Among pollution cleaning-up techniques of these atmospheric effluents, thermodestruction proves to be effective. It can be used in cogeneration-based electrical production (Olsommer *et al*., 1997) and meets the

---

Corresponding Author: Kalifa Palm, Universite de Ouagadougou, LCOPA, BP 7021, Ouagadougou, Burkina Faso

characteristics of waste burning power stations. This operation can be carried out in partial load or in overload. The analysis of methods to minimize dioxin gases production in municipal waste burning systems shows that most of these power stations produce dioxins beyond standards set in 1996 (McKay, 2002). To illustrate the mass transfer in the modelings, Belkacem *et al*. (2008) conducted a mathematical study of reverse osmosis process by orthogonal collocation on finite elements method. The model is based on the type of solution-diffusion mass transfer. Heat and mass transfers have been highlighted by Moraveji *et al*. (2011). They study the initial and final sizes of solid particles, the temperatures of the inlet gas and the solid entry. A study by Kumar and Tiwari (2006) on a greenhouse drying of onions, showed the effect of mass loss on the coefficient of heat transfer by convection.

A numerical study of transfers generated by fuel-oxygen mixture combustion in a cubic enclosure shows that speed to which combustion products are formed and the average temperature of gases increases quickly all along the time). Transfer equations are solved by an explicit method with finite differences and Runge-Kutta's level 3 methods (De Bortoli, 2003).

The analysis of volatile gases (CH_4 and C_3H_8) combustion fluidized with a burner, shows the formation of pollutants such as CO and C_2H_4. Their concentrations decrease as areas considered are located around the higher end of the flame (Srinivasan *et al*., 1998). Moreover, the temperature of the flame may be higher than 2,500 K. The experimental analysis based on the structure of a laminar flame of methane combustion and 1.3-butadiene (1,3-C_4H_6) highlights the formation of 154 carbonaceous gas species (Gueniche *et al*., 2007). One part of these gas components undergoes chemical reactions and this process can be modeled by 1,055 chemical reactions. The numerical study carried out using CHEMKIN II software PREMIX program to simulate the combustion of a mixture of impurities and 1.3-butadiene. It revealed a thermal disturbance for the lowest temperatures and a parabolic evolution of molar fractions of combustion products and a temperature of the flame which can reach up to 2,200 K at the upper part of the flame. Yeoh *et al*. (2003) conducted a numerical study of transfers generated by this combustion after solving transfer equations using a finite difference-based implicit method (Stone, 1968). This, to highlight the influence of the combustion model, the radiative transfers and forced turbulent convection on flames produced by propane gas combustion in a compartmentalized parallelepipedic enclosure. In addition, the temperature of the flame can reach 2,100 K. This making the identification of methylene rather difficult, especially as this product reacts in contact with CO_2 to form CO in gases rejected into atmosphere.

This article focused on the modeling of transfers during thermo destruction in a cylindrical incinerator containing smoke. In this model, the composition of garbage used, was given by Tezanou (2003). Transfers generated by chemical reactions due to thermodestruction of the main compounds of smoke (CO, CO_2, CH_4, C_2H_2, H_2O) have been carried out together with transfers of heat, mass and impulsion. One of the goals of this study is to analyze the effectiveness of the incineration of smoke resulting from household wastes combustion.

MATERIALS AND METHODS

This study was conducted in the laboratory of mathematical and physical systems (University of Perpignan, France) and in the laboratory of organic chemistry and applied physics (University of Ouagadougou, Burkina Faso) from November 2005 to May 2008.

Description of the system: The incinerator is a vertical roll, dimensions H = 1 m, d = 1 m, with an entry and a chimney located respectively on the lower and higher parts of the cylinder (de = ds = 0.20 m) (Fig. 1). The walls of the incinerator are made of refractory bricks, isolated by a glass wool layer imprisoned in a steel iron sheet (Palm *et al*., 2008).

Smoke from household wastes combustion enters into the oven through the lower conduit and gases produced by their incineration are rejected outside through the chimney. The study of smoke made up of a simple mixture of gas (sorted waste) which composition may vary (Table 1).

Referential (O, R, Z) has been given to the incinerator, with O as the origin located in the center of its base, the ordinate Z counted positively opposite to the gravity acceleration vector and the r axis perpendicular to the Z axis.

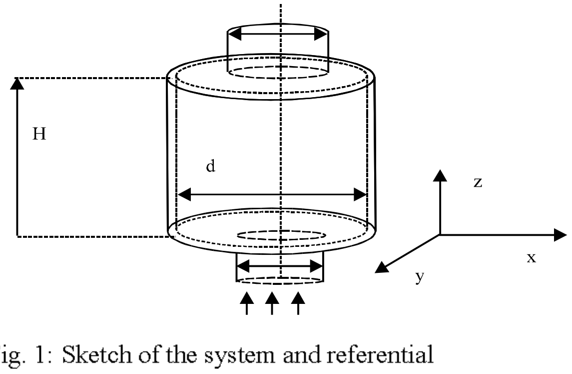

Fig. 1: Sketch of the system and referential

Table 1: Composition of smoke from the burning of pre-selected wastes mixed with air

Mass part	Composition1	% / of smoke	Composition2	%/ of smoke
Y_{air}	0.6918	100 excess of air	0.6918	100 excess of air
Y_{O_2}	0.145278	21 air	0.145278	21 air
Y_{CO}	0.00389	1.26	0.00778	2.52
Y_{CO_2}	0.1738	56	0.1738	56
Y_{H_2O}	0.12251	39.75	0.11262	36.54
Y_{CH_4}	0.003	0.97	0.006	1.95
$Y_{C_2H_4}$	0.005	1.62	0.008	2.59

Let's make the following simplifying hypotheses:

H1: Viscous dissipation is not significant
H2: Smoke composition is homogenous
H3: Dufour and Soret effects are not significant
H4: Pressure gradient according to (O, r) axis is not significant
H5: The system shows a symmetric revolution according to (O, z) axis
H6: The air is made of oxygen O_2 at 21% and nitrogen N_2 at 79%

Transfer equations: Considering simplification hypotheses made below, equations on mass, movement, conservation of energy as well as species diffusion equation must be written in (O, r, z) referential:

Mass conversion equation:

- ∂/∂: Partial derivative:

$$\frac{1}{r}\frac{\partial(rU)}{\partial r} + \frac{\partial(V)}{\partial z} = 0 \tag{1}$$

Equation of motion:

- Following (O, r) axis:

$$\rho\left(\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial r} + V\frac{\partial U}{\partial z}\right) = \mu\left[\frac{\partial^2 U}{\partial r^2} + \frac{1}{r}\frac{\partial U}{\partial r} - \frac{U}{r^2} + \frac{\partial^2 U}{\partial z^2}\right] \tag{2}$$

- Following (o, z) axis:

$$\rho\left(\frac{\partial V}{\partial t} + U\frac{\partial V}{\partial r} + V\frac{\partial V}{\partial z}\right) = -\frac{\partial P}{\partial z} \quad \mu\left(\frac{\partial^2 V}{\partial r^2} + \frac{\partial^2 V}{\partial z^2} + \frac{1}{r}\frac{\partial V}{\partial r}\right) - \rho g \tag{3}$$

- Energy equation:

$$\rho C_p\left(\frac{\partial T}{\partial t} + U\frac{\partial T}{\partial r} + V\frac{\partial T}{\partial z}\right) = \lambda\left(\frac{\partial^2 T}{\partial r^2} + \frac{\partial^2 T}{\partial z^2} + \frac{1}{r}\frac{\partial T}{\partial r}\right) + Q'_{rea} \tag{4}$$

- Species diffusion equation:

$$\frac{\partial Y_k}{\partial t} + U\frac{\partial Y_k}{\partial r} + V\frac{\partial Y_k}{\partial z} = D_k\left(\frac{\partial^2 Y_k}{\partial r^2} + \frac{\partial^2 Y_k}{\partial z^2} + \frac{1}{r}\frac{\partial Y_k}{\partial r}\right) + \sigma_k \tag{5}$$

$$k = O_2, CO, CO_2, H_2O, CH_4, C_2H_4.$$

Conditions on limits and initial conditions are as follow:

- Initial conditions

$\forall\, t<t_0$, t_0 time when smoke enters in the incinerator:

$$U = V = 0.\ T_{inci} = T_0;\ Y_k = Y_{melange}.$$

- Conditions on limits:

$$\forall t \geq t_0$$

- When entering:

$$\frac{d-d_e}{2} \leq r \leq \frac{d+d_e}{2} \quad \text{et} \quad z = 0$$

$$V = V_0;\ U = 0;\ T = T_{entree};\ Y_k = Y_{entree};\ P = -\frac{\rho V_0^2}{2}. \tag{6}$$

- When going out:

$$\frac{d-d_e}{2} \leq r \leq \frac{d+d_e}{2} \quad \text{et} \quad z = H$$

$$\frac{\partial V}{\partial z} = 0;\ \frac{\partial U}{\partial z} = 0;\frac{\partial Y_k}{\partial z} = 0;\frac{\partial T}{\partial z} = 0;\frac{\partial P}{\partial z} = 0 \tag{7}$$

- Lateral walls: $0 \leq z \leq H$ et r = 0 ou r = d:

$$\begin{gathered} U = 0;\ V = 0;\frac{\partial Y_k}{\partial r} = 0\frac{\partial Y_k}{\partial r} = 0; \\ -2\pi H r_1 \lambda\left(\frac{\partial T}{\partial r}\right) = \frac{1}{R_t}\left(T_{pi} - T_{pe}\right) = 2\pi H r_5 h_{air}\left(T_{pe} - T_{amb}\right) \end{gathered} \tag{8}$$

d: Incinerator diameter (m)
H: Incinerator height (m). See the nomenclature

- With:

$$R_t = \frac{1}{2\pi H\lambda_1}\text{Log}\frac{r_2}{r_1} + \frac{1}{2\pi H\lambda_2}\text{Log}\frac{r_3}{r_2} + \frac{1}{2\pi H\lambda_3}\text{Log}\frac{r_4}{r_3} + \frac{1}{2\pi H\lambda_2}\text{Log}\frac{r_5}{r_4}$$

- Horizontal walls:

$$0 \leq r \leq \frac{d-d_e}{2} \quad \text{et} \quad z = 0 \quad \text{ou} \quad z = H$$

$$\frac{d+d_e}{2} \leq r \leq d \quad \text{et} \quad z = 0 \quad \text{ou} \quad z = H$$

$$U = 0;\ V = 0\ \frac{\partial Y_k}{\partial z} = 0;\ \frac{\partial T}{\partial z} = 0 \tag{9}$$

- Axis of symmetry:

$$r = \frac{d}{2} \quad \text{et} \quad 0 \le z \le H \tag{10}$$

Modeling of chemical kinetics: Smoke produced by the burning of household wastes basically contains CO_2, CO, H_2O, CH_4, C_2H_4 NO_x. We therefore, suppose that nitrogenized compounds were eliminated by filtration and microscopic description of chemical kinetics as well as the complete chemical reactions from the combustion of Compounds: CO_2, CO, H_2O, CH_4, C_2H_4 contained in smoke produced through the burning of household wastes are characterized by:

$$CO + \frac{1}{2}O_2 \rightarrow CO_2 \tag{11}$$

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O \tag{12}$$

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O \tag{13}$$

The reaction speeds of these three chemical reactions cannot be used separately since the reaction speed of each fuel species depends on the local oxygen mass fraction which in turn, depends on the progress the other reactions known as concurrent. To solve this problem, we consider a model of overall kinetics, allowing to couple speeds of the three chemical reactions described above.

$$\dot{W} = -kYY_{O_2}\frac{\rho(T)}{M_{O_2}}\exp\left(-\frac{E}{RT}\right) \tag{14}$$

Overall smoke combustion speed (Bergeron and Hallett, 1989).

With:

$$\begin{gathered} k = \sum_i x_i k_i, k_i = k_{0_i}\exp\left(-\frac{E_i}{RT}\right), \\ Y = \sum_i Y_i, M = \sum_i x_i M_i, E = \sum_i x_i E_i \end{gathered} \tag{15}$$

As for every fuel, kinetics constant values are given in Table 2 (Kulasekaran *et al.*, 1999).

In Table 2, the first column contains the values of the frequency factor or pre-exponential k_0 for the Eq. 15. Values in columns 2 and 3 represent the ratio K/E which depends on the temperature of the component considered. E is the activation energy of the gas and R, the gas constant ($R = 8.314$ J mol^{-1} K^{-1}). Being in combustion in our study, the temperature of each component of smoke has been taken equal to the temperature of combustion of fumes. This temperature of fumes in combustion differs from one place to another in the incinerator. Therefore, it should always be compared to 1073 K. When T<1073 K, data in column 2 have been used. Otherwise, use those in column 3 to calculate the rate of disappearance of chemical species (Eq. 14).

Table 2: Kinetic constant values (Kulasekaran *et al.*, 1999)

Component i	k_0 (10^{11}) m^3 mol^{-1} s^{-1}	Ei/R (K) T<1.073 K	Ei/R (K) T>1.073 K
Ethylene (C_2H_4)	37.00	22.753	27.679
Hydrogen (H_2)	2.45	19.551	23.855
Carbon Monoxide (CO)	22.30	19.655	20.734
Methane (CH_4)	7.00	30.196	31.706
Carbon gas (Cgas)	2.50	21.890	21.890

Combustion heat of components selected in this study is supposed to be equal to the sum of heat produced during various combustions of these components. Thus, for (11-13) reactions, it gives (Oturan and Robert, 1997):

$$\Delta H_{CO} = \Delta H_{0CO}^{298} + \int_{298}^{T}\left(M_{CO_2}Cp_{CO_2} - M_{CO}Cp_{CO} - \frac{1}{2}M_{O_2}Cp_{O_2}\right)dT \tag{16}$$

And $Q_{CO} = n_{CO}\Delta H_{CO}$:

$$\Delta H_{CH_4} = \Delta H_{0CH_4}^{298} + \int_{298}^{T}\left(M_{CO_2}Cp_{CO_2} + 2M_{H_2O}Cp_{H_2O} - M_{CH_4}Cp_{CH_4} - 2M_{O_2}Cp_{O_2}\right)dT \tag{17}$$

$$\Delta H_{CO} = \Delta H_{0C_2H_4}^{298} + \int_{298}^{T}\left(2M_{CO_2}Cp_{CO_2} + 2M_{H_2O}Cp_{H_2O} - M_{C_2H_4}Cp_{C_2H_4} - 3M_{O_2}Cp_{O_2}\right)dT \tag{18}$$

Therefore, $Q_{CH_4} = n_{CH_4}\Delta H_{CH_4}$, $Q_{C_2H_4} = n_{C_2H_4}\Delta H_{C_2H_4}$.

Finally, heat quantity in the overall combustion during the burning of CO, CH_4, $C2H_4$ works according to the following relationship:

$$Q_{rea} = Q_{CO} + Q_{CH_4} + Q_{C_2H_4} \quad \text{et} \quad Q'_{rea} = \frac{Q_{rea}}{deS\Delta t} \tag{19}$$

The numerical resolution of a dimensionalized and discretized Eq. 1-5 together with conditions in limits (6-10) was conducted using implicit methods with finite differences, in which axial concentration term was questioned using upstream differences while the other terms with centered differences (Euvrard, 1994; Saatdjian, 1998).

RESULTS AND DISCUSSION

The flow is described by counter-rotating cells around the axis of symmetry of the incinerator in line with one of our hypotheses (Fig. 2a-c). The slight asymmetry is rather due to the use of SURFER software. They start as

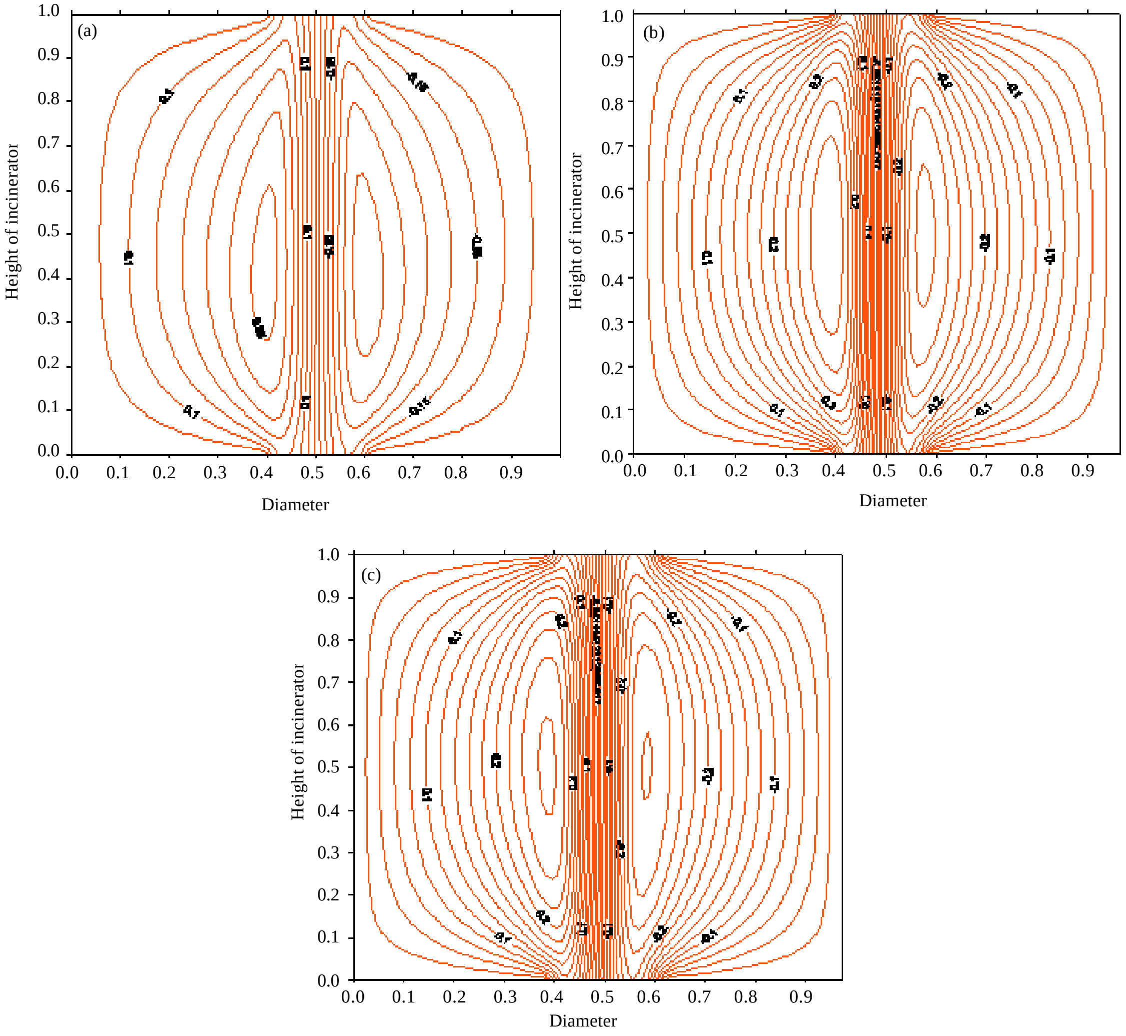

Fig. 2(a-c): Stream functions; (a) Re = 500, (b) Re = 1000 and (c) Re = 1750

soon as they enter the incinerator and merge when they get out. The values of the current lines, upper at the middle of the incinerator, gradually decrease toward the vertical walls. Thus, the distribution of current lines and their values show that the flow goes through its symmetry lining. This is characterized by a transport pulse from the middle to the rest of the incinerator. The values of current lines increase progressively due to the intensification of convective transfer in the incinerator while keeping the structure described above.

The increase in Reynolds number naturally leads to the intensification of convection transfers characterized by higher values in current lines (Fig. 2a-c) and a slight change of flow.

The increase in Reynolds number naturally leads to the intensification of convection transfers characterized by higher values in current lines (Fig. 2a-c) and a slight change of flow.

The analysis of Fig. 3a-c show that isotherms are located in the middle of the incinerator and describe a set of curves symmetrical to the axis of symmetry. This distribution, somehow surprisingly, derives from values given both to the initial temperature and to smoke when entering the incinerator considered equal. In these conditions, thermal loss by conduction-convection through the vertical walls and external environment does not affect significantly thermal transfer in the incinerator. It takes place basically in the middle and does not extend all over the incinerator. The distribution of isotherms is

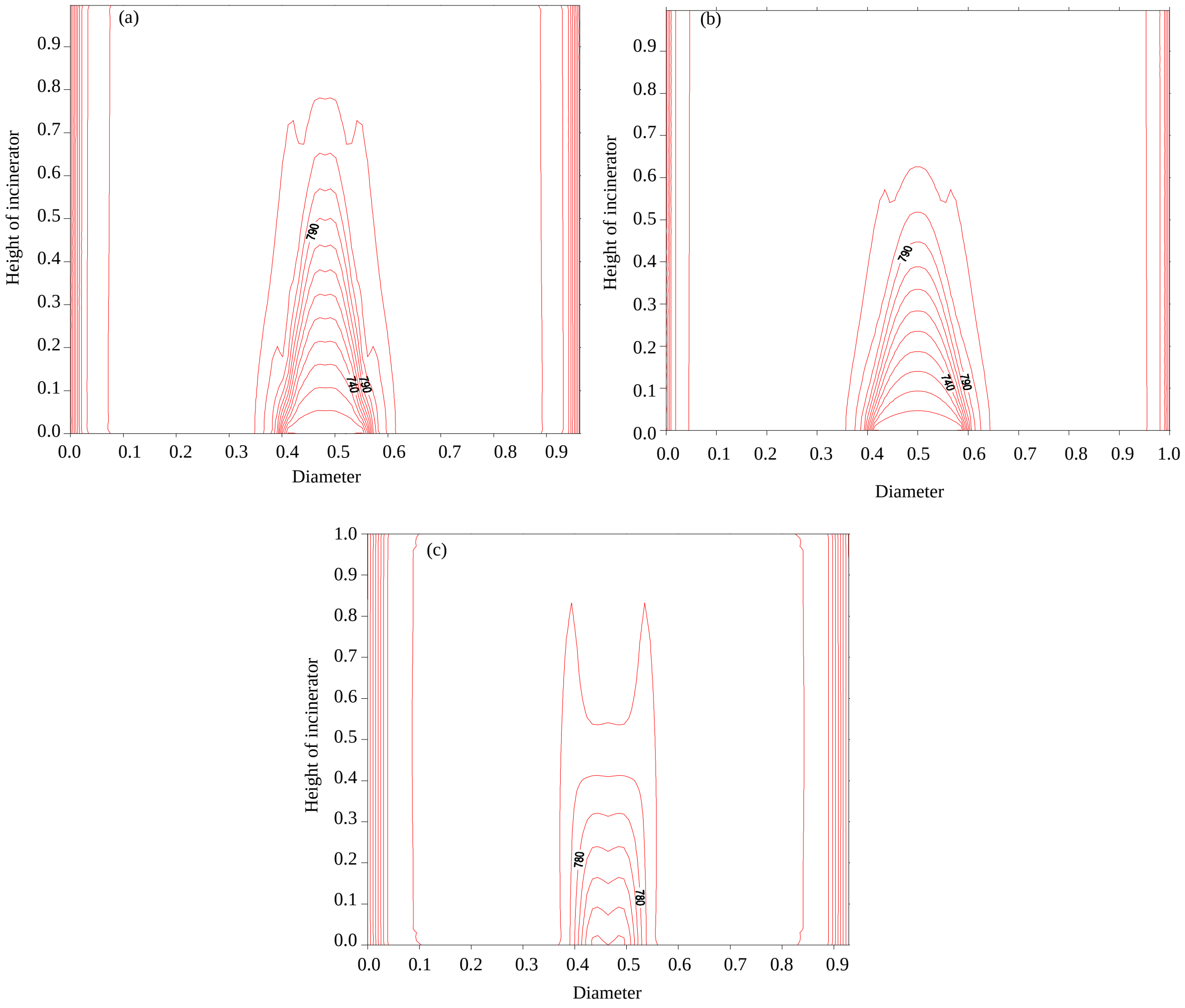

Fig. 3(a-c): Isotherms; (a) Re = 500, (b) Re = 1000 and (c) Re = 1750

similar to that of the current lines characterized by the presence of counter-rotating cells. Near the walls, isotherms that reach their maximum values describe vertical lines, parallel to the walls, showing that thermal transfers mainly occur by conduction.

Yeoh *et al.* (2003) showed the adequacy between the fields of pressure and velocity that was ensured by a SIMPLE algorithm (Patankar, 1980). Thus, their results showed that such laminar flame combustion allowed making a rigorous determination of fractions mass of CO and CO_2 produced by this combustion while radiative and turbulent transfers intensified combustion. Marra and Continillo (1996) made the description of a numerical study of methane flame propagation dynamics in a cylindrical enclosure. The model suggested was based on a pseudo-compressible flow approach, with a projection method to derive the elliptic equation which characterizes pressures disturbances. The results showed the propagation of flame following various combinations of the incinerator geometry and the initial conditions. McLlroy (1998) experimentally determined, using a laser with spectroscopic absorption, the presence of methylene (CH_2) in a flame generated by methane (CH_4) combustion in a parallelepipedic enclosure. The mass fraction of methylene increased with the distance to the burner up to a maximum value before decreasing till zero.

Figure 4a-c show that all combustibles contained in smokes, namely CH_4, C_2H_4 and CO are converted by

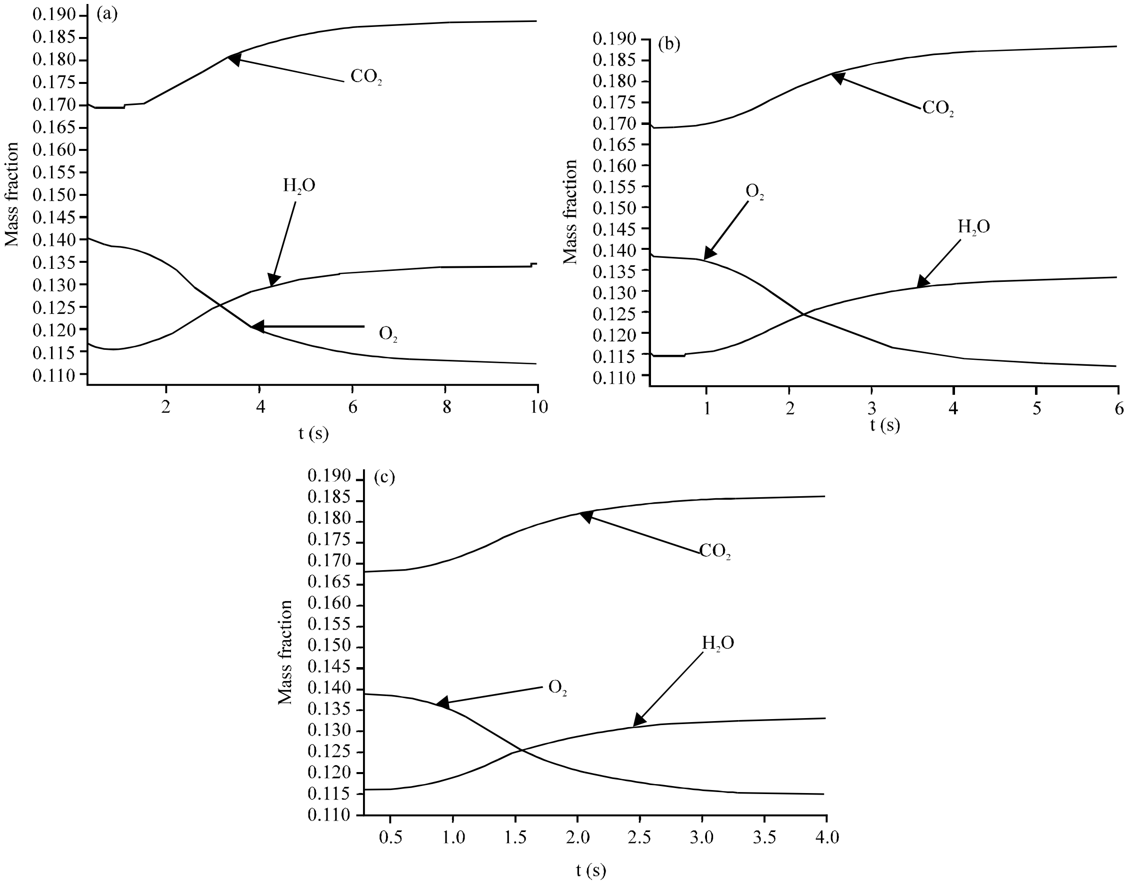

Fig. 4(a-c): Appearance and disappearance of gas just out of the incinerator over time; (a) Re = 500, (b) Re = 1000 and (c) Re = 1750

combustion into water vapor and carbon dioxide. This result is very interesting since house wastes combustion time is about one hour and thirty minutes (1 h 30 min) (Gargouri, 2004).

Mass fractions of CO_2 and H_2O produced increase asymptotically toward maximum values. Mass fraction of CO_2 is 0.18525 after 10 sec for Fig. 4a, 0185 after 2.5 sec for Fig. 4c. As for H_2O, the maximum fraction is 0.13525 after 10 sec in Fig. 4a and 0.12525 after 2.5 sec for Fig. 4c. When Reynolds number increases, the quantities of these two products decrease over time. It appears that the decrease in oxygen mass fraction is actually faster when going from Fig. 4a to 4b and c. This means that the combustion is faster and the quantity of oxygen used over time gets even higher as the Reynolds number increases. Anomohanran (2011) assessed greenhouse gas emissions in the combustion of petroleum products in Nigeria. This revealed that 518.84 million metric tons of CO_2 were released into the atmosphere between 1990 and 2009 in Nigeria; showing that many existing combustions release huge quantities of CO_2 into the atmosphere.

Thus, mass fraction of harmful gases such as CO, released into the atmosphere after 5s of operation does not exceed $5\ 10^{-4}$ (Fig. 5 a-c). In Fig. 5a, mass fractions of CH_4, C_2H_4 and CO decrease hyperbolically to cancel each other out as for the first two and asymptotically toward 0 as for CO. CH_4 complete destruction time is 3.5 sec while that of C_2H_4 is 8 sec. The same types of decreases were noticed in Fig. 5b, c. When going from Fig. 5b to 5c, it can be noticed that this disapearence time decreases from 2.8 sec to 1.75 sec as for CH_4 and from 5.5 sec to 4 sec as for C_2H_4. Regarding the quantity of CO, it reaches its minimum value ($1.25\ 10^{-4}$) within 10 sec for Fig. 5a. This time increases to 6 sec for Fig. 5b and 4 sec for Fig. 5c. So, when Reynolds number increases, thermodestruction gets more and more rapid. Zhang *et al.* (2011) have shown that in a catalytic combustion of natural gas, all CO produced is eliminated by it. They have noticed neither any unburned nor the presence of NO_x in this type of combustion.

The observation shown that methane is the first component to be destroyed followed by ethylene. Carbon

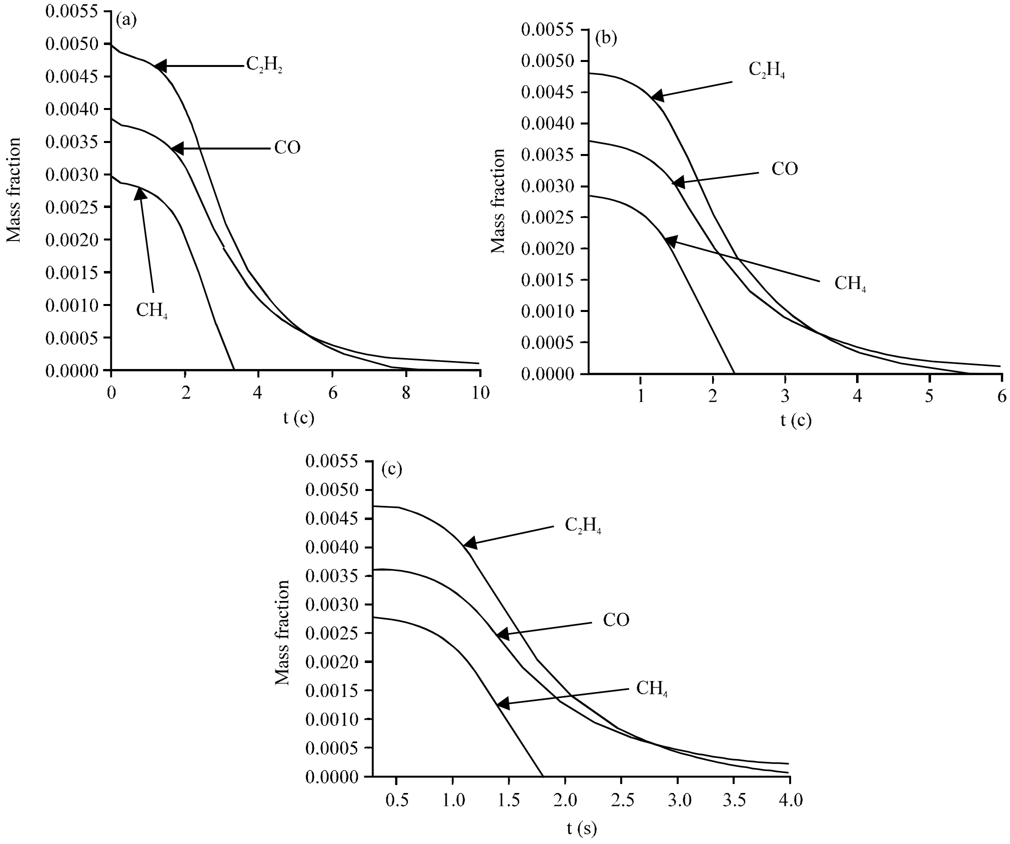

Fig. 5(a-c): Disappearance of gaseous effluents just out of the incinerator over time; (a) Re = 500, (b) Re = 1000 and (c) Re = 1750

oxide is not completely transformed into carbon dioxide but its mass fraction is greatly reduced as it decreases from $50\ 10^{-4}$ to $1.25\ 10^{-4}$ after 9 sec (Fig. 5a). Oxygen is not used up during combustion because mass fraction used in the mixture of smokes when entering the incinerator is that of combustion with 100% excess of air (Table 1). From the highest given value 0.145278 (Table 1) we found the lowest value 0.11 after combustion. Note that for smoke consisting of a mixture of CH_4, C_2H_4, CO, CO_2, H_2O and air whose mass fractions are equal to 0.003, 0.005, 0.0039, 0.1738, 0.1225 and 0.6918, the increase in smoke flow does not impact significantly on thermodestruction components, namely CO, CH_4 and C_2H_4. Thermodestruction time of components like C_2H_4 decreases with the increase in Reynolds number. Indeed, for a Reynolds number of 500, thermodestruction time of C_2H_4 decreases from 9 to 6 sec for a Reynolds of 1000. This method of incineration of gases from household wastes combustion is therefore efficient in the cleaning-up of these smokes.

CONCLUSION

Hereby the incineration of smokes produced by the combustion of household wastes has been equated. This phenomenon is governed by Navier-Stokes' equations on energy and distribution of smoke components. By making these equations discrete through an implicit method we have solved using Gauss' algorithm for motion equation and Thomas' algorithm for other equations. This method uses finite differences and leads to algebraic equation systems. It included a global kinetic model and the equation of radiative transfer in the incinerator. Waste combustion is particularly popular in countries where land is a scarce resource; volume of combusted waste is reduced by approximately 90%.Incineration converts the waste into ash, flue gas and heat. The flue gases must be cleaned of gaseous and particulate pollutants before they are dispersed into the atmosphere. We conducted a numerical study of the incineration of smoke produced through household wastes combustion using laminar system. Then, we analyzed, by using an overall chemical kinetic model, the influence of smoke flow on the evolution of smoke composition over time. Finally, the results show that polluting compounds of this smoke are easily destroyed. So, it shows the effectiveness of this type of incineration of smoke from household wastes combustion.

NOMENCLATURE

Cp = Smoke-air mixture calorific capacity ($J\ kg^{-1}\ k^{-1}$)
d = Incinerator diameter (m)
D = Diffusion coefficient ($m^2\ s^{-1}$)
E = Activation energy ($J\ mol^{-1}$)
g = Gravity acceleration (≅ 9.81 $m\ s^{-2}$)
h = Natural convection heat transfer coefficient ($W\ m^{-2}\ K^{-1}$)
H = Incinerator height (m)
ΔH = Heat content ($KJ\ mol^{-1}$)
Q = Heat produced during the burning (KJ)
Q’ = Burning heat ($w\ m^{-3}$)
M = Molar mass ($kg\ mole^{-1}$)
n = Moles number (mole)
ΔH_0^{298} = Burning standard heat content at 298 K ($KJ\ mol^{-1}$)
k = Reaction speed constant ($m^3\ mol^{-1}\ s^{-1}$)
K_0 = Frequency factor or pre-exponential ($m^3\ mol^{-1}\ s^{-1}$)
P = Dynamic pressure (Pa)
Q_{rea} = Reaction heat (KJ)
r = Radial ordinate (m)
R = Perfect gases constant (≅ 8.314 $J\ mol^{-1}\ K^{-1}$)
S = Surface (m^2)
R_t = Isolation thermal resistance ($W^{-1}\ K$)
Re = Reynolds number ($= \frac{V_0\, de}{v_0}$)
T = Temperature (K)
U = Speed radial component ($m\ s^{-1}$)
V = Speed axial component ($m\ s^{-1}$)
$\dot{W}$ = Smoke burning overall speed (s^{-1})
x = Molar fraction
Y = Mass fraction
z = Axial ordinate (m)
λ = Thermal conductivity ($W\ M^{-1}\ K^{-1}$)
μ = Mixture dynamic viscosity ($kg\ m^{-1}\ s^{-1}$)
ρ = Density of air-smoke mixture ($kg\ m^{-3}$)
σ = Species disappearance and appearance speed (s^{-1})
∂ / ∂ = Partial derivative

Indexes:

amb = Ambient
e = Incinerator entry
F = Fluid
I = Types of isolation
inci = Incinerator
k = Various species contained in smoke
pe = External wall
pi = Internal wall
rea = Smoke burning reaction
s = Incinerator exit

REFERENCES

Al-Redhaiman, K.N., I.N. Nassar and I.S. Al-Salamah, 2003. Effect of the municipal garbage on the growth of lettuce. Asian J. Plant Sci., 2: 731-737.

Anomohanran, O., 2011. Estimating the greenhouse gas emission from petroleum product combustion in Nigeria. J. Applied Sci., 11: 3209-3214.

Bahillo, A., L. Armesto, A. Cabanaillas and J. Otero, 2004. Thermal valorization of footwear leather wastes in bubbling fluidized bed combustion. Waste Manage., 24: 935-944.

Belkacem, A., S.E.M.L. Kad and O. Belhamiti, 2008. Mathematical modeling of reverse osmosis process by the orthogonal collocation on finite element method. Asian J. Applied Sci., 1: 1-18.

Bergeron, C.A. and W.L.H. Hallet, 1989. Autoignition of single droplets of two-component liquid fuels. Combust. Sci. Technol., 65: 181-194.

De Bortoli, A.L., 2003. Mixing and chemical reacting flow simulation inside square cavities. Applied Numerical Math., 47: 295-303.

Euvrard, D., 1994. Numerical Solving of Partial Differential Equations. 3rd Edn., Masson, Paris, pp: 329.

Gargouri, T., 2004. Theoretical and experimental study of combustion-incineration of air effluents generated by burning wood. Ph.D. Thesis, University of Perpignan.

Gueniche, H.A., P.A. Glaude, R. Fournet and F. Battin-Leclerc, 2007. Rich premixed laminar methane flames doped by light unsaturated hydrocarbons. II. 1,3-butadiene. Combust. Flame, 151: 245-261.

Kulasekaran, S., T.M. Linjewile and P.K. Agarwal, 1999. Mathematical modelling of fluidized bed combustion 3. Simultaneous combustion of char and combustible gases. Fuel, 78: 403-417.

Kumar A. and G.N. Tiwari, 2006. Effect of mass on convective heat transfer coefficient during onion flakes drying. Am. J. Food Technol., 1: 1-18.

Marra, F.S. and G. Continillo, 1996. Numerical study of premixed laminar flame propagation in a closed tube with a full Navier-Stokes approach. Symp. (Int.) Combustion, 26: 907-913.

McKay, G., 2002. Dioxin characterization, formation and minimization during municipal solid waste (MSW) incineration: Review. Chem. Eng. J., 86: 343-368.

McLlroy, A., 1998. Direct measurement of ${}^1CH_2$ in flames by cavity ringdown laser absorption spectroscopy. Chem. Phys. Lett., 296: 151-158.

Mobasheri, R., Y. Fotrosy and S. Jalalifar, 2009. Modeling of a spark ignition engine combustion: A computational and experimental study of combustion process effects on NO_x emissions. Asian J. Applied Sci., 2: 318-330.

Moraveji, M.K., S.A. Kazemi and R. Davarnejad, 2011. CFD modeling of heat and mass transfer in the fluidized bed dryer. Trends Applied Sci. Res., 6: 595-605.

Nammari, D.R.N., W. Hogland, M. Marques, S. Nimmermark and V. Moutavtchi, 2004. Emissions from a controlled fire in a municipal solid waste bales. Waste Manage., 24: 9-18.

Olsommer, B., Y. Duperrex, M. Von Spakovsky and J. Van Gilst, 1997. Numerical Simulation of industrial waste incinerator coupled up with natural operating boiler. Rev. Gen. Therm., 36: 135-148.

Oturan, M.A. and M. Robert, 1997. Chemical Thermodynamics. University Press of Grenoble, Grenoble, pp: 253.

Palm, K., 2008. Modeling a process for thermodestruction of gas effluents generated by the burning of household wastes. Ph.D. Thesis, University of Perpignan.

Palm, K., I. Ouedraogo, A. Ouedraogo, X. Chesneau and B. Zeghmati, 2008. Modeling heat and mass transfer of a reactive laminar flow in a cylindrical enclosure. J. Soc. Ouest-Afr. Chim., 026: 29-40.

Patankar, S.V., 1980. Numerical Heat Transfer and Fluid Flow. McGraw Hill, New York, USA.

Saatdjian, E., 1998. Transport Phenomena and their Numerical Solving. 2nd Edn., Polytechnica, France, ISBN: 9782840540571, Pages: 394.

Srinivasan, R.A., S. Sriramulu, S. Kulasekaran and P.K. Agarwal, 1998. Mathematical modeling of fluidized bed combustion-2: Combustion of gases. Fuel, 77: 1033-1049.

Stone, H.L., 1968. Iterative solution of implicite approximation of multidimensional partial differential equations. SIAM J. Numer. Anal., 5: 530-558.

Syamsiro M., H. Saptoadi and B.H. Tambunan, 2011. Experimental investigation on combustion of Bio-pellets from indonesian cocoa pod husk. Asian J. Applied Sci., 4: 712-719.

Tezanou, J., 2003. Environmental assessment and household wastes management technique in Ouagadougou: Management schemes and experimental heat treatment. Ph.D. Thesis, University of Poitiers.

Yeoh, G.H., R.K.K. Yuen, S.M. Lo and D.H. Chen, 2003. On numerical comparison of enclosure fire in a multi-compartment building. Fire Safety J., 38: 85-94.

Zhang, S., N. Li and Z. Wang, 2011. Mecanisms and applications of catalytic combustion of natural gas. Frontiers Heat Mass Transfer, Vol. 2.