Appendix A-4

Guidelines on Estimating Height Restriction and Position of Fresh Air Intake Using Gaussian Plume Models

1. Introduction

1.1 Two situations in Hong Kong call for an assessment of ambient pollution concentration as a function of height, namely, the determination of

(i) height restriction for new buildings in areas subject to poor air quality aloft as a result of elevated emission sources nearby; and

(ii) optimum / acceptable location of fresh-air intakes for centrally air-conditioned buildings.

1.2 Simple Gaussian plume models like the Industrial Source Complex Dispersion Model - Short Term Version 3 (ISCST3) have been commonly used in Hong Kong for predicting air quality with a view to addressing the two situations above. This guideline provides a practical approach to applying the ISCST3 model to these two situations in order to safeguard air quality. The application limits of the ISCST3 model must, however, be observed (refer to its User's Guide). Suitable alternatives such as wind tunnel modeling or more sophisticated numerical modeling may have to be used instead if the situation warrants.

2. Approach

2.1 The concentration pattern at sensitive receivers produced by emissions from a single stack is different from that produced by multiple stacks. However, in most cases, the emission characteristics of one particular stack can be used to approximate the concentration pattern at sensitive receivers due to its dominance. An exception to this generalization occurs when there exist a number of stacks concentrating in a small area but having large differences in emission characteristics such as emission height, stack dimensions, efflux velocity and temperature.

General Situation

2.2 A case can be considered general if it belongs to one of the following categories:

(i) Vertical concentration profile at receptors is contributed solely by emissions from one stack with diameter less than or equal to 1m;

(ii) Vertical concentration profile at receptors is dominated by emissions from one stack with none of the contributing stacks having tip diameter larger than 1m and the stacks are not clustered in space (i.e. not of similar distance nor in the same direction from the receptor);

(iii) Vertical concentration profile at receptors is dominated by emissions from more than one stack with no contributing stack(s) having tip diameter larger than 1m and the stacks are not clustered horizontally; and

(iv) Vertical concentration profile at receptors is dominated by emissions from more than one stack with no contributing stack(s) having tip diameter larger than 1m and the dominant stacks clustered horizontally, but the stack gas characteristics and emission heights of these dominant stacks are not significantly different.

2.3 Since only fewer than 3% of stacks registered in Hong Kong have tip diameter larger than 1m, these "large" stacks are treated individually as suggested in section 2.5.

2.4 For the general case, we have performed a sensitivity study (Annex 1) based on a single stack to determine the uncertainty associated with plume heights arising from input data of limited accuracy. On the basis of these findings, we recommend the followings:

(i) Conduct an air quality modelling exercise using the stack emission characteristics dictated by the situation.

(ii) The restricted height range will be the region of unacceptable air quality with a 10m safety margin added to both ends. The modeling exercise should therefore address the full receptor height range and 10m beyond.

Special Situation

2.5 For all other situations not covered by those in Section 2.2 above, the following procedures are recommended:

(i) Conduct an air quality modelling exercise using the minimum values of stack gas exit velocity and stack gas temperature (i.e. $6ms^{-1}$ and 373K, respectively).

(ii) Conduct a second modeling exercise based on the maximum (or calculated, whichever is higher) values of stack gas exit velocity and stack gas temperature of the respective ranges (Table 1).

(iii) The results from the first and second runs above are then used to delimit the upper and lower end of the range of unacceptable air quality, respectively.

2.6 In conducting the air quality modeling exercise, background pollutant concentrations should also be allowed for. The "Guidelines on Assessing the 'TOTAL' Air Quality Impacts" can be referred to.

Annex I

Sensitivity Study on the Height of Maximum Impact at a Receptor

A. Approach

A.1 In assessing the impact of emission from a point source using ISCST3, the following parameters would affect the plume rise:

a. stack height;

b. stack diameter;
c. stack gas temperature;
d. stack gas exit velocity;
e. ambient temperature; and
f. stack tip wind velocity.

A.2 The first two parameters above are clearly specified and not subject to change. The last two parameters are part of the meteorological input independent of plume characteristics. Uncertainty in the plume rise calculation is introduced through:

a. the limited ability of the plume rise algorithm to replicate nature; and

b. the uncertainty in the effluent's characteristics as represented by the stack gas temperature and stack gas exit velocity.

A.3 The first type of uncertainty attends all mathematical representation of complex reality. Users of model results will have to come to terms with this limitation. However, in modeling air quality for general environmental assessment (e.g. ground level concentration, safe set-back distance, ..., etc.), attempts are usually made to produce a 'conservative' estimate. Though this conservative estimate does not address the accuracy of the algorithm, which varies from case to case and cannot be determined without an unrealistic amount of monitoring in most cases, it is generally practiced and accepted as sufficient to safeguard the air quality at sensitive receivers.

A.4 In the same vein, we are attempting to specify procedures that would produce 'conservative' results to safeguard air quality at air sensitive receptors that are dependent on the vertical position of the plume. The complication in this attempt is the definition of 'conservative' results. For the case of height restriction, estimation based on a lower plume rise would be conservative. For determining the optimum locations of fresh-air intakes, enough margin would have to be allowed for at both the upper and lower ends of the acceptable locations.

A.5 Since the values of the stack gas temperature and stack gas exit velocity affect the plume rise, a sensitivity test was conducted to delimit the uncertainty in plume rise due to these two parameters.

B. Sensitivity Study

B.1 The base case of the sensitivity test is selected such that the plume rise due to buoyancy (represented by the stack gas temperature) and momentum (represented by the stack gas exit velocity) is at a minimum. This corresponds to choosing the minimum values of the stack gas exit velocity and temperature in the respective ranges. Performing sensitivity tests on this base case would amplify the resulting deviation, thus producing conservative results.

B.2 By studying the emission characteristics of the industrial stacks in Hong Kong, it is found that exit velocities and stack gas temperatures for most industrial stacks vary between 6 - 10 ms^{-1} and 373 - 573K. For the sensitivity tests, the values of the exit gas velocity and exit gas temperature are varied within these ranges to determine the maximum uncertainty in plume rise. The details of the parameters used in the base case are given in Table 1.

B.3 The same procedure was repeated for different values of the stack tip diameter (between 0.1 and 1m) and for different ambient temperatures (between 0 and 40^{o}C).

C. Results

C.1 Within a horizontal distance of 20 to 1,000m from the stack, the sensitivity tests' results show that the plume centre line height will not differ by more than 10m from that of the base case for the specified ranges of parameter values. Also, within the ranges tested, this plume centre line height is not significantly affected by the ambient temperature and stack tip diameter. Furthermore, the maximum concentration at a certain distance from the stack is not sensitive to the changes in the stack gas exit velocity and stack gas temperature.

C.2 Further tests show that some plume rise values resulting from the specified ranges of parameters may deviate from the base case plume rise by more than 10m if the stack tip diameter is larger than 1m.

Table 1
Input Parameters in the Base Case

Chimney Characteristics	**Rationale**
height of emission - 100m	the height was chosen to represent the typical height of emission for chimneys in industrial areas
stack tip diameter - 1m	approximate 97% of the stacks have diameters less than 1m according to EPD's Enforcement Management System (EMS)
exit velocity - 6 ms^{-1}	the minimum exit velocity required by the licence
exit gas temperature - 373K	the minimum of the range typical of those stacks servicing industrial boilers
emission strength - 1gs^{-1}	a reference emission strength

Meteorological Conditions	**Rationale**
(included in a meteorological file) wind speed & stability class	follows the USEPA's meteorological conditions for screening procedure, i.e. A: 1, 2, 3 ms^{-1} B: 1, 2, 3, 4, 5 ms^{-1} C: 1, 2, 3, 4, 5, 8, 10 ms^{-1} D: 1, 2, 3, 4, 5, 8, 10, 15, 20 ms^{-1} E: 1, 2, 3, 4, 5 ms^{-1} F: 1, 2, 3, 4 ms^{-1}
mixing height - 500m	as the emission height of the source is at 100m, the predicted concentration and the height of maximum impact are insensitive to this value
ambient temperature - 298K	a typical ambient temperature used in Hong Kong

Receptor
receptor distance
- 20, 40, 60, 80, 100, 150, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000m downwind from the source
receptor height
- 80 - 200m of 10m intervals

Other Options
(following typical choices in modeling exercises)
dispersion coefficient - urban
wind profile exponents - default
vertical temperature gradient - default
gradual plume rise option
stack tip downwash option
no building downwash option

The information contained in this Appendix is only meant to assist the Applicant in performing the air quality assessment. The Applicant must exercise professional judgment in applying this general information for the Project.