A Numerical simulation of emissions of pollutants from industrial chimney

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***Abstract*- The prediction of the concentration fields of pollutants released to the atmosphere is a key factor in assessing possible environmental damages caused by industrial emissions. To solve the concentration equation for gaseous or particulate effluents it is necessary to know as accurately as possible the velocity field and turbulence intensities at the atmospheric boundary layer in the region of interest. A two dimensional mathematical model based on the equations of fluid mechanics along with a modified non-isotropic k-ε turbulence model are employed to calculate the flow and dispersion at the atmospheric micro scale (distances of the order of kilometers).**

Results of investigation are obtained by using the finite volume method (FVM) to solve the average Navier Stock equations coupling with turbulent k- ε model. The calculation was carried out for plume flow from the industrial chimney with different plume velocities, wind velocities and heights of stack. The equations of model are solved with SIMPLE schemes.

FLUENT program used to show the results of the plume flow at the variable parameters of wind and plume velocities and heights of stack, the code is applied to simulate several cases of flow and dispersion. Comparisons against experimental results show that the non-isotropic turbulence model has better ability to foresee the plume dispersion than the standard k- ε, in which the non-isotropic character of turbulence is relevant. The computational results show that the plume path and concentrations are correctly predicted by the numerical model.

Key words
Chimney, Navier-Stock equation, k-ε model, Emission of pollutant, FLUENT codeIntroduction:

1. Introduction

The air pollution dispersion is a complex process; it covers the pollution transport and diffusion in the atmosphere. The improvement of living conditions of the population on the planet invariably requires the development of agriculture, trade and industry at increasingly high levels in order to meet the demand for products and services that also grows in geometric progression [1].

The air pollution or contamination is caused mainly by three types of emissions:

a) Resulting Gasses from combustion engines in motor vehicles, which contain nitrogen oxides, carbon monoxide and carbon dioxide, sulfur dioxide, derived from hydrocarbons, responsible for 40% of air pollution in big cities.

b) Gases and particles matter released from the chimneys of the chemical industries; steel industries, cement and paper factories, thermoelectric and petroleum refineries, containing a wide variety of chemical species.

c) Burning and incineration of industrial and domestic waste, responsible for the emission of smoke containing mixtures of gases with the most different chemical compositions [2].

During a reversal the pollutants are trapped in a region close to the ground, in a layer of stable air highly stratified it difficult the dispersion, increasing substantially the concentration of contaminants. Combating the problem of air pollution, in general, can be done through [3]:

Reduction in the quantity of emissions.

Treatment of effluents before the emissions.

Repositioning of emission sources.

2. Simulation of air pollution

Figure(1) shows schematically the calculation domain of the simulated problems. Air is discharged by the chimney diameter (D) to the atmospheric boundary layer that is 27 ° C. In this study, different height of stacks was considered and the dispersion models have simulated. The source is positioned 200 m after of the a. point. For the concentration, the calculation domain in the direction of the wind begins 200 m before the source finishes 2000 m after this. The height is of 600m.

3. Governing Equation

The Governing equations of the dispersion model are presented. The fluid mechanics (continuity, Navier-Stokes and energy) in general form.

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i}(\rho u_i)=0 \qquad (1)$$

$$\rho\left(\frac{\partial u_i}{\partial t} + u_j \frac{\partial u_i}{\partial x_j}\right) = -\frac{\partial p}{\partial x_i} + \mu \frac{\partial^2 u_i}{\partial x_j \partial x_j} + \frac{\mu}{3}\frac{\partial}{\partial x_i}\left(\frac{\partial u_j}{\partial x_j}\right) - \rho g \delta_{ij} + F_i \qquad (2)$$

$$\rho C_p\left(\frac{\partial T}{\partial t} + u_j \frac{\partial T}{\partial x_j}\right)=k_a\frac{\partial^2 T}{\partial x_j \partial x_j}+\beta T\frac{Dp}{Dt}+\mu\Phi+S \qquad (3)$$

In fact, as the density variations in the atmosphere flows are very small and based on the previous assumption, the continuity Equation (1) has the following form [1].

$$\frac{\partial u_i}{\partial x_i} = 0 \qquad (4)$$

The term of force Fi, in the case of atmospheric flows is the Coriolis force.

$$\vec{F} = -2\rho(\vec{\Omega} x \vec{u}) \qquad (5)$$

Expressing that balance mathematically, the equation of the mass conservation for the species or also called equation of the concentration [1].

$$\rho\left(u_j \frac{\partial c_i}{\partial x_j} \right) = \frac{\partial}{\partial x_j}\left(D_i \frac{\partial c_i}{\partial x_j} \right) + R_i + S_i \quad (i=1,2...N) \qquad (6)$$

The term of chemical reactions depends on temperature and pressure. In general case, the concentrations of species involved in reaction , the concentration of another species in this case be a reagent, and also the temperature. The equation write in general Ri = Ri (ci, T).The speed of reaction usually depends on the temperature and pressure. It will also be greater, since the greater internal energy provides more collisions intermolecular, which speeds up the reaction.

4. The treatment of the Turbulence

Most of the flows includes the air flow in the Atmospheric Boundary Layer "ABL" occur in turbulent regime. It is difficult to define the turbulence, but it is possible to mention some characteristics of the turbulent flow. Such flow provides a series of vortexes (whirls) of various sizes, from the size of the domain to vortexes many smaller magnitude orders. Those vortexes are distributed over the second spectrum of frequencies. Larger vortexes have smaller frequency and the smallest have larger frequencies.
As the spatial and temporal variation of the components of speed in a turbulent flow occur in a very small scale (although often greater than the molecular scale), the description of these movements by the Navier-Stokes equation would only be achieved if achieve an analytical solution or a numerical solution on a mesh so refined, with intervals of time in advance of the solution so small that could capture even the smallest vortexes of flow. The analytical solution does not exist yet Current capacity and computational direct numerical solution makes it prohibitive (Direct Numerical Simulation - DNS) for flow of practical interest. As yet you cannot solve the chaotic movements of irregular turbulence; the approach used to study such flow is to make a Statistical description of the phenomenon. The instantaneous value of a flow property in an average value (or deterministic) and of fluctuation (or stochastic).

$$\phi = \bar{\phi} + \phi' \quad (7)$$

The interval of time must be on a scale far greater than the time-scale fluctuations but also greatly reduce the time scale of the problem of macroscopic phenomena of interest. Soon,

$$\bar{\phi}(t) = \frac{1}{T}\int_{t-T/2}^{t+T/2} \phi(t')\,dt' \quad (8)$$

From eq. (5) and eq. (6) we have

$$\bar{\phi}' = 0 \quad (9)$$

Applying that procedure to the equation (4) obtained

$$\frac{\partial \bar{u}_i}{\partial x_i} + \frac{\partial ú i}{\partial x_i} = 0 \quad (10)$$

The second term of eq. (10) will be neglected, because the variation of fluctuations of density in atmospheric flows is negligible (flow typically incompressible). The equation become

$$\frac{\partial \bar{u}_i}{\partial x_i} = 0 \quad (11)$$

Applying the same procedure on the mean time of Navier-Stokes equation (2) get the equation of conservation of the amount of movement for the turbulent flow, also called the equation of Reynolds.

$$\bar{\rho}\left(\bar{u}_j \frac{\partial \bar{u}_i}{\partial x_j}\right) = -\frac{\partial \bar{p}}{\partial x_i} + \frac{\partial}{\partial x_j}\left(\mu \frac{\partial \bar{u}_i}{\partial x_j} - \bar{\rho}\,\overline{ú_i ú_j}\right) - \tilde{\rho} g \delta_{ij} \quad (12)$$

The energy equation, written in terms of average temperature potential and a term of fluctuations.

$$\bar{\rho}\, C_p\left(\bar{u}_j \frac{\partial \bar{\theta}}{\partial x_j}\right) = \frac{\partial}{\partial x_j}\left(k_a \frac{\partial \bar{\theta}}{\partial x_j} - \bar{\rho}\, C_p\, \overline{ú_j \theta'}\right) \quad (13)$$

Equation of the concentration (6) to turbulent flow in the atmosphere as following:

$$\bar{\rho}\, \bar{u}_j \frac{\partial \bar{c}_i}{\partial x_j} == \frac{\partial}{\partial x_j}\left(\bar{\rho} D_i \frac{\partial \bar{c}_i}{\partial x_j} - \bar{\rho}\, \overline{ú_j c_{i'}}\right) + R_i + S_i \quad (14)$$

The study goal is to calculate the dispersion in the atmosphere with an equation as (14), and knowing that the turbulent effects as contributing to increase the diffusion characteristics of the phenomenon, it is not essential to know how valid the words involving correlation between fluctuations of properties, but we need know quantitatively the effect of these fluctuations on the turbulent rise of diffusion. According to the concept of diffusion of turbulent Boussinesq, the terms fluctuations in the surrounding properties equations (12) (13) (14) are modeled on the basis of gradients of average properties .

$$\bar{\rho} ú_i ú_j = -\mu_t \left(\frac{\partial \bar{u}_i}{\partial x_j} + \frac{\partial \bar{u}_j}{\partial x_i}\right) + \frac{2}{3}\bar{\rho}\, k\, \delta_{ij} \quad (15)$$

$$\bar{\rho}\, C_p ú_j \theta' = - k_t \frac{\partial \bar{\theta}}{\partial x_j} \quad (16)$$

$$\bar{\rho}\, ú_j ć_i = -\bar{\rho} D_t \frac{\partial \bar{c}_i}{\partial x_j} \quad (17)$$

By substitution of equations (15) and (17) in (12) and (14), respectively, the equations of momentum, energy and concentration on Atmospheric boundary layer "ABL", become,

$$\bar{\rho}\bar{u}_j \frac{\partial \bar{u}_i}{\partial x_j} = -\frac{\partial}{\partial x_i}\left(\bar{p} + \frac{2}{3}\bar{\rho} k\right) + \frac{\partial}{\partial x_j}\left[(\mu + \mu_t)\left(\frac{\partial \bar{u}_i}{\partial x_j} + \frac{\partial \bar{u}_j}{\partial x_i}\right)\right] - g\delta_{ij} \quad (18)$$

$$C_p\left(\bar{u}_j \frac{\partial \bar{\theta}}{\partial x_j}\right) = \frac{\partial}{\partial x_j}\left[(k_a + k_t)\frac{\partial \bar{\theta}}{\partial x_j}\right] \quad (19)$$

$$\bar{\rho}\, \bar{u}_j \frac{\partial \bar{c}_i}{\partial x_j} = \frac{\partial}{\partial x_j}\left[(D_i + D_t)\frac{\partial \bar{c}_i}{\partial x_j}\right] + R_i + S_i \quad (20)$$

The viscosity of gas, the kinetic theory of gases, is given by one-third of the proceeds of its density by free path and mean speed of molecules characteristic [4].

$$\mu_t \propto \rho\, l\, v_c \quad (21)$$

5. The Isotropic k - ε model

In the classic k-ε model the scale length of turbulence is given by

$$l = C_\mu^{3/4} \frac{k^{3/2}}{\varepsilon} \quad (22)$$

Substituting (22) in (21) with the proportionality constant equal to C and vc = k1/2, we have

$$\mu_t = \frac{c_\mu \rho k^2}{\varepsilon} \quad (23)$$

This is known as the ratio of Komogorov - Prandlt. The coefficients of turbulent transport (diffusion) of energy and concentration equations are the same order of magnitude of the turbulent viscosity μt and relate to this by [2].

$$\frac{k_t}{C_p} = \frac{\mu_t}{pr_t} \quad (24)$$

$$\bar{\rho} D_t = \frac{\mu_t}{Sc_t} \quad (25)$$

The equation for the turbulent kinetic energy (k=úiúj/2) is obtained from the transport equation to the tensor of Reynolds (úiúj) making up i = j and modeling to the terms of diffusion transport and viscous dissipation and introducing new correlations unknown (involving fluctuations of properties). For high Reynolds number, where the local isotropy of turbulence prevails, the equation for turbulent kinetic energy is

$$\bar{\rho}\left(\bar{u}_j \frac{\partial k}{\partial x_j}\right) = \frac{\partial}{\partial x_j}\left(\frac{\mu_t}{\sigma_k}\frac{\partial k}{\partial x_j}\right) + P + G - \bar{\rho}\,\varepsilon \quad (26)$$

Where

$$P = -\bar{\rho}\,\overline{\acute{u}_i \acute{u}_j}\frac{\partial \bar{u}_i}{\partial x_j} = \mu_t\left(\frac{\partial \bar{u}_i}{\partial x_j} + \frac{\partial \bar{u}_j}{\partial x_i}\right)\frac{\partial \bar{u}_i}{\partial x_j} \quad (27)$$

It is the term of production of turbulent kinetic energy starting from the rate of strain of the mean flow and

$$G = \bar{\rho}\, g\, \beta\, \overline{w'\theta'} = -g\,\beta \frac{\mu_t}{pr_t}\frac{\partial \theta}{\partial z} \quad (28)$$

It is the production term or destruction of turbulent kinetic energy for buoyancy effects.
The transport equation for the dissipation of the turbulent kinetic energy ($\varepsilon = \nu \frac{\partial \acute{u}_i}{\partial x_j}\frac{\partial \acute{u}_i}{\partial x_j}$) is obtained from the equation of Reynolds and contains terms with complex correlations whose behavior is little known and for which it is necessary to assume a modeling to turn treatable the equation. The equation for the dissipation of the turbulent kinetic energy becomes [5].

$$\bar{\rho}\left(\bar{u}_j \frac{\partial \varepsilon}{\partial x_j}\right) = \frac{\partial}{\partial x_j}\left(\frac{\mu_t}{\sigma_\varepsilon}\frac{\partial \varepsilon}{\partial x_j}\right) + C_{1\varepsilon}\frac{\varepsilon}{k}(P+G) - C_{2\varepsilon}\bar{\rho}\frac{\varepsilon^2}{k} \quad (29)$$

The constants that appear in the classic k-ε model have their values given by the table 1.

Table 1 constant of the classic k - ε model [4]

C_μ	$C_{1\varepsilon}$	$C_{2\varepsilon}$	σ_k	σ_ε
0.09	1.44	1.92	1.0	1.3

Care should be accorded to the value of Cμ =0.09. However an analysis done for atmospheric flows reveals that this value is inadequate. Let us consider the flow in balance near the surface where the shear stresses are practically constant with the height and the generation of turbulent kinetic energy is locally balanced by the dissipation. Then we can write to the surface Shear stress

$$\tau_{z=0} = \tau_0 = \mu_t \frac{\partial \bar{u}}{\partial z} \quad (30)$$

And for the dissipation

$$\varepsilon \cong \frac{P}{\bar{\rho}} = \frac{\tau_0}{\bar{\rho}}\frac{\partial \bar{u}}{\partial z}$$

(31)

Substituting μt given by eq. (23) in eq. (30) and then eliminating ε by eq. (31) it results

$$\frac{1}{\sqrt{C_\mu}} = \frac{k}{u_*^2} \quad (32)$$

Where

$$u_* = \sqrt{\frac{\tau_0}{\bar{\rho}}} \quad (33)$$

6. The non- isotropic k- ε model

This is a modification of classic k-ε, based on the model of tensor in Reynolds algebraic (Algebraic Stress Model - ASM).
In the environmental flow of non-isotropic turbulence is remarkable, especially in atmospheric flows. This non-isotropic is particularly important for the dispersion of a scalar (pollutant) in flow. For such situations, a better description of non- isotropic in trade is necessary turbulent. Proposed a change in the k-ε classic model, based on algebraic model of the Reynolds stresses, including the effects of proximity ground .A main characteristics of this model changed, and that much of the difference from classic k-ε, is the fact it is non- isotropic.
In our work we extend the application of the k-ε model non-isotropic of flow and dispersion of pollutants. A description of this modified k-ε is made below, while their acquisition (from the model of algebraic stresses of Reynolds).
According to the concept of turbulent viscosity of Boussinesq, the stresses of Reynolds gradients are related to the main speed for [4]

$$-\overline{\acute{u}_i \acute{u}_j} = K_m^j\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) - \frac{2}{3}k\,\delta_{ij} \quad (34)$$

K is the coefficient of transport turbulent diffusion of momentum quantity (Kinematic turbulent viscosity) in direction j. That is mean, is not a characteristic of fluid but a flow property, heavily dependent on the state of turbulence.
Similarly to what was done for the transport of turbulent quantity of momentum, the concept of turbulent diffusivity assumes that the turbulent transport of heat or mass (chemical species) is related to the gradients of the property carried

$$-\acute{u}_j\,\theta' = K_h^j \frac{\partial \theta}{\partial x_j} \quad (35)$$

$$-\acute{u}_j\,c' = K_c^j \frac{\partial c}{\partial x_j} \quad (36)$$

K and K are, respectively, the coefficients of transport diffusion turbulent heat and mass in direction j. They are also called turbulent diffusivity. The viscosities turbulent (for momentum) and turbulent diffusivity (for heat and mass) are expressed in function of the turbulent kinetic energy and its rate of dissipation. For the vertical direction we have [4]

$$K_m^z = C_m \frac{k^2}{\varepsilon} \quad (37)$$

$$K_h^z = C_h \frac{k^2}{\varepsilon} \quad (38)$$

$$K_c^z = C_c \frac{k^2}{\varepsilon} \quad (39)$$

And for the horizontal directions

$$K_m^x = K_m^y = C_\mu \frac{k^2}{\varepsilon} \quad (40)$$

$$K_h^x = K_h^y = \frac{K_m^x}{pr_t} \quad (41)$$

$$K_c^x = K_c^y = \frac{K_m^x}{Sc_t} \quad (42)$$

Cm, Ch and Cc are proportionality coefficients for the viscosity and the turbulent diffusivity in the vertical direction. They are defined for functions of the structure of the flow, from the algebraic model of stresses.

$$C_m = \frac{2}{3} \frac{(c_1-1)(E_7-AG_H)}{E_4+\frac{E_4 E_5}{C_{1T}}G_H-E_5 E_7 G_M+E_5 A G_H G_M} \quad (43)$$

$$C_h = \frac{2}{3} \frac{(c_1-1)+E_5 G_M C_m}{(c_{1T}+c'_{1T} f)E_4+(\frac{2E_4 E_9}{E_{10}}+E_8)G_H} \quad (44)$$

It is fair to adopt the same turbulent diffusivity for the transport of heat from other scalars. This implies that the numbers are Schmidt and Prandlt turbulent equal and that CC = Ch. The effect of proximity to the ground on the stresses is the Reynolds considered in parameter

$$f = \frac{C_\varepsilon k^{3/2}}{k_v z \varepsilon} \quad (45)$$

Where z is the distance from the ground and Cε = 0.13.
Cm and Ch are functions of GM and GH. These are dimensionless parameters that take into account, respectively, the rate of strain and stratification of the flow in vertical direction.

$$G_M = \left(\frac{k}{\varepsilon}\right)^2 \left[\left(\frac{\partial u}{\partial z}\right)^2 + \left(\frac{\partial v}{\partial z}\right)^2\right] \quad (46)$$

$$G_H = g\,\beta \left(\frac{k}{\varepsilon}\right)^2 \frac{\partial \theta}{\partial z} \quad (47)$$

The turbulent kinetic energy and its rate of dissipation are calculated by their equations of conservation

$$u_j \frac{\partial k}{\partial x_j} = \frac{\partial}{\partial x_j}\left(\frac{K_m^j}{\sigma_k}\frac{\partial k}{\partial x_j}\right) + P + G - \varepsilon \quad (48)$$

$$u_j \frac{\partial \varepsilon}{\partial x_j} = \frac{\partial}{\partial x_j}\left(\frac{K_m^j}{\sigma_\varepsilon}\frac{\partial \varepsilon}{\partial x_j}\right) + C_{1\varepsilon}(P+G)\frac{\varepsilon}{k} - C_{2\varepsilon}\frac{\varepsilon^2}{k} \quad (49)$$

P is the production term due to the gradients of speed.

$$P = -\overline{u'_i u'_j}\frac{\partial u_i}{\partial x_j} = K_m^j\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\frac{\partial u_i}{\partial x_j} \quad (50)$$

G is the production term or destruction due to the buoyancy (stratified) effects.

$$G = g\,\beta\,\overline{w'\theta'} = -g\,\beta\,K_h^z \frac{\partial \theta}{\partial z} \quad (51)$$

The constants of the equations (48) and (49) they are the same of the classic k-ε.

7. Final governing equations

The final governing equations are the conservation of mass, momentum, energy and transport of scalar (concentration) are respectively

$$\frac{\partial}{\partial x_i}(u_i) = 0 \quad (52)$$

$$u_j \frac{\partial u_i}{\partial x_j} = -\frac{1}{\rho}\frac{\partial}{\partial x_i}\left(p + \frac{2}{3}\rho k\right) + \frac{\partial}{\partial x_j}\left[K_m^j\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\right] - \frac{\tilde{\rho}}{\rho} g \delta_{i3} \quad (53)$$

$$u_j \frac{\partial \theta}{\partial x_j} = \frac{\partial}{\partial x_j}\left(K_h^j \frac{\partial \theta}{\partial x_j}\right) \quad (54)$$

$$u_j \frac{\partial c}{\partial x_j} = \frac{\partial}{\partial x_j}\left(K_h^j \frac{\partial c}{\partial x_j}\right) + S \quad (55)$$

8. Results

The simulations of the pollution proplem consider these varibles and the results of the present work could be summarized into three main categories:

i. Study the effect height of stack on the air pollution problem at the domain.

ii.Study the effect of plume velocity which exit from stack to atmospheric boundary layer, to simulate the air pollutionproblem.

iii.Study the concentration results and affected on the area near the industrial station.

8.1 Effect of stack height

The specified effect stack height is actually a predic¬tion of the exhaust plume centerline's final height, based on a mathematical plume rise equation. This final height typically occurs far downwind of the exhaust stack (on the order of 30 to 60 m). A more general mathematical equation is available that predicts the height of the plume centerline as a function of downwind distance. A better method of comparing two different exhaust systems is to specify the effect of increasing in the plume height versus downwind distance. The increase may not be as great as one might expect, as the following analysis points out. The predicted plume centerline height versus downwind distance for an induced-air exhaust stack and a conventional exhaust fan system at a 20 mph stack height wind speed. The curves indicate that the dif¬ference in the plume height between the two exhaust sys-tems is only 0.3 to 0.6 m at 6.6 m downwind with a maximum difference of 2 m after both plumes have reached their final rise. Therefore, using an induced-air fan may reduce the necessary stack height by only a few meters, depending on the location of the nearby air intake locations. This analy¬sis shows why the effect stack height specification is misleading.

In Fig.(2) has seen the counters of velocity magnitude at height of chimney = 100m, 75 m and 50 m. Where the air velocity = 4 m/s, smoke velocity = 14 m/s and diameter of chimney = 5m. Shows the better stack height is 100 m. In areas of high turbulence ,then, the only method for obtaining an adequate plume centerline may be to increase the physical height of the stack The increasing in stack height is reducing the downwash of pollutants to the ground.

When the height of stack equal to 100 m we can see the plume rise is in good condition due to high height, adequate plume rise important to ensure that the exhaust escapes the high turbulence. Plume rise is adversely affected by atmospheric turbulence because the vertical momentum of the exhaust jet is more quickly diminished.

At the stack height 75 m shows the plume rise less than above, in this case the probability to occurs the diminished in exhaust jet. When the height of stack equal to 50 m, the plume rise is very poor and this is lead to appears the downwash and pollute the area close to stack and in the domain.

8.2 Effect of velocity of plume

Fig.(3)represents the effect of plume velocity on counters of velocity magnitude for the parameters of the study are height of chimney = 100 m. diameter of chimney = 2.5m. Air velocity = 4 m/s, shows the effect of stack plume velocity with the range from 4 m/s to 14 m/s. in the plume velocity 4m/s this it is very small that is lead to downwash. The counters of velocity magnitude at smoke velocity = 10 m/s, there is increasing in the stack plume velocity guides a small change to prevent downwash. When increasing the velocity of stack exit to 14 m/s leads to good modified in plume rise to acceptable level.

8.3 Results of concentration

The dispersion of plume to the atmosphere presents the characteristic of that the plume covers a long stretch until touching the ground. We noticed that in the closest positions of the source the situation with k - ε analytical in the entrance (smaller turbulence level) it provoked a great increase in the concentration profiles. To measure where if it moves away from the source, the differences decrease. It is important, however, the fact of that exactly downstream the concentration level is significantly higher, in the case of k and ε analytical in the entrance. There one is noticed greater difficulty to simulate real cases in that are not usually had measured values of turbulent kinetic energy and mixture length for they be prescribed in the entrance.

The figures (4- 9) show vertical profiles of concentration along a vertical plan in the longitudinal direction of the problem at the height of stack = 35 m. and the different distances of domain that is study, with different elevations of (Z). To explain the concentration behavior, these figures show the comparison for effect of concentration percentage in different distances in classic, non-isotropic (coarse and fine mesh). The concentration reduce when the distance from the chimney is increased.

In Fig.(4) the concentration is very large at the exit of chimney when z = 35 m, and then will be reduced in above and under 35m. This lead to say the critical area is near the chimney (90 m from the source). Fig.(5) shows the concentration of plumes at x = 590m, in this case the plume was a rise above the 35m and the concentration profile was reduced to 2500 ppt at 50 m above the ground. The concentration reduce to 1800 ppt at 85 m, when the x = 790 m as explained in Fig.(6) and there is very small amount of concentration in the under the z = 85 m. we can see the increase with distance the concentration amount reduced and the levels of the z in all distances was increased like in Fig.(7). Its 600 ppt at the height of z = 100m, when the x = 990 m. while the amount of concentration is 1100 ppt at the same dimensions in the x = 790m. In figures (8) and (9) has seen the concentration amount fall down to the ground at the distances of 1290 and 1590 with the values 1000 ppt and 650 ppt.

Fig.(10) shows the ground level of concentration amount variables with the distance (x), when the x is increased the concentration will be reduced.

9. Conclusions

The following remarks could be concluded:

1. The main conclusion of the study work are the using a complete set of computational tools had been implementation and verification of performance of a two - dimensional numerical model to predict the flow and dispersion of plumes in the ABL.
2. The height of chimney reduces the concentration of pollution that is bad effecting on the life in the earth due to the most of plumes going far distances and the percentage of concentration becomes very small.
3. High smoke velocity from chimney gives the plumes a great tall and distance to reduce the concentration due to the high velocity should be able to produce the good dispersion of the plumes.
4. The best smoke velocity is the more than 1.5 of air velocity because the high velocity of air causes downwash for the pollutants and the very small velocity cannot able to remove the plumes for far distance.

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List of symbols

c	Mass concentration
ci	Mass concentration of species i
Cp	Specific heat at constant pressure
$C_\mu, C_{1\varepsilon}, C_{2\varepsilon}$	Constant of the turbulence model
D, Di	Coefficient of mass diffusion of the pollutant (i)
D/Dt	Substantial derivative($\partial/\partial t + u_j\, \partial/\partial x_j$)
f	Coriolis parameter (= 2 Ω sin φ)
F	Coriolis force
g	Gravity acceleration
G	Rate of production of turbulent kinetic energy

H Height of the atmospheric boundary layer
k Turbulent kinetic energy
ka thermal conductivity of the air constant
kB constant of Boltzmann (= 1. 380622e-23)
kv constant of Von Karman (= 0. 4)
kt turbulent thermal conductivity
K turbulent diffusivity
l length of turbulence scale (mixing length)
L length of Monin-Obukhov
n normal direction
N number of linear equations system
P Production of turbulent kinetic energy
Pr Prandlt number
Subscript
a air
e equilibrium state or reference

q intensity of the emission source
r position vector
Ri term of chemical reaction of species i
S source term
T temperature
t time
u velocity vector components of the speed u , v, w vector in the Cartesians directions x, y, z

u* velocity of friction
um velocity prescribed to the upstream boundary
xi direction in the Cartesian system of coordinates (x1 = x, x2 = y , x3=z)
zo parameter of terrain roughness
GREEK LETTER
β coefficient of volumetric expansion
χi volumetric concentration of the species i
ε dissipation Rate of the turbulent kinetic energy
σk, σε constant of the model of turbulence
σy, σz coefficients of horizontal dispersion of vertical Gaussian model
τ Shear stress
τij Reynolds tensor
ρ density
Φ Flow property
δ latitude
μ absolute viscosity of the fluid
μe effective viscosity of the turbulence model
υ kinematic viscosity of the fluid
θ potential temperature
Ω angular velocity of the earth

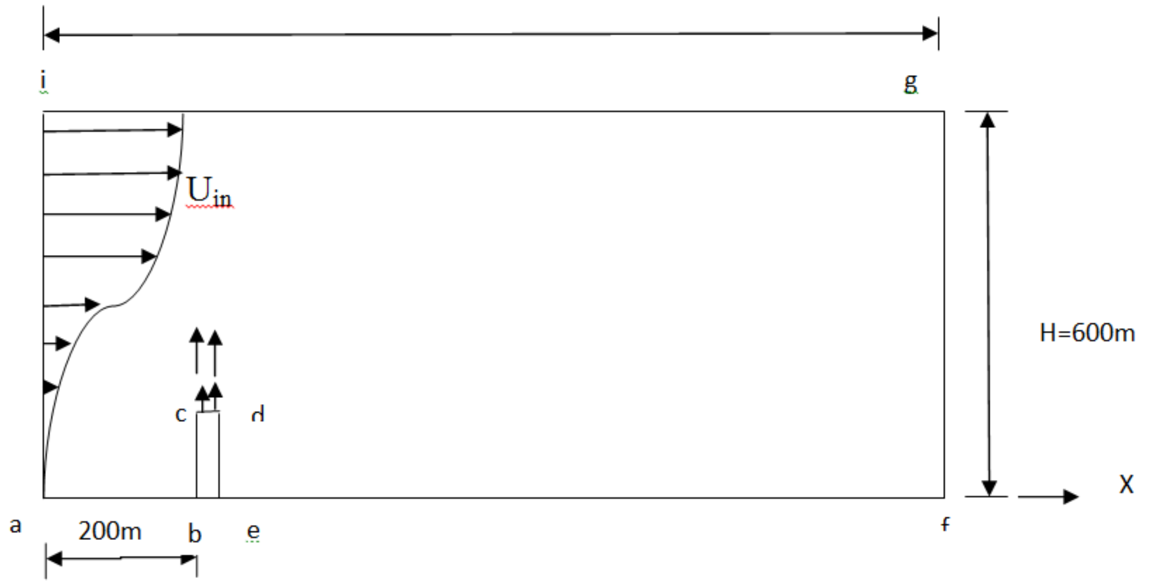
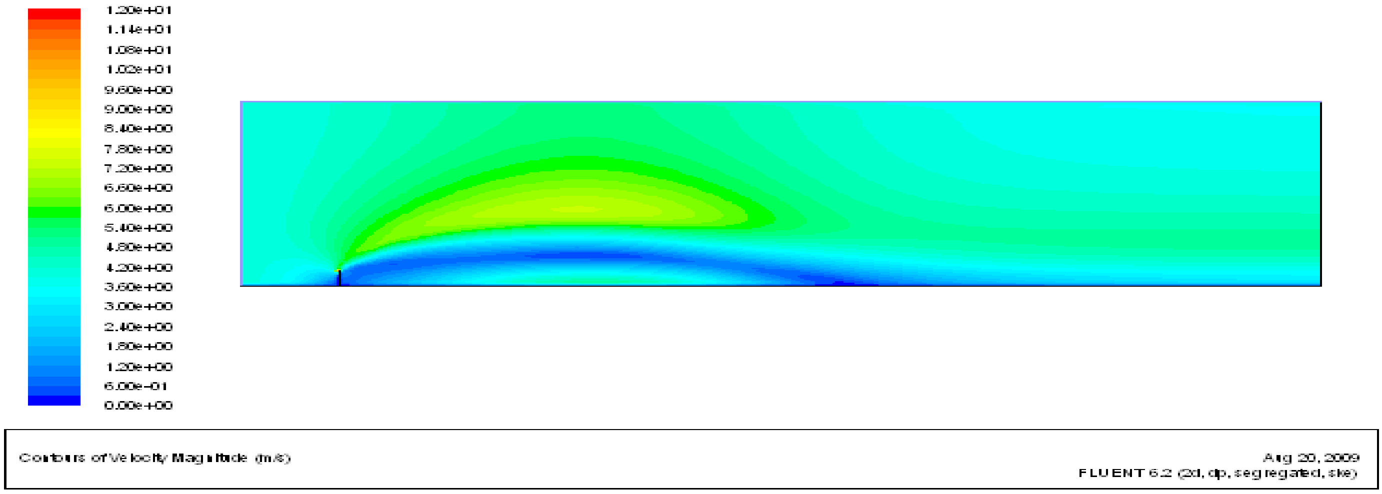


Fig. 1 The plume plan of the Problem of the air pollution.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1.08e+01
1.02e+01
9.60e+00
9.00e+00
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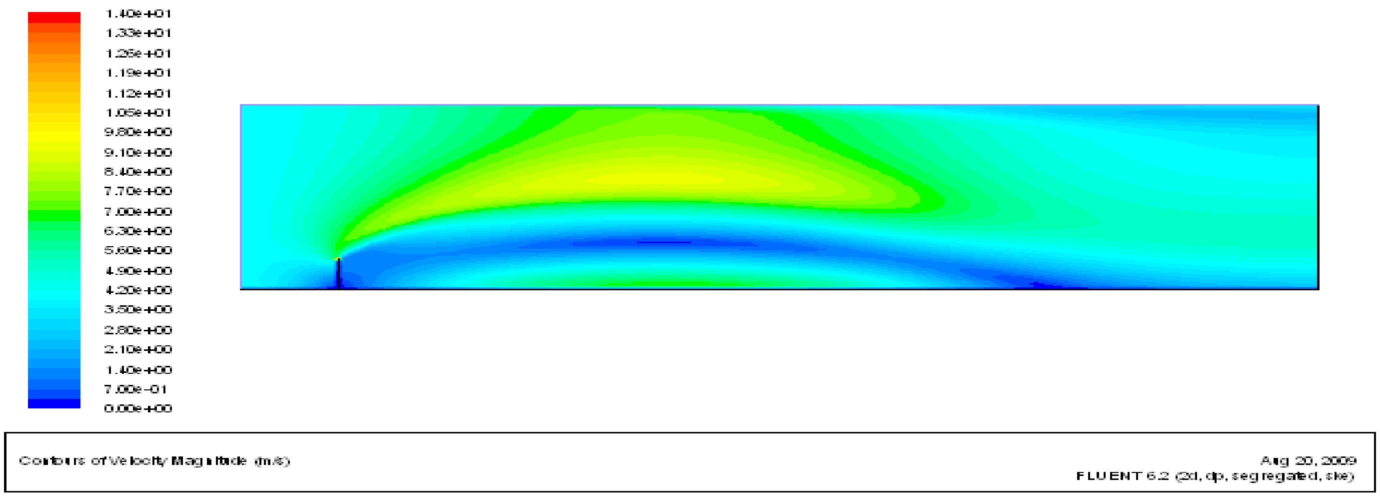
7.80e+00
7.20e+00
6.60e+00
6.00e+00
5.40e+00
4.80e+00
4.20e+00
3.60e+00
3.00e+00
2.40e+00
1.80e+00
1.20e+00
6.00e-01
0.00e+00
Contours of Velocity Magnitude (m/s)
Aug 20, 2009
FLUENT 6.2 (2d, dp, segregated, ske)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7.70e+00
7.00e+00
6.30e+00
5.60e+00
4.90e+00
4.20e+00
3.50e+00
2.80e+00
2.10e+00
1.40e+00
7.00e-01
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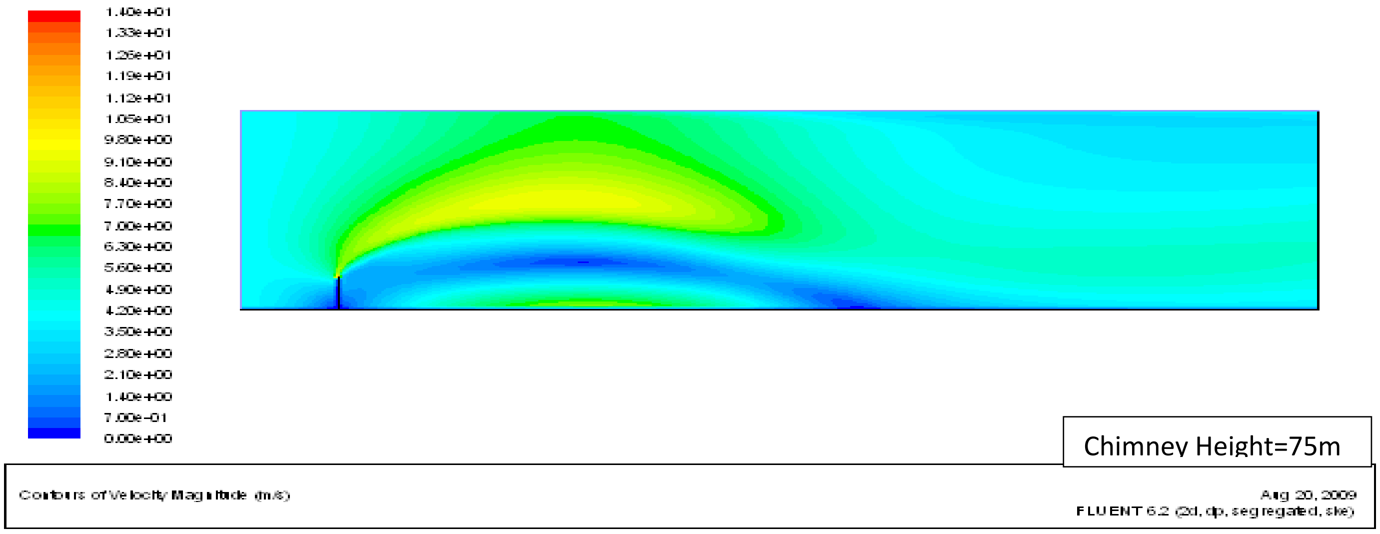
Contours of Velocity Magnitude (m/s)
Aug 20, 2009
FLUENT 6.2 (2d, dp, segregated, ske)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1.19e+01
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8.40e+00
7.70e+00
7.00e+00
6.30e+00
5.60e+00
4.90e+00
4.20e+00
3.50e+00
2.80e+00
2.10e+00
1.40e+00
7.00e-01
0.00e+00
Chimney Height=75m
Contours of Velocity Magnitude (m/s)
Aug 20, 2009
FLUENT 6.2 (2d, dp, segregated, ske)

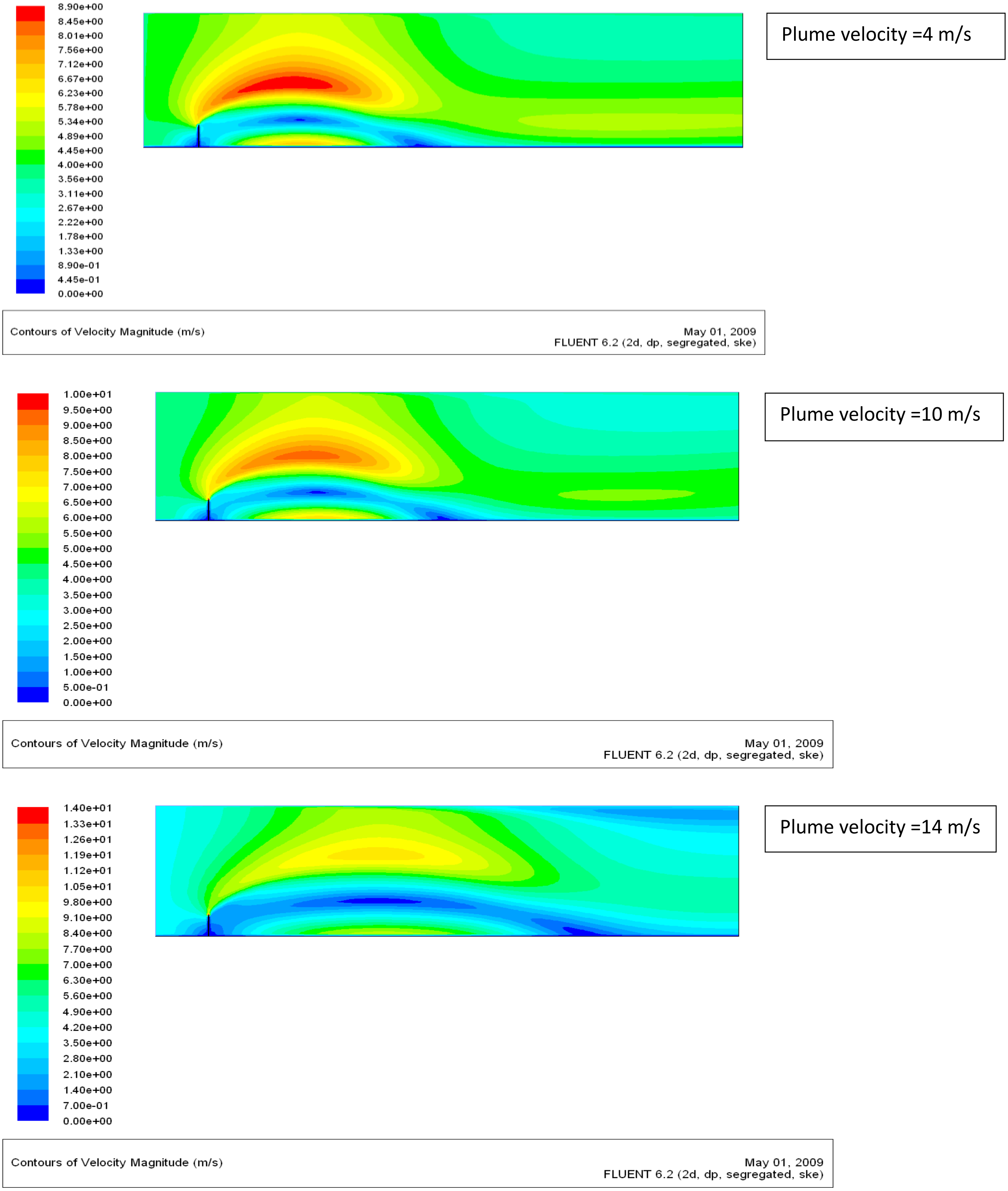
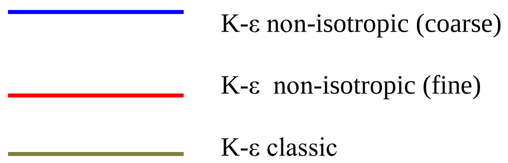


Fig.3. Effect of plume velocity on counters of velocity magnitude at air speed 4m/s, plume height of stack 100 m and stack diameter 2.5 m.



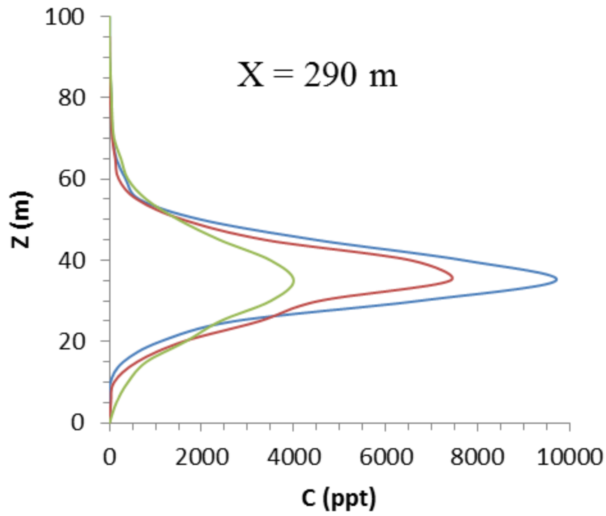


Fig. 4 The concentration profiles at the turbulence levels in entrance h_s = 35m.

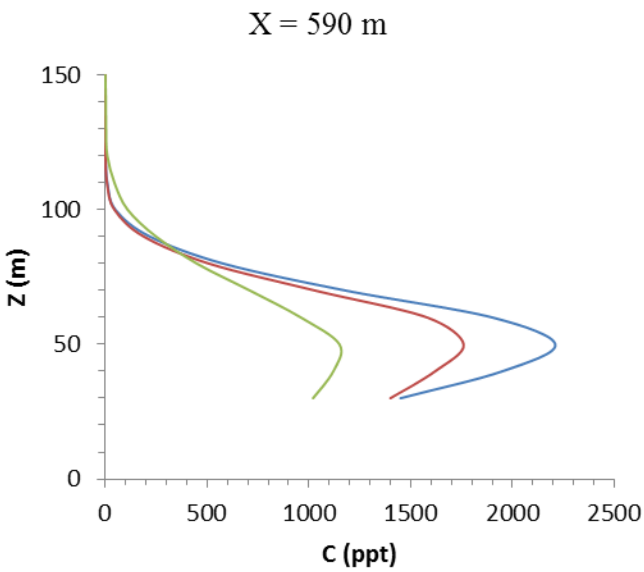


Fig. 5 The concentration profiles at the turbulence levels in entrance h_s = 35m.

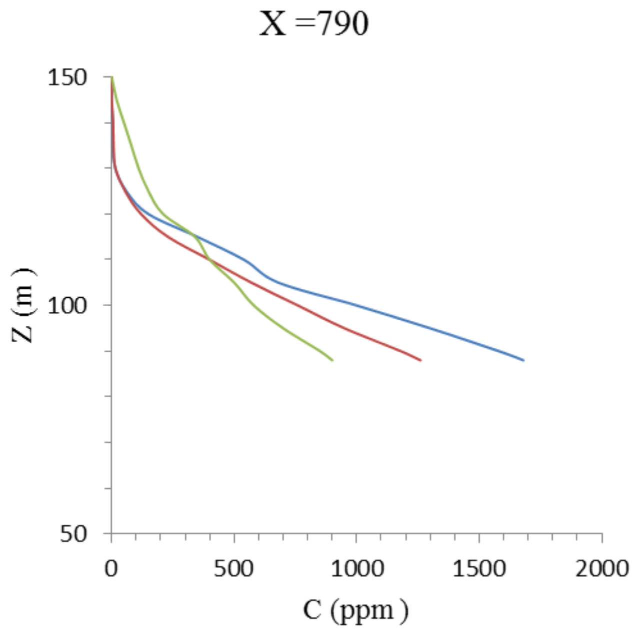


Fig. 6 The concentration profiles at the turbulence levels in entrance h_s = 35m.

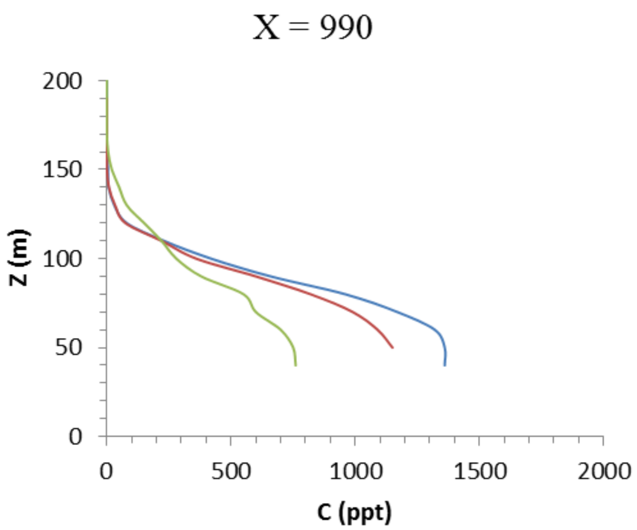


Fig. 7 The concentration profiles at the turbulence levels in entrance h_s = 35m.

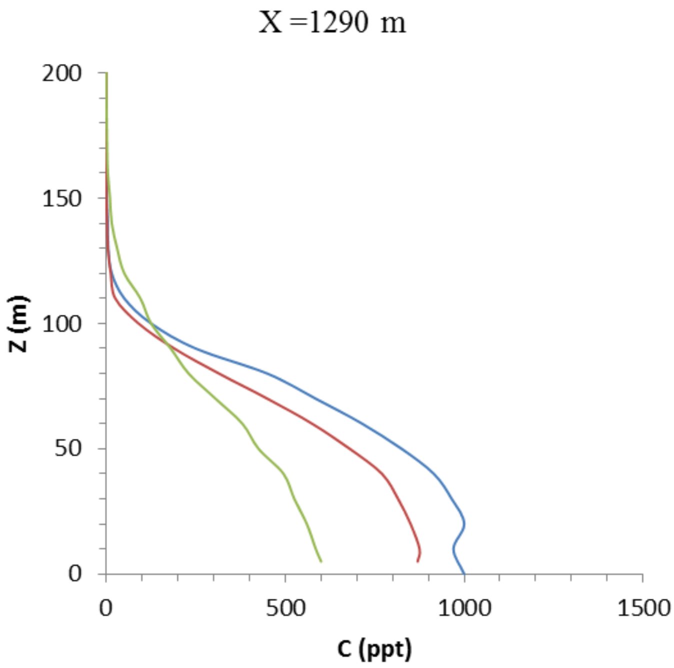


Fig.8 The concentration profiles at the turbulence levels in entrance h_s = 35m.

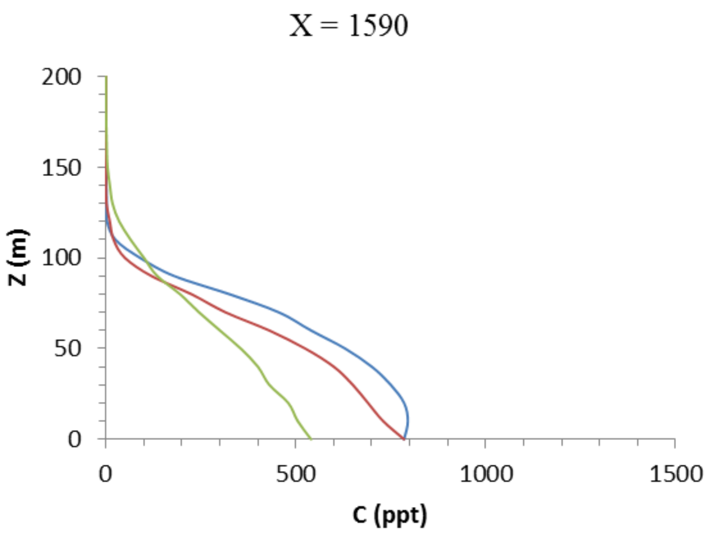


Fig. 9 The concentration profiles at the turbulence levels in entrance h_s = 35m.

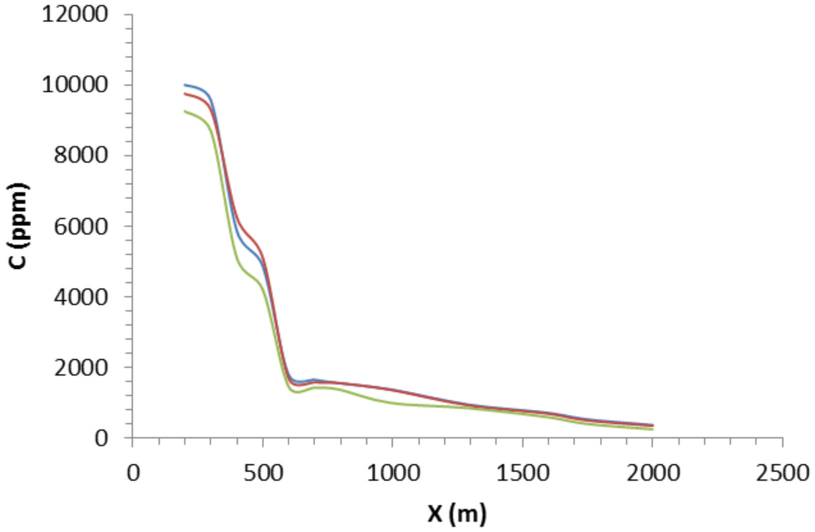


Fig. 10 Sensibility of the concentration profiles in the ground level.