ENVIRONMENTAL IMPACTS OF RADIATION RELEASES FROM NUCLEAR POWER PLANTS

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Dabaa, 140 Km west Alexandria is the selected site for the first nuclear power plant in Egypt. The paper provides eight dispersion models to describe routine / accidental, short term / long term, and ground-level / elevated releases. The dispersion ratios, as well as the isopleths around the site, have been evaluated for all types of releases The analysis of meteorological data showed that Dabaa site has great stability over the whole year .Isopleths plotted revealed the suitability of the selected site to construct the first nuclear power plant in Egypt.

1-INTRODUCTION

No explicit statement has been declared on the future of the constructing plan for the first nuclear power plant included in the nuclear energy program in Egypt. Hence it is understood that the construction is postponed but not canceled.

2-DISPERSION MODELS

The Gaussian plume model is recommended in many regulatory guides to be applied in practical situations such as:

A- Ground-level / Elevated release (G / E)

Ground –level releases include the estimation of the average affluent concentration normalized by source strength (χ / Q) at all release points or areas that are lower than two and half times the height of adjacent structures. At far points, the estimation of χ / Q is termed as elevated releases.

B- Long term / Short term release (L / S)

In long term calculations, the annual average values of “χ / Q” are estimated. The continuous release and the resulting effluents concentrations will be distributed evenly across each azimuthally sector. In short term calculations the centerline values of “χ / Q” are calculated at given individual receptor locations for each combination of wind speed and atmospheric stability category.

C- Routine / Accidental release (R / A)

Routine releases include the calculation of the controlled values of” χ / Q” under normal operation of the NPP. Accidental releases include the application of atmospheric dispersion models for potential accident consequences.

According to the previous classifications, eight dispersion models can be formulated and denoted as RLE, RLG, RSE, RSG, ALE, ALG, ASE, and ASG models.

The mathematical formulation is presented in section-4.

3-DISCRETE VARIABLES

Spatial wind direction sectors (i)

Total number of sectors is 18, each of width π / 9.

Wind speed class (k)

Six wind speed classes are assigned as follows:

Class	Wind speed (v, m / s)
1	$v < 1$
2	$1 \leq v < 2.5$
3	$2.5 \geq v < 5.5$
4	$5.5 \geq v < 10.5$
5	$10.5 \geq v < 15.5$
6	$v. \geq 15.5$

Atmospheric stability class (k)

Grouping are suggested to contain seven classes according to the vertical temperature difference as follows [1]

Stability classification	Pasquill categories	Temperature change With height (0C / 100 m)
Extremely unstable	A	$\Delta T/\Delta Z \leq -1.9$
Moderately unstable	B	$-1.9 < \Delta T/\Delta Z \leq -1.7$
Slightly unstable	C	$-1.7 < \Delta T/\Delta Z \leq -1.5$
Neutral	D	$-1.5 < \Delta T/\Delta Z \leq -0.5$
Slightly stable	E	$0.5 < \Delta T/\Delta Z \leq 1.5$
Moderately stable	F	$1.5 < \Delta T/\Delta Z \leq 4.0$
Extremely stable	G	$\Delta T/\Delta Z > 4.0$

4- MATHEMATICAL MODELING (3, 4)

RLE- Model

$$(\chi / Q)_{i,x} = 2.286 \sum_{J,k} P_{ijk} [x\bar{U}_k \sigma_{zj} (x)]^{-1} \exp [-H_e^2 / 2 \sigma_{zj}^2 (x)]. DEC_k (x)$$

RLG Model

$$(\chi / Q)_{i,x} = 2.286 \sum P_{ijk} [x\bar{U}_k \Sigma_{zj}(x)]^{-1}. DEC_k (x),$$

J, k

$$\Sigma_{zj}(x) = (\sigma^2_{zj}(x) + 0.5D_z^2 / \pi)^{1/2}$$

$$\Sigma_{zj}(x) \le \sqrt{3}\, \sigma_{zj}(x)$$

RSE- Model

$$(\chi / Q)_{i,x} = \sum_{J,k} [U_k \pi\sigma_{yj}(x)\, \sigma_{zj}(x)]^{-1} \exp[- H_e^2 / 2\sigma_{zj}(x)^2]$$

$$(\chi / Q)_{i,x} = 2.286 \sum_{J,k} [\sigma_{zj}(x) U_k . x]^{-1} \exp[-H_e^2 / 2\sigma_{zj}(x)^2]$$

RSG Model

$$(\chi / Q)_{i,x} = \sum_{J,k} [U_k(\pi\, \sigma_{yj}(x)\, \sigma_{zj}(x) + CA)]^{-1}$$

$$(\chi / Q)_{i,x} = \sum_{J,k} [3 U_k \pi\, \sigma_{yj}(x)\, \sigma_{zj(x)}]^{-1}$$

$$(\chi / Q)_{i,x} = 2.286 \sum_{J,k} [x\, U_{k(}\sigma_{zj}^2(x) + CD^2 z/\pi)^{1/2}]^{-1}$$

$$(\chi / Q)_{i,x} = 2.286 \sum_{J,k} [3\, U_k \sigma_{zj}(x).x]^{-1}$$

ALE Model

$$(\chi / Q)_{i,x} = 2.286 \sum_{J,k} P_{ijk} \exp[-H_e^2 / 2\sigma_{zj}(x)^2]\, [x\, \bar{U}_{k(h)} \sigma_{zj}(x)]^{-1}$$

ALG Model

$$(\chi / Q)_{i,x} = 2.286 \sum_{J,k} P_{ijk}\{x.\, \bar{U}_{k(10)}[\sigma^2_{zj}(x) + CD^2 z/\pi]^{1/2}\}^{-1}$$

$$(\chi / Q)_{i,x} = 2.286 \sum_{J,k} P_{ijk}[x.\sqrt{3}\, \bar{U}_{k(10)}\, \sigma_{zj}(x)]^{-1}$$

ASE Model

$$(\chi / Q)_{i,x} = \sum_{J,k} [\pi U_{k,j}(He)\, \sigma yj(x)\, \sigma_{zj(x)}]^{-1} \exp[He2 / \sigma_{zj}^2]$$

References [3, 5] suggest the mathematical models used in this respect under fumigation and no fumigation conditions.

ASG Model

$$(\chi / Q)_{i,x} = \sum_{J,k} \{U_{jk(10)}[\pi\sigma_{yij}(x) + \sigma_{zj(x)} + CA]\}^{-1}$$

$$(\chi / Q)_{i,x} = \sum_{J,k} [3U_{jk\,(10)} \pi \sigma_{yj}(x)\, \sigma_{zj(x)}]^{-1}$$

$$(\chi / Q)_{i,x} = \sum_{J,k} [U_{jk} \pi\, M_{jk(x)} \sigma_{yj}(x)\, \sigma_{zj(x)}]^{-1}$$

Parameters definitions

$(\chi / Q)_{i,x}$ = Average Effluent concentration ,x, normalized by source strength, Q, at distance x in directional sector I (second / cubic meter)

P_{ijk} =Joint probability of occurrence of the k th wind speed class, j th stability class, and i th wind direction sector.

2.286 = $(2\pi^3)^{\frac{1}{2}}$ divided by the width in radians of 20° sector.

$\bar{U}_k$ = mid-point value of the k^{th} wind speed class.

$\sigma_{zj}(x)$ = vertical plume spread for stability class (j) at distance x (meters).

x = Downwind distance (meters)

DEC_k (x) = reduction factor due to radioactive decays at distance x for the k th wind –speed class.

He = effective plume height (meters)

D_z = Maximum adjacent building height either up or downwind from the release point.

$\sum_{zj}(x)$ = Vertical plume spread with a volumetric correction for additional Dispersion within the building wake cavity.

C = building –wake constant (a reasonable value is 0.5)

A = minimum cross – section area of the reactor building (m^2)

$\bar{U}_k$ (h) = Average wind speed for wind-speed for wind – speed category k and stability Category j adjusted to release height (m/sec).

U_{kj} (10) =Average wind speed for wind speed category k, and stability category (j) adjusted to 10.0 meters (meters/sec).

$M_{kj}(x)$ = meander factor for lateral plume spread for wind – speed category k and stability Category (j) at a distance x.

5- DABAA SITE

Examination of many sites against relevant site attributes revealed that Dabaa is an appropriate sit for constructing the first NPP in Egypt. Dabaa is a small town about 140 Km west Alexandria city. Data , from six meteorological stations, on environmental conditions along the north west coast of Egypt in general and Dabaa site in specific are provided in a report prepared by Sofratom in 1984 [2]. The report includes data on air temperature, relative humidity, rain fall, hail / snow, thunderstorms, sand-storms, hydrology, geology / tectonics, and seismology. Complete analyses of the reported data enhanced the selection of the site for constructing a NPP.

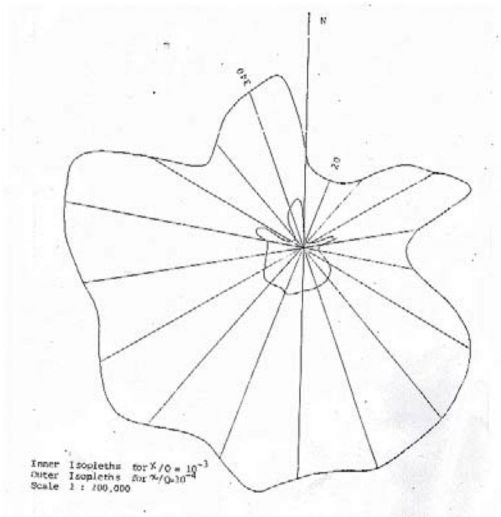
6- RESULTS AND CONCLUSIONS [5]

All relevant data for Dabaa site was fed to a computer program written in Fortran-IV and the values of "χ / Q" were computed at different radial distances for the eight models presented in section--5.

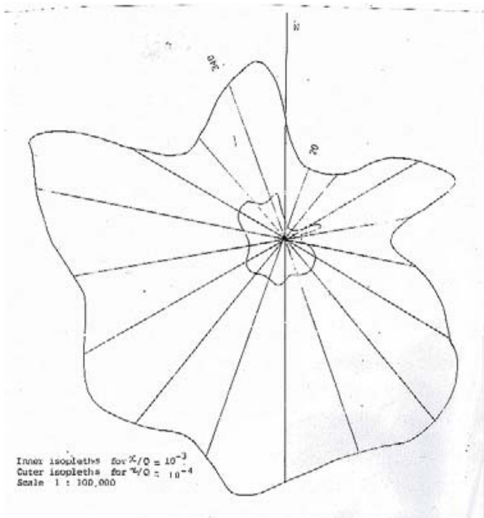
Isopleths, contours connecting the same values of "χ / Q", were mapped. The isopleths give a complete idea about the dispersion characteristics in different sectors… Figure-1 shows the isopleths for RLE, RLG, RSE, and RSG models

Based on the results obtained, the following conclusions could be extracted:

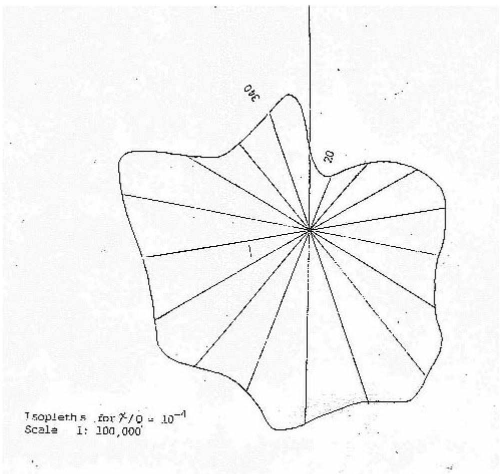
i) Meteorological data of Dabaa site revealed great stability over the whole year (classes E and F are the most frequent ones).



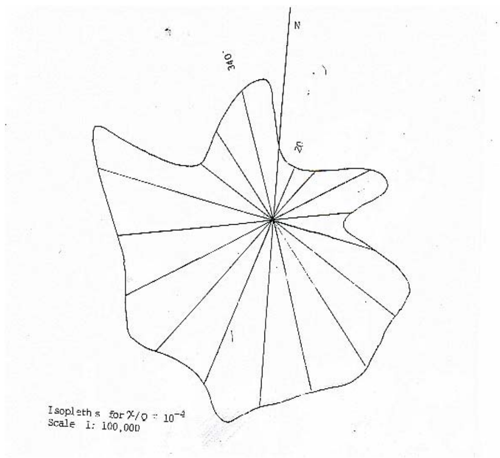
RLE MODEL



RLG MODEL



RSE MODEL



RSG MODEL

Figure 1. Isopleths for RLG, RLE, RSE, RSG Models

ii) Application of routine release models assured the suitability of Dabaa site for constructing the first NPP in Egypt. Sector 15 (280^0-300^0), the most dominant sector, is fortunately directed to the Mediterranean Sea.

iii) Application of accidental release showed the low population zone (LPZ) includes sectors (8) and (9) (140^0-180^0). Although the population density within these sectors is very small, future expansion has to take into consideration that these sectors must be always treated as a low population zone (LPZ).

7- CONCLUDING REMARK.

It should be noted that the dispersion models addressed in this work concern the determination of the dispersion factor "χ / Q ". To compute the actual activity dispersed (χ, Ci / m^3), the source term (Q, Ci / sec.) should be firstly calculated. Q in this case may be defined in three different ways. [6] It is the inventory of radionuclide:

- Available for dispersal from the containment
- Dispersed over the area outside the containment
- Potentially available for release to the containment during a hypothetical accident.

Whatever the release is under routine or accident conditions, the source term calculation originates from the inventory of fission fragments inside the fuel elements.

In the case of routine releases, the calculation is straightforward and can be done by hand calculations [7]or using computer codes such as ORIGEN [8].Reference [9] provides some calculated and measured radioactive releases from some typical NPPs.

Accidental releases depend on the accident scenario which includes all errors involved, situation of barriers, and functioning of engineered safety feature systems.

There are many available codes dealing with accidental release and provided in references [10-14].

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