International Journal of Environmental Sciences
Vol. 5 No. 2 (December, 2019)

PRELIMINARY ASSESSMENT OF CONTINUOUS ATMOSPHERIC DISCHARGE FROM THE LOW RADIOACTIVE WASTE INCINERATOR

R.O. Abdel Rahman
Hot Laboratory Center, Atomic Energy Authority of Egypt, P.O. 13759, Inshas, Cairo, Egypt, E-mail: alaarehab@yahoo.com

Abstract: The concern of society for the quality of environment and the realization that all human activities have some environmental effects, has led to the development of predictive environmental impact assessment procedure. This procedure predicts probable environmental effects before the decision of construction, operation, and closure of any facility. The primary goal of this study is to preliminary assess the environmental impact of continuous operational mode of low radioactive waste incinerator. This assessment is intended to screen the steady-state near field radio-contaminant concentration profile in a plume immersion scenario. In this respect, simple analytical Gaussian model was developed and applied to predict the radio-contaminant concentration profile to support the preliminary assessment of worker exposure. The maximum radio-contaminant concentration was found to occur at the 6m and breathing levels for totally reflected radio-contaminant. The consideration of subjective uncertainty in wind speed and eddy diffusion coefficient indicates that workers will expose to the highest radio-contaminant concentration at the breathing level and there is 95% confidence that the value of this concentration will not exceed $1.6*10^{-2}$ Bq/m^3 for each release unit.

Keywords: Radioactive waste, Incineration, Gaussian plume, Mathematical model, Uncertainty analysis.

1. INTRODUCTION

Radio-contaminants are discharged to the environment by nuclear power industry, military establishment, hospitals and general industry. The assessment of these discharges is an important aspect in ensuring the radiological safety of any facility. To assess these emissions to the atmosphere, the atmospheric diffusion equation is used. Analytical solutions of this equation possess several advantages since the input parameters are explicitly expressed in a mathematically closed form, so the effect of each parameter on the model outputs could be easily investigated. Also, thorough studies of the analytical solutions allow valuable insights to be gained regarding the behavior of the system [1, 2]. The solution of Gaussian plume dispersion model has received much attention and has been studied extensively. This model assumes homogonous wind speed and turbulence and constant topography and metrology over time and distance between the source and the receptor [3-5]. Simple Gaussian plume dispersion models are used to assess the dispersion of routine atmospheric discharges from nuclear facility [6–8]. Though these simple models are extremely economical to run and are often used to make such assessments, it was found that these models over estimate the far field concentration by four orders of magnitude [9].

This paper briefly presents the components of the Egyptian radioactive combustible solid waste management system and addresses environmental aspects linked to the continuous operational mode of the low active incinerator facility. The effort in this work was directed to systematically derive a simplified two dimensional analytical solution of the Guassian plume model for two boundary condition types by applying the Green’s function concept to predict the maximum radio-contaminant concentration in a plume immersion scenario. Then the effect of uncertainty in the input parameters on the model output will be investigated.

2. RADIOACTIVE WASTE MANAGEMENT SYSTEM

Over the past twenty years, the waste management center at Inshas has begun to build an integrated waste management system to serve the peaceful Egyptian nuclear activities. To address the radioactive waste issue, a comprehensive policy plan is needed that includes internationally accepted principles developed by the International Atomic Energy Agency (IAEA) in addition to national policy principles. The IAEA policy principles are the protection of human health and the environment, now and in the future without imposing undue burden on future generation [10]. The Egyptian national policy principles includes principles related to the organization of the waste management system such as the existence of national legal framework, control of radioactive waste generation, safety of facilities, waste generator pays, and decision-maker should be supported by scientific information, risk analysis results and availability of resources [11].

During the establishment of the waste management system, all stages in waste processing have been considered, starting from waste generation, through sorting and treatment until disposal of these wastes. To achieve the overall safety goal of waste management, the components of the system must be complementary and compatible with each other. Figure 1 illustrates the basic components in the Egyptian radioactive combustible solid waste management system.

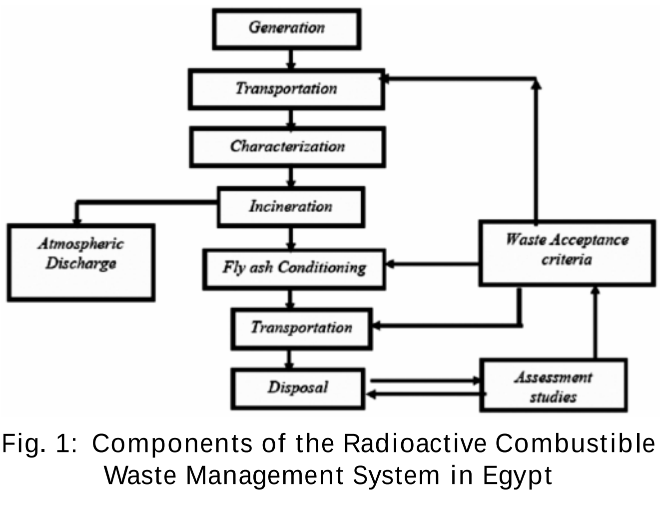


Fig. 1: Components of the Radioactive Combustible Waste Management System in Egypt

2.1 Waste Generation

A substantial portion of the low level radioactive wastes generated in various parts in nuclear laboratories and other places where radionuclides are used for research, and in industrial, medical and other activities, is combustible. Combustible wastes comprise organic ion exchange resins, filter sludge, wastes containing a significant amount of plastics, and biological wastes.

2.2 Treatment

Solid radioactive waste treatment comprises of two steps the first is sorting and segregation according to the activity and/or nature, and the second is the volume reduction. Incineration of these wastes provides a very high volume reduction and converts the wastes into radioactive ashes and residues that are non-flammable, chemically inert and much more homogeneous than the initial wastes.

Within the framework of the German Egyptian cooperation, the low radioactive waste prototype incineration facility was devised and constructed by KFA Julich (research center Julich) according to the principle of the Julich thermo-process. The radioactive wastes are delivered in drums of different sizes and introduced into the facility through airlock. The delivered waste characteristics are then investigated to check the waste acceptance criteria which include weight, composition and dose rate measurements. Then sorting process is carried out manually or pneumatically, and the waste feed to the gas reactor. The waste package should be suitable for direct incineration (i.e. drum size, packaging material). If the packages don’t meet these conditions they must repacked.

The incineration process is compromised of two stages, at the first stage the waste is feed from above into the reactor through a charging device and forms a bed on the movable grid. In stationary operating conditions, the bed has a positive temperature gradient from ambient temperature at the top approximately 800°C, which means that a glowing bed is formed on the movable grid. In the second stage, the pyrolysis gases are vortexed with clearly hyperstoichiomtric volume of air and completely burned at temperature 1000°C. Then the flue gases are cooled to 200°C, three cleaning stages are used to separate the solids (ashes, dust, and aerosol) namely; coarse, fine, and ultrafine separation. Figure 2 schematically shows the components of facility, the facility is operated in batch mode.

2.3 Conditioning

The ashes of combustible solid wastes achieved the highest volume reduction are then routed to the

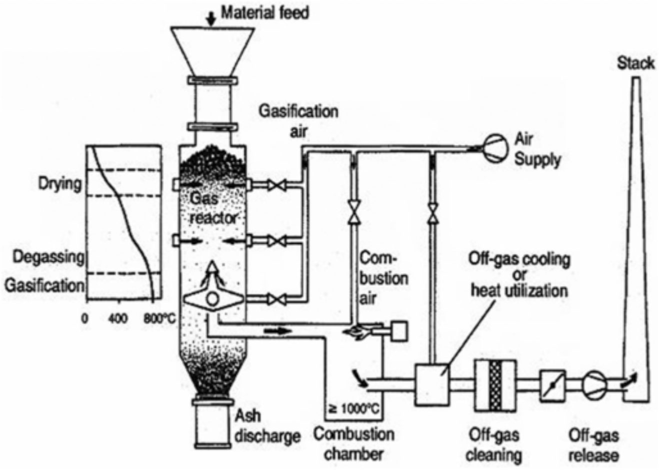


Fig. 2: Schematic Drawing of the Low Active Waste Incinerator

appropriate conditioning step where the final package for interim storage or disposal is obtained. Conditioning includes operations that produce a waste package suitable for subsequent management steps. The choice of cement matrix for the immobilization has been based on the physical and chemical nature of the waste, low cost, suitability for sludge, good thermal, chemical, and physical stability, and good compressive strength of the waste forms. Then the immobilized waste is packed, the packages must be capable of meeting shielding and containment requirements for handling, storage, transportation and finally the waste disposal site requirements.

2.4 Disposal

Disposal is intended to isolate the waste from water and the human environment under controlled conditions for long time to allow the radioactivity to either decay naturally or slowly disperse to an acceptable level. Egypt selects the closed-vault disposal facility design to dispose conditioned low-level radioactive wastes; the disposal site accommodates four vaults (3 × 5 × 10 m each) with capacity of 6000 concrete containers. The water movement is controlled by a drainage system links the four modules to drain the precipitation away from the vault surface. The facility has fully engineered structure: backfill material, reinforced concrete walls, and multi-layer cover [12–14].

3. DEVELOPMENT OF THE ASSESSMENT MODEL

3.1 Source-pathway-receptor Analysis

IAEA recommended that assessment study has to be developed and well adapted to situations of concern to ensure the protection of human health and the environment [15]. To apply this recommendation, an initial assessment of the planned practice needs to be performed that identifies the radiological sources, foresees potential exposures, estimates relevant doses and probabilities, and identifies the required radiological protection measures. Various methodologies with varying complexity have been and are being developed to assist in the evaluation of radiological impact of nuclear facilities. Despite there are differences in the details of these methodologies to correspond to each facility, the general objective of any radiological assessment is to determine the impact of radioactive material on individuals and their environment. This requires the consideration of source-pathway-receptor analysis at which different aspects are identified, i.e how radio-contaminants released from the studied facility, the pathways along which they can migrate, and their impacts on human. In developing such analysis, it is important to understand that radio-contaminants are transported by air, soil or water through advective or diffusive processes and that the principal means of human exposure is by direct radiation exposure, inhalation of gases or particulates, and ingestion of contaminated food or water. The pathways that lead to these types of exposures are illustrated in Fig. 3.

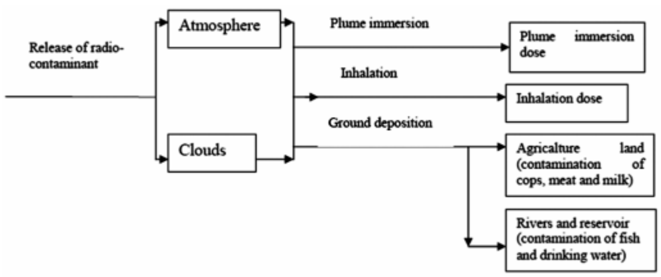


Fig. 3: Exposure Pathways for the Atmospheric Discharge

To develop a conceptual model for this study, the environmental system was divided into the near field, far field and biosphere subsystems. In this assessment only the near field subsystem was addressed, the source of the radio-contaminants is the continuous discharge form the low active incineration facility stake and the assessment end-point is the radio-contaminant concentration profile in the downwind and vertical directions. After discharge to the atmosphere, the radio-contaminant will undergo advective downwind transport and gradient turbulent flux in wind direction. Radio-contaminants, as any other pollutant, will be removed from the atmosphere by both wet and dry deposition to the ground, in addition to the radioactive decay. These removal mechanisms were neglected to estimate the concentration under most conservative conditions, neglecting these assumption is related to the low annual precipitation rate in the site and to the fact that most of the radio-contaminant of concern have respectively long half life when compared to the duration of worker exposure at the site. The receptors are the workers at the near field area in Inshas nuclear campus. It was assumed that the workers expose to the radio-contaminant plume according to a plume immersion scenario that will lead to external irradiation, and inhalation of radionuclides. In developing and conducting this screening assessment, the systematic approach was adapted combined with conservative assumption and consideration of subjective uncertainty.

3.2 Analytical Solution of the Atmospheric Diffusion Equation

This section describes the derivation of simple analytical atmospheric dispersion model that allows for the prediction of two dimensional radio-contaminant concentration profile. Dispersion of pollutants in the atmosphere is governed by the mean air flow that transports the pollutants downwind, and turbulent velocity fluctuations that disperse the pollutants in all directions [16]. The two-dimensional steady-state diffusion equation for a nonreactive, continuously released contaminant is given by:

$$U(z)\frac{\partial C(x,z)}{\partial x} = \frac{\partial}{\partial z}\left(K(z)\frac{\partial C(x,z)}{\partial z}\right) + S(x,z) \quad \text{... (1a)}$$

where x and z are the Cartesian coordinates in the downwind direction and the crosswind direction, respectively, C (x, z) is the ambient concentration of the contaminant (Bq/m^3), S is the source strength function (Bq/m^3s), U wind speed (m/s) and K the vertical eddy diffusivity (m^2/s).

Equation (1a) includes unidirectional wind, gradient turbulent flux, and negligible turbulent diffusion (compared to advection) in the wind direction. In the present analysis, for constant eddy diffusivity and wind speed the radio-contaminant is assumed to transport freely without the consideration of inversion layer. This unbounded atmosphere assumption locates the boundaries at z = 0 and z = ∞. Two case studies are considered, at the first the discharged radio-contaminant is assumed to be removed immediately after the connection between the plume and the soil due to the high soil sorbitivity for the studied radio-contaminant. This situation could be described by first kind Dirichlet boundary condition given by:

$$C(x_0, z_0) = 0 \text{ at } z = 0 \quad \text{... (1b)}$$

The other case is considered if the soil is impermeable at this case the discharged radio-contaminant will completely reflected back into the atmosphere. This case could be described by Neumann type boundary condition as indicated in Eq. (1c)

$$\left.\frac{\partial C(x,z)}{\partial z}\right|_{z=z_0} = 0 \quad (1c)$$

To find the solution of the atmospheric dispersion equation, Green function concept was utilized. This concept is a powerful tool to solve boundary value partial differential equations with complicated boundary conditions and Dirac delta functions (the definition of Dirac delta function is explained in the Appendix A) [17–20].

The solution of Eq. (1a) was obtained by introducing Green function G (ξ, η; x, z), which could be physically interpreted as the response of the environment at a field point (x, z) to a Dirac Delta function discharge at point (ξ, η), (the definition of Green function is listed in the Appendix B).

Using the Laplace operator where

$$L[\theta] = K\frac{\partial^2 C}{\partial z^2} - u\frac{\partial C}{\partial x} \quad \text{... (2)}$$

By substituting Laplace operator in Eq. (1a)

$$L[\theta] = -S(\xi, \eta) \quad \text{... (3)}$$

Then the adjoint operator L* is definded so that

$$L^*[\varphi] = K\frac{\partial^2 G}{\partial z^2} - u\frac{\partial G}{\partial x} \quad \text{... (4)}$$

$$L^*[\varphi] = -\delta(\xi - x)\,\delta(\eta - z) \quad \text{... (5)}$$

By multiplying Eq. (3) by φ and Eq. (5) by θ, subtracting one from the other and integrating over the domain (from $\xi = 0 \to x$, and $\eta = 0 \to z$), we get the following equation:

$$\iint \varphi L[\theta] - \theta L^{*}[\varphi]\, d\xi d\eta$$

$$= -\iint \varphi S(\xi, \eta) + \theta\delta(\xi - x)\,\delta(\eta - z)\, d\xi d\eta \quad \text{... (6)}$$

The double integral is transformed into line integral using Green second formula [20]

$$C(x, z)$$

$$= -u\int G(\xi, \eta; x, z)\, C(\xi, \eta)\, d\eta + \iint G(\xi, \eta; x, z)$$

$$S(\xi, \eta)\, d\xi d\eta + K\int \begin{bmatrix} G(\xi, \eta; x, z)\dfrac{\partial C(\xi, \eta)}{\partial \xi} - \\ C(\xi, \eta)\dfrac{\partial G(\xi, \eta; x, z)}{\partial \xi} \end{bmatrix} d +$$

$$u\int C(\xi, \eta)\, G(\xi, \eta; x, z)\, d\eta \quad \text{... (7)}$$

$$C(x, z)$$

$$= a + b + c + d \quad \text{... (8)}$$

To solve Eq. (8) the upper boundary conditions for unbounded atmosphere are defined as follow:

$$C(\xi, \eta) = 0 \quad \frac{\partial C(\xi, \eta)}{\partial \xi} = 0, \quad z = \infty \quad \text{... (9)}$$

$$G(\xi, \eta; x, z) = 0 \quad \frac{\partial G(\xi, \eta; x, z)}{\partial \xi} = 0 \quad z = \infty \quad \text{... (10)}$$

The lower boundary conditions for total reflected radio-contaminant (first kind Drichlet) are given by Eq. (11 a, b) while for total adsorbed radio-contaminate (second kind Neumann) are defined by Eq. (12).

$$C(\xi, \eta) = 0 \quad z = 0 \quad \text{... (11a)}$$

$$G(\xi, \eta; x, z) = 0 \quad \text{If } C(\xi, \eta)\big|_{\eta=0} = 0 \quad \text{... (11b)}$$

$$\left.\frac{\partial G(\xi, \eta; x, z)}{\partial \eta}\right|_{\eta=0} = 0 \quad \text{If } \left.\frac{\partial C(\xi, \eta)}{\partial \eta}\right|_{\eta=0} = 0 \quad \text{... (12)}$$

By using the definition of Green and Dirac Delta given in the appendices we get:

$$C(x, z) = \iint G(x_s, z_s; x, z)\, S(\xi, \eta)\, d\xi d\eta \quad \text{... (13)}$$

By assuming that

$$S(\xi, \eta) = Q\delta(\xi - x)\,\delta(\eta - z) \quad \text{... (14)}$$

$$C(x, z) = QG(x_s, z_s; x, z) \quad \text{... (15)}$$

To find the Green function for this problem the non-homogenous equation for this problem will be solved

$$K\frac{\partial^2 G}{\partial z^2} - u\frac{\partial G}{\partial x} = 0 \quad \text{... (16)}$$

By applying Laplace transformation we can proof that

$$C(x, z) = \frac{Q}{\sqrt{4\pi ku(x - x_s)}}\begin{bmatrix} \exp\left(-\dfrac{u(z - z_s)^2}{4K(x - x_s)}\right) - \\ \exp\left(-\dfrac{u(z + z_s)^2}{4K(x - x_s)}\right) \end{bmatrix} \quad \text{... (17)}$$

Solution for Neumann boundary conditions

$$C(x, z) = \frac{Q}{\sqrt{4\pi ku(x - x_s)}}\begin{bmatrix} \exp\left(-\dfrac{u(z - z_s)^2}{4K(x - x_s)}\right) + \\ \exp\left(-\dfrac{u(z + z_s)^2}{4K(x - x_s)}\right) \end{bmatrix} \quad \text{... (18)}$$

4. RESULT AND DISCUSSION

4.1 Prediction of Radio-contaminant Concentration Profile

The emission height for the assessment was chosen, so as to reflect the nature of emission from the low active waste incinerator, to be 10 m. Real release rates were not used in this study, as the exact emission details will change according to the rate of waste generation. Instead, a single unit release per second was incorporated, which effectively provided a set of scaling factors reflecting total annual emissions for any radio-contaminant of interest. Figure 4 represents the concentration mapping for the studied cases at wind velocity 5 m/s and eddy diffusivity of 7 m^2/s that are representative for Cairo weather observations. The studied area represents possible location for workers at the site. The examination of this figure indicates that for both studied cases the lower the receptor height the greater the radio-contaminant concentration value. For the first boundary condition the concentration drops rapidly with increasing the distance from the incinerator and that might attribute to the increase in the sorbitivity of the radio-contaminant by increasing the area of connection between the soil and contaminant, where

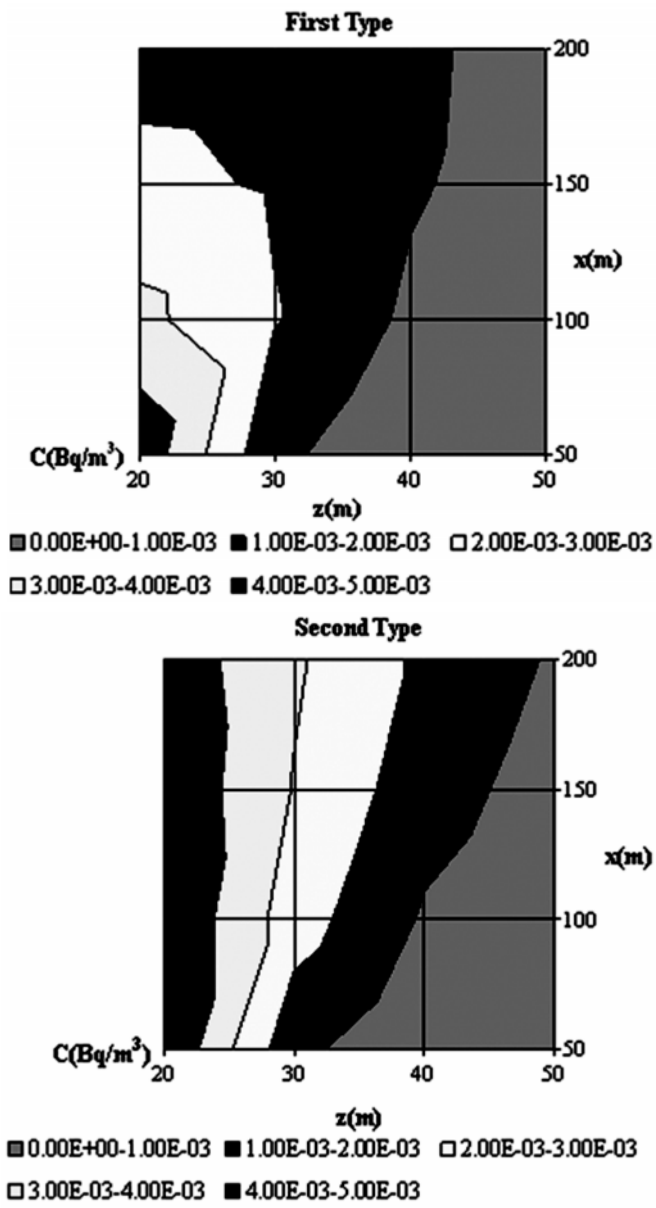
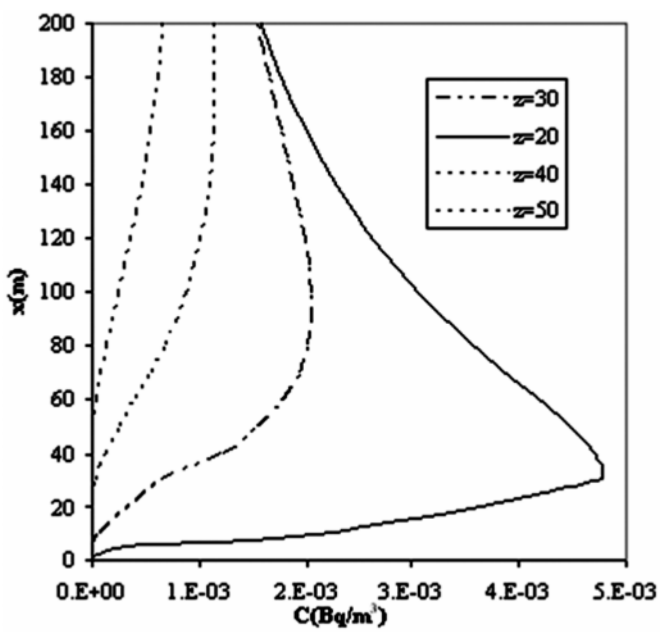


Fig. 4: The Concentration Profile for the Studied Area

for the second type the concentration is not affecting by increasing that distance.

The variation in downwind concentration with the receptor height ($z > z_s$) is shown in Fig. 5 (a, b). It is obviously shown that totally reflected radio-contaminants have higher concentration values than that of a totally absorbed radio-contaminants. Also, it is notable that increasing the height of the receptor will reduce the extent of worker exposure. For both studied boundary conditions, the downwind location at which the peak concentration occurs move closer to the source as the receptor height reduced, this result is consistent with the prediction obtained with Gaussian plume solution [21]. The examination of the variation in the downwind concentration profile with receptor height less than the release height ($z < z_s$) has been also studied for two receptor locations the first is at 6 m and the other is the breathing level z = 2 m (Fig. 5 c, d), indicates that for totally reflected radio-contaminant the predicted concentration is nearly equal for the studied height where for the totally absorbed radio-contaminant the 6 m height have higher concentration. By comparing the results illustrated in Fig. 5, it was found that the maximum predicted radio-contaminant concentration in studied area will be for the receptor locations at 6 m and breathing level for totally reflected radio-contaminant at 5 m and 30 m downwind respectively.

In order to investigate under which boundary conditions the receptor will expose to the highest



(a)

crosswind concentration within the near field distance, the crosswind concentration profile for various near-field downwind distance have been studied as illustrated in Fig. 6. From this figure it is clear that the magnitude of the difference of the concentration between the two boundary conditions is very considerable near the ground level, as the height of the receptor increase the difference is reduced. So for low elevations the totally reflected radio-contaminant have the highest concentrations. The examination of the concentration profile for the four selected distances indicate that, for small downwind distance x = 30 m, the plume has non bending profile near the ground and the emission start to vanish at lower heights.

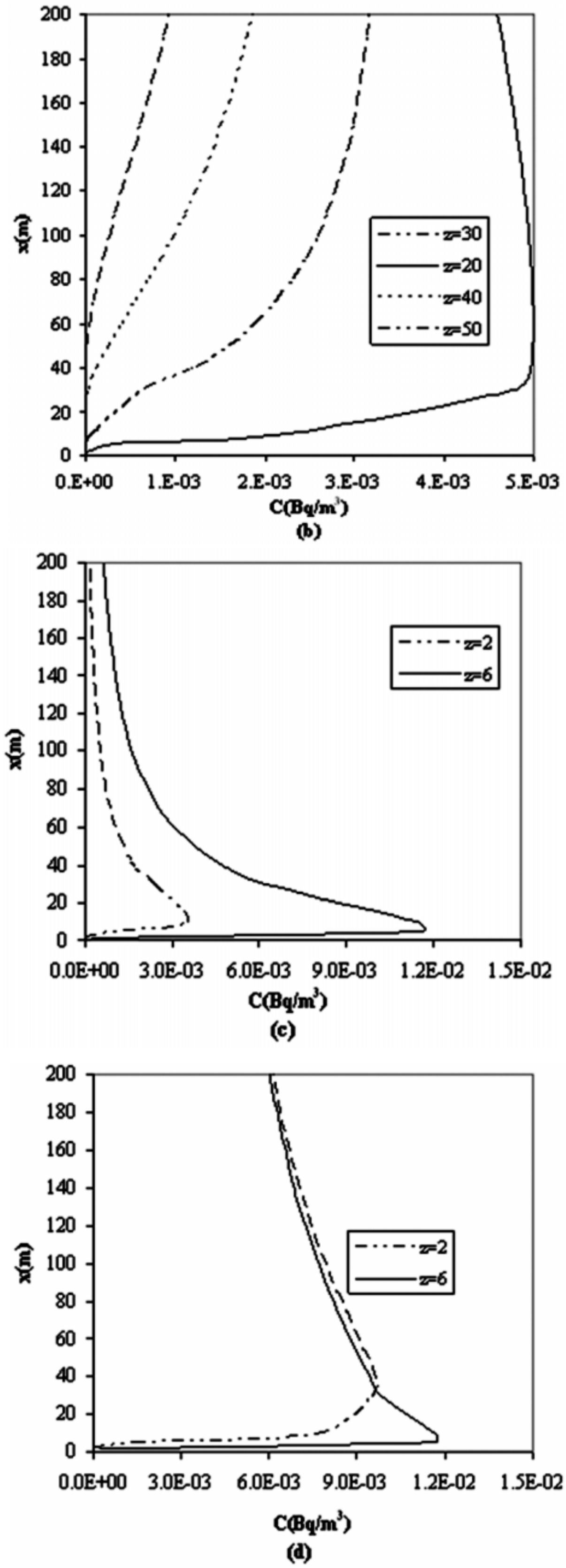
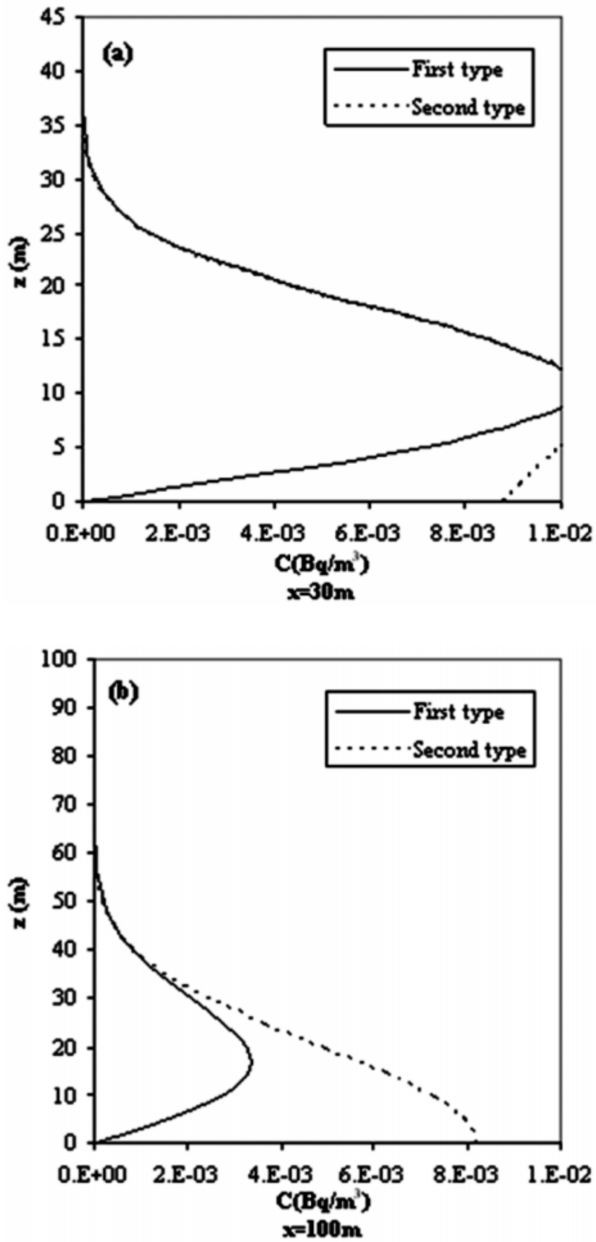


Fig. 5 (a-d): Variation of Downwind Concentration Profile for the First and Second Boundary Conditions for Different Receptor Heights ($z > z_s$)



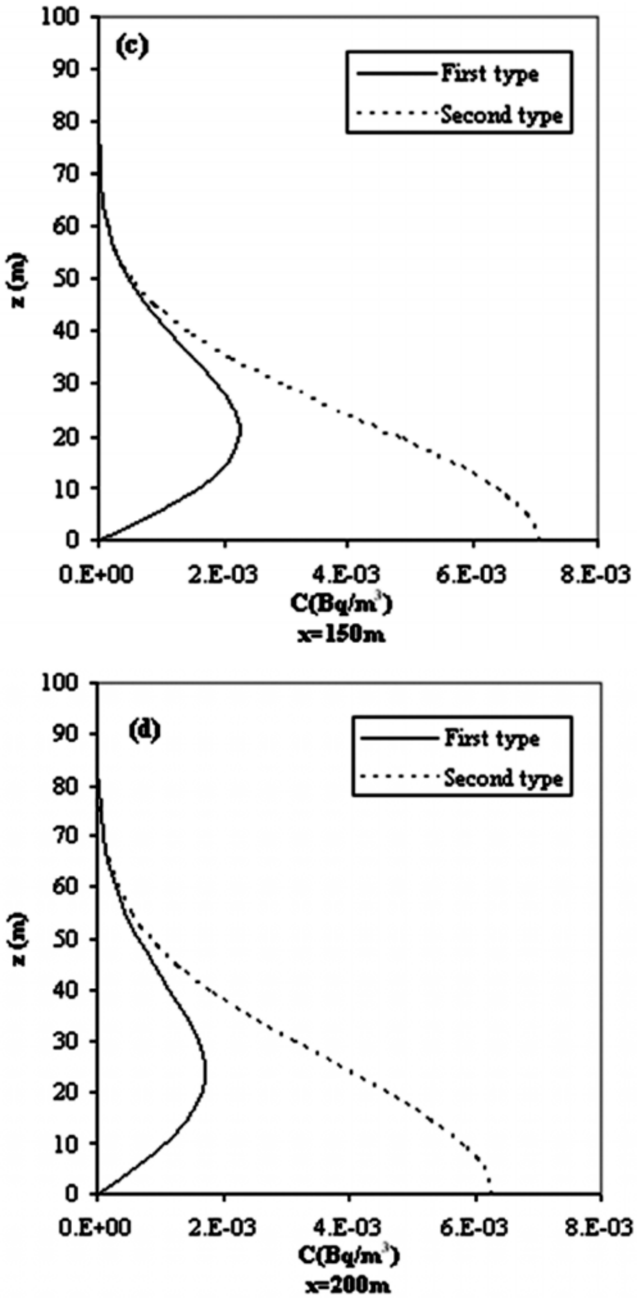


Fig. 6 (a-d): Variation of Crosswind Concentration Profile with Near Field Downwind Distance for the First and Second Boundary Conditions

4.2 Sensitivity and Uncertainty Analysis

Subjective uncertainty (uncertainty and variability in data) can lead to uncertainty in the decision making process. Uncertainty in the input parameters can arise from the lake of sufficient data or due to human and/or instrument errors, while data variability represents the heterogeneity in sample population [22]. The identification of the source of subjective uncertainty is necessary for the analyst to quantify and improve the degree of confidence in the assessment results. In this analysis, the subjective uncertainty will be conducted using random sampling concept to assess the effect of combined variability of all the input parameters on the concentration. In this method random sample of the wind speed and eddy diffusion coefficient will be generated then the output distribution will be analyzed to predict the 90% confidence level in the predicted concentration.

The first step in this analysis is to define the distribution that characterize the uncertainty in the inputs, normal Probability Density Function (PDF) will be used to characterize the uncertainty of the wind speed with mean value 6, 69 m/s and standard deviation 2.33 and uniform distribution for the eddy diffusion coefficient. Then the size of the sample will be determine from the hypergeometric distribution (g) to produce reliability in the result of 90% for small sample size compared with the whole population size with zero defective sample according to the following equation [23]:

$$g\,(1 - R) = R^n$$

This equation can be written in terms of confidence level (Con) as follow [24]:

$$n = \frac{\ln(1 - \mathrm{Con})}{\ln R}$$

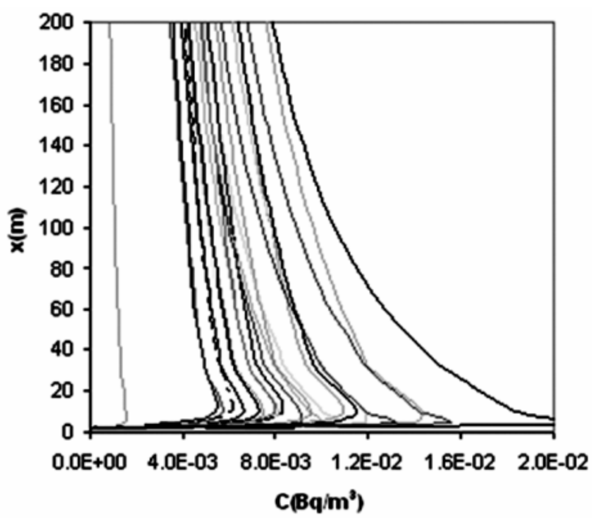
Applying the above equation for a reliability equal 0.9 and 90% confidence level will lead to sample size nearly equal 22.

Several sampling techniques are available, including random sampling, importance sampling, and Latin hypercube sampling. Latin Hypercube Sampling (LHS) was developed to address the need for uncertainty assessment; this technique is capable on extracting large amount of uncertainty and sensitivity information with a relatively small sample size. Latin Hypercube Sampling (LHS) software has been chosen to be used in this part of study for sampling and pairing purposes [25]. The different combinations of input parameters obtained from the sampling step are given in Table 1.

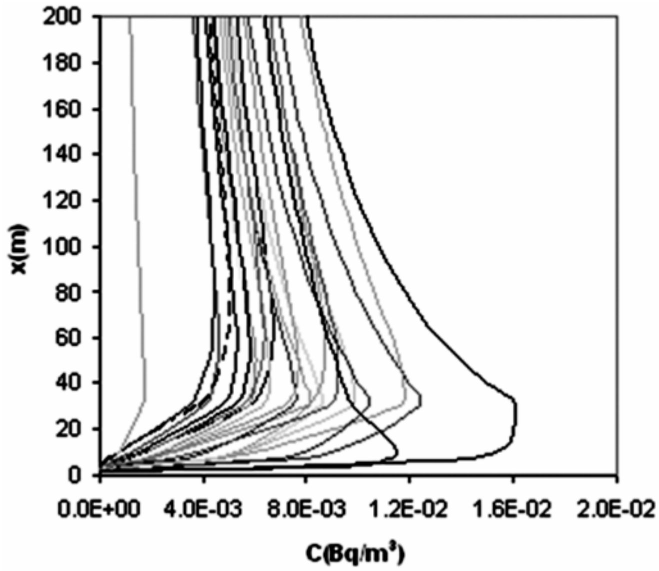
As indicated in Section 4.1, the maximum radio-contaminant concentration is located at the breathing level and the 6 m level for totally reflected radio-contaminant. So the propagation of uncertainty in the input parameters through the model has been performed for these two cases as illustrated in Fig. 7 (a, b). The distribution of the maximum predicted concentration for the two studied receptor

Table 1: Tabulated Value for the Maximum Concentration Obtained for the Second Type Boundary Condition

Number of realization	K (m^2/s)	v (m/s)	C Max at 6m (Bq/m^3)	C Max at breathing level (Bq/m^3)
1	9.46424	2.35230	5.74E-03	2.02E-02
2	8.60406	10.5262	2.08E-02	4.60E-03
3	8.06932	2.84341	1.05E-02	1.61E-02
4	9.24002	5.68218	5.37E-03	8.52E-03
5	7.11947	10.9512	8.31E-03	4.42E-03
6	5.69324	7.24901	1.54E-02	6.67E-03
7	7.41988	3.92146	6.60E-03	1.23E-02
8	7.78932	9.15979	1.10E-02	5.28E-03
9	5.01355	5.51268	7.50E-03	8.77E-03
10	8.41728	8.02142	7.30E-03	6.03E-03
11	6.69082	6.59239	6.10E-03	5.85E-03
12	5.98785	9.57182	8.17E-03	5.06E-03
13	7.82952	7.36284	1.44E-02	6.56E-03
14	5.22115	4.10881	7.50E-03	1.18E-02
15	5.53302	5.22942	1.15E-02	6.03E-03
16	7.25255	8.35743	7.24E-03	9.24E-03
17	8.89171	6.43998	9.08E-03	5.79E-03
18	6.22272	6.33223	9.54E-03	7.49E-03
19	9.89188	5.99493	9.49E-03	7.64E-03
20	6.82794	4.92823	1.15E-02	7.93E-03
21	9.74565	8.65272	1.19E-02	9.24E-03
22	6.05310	7.66811	1.56E-03	9.79E-03
23	9.16566	4.62712	7.98E-03	1.68E-03
24	6.45143	6.90671	1.31E-02	6.35E-03
25	8.38659	8.26694	1.15E-02	1.04E-02



(a)

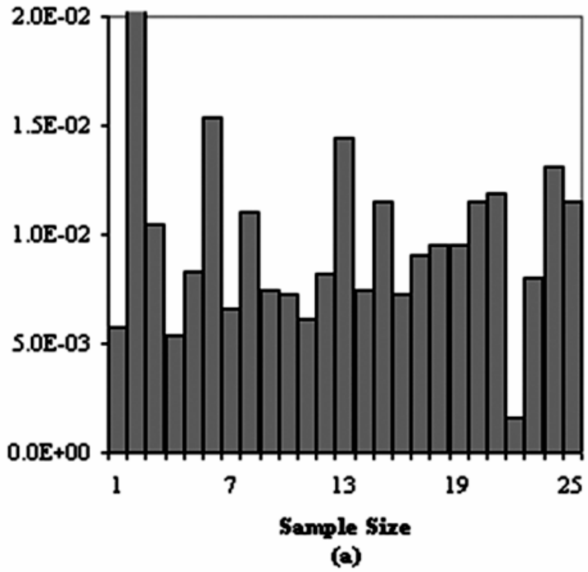


(b)

Fig. 7: Downwind Concentration Profile for Totally Reflected Radio-contaminant at: (a) 6 m and (b) 2 m Receptor Height

location is illustrated in Fig. 8. From this figure it could be concluded that each realization will produce different value for the maximum concentration and that the downwind location at which this maximum value occurs is changed. To summarize the uncertainty in the maximum predicted concentration, the cumulative distribution function (CDF) is plotted as shown in Fig. 9. From this figure, it could be concluded that for the 6 m receptor location there is a 0.05 probability that the relative concentration will have a value less than $5*10^{-3}$ Bq/m^3. There is a 0.95 probability that the relative concentration will not exceed $1.5*10^{-2}$ Bq/m^3. While at the breathing level there is a 0.05 probability that the relative concentration will have a value less than $4.4*10^{-3}$ Bq/m^3. There is a 0.95 probability that the relative concentration will not exceed $1.6*10^{-2}$ Bq/m^3. Form these results it is clear that the consideration of the subjective uncertainty indicates that at the breathing level the receptor will expose to the maximum radio-contaminant concentration.

The results of any assessment are more sensitive to change in some input parameters than changes in others. A sensitivity analysis is therefore needed to check whether changes in an input parameter make significant contribution to the output in order to reduce uncertainty in the results. The examination of the scatter plot of the predicted maximum radio-contaminant concentration versus the uncertain parameters Fig (10, 11) indicates that linear



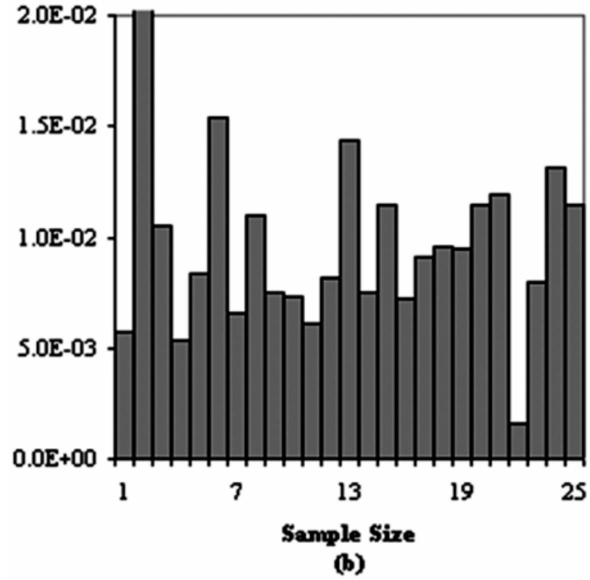
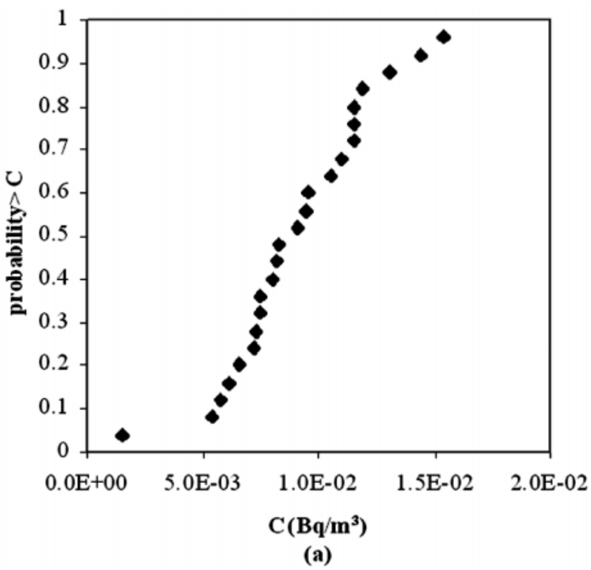


Fig. 8: Distribution of the Maximum Concentration for the Second Type Boundary Conditions: (a) at 6 m (b) at 3 m



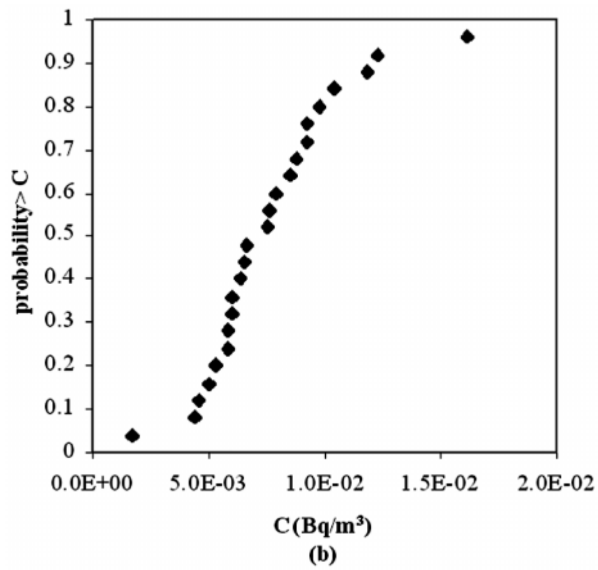
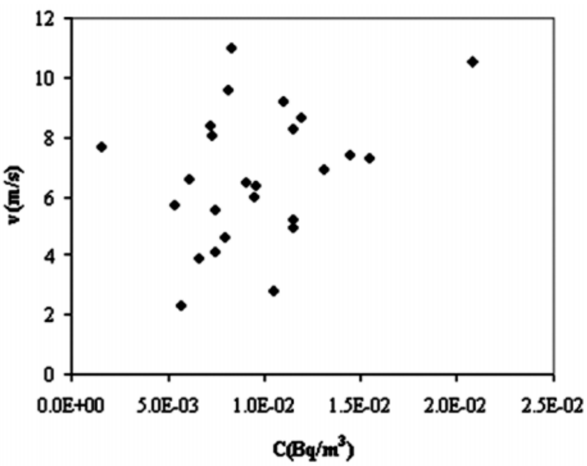


Fig. 9: CDF for Maximum Concentration: (a) 6 m, (b) 2 m



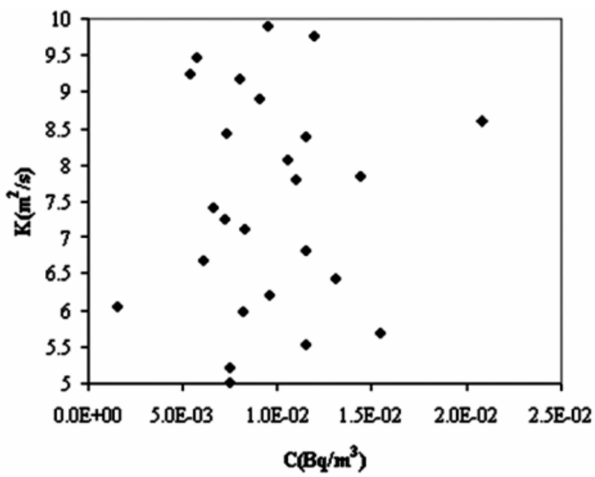


Fig. 10: Scatter Plot of the Maximum Concentration for 6 m

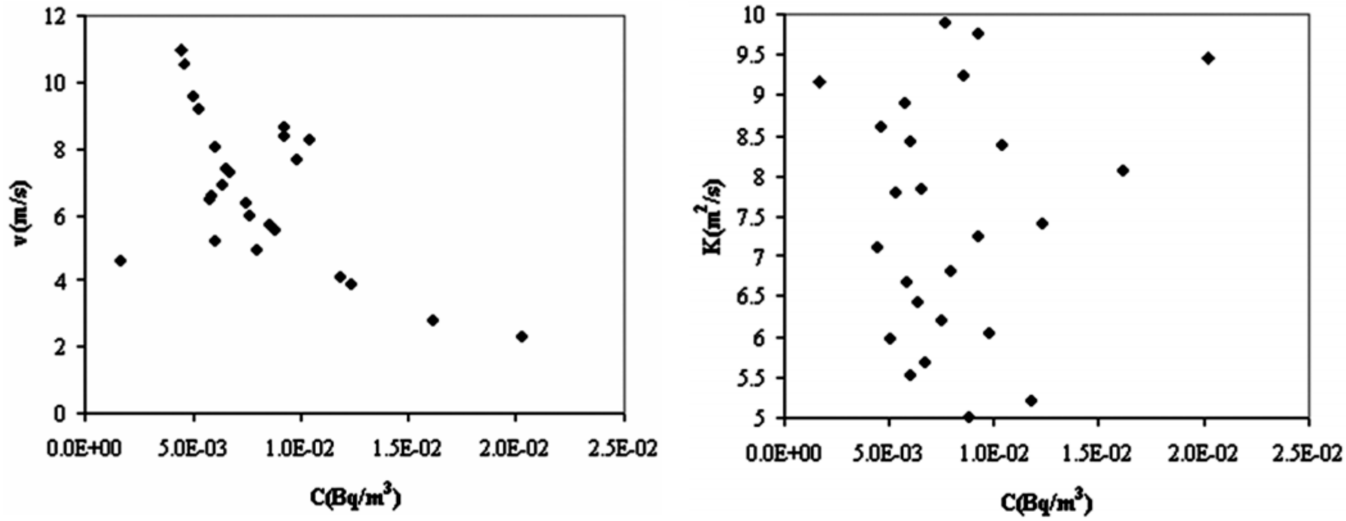


Fig. 11: Scatter Plot of the Maximum Concentration for 2 m

relationship exists between the maximum radio-contaminant concentration and the wind velocity at both studied levels, where there is unclear relationship with the eddy diffusion coefficient. Also, it is clearly shown form Fig. (11-a) that the relationship between the wind speed and the maximum concentration is a negative linear relationship.

5. CONCLUSION

The fate of accidental or routine emissions of radioactive material from the incinerator is a topic of great interest and concern. This paper represents an initial assessment for the continuous operational mode of the low active waste incineration facility. The specific conclusions pertaining to the results presented herein can be drawn as follow:

1. Conceptualization of the assessment model has been developed based on the adaptation of systematic approach combined with conservative assumptions,
2. Simple Gaussian model have been analytically driven using Green function method,
3. The model was applied to preliminary assess the radio-contaminant discharge into the environment for totally reflected and totally adsorbed cases. The maximum concentration was found to occur at the 6 m and breathing levels for totally reflected case,
4. Subjective uncertainty was conducted using random sample concept to assess the effect of combined variability in the wind speed and eddy diffusion coefficient on the predicted maximum concentration, it was found that the consideration of subjective uncertainty indicates that the receptor will expose to the maximum radio-contaminant concentration at the breathing level and there is 95% confidence that the value of this concentration will not exceed $1.6*10^{-2}$ Bq/m^3 for each release unit,
5. Graphical sensitivity analysis examination was conducted and it was found that there is a linear relationship between the wind speed and the predicted concentration.

APPENDIX A

$$\delta(x-\xi, z-\eta) = 0, \quad x \neq \xi \quad z \neq \eta$$

$$\iint_{R_\varepsilon} \delta(x-\xi, z-\eta)\, dxdz = 1, \quad R_\varepsilon : (x-\xi)^2 + (z-\eta)^2 \prec \varepsilon^2$$

$$\iint_{R} F(x,z)\, \delta(x-\xi, z-\eta)\, dxdz = F(\xi, \eta),$$

$$\iint_{R} F(x,z)\, \delta(x-\xi)\, \delta(z-\eta)\, dxdz = F(\xi, \eta),$$

$$\delta(x-\xi, z-\eta) = \delta(x-\xi)\, \delta(z-\eta)$$

APPENDIX B

$$L\left[G(x-\xi, z-\eta)\right] = \delta(x-\xi, z-\eta) \text{ in } D$$

$$G = 0 \quad \text{on } B$$

And G is systematic that is,

$$G(x, z; \xi, \eta) = G(\xi, \eta; x, z)$$

G is continuous in x, z, ξ, η, but its first and second derivatives has a discontinuity at the point (ξ, η) which is specified by the equation

Where n is the outward normal to the circle

$$C_{\in} : (x - \xi)^2 + (z - \eta)^2 = \in^2$$

REFERENCES

Seinfeld J.H., 1986, “Atmospheric Chemistry and Physics of Air Pollution”, Wiley, New York.

Nieuwstadt F.T.M., 1980, “An Analytic Solution of the Time-dependent, One-dimensional Diffusion Equation in the Atmospheric Boundary Layer”. Atmospheric Environment, 14, 1361–1364.

Clark M.J., Smith F.B., 1988. “Wet and Dry Deposition of Chernobyl Releases”. Nature, 332, 245–249.

Jones J.A., 1981. “A Procedure to Include Deposition in the Model for Short and Medium Range Atmospheric Dispersion of Radionuclides”. The Second Report of a Workshop on Atmospheric Dispersion, National Radiological Protection Board, Chilton.

Simmonds J.R., Lawson G., Mayall A., 1995. “Methodology for Assessing the Radiological Consequences of Routine Releases of Radionuclides to the Environment”. EUR-15760, European Commission, Luxembourg, DG-XIII.

Clarke R.H., 1979. “A Model for Short and Medium Range Dispersion of Radionuclides Released in the Atmosphere”. The First Report of a Working Group on Atmospheric Dispersion. National Radiological Protection Board, Chilton.

US EPA, 1995. “User Instructions. User’s Guide for the Industrial Source Complex (ISC3) Dispersion Models”, 1, EPA-454/B-95-003a.

US EPA, 1995. “Description of Model Algorithms. User’s Guide for the Industrial Source Complex (ISC3) Dispersion Models”, 2, EPA-454/B-95-003b.

Jones J.A., 1986. “The Uncertainty in Dispersion Estimates Obtained from the Working Group Models”. The Seventh Report of a Working Group on Atmospheric Dispersion. National Radiological Protection Board, Chilton.

International Atomic Energy Agency, 1995, “The Principles of Radioactive Waste Management”, Safety series no. 111-f, IAEA, Vienna,.

“Egyptian Regulation for Radioactive Wastes Resulted from Different Users”, Al Waqaa Al Masraya, issued on July 12, 1999.

El-Sourougy M.R., 1997, “Planning and Operating of Low Level Wastes Disposal Facilities”, International symposium on experience in the planning and operating of low-level waste disposal facility.

R.O. Abdel Rahman, “Performance Assessment of Unsaturated Clay as a Part of Radioactive Waste Disposal Site”, Ph.D. Thesis, Faculty of engineering, Alexandria University 2005.

R.O. Abdel Rahman, A.M. El Kamash, A.A. Zaki, M.R.El Sourougy, 2005, “Disposal: A Last Step Towards an Integrated Waste Management System in Egypt”, International Conference on the Safety of Radioactive Waste Disposal, Tokyo, Japan, IAEA-CN-135/81, 317–324.

International Atomic Energy Agency, 1993, “Use of Probabilistic Safety Assessment for Nuclear Installations with Large Inventory of Radioactive Material”, IAEA-TECDOC-711, Vienna.

Wark K., C. F. Warner, and W. T. Davis, 1998, “Air Pollution. Its Origin and Control”. Harper and Row Publisher, New York.

Roach G.F., 1970, “Green’s Functions: Introductory Theory with Applications”. Van Nostrand Reinhold, New York.

Greenberg M.D., 1971, “Application of Green’s Functions in Science and Engineering”. Prentice-Hall, Englewood Cliffs, New Jersey.

Beck J.V., Cole K.D., Haji-Sheikh A. and Litkouhi B., (1992), “Heat Conduction using Green’s Functions”, Hemisphere Publishing Corp., Washington, District of Columbia.

Tyn Myint U, L. Debnath, 1996, “Partial Differential Equations for Scientists and Engineers”, North Holland, New York.

Lin J.S. and Hildemann L.M., 1997, “A Generalized Mathematical Scheme to Analytically Solve the Atmospheric Diffusion Equation with Dry Deposition”, Atmospheric Environment, 31, 1, 59–71,

J.C. Helton, 1993. “Uncertainty and Sensitivity Analysis Techniques for use in Performance Assessment for Radioactive Waste Disposal”, Reliability Engineering and System Safety, 42, 2, 327–367.

Ang H-S.A., Tang H.W., 1975, “Probability Concept in Engineering Planning and Design”, 1, Basic Principles, John Wiley & Sons.

Hald A., “Statistical Theory with Engineering Applications”, Wiley, New York, 1952.

Iman R.L. and Shortencarier M.J., 1984, “A FORTRAN 77 Program and user’s Guide for the Generation of Latin Hypercube and Random Samples for use with Computer Models”. Rep. NUREG/CR-3624. Sandia National Laboratory, Albuquerque, New Mexico.