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Estimation of the Maximum Concentration for Non-Gaussian Under Using Different Schemes of Dispersion Parameters for Isotopes

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Abstract

In this paper, we have calculated of the maximum concentration for non-Gaussian and maximum downwind distance under using different schemes of dispersion parameters for isotopes. We have compared between maximum predicated, concentrations for non-Gaussian under using different schemes of dispersion parameters for I_{131} and Cs_{137} via observed and maximum downwind distance.

Keywords: Dispersion parameters for isotopes; Maximum downwind distance; Non-Gaussian

Introduction

Atmospheric dispersion modeling refers to the mathematical description of contaminant transport in the atmosphere. The term dispersion in this context used to describe the combination of diffusion (due to turbulent eddy motion) and advection (due to the wind). Analytical and approximate solutions for the atmospheric dispersion problem have been derived under wide range of simplifying assumptions, as well as various boundary conditions and parameter dependencies. These analytical solutions are especially useful to engineers and environmental scientists who study pollutant transport, since they allow parameter sensitivity and source estimation studies to be performed [1].

Both our scientific understanding and technical developments have greatly increased by the use of empirical, analytical and numerical models to predict the air pollution concentration in atmosphere. For this purposed, the advection – diffusion equation has been largely applied in operational atmospheric dispersion models, in principal, from this equation it is possible to obtain the dispersion from a source given appropriate boundary and initial conditions plus knowledge of the mean wind velocity and concentration turbulent fluxes [2].

The advection–diffusion equation has largely calculated in operational atmospheric dispersion models to predict mean concentrations of contaminants in the planetary boundary dispersion from a continuous point source given appropriate boundary and initial conditions as well as knowledge of the mean wind velocity and concentration turbulent fluxes.

Many turbulent dispersion studies are relating to the specification of these turbulent fluxes to allow the solution of the averaged advection –diffusion equation, this procedure used to know as the closure of the turbulent diffusion problem.

In this paper, we have calculated of the maximum concentration for non-Gaussian and maximum downwind distance under using different schemes of dispersion parameters for isotopes. We have compared between maximum predicated, concentrations for non -Gaussian under using different schemes of dispersion parameters for I_{131} and Cs_{137} via observed and maximum downwind distance.

Non-Gaussian distributions

The concentration from a continuous point source of strength Q with interference from the ground at a mean wind speed U using non-Gaussian plume formula as follows [3]:

$$\bar{C}_n(x,y,z,t)=\left\{\frac{1}{U\pi^2 x t}-\frac{h_s\sqrt{t}}{\sqrt{K_n\pi}}+\frac{1}{2\sqrt{K_n\pi t}}\left(\exp\left(\frac{(z-2h+h_s)}{(z+h_s)}\right)\right)\right\}Q\exp(-\lambda x/U)\frac{\exp\left(-y^2/2\sigma_y^2\right)}{\sigma_y\sqrt{2\pi}} \quad (1)$$

Where:

C is the mean concentration of the effluent at a point (x, y, z), (Bq/m^3).

Q is the source strength (Bq).

U is the mean wind speed (m/s).

X, y, z refer to a downwind, crosswind and vertical coordinate system at the center of the moving cloud.

Σ_i (i=x, y, z) are the plume dispersion coefficients in the x, y and z directions respectively (m) [4,5].

Exp(-x λ/U) is the radioactive decay for the specified nuclide.

H is the effective stack height {h_s (stack height) +Δ h (plume rise)} (m).

Maximum mean concentration of the effluent concentration occurs when $\partial C_n/\partial x=0$ which gives:

$$\frac{\delta\bar{C}_n}{\delta x}=\left(\frac{1}{x^2}+\frac{\lambda}{U^2\pi t x}+\left(\frac{h_s\lambda}{U}\sqrt{\frac{t}{K_n\pi}}-\frac{\lambda}{2U\sqrt{K_n\pi t}}\left(\exp\left(\frac{(z+2h+h_s)}{z+h_s}\right)\right)\right)\right)Q=0 \quad (2)$$

From which we get

$$\frac{1}{x^2}+\frac{\lambda}{U^2\pi t x}+\left(\frac{h_s\lambda}{U}\sqrt{\frac{t}{K_n\pi}}-\frac{\lambda}{2U\sqrt{K_n\pi t}}\left(\exp\left(\frac{(z-2h+h_s)}{z+h_s}\right)\right)\right)=0 \quad (3)$$

Multiply the equation (3) in x^2, we get:

$$\left(\frac{h_s\lambda}{U}\sqrt{\frac{t}{K_n\pi}}-\frac{\lambda}{2U\sqrt{K_n\pi t}}\left(\exp\left(\frac{(z-2h+h_s)}{z+ah_s}\right)\right)\right)x^2+\frac{\lambda}{U^2\pi t}x+1=0 \quad (4)$$

From which we get

$$x_{\max}=\left(\frac{-\frac{\lambda}{U^2\pi t}\pm\sqrt{\left(\frac{\lambda}{U^2\pi t}\right)^2-4\left(\frac{h_s\lambda}{U}\sqrt{\frac{t}{K_n\pi}}-\frac{\lambda}{2U\sqrt{K_n\pi t}}\left(\exp\left(\frac{(z-2h+h_s)}{z+h_s}\right)\right)\right)}}{2\left(\frac{h_s\lambda}{U}\sqrt{\frac{t}{K_n\pi}}-\frac{\lambda}{2U\sqrt{K_n\pi t}}\left(\exp\left(\frac{(z-2h+h_s)}{z+h_s}\right)\right)\right)}\right) \quad (5)$$

Substituting from equation (5) on equation (1), we get maximum

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mean concentration of the effluent concentration:-

$$\bar{C}_{n(\max)}(x,y,z,t)=\left\{\frac{2A}{\pi^2 t B}-\frac{h_s\sqrt{t}}{\sqrt{K_n\pi}}+\frac{1}{2\sqrt{K_n\pi t}}\left(\exp\left(\frac{(z-2h+h_s)}{z+h_s}\right)\right)\right\}\left(\exp\left(-\frac{\lambda B}{2C}\right)+\frac{\exp\left(-y^2/2\sigma_y^2\right)}{\sigma_y\sqrt{2\pi}}\right)Q \quad (6)$$

Where

$$A=\left(h_s\lambda\sqrt{\frac{t}{K_n\pi}}-\frac{\lambda}{2\sqrt{K_n\pi t}}\left(\exp\left(\frac{(z-2h+h_s)}{z+h_s}\right)\right)\right)$$

$$B=\left(-\frac{\lambda}{U^2\pi t}\pm\sqrt{\left(\frac{\lambda}{U^2\pi t}\right)^2-4\left(\frac{h_s\lambda}{U}\sqrt{\frac{t}{K_n\pi}}-\frac{\lambda}{2U\sqrt{K_n\pi t}}\left(\exp\left(\frac{(z-2h+h_s)}{z+h_s}\right)\right)\right)}\right)$$

$$C=h_s\lambda\sqrt{\frac{t}{K_n\pi}}-\frac{\lambda}{2\sqrt{K_n\pi t}}\left(\exp\left(\frac{(z-2h+h_s)}{z+h_s}\right)\right)$$

Dispersion parameters schemes

We select the four different methods namely, power law , Briggs, Irwin and standard method for calculating σ_y and σ_z to select the most accurate one [6], as follows.

A-Power-law method

In this method, σ_y and σ_z can be calculated from the following formula:

$$\sigma_y = c\,x^m \quad \sigma_z = d\,x^n$$

Where c, d, m, n values differ according to stability classes, as given in Table 1.

B- Standard method

In this method, σ_y and σ_z are in the form:

$$\sigma_y=\frac{r\,x}{\left(1+\frac{x}{a}\right)^p} \quad \sigma_z=\frac{s\,x}{\left(1+\frac{x}{a}\right)^q}$$

Where r, s, p and q are constants depending on the atmospheric stability. These values are explained in Table 2

C-Briggs method

In this method, σ_y and σ_z can be calculated from the Tables 3-6 according to Briggs [7].

D- Irwin method

In this method, σ_y and σ_z are taking the following formula:

$$\sigma_y(x)=\frac{\sigma_\theta x}{1+0.9\sqrt{\frac{x}{1000U}}} \quad \sigma_z(x)=\sigma_\phi x$$

Where σ_θ and σ_φ are the standard deviation of the wind direction in the horizontal and vertical directions, respectively. Specification of σ_θ and σ_φ can be found [8], based on the Pasquill stability classes from A to F.

The comparison between observed and predicated, maximum concentrations for non-Gaussian under using different schemes of dispersion parameters for I131 are shown in Figure 1. It is clear that in case power law method the most values both predicated and maximum concentrations are near from the observed values, while the most values for both predicated and maximum concentrations are far from observed values in cases of standard, Briggs and Irwin methods.

The comparison between observed and predicated, maximum concentration via maximum downwind distance for non-Gaussian under using different schemes of dispersion parameters for I131 are shown in Figure 2. It is clear that the most values of observed, predicated and maximum concentrations are far from maximum downwind distance values in cases of standard , Briggs and Irwin methods , while , the most values of observed, predicated and maximum concentrations are near from maximum downwind distance values in case power law method.

The comparison between observed and predicated, maximum

Stability	σ_y (m)		σ_z (m)	
	C	M	D	N
A-B	1.46	0.71	0.01	1.54
C	1.52	0.69	0.04	1.17
D	1.36	0.67	0.09	0.95
E-F	0.79	0.70	0.40	0.67

Table 1: values of the dispersion parameters for the Pasquill stability classes.

Stability classes	A	B	C	D	E	F
r (m/km)	250	202	134	78.7	65.6	37
S (m/km)	102	96.2	72.2	47.5	33.5	2
a (km)	0.927	0.370	0.283	0.707	1.07	1.17
P	0.189	0.162	0.134	0.135	0.137	0.134
Q	-1.918	-0.101	0.102	0.465	0.624	0.70

Table 2: Values of the dispersion parameters for the Pasquill stability classes.

Stability classes	σ_y (x)	σ_z (x)
A	$0.32x\,(1+0.0004x)^{-1/2}$	$0.24x\,(1+0.001x)^{1/2}$
B	$0.32x\,(1+0.0004x)^{-1/2}$	$0.24x\,(1+0.001x)^{1/2}$
C	$0.32x\,(1+0.0004x)^{-1/2}$	0.20x
D	$0.16x\,(1+0.0004x)^{-1/2}$	$0.14x\,(1+0.0003x)^{-1/2}$
E	$0.11x\,(1+0.0004x)^{-1/2}$	$0.08x\,(1+0.00015x)^{-1/2}$
F	$0.11x\,(1+0.0004x)^{-1/2}$	$0.08x(1+0.00015x)^{-1/2}$

Table 3: Formulas produced by Briggs (1973) for σ_y (x) and σ_z (x).

Exp.	downwind distance (m)	U U (m/s)	Stability Classes	H (m)
1	92	4	A	49
2	96	4	A	48
3	97	6	B	45
4	98	4	C	46
5	99	4	A	45
6	100	4	D	45
7	115	4	E	47
8	132	4	C	46
9	134	4	A	47
10	165	3	D	28
11	184	2	B	28.3
12	200	3	A	30.8
13	300	3	A	30.6

Table 4: Meteorological data (downwind distance ‘x’, Wind speed ‘U’, stability classes and effective heights).

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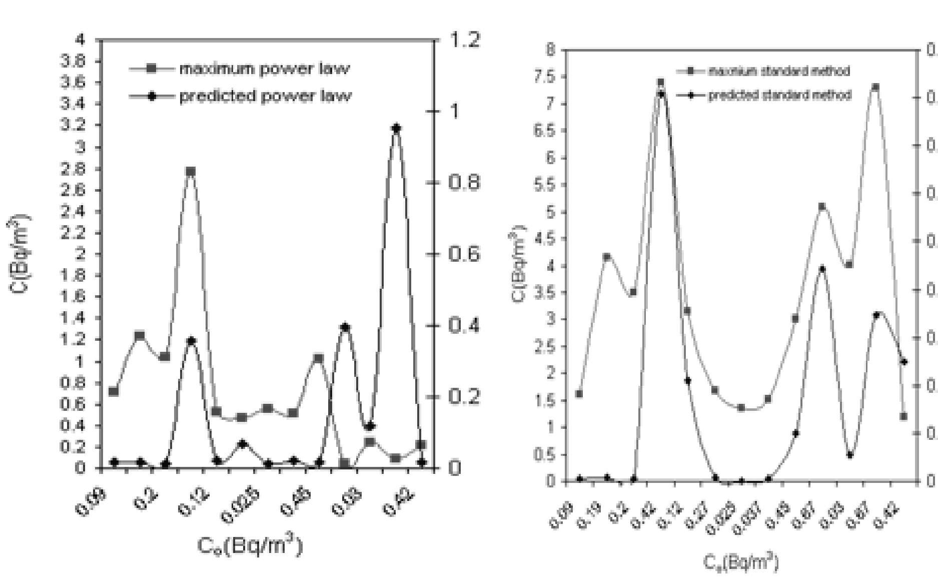
Observed (Bq /m³)	Predicated concentration Non-Gaussian (Bq / m³)				Maximum concentration Non-Gaussian (Bq / m³)				Maximum downwind distance (x) m			
	Power law method	Standard method	Briggs Method	Irwin method	Power law method	Standard method	Briggs method	Irwin method	Power law method	Standard method	Briggs method	Irwin method
0.025	0.011	0.001	0.05	0.054	0.56	1.35	1.6730	1.24	0.34	0.308	1.080	0.828
0.037	0.021	0.005	0.261	0.129	0.51	1.52	1.6733	1.09	0.36	0.124	1.081	0.820
0.090	0.018	0.005	0.0645	0.035	0.71	1.61	1.6486	1.35	0.18	0.146	1.450	1.426
0.200	0.011	0.006	0.676	0.011	1.04	3.51	5.7517	3.74	0.22	0.100	1.461	1.266
0.270	0.069	0.008	0.795	0.039	0.47	1.67	1.6741	1.00	0.38	0.133	1.084	0.904
0.190	0.015	0.009	0.1961	0.043	1.24	4.15	0.6573	5.82	0.28	0.085	0.854	1.386
0.450	0.018	0.101	0.429	0.078	1.02	3.00	0.1033	6.40	0.31	0.117	0.648	0.637
0.120	0.023	0.211	0.61	0.096	0.52	3.15	5.7517	1.56	0.30	0.112	1.461	1.015
0.030	0.12	0.0563	0.564	0.113	0.24	4.01	1.6735	0.41	0.60	0.136	1.082	0.414
0.420	0.357	0.807	0.135	0.06	2.76	7.40	0.8819	1.83	0.12	0.063	0.756	1.258
0.420	0.016	0.25	0.65	0.055	0.21	1.20	4.9618	0.68	1.19	0.059	0.856	0.180
0.670	0.953	0.347	0.907	0.022	0.09	7.31	2.2407	0.17	1.56	0.064	0.960	0.353
0.670	0.394	0.443	0.987	0.068	0.04	5.09	2.2407	0.05	2.91	0.092	0.960	0.468

Table 5: Values for observed, predicated and maximum concentration downwind distance in Non-Gaussian under using different schemes of dispersion parameters for I_{131}.

Observed (Bq /m³)	Predicated concentration (Bq/m³)				Maximum concentration (Bq/m³)				Maximum downwind distance (x) m			
	Power law	Standard method	Briggs method	Irwin method	Power Law	Standard Method	Briggs Method	Irwin Method	Power Law	Standard method	Briggs Method	Irwin Method
0.002	0.0032	0.004	0.032	0.012	0.56	1.35	1.6727	1.238	0.538	0.041	0.531	0.804
0.004	0.0029	0.003	0.023	0.033	0.51	1.52	1.6729	1.092	0.543	0.008	0.525	0.797
0.005	0.0032	0.006	0.003	0.004	0.71	2.90	1.6481	1.348	0.688	0.008	0.792	1.413
0.007	0.0039	0.004	0.002	0.001	1.04	6.01	5.7504	3.743	0.456	0.006	0.612	1.245
0.009	0.0027	0.006	0.003	0.002	0.47	1.67	1.6737	0.998	0.534	0.009	0.509	0.886
0.007	0.0047	0.007	0.004	0.004	1.23	7.50	0.6572	5.822	0.485	0.005	0.433	1.367
0.007	0.0034	0.012	0.006	0.002	1.02	7.76	0.1033	6.397	0.512	0.005	0.363	0.616
0.019	0.0015	0.038	0.001	0.02	0.52	5.28	5.7504	1.562	0.501	0.007	0.612	0.995
0.006	0.0029	0.007	0.005	0.005	0.24	4.01	1.6732	0.411	0.621	0.009	0.520	0.393
0.002	0.0024	0.001	0.004	0.002	2.76	1.25	0.8819	1.832	0.199	0.004	0.268	1.250
0.004	0.0011	0.005	0.009	0.004	0.21	1.40	4.9614	0.677	0.203	0.005	0.191	0.168
0.008	0.001	0.002	0.006	0.005	0.09	1.23	2.2404	0.174	0.419	0.004	0.312	0.345
0.009	0.0009	0.005	0.003	0.004	0.04	7.42	2.2404	0.054	0.460	0.006	0.312	0.476

Table 6: Values for observed, predicated and maximum concentration downwind distance in non-Gaussian under using different schemes of dispersion parameters for Cs_{137}.



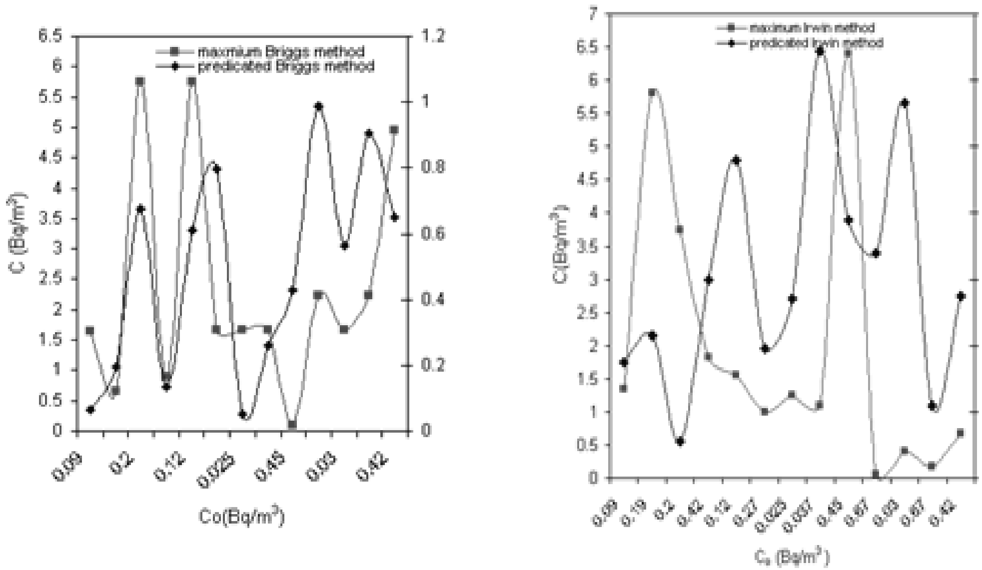


Figure 1: Comparison between observed and predicated, maximum concentration for non-Gaussian under using different schemes of dispersion parameters for I_{131}.

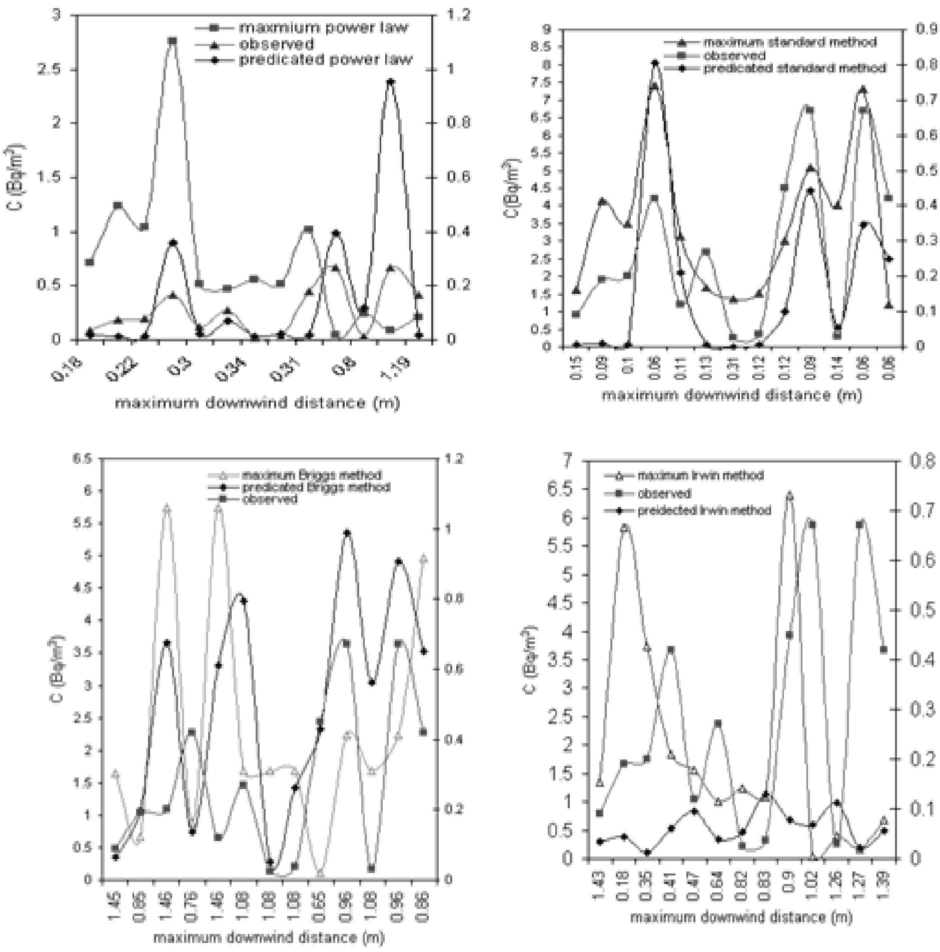


Figure 2: Comparison between observed and predicated, maximum concentration via maximum downwind distance for non-Gaussian under using different schemes of dispersion parameters for I_{131}.

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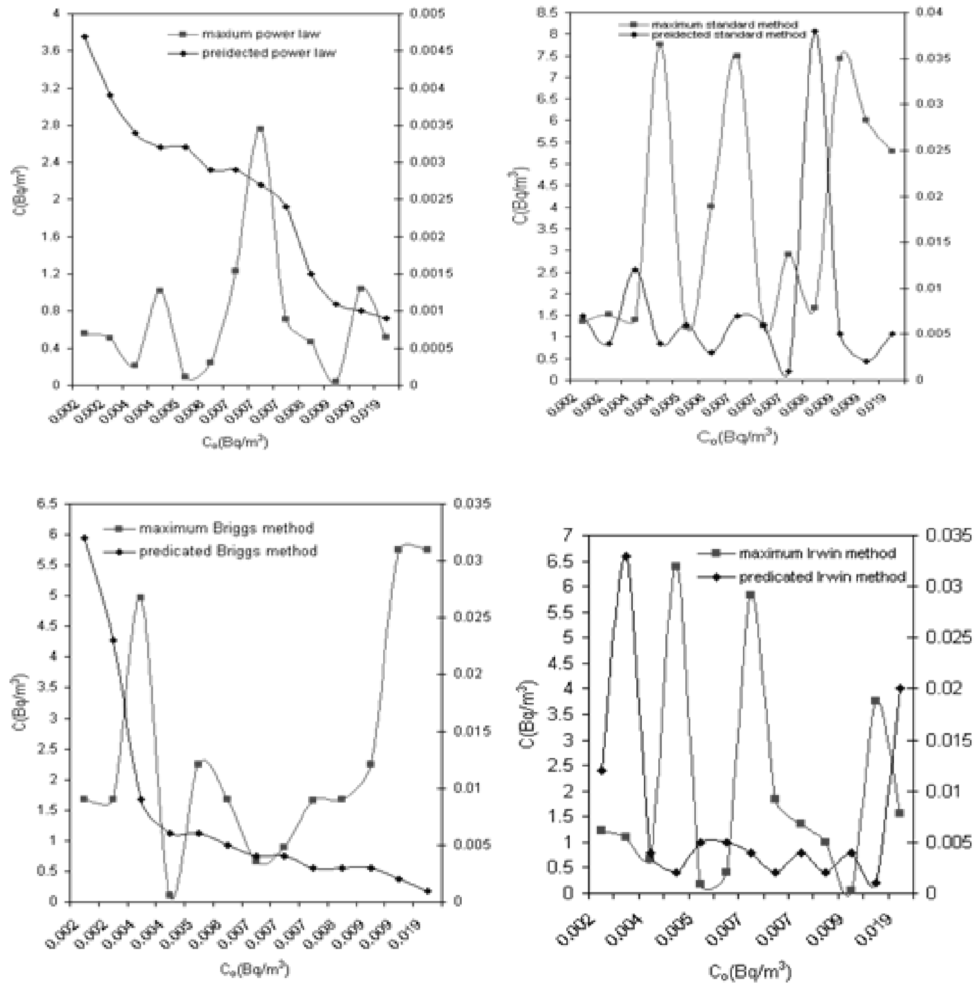
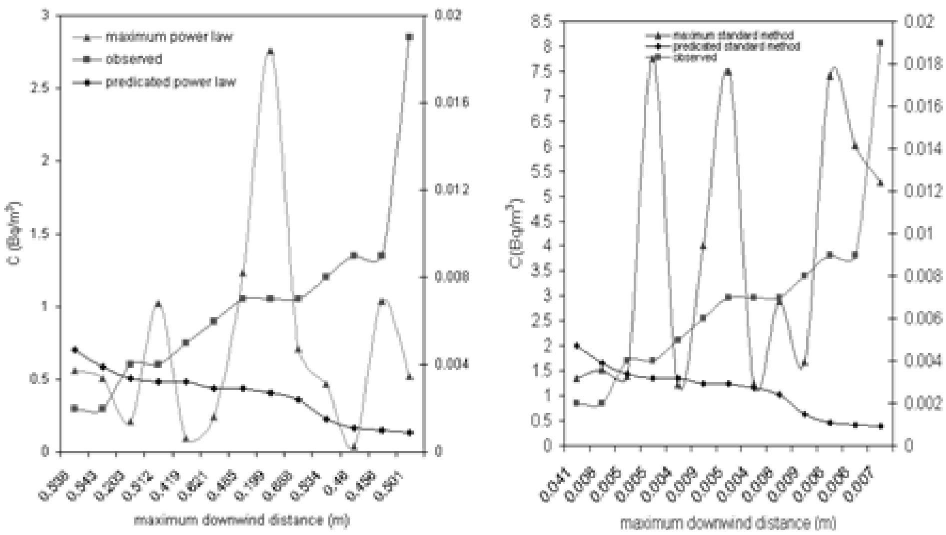


Figure 3: Comparison between observed and predicated, maximum concentrations for non-Gaussian under using different schemes of dispersion parameters for Cs_{137}.



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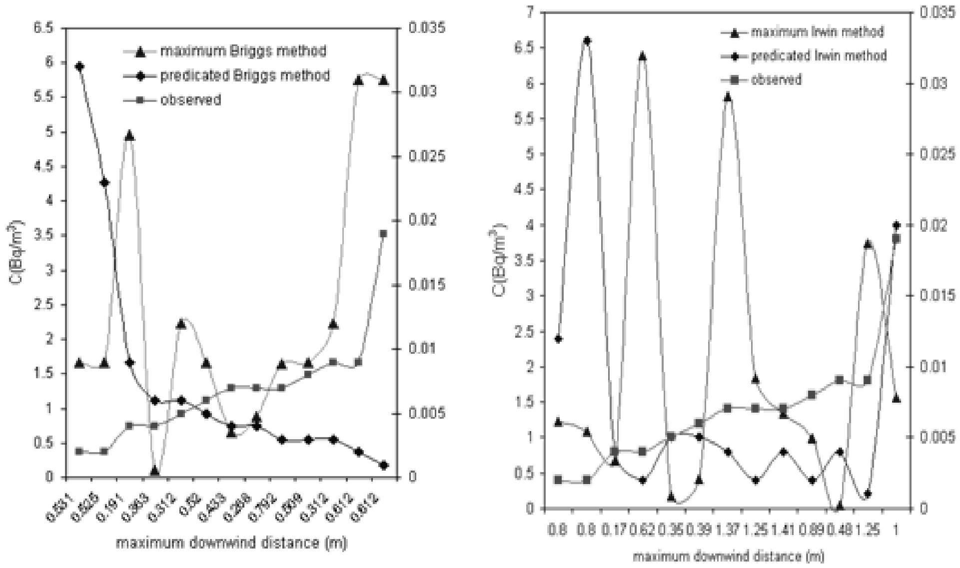

Figure 4: Comparison between observed and predicated, maximum concentration via maximum downwind distance for non-Gaussian under using different schemes of dispersion parameters for Cs_{137}.

concentrations for non-Gaussian under using different schemes of dispersion parameters for Cs137 are shown in Figure 3. It is clear the most values of predicated and maximum concentrations agreement with observed data in cases of standard, Briggs and Irwin methods, while in case power law method the values of maximum concentration are best from predicated concentration with observed data.

The comparison between observed and predicated, maximum concentration via maximum downwind distance for non-Gaussian under using different schemes of dispersion parameters for Cs137 are shown in Figure 4. It is clear in cases of Briggs and Irwin methods the values of observed and predicated concentrations are best from maximum concentrations with maximum downwind distance, while, in cases power law and standard methods the values of predicated concentration are best from observed and maximum concentrations with maximum downwind distance.

Conclusions

The maximum concentration for non-Gaussian and maximum downwind distance under using different schemes of dispersion parameters for isotopes has evaluated. Comparison between maximum predicated concentrations for non-Gaussian under using different schemes of dispersion parameters for I131 and Cs137 via observed and maximum downwind distance are calculated.

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