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Guidelines on the Estimation of PM2.5 for Air Quality Assessment in Hong Kong

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1. Background

PM2.5 is defined as particulates that can be suspended in the air which have equivalent diameters of less than 2.5 microns.

The Administration is making preparations to promulgate a new set of air quality objectives (AQOs), which includes PM2.5. As compliance with the AQOs is a criterion for assessing air quality impact in an environmental impact assessment, the following sections provide guidance on how the concentration of PM2.5 can be calculated based on tools currently employed by Hong Kong's air quality modeling community. The suggested method will evolve with time and updates will be issued accordingly.

2. Introduction to PM2.5 Estimation Method

Unlike gaseous air pollutants, PM2.5 is often a mixture of different chemicals. For air quality impact assessment against HK's air quality objectives, only the total mass, expressed as the concentration, of PM2.5 is required.

To cater for the diverse composition of PM2.5, there are sophisticated air quality models that estimate PM2.5 concentrations from the constituent precursors. These models require inputs relating to emissions of the relevant constituents and/or precursors. For regions in and around Hong Kong, an emission inventory to support such sophisticated predictions of PM2.5 concentration is to be developed. Yet even with the best available emission estimates, the model-predicted concentrations have not always been satisfactory based on overseas experience (Smyth 2006), hence a simpler approach is considered for air quality impact assessments now that estimation models and supporting databases for the region are available.

3. Recommended Approach

EPD's guidelines on air quality assessment recommend a three-tier approach to arrive at an impact assessment (Guidelines on Assessing the 'Total' Air Quality Impacts).

Since source impacts are important to assessment in the near-field, the first two tiers' contributions are usually estimated using local-scale Gaussian models by assuming that the emitted pollutants are not chemically transformed into another form, i.e. pollutants are treated as inert species. On the other hand, because third-tier impacts are diffuse, it is not necessary to identify them to specific sources; their contributions can be estimated from measurements or from a regional-scale air quality model. Correspondingly, two types of information are needed: 1.) source strengths for model calculation, and 2.) PM2.5 concentrations in the background.



PM2.5 is a component of PM10. For a good first approximation, PM2.5 can be treated as a weight fraction of PM10 and this is the approach we suggest until more advanced methods are developed.

Since each activity emitting particulates can have different PM2.5 to PM10 ratio and local Gaussian models can simulate each activity (source) individually, estimating PM2.5 impacts at the first two tiers has to make use of appropriate source-specific emission characteristics.

Emission factors for PM10 exist for many activities. Multiplying weight fractions of PM2.5, either as emission factors for model input or as concentrations from model predictions, by the activity in question gives predictions for the first two tiers' contributions in an air quality assessment using model(s).

For background PM2.5 concentration estimation, when a conservative weight fraction of PM2.5 in PM10 is multiplied to either measurements or regional model output of PM10, a conservative PM2.5 estimate is obtained.

4. Values Suggested for Calculating PM2.5 Concentration from PM10

For model calculation, the weight fractions of PM2.5 in PM10 for various activities can be obtained from the following sources:

1. Appropriate local project-specific measurements;
2. Appropriate data published by EPD, e.g. from EMFAC for motor vehicles;
3. Most recent marine emission study, e.g. USEPA 2009 Study Report, Port of Los Angeles 2009 Study Report.
4. USEPA's or European Environment Agency's (EEA) most recent published data, e.g. EMEP/EEA Air Pollutant Emission Inventory Guidebook – 2009.

For third-tier PM2.5 concentration calculations, the following conservative formulae are recommended:

Annual($\mu\text{g}/\text{m}^3$)	Daily($\mu\text{g}/\text{m}^3$)
$\text{PM}_{2.5} = 0.71 \times \text{PM}_{10}$	$\text{PM}_{2.5} = 0.75 \times \text{PM}_{10}$

Other values or calculation methods, based on local measurements and scientific research, can also be considered by EPD.

The basis for the above formulae is given in the appendix below.

Appendix. Basis of Estimating background PM2.5 concentrations from background PM10 concentrations

10 years (2002 – 2011) of PM hourly measurements from Hong Kong's AQMS are analyzed to come up with the annual and daily PM2.5 formulation. The stations (five) measuring PM10 during this period are: Tap Mun, Tsuen Wan, Tung Chung, Yuen Long and Central (Roadside).

Since no significant and consistent trend is discerned for the annual ratios within this period, the recommended annual PM2.5 to PM10 ratio is the highest ratio averaged over the entire period (2002-2011) among the above AQMS stations, rounded up to the second decimal point and can be applied to observations or regional model outputs of PM10 as appropriate.

The ten years of daily observed concentrations form two frequency distributions, of PM10 and PM2.5. Each of these distributions is defined by two parameters: the mean and spread. These two parameters can be simultaneously transformed between the PM2.5 and PM10 concentration distributions to define how each value in the distributions can be transformed.

Using this transformation would enable PM2.5 to be predicted from available PM10 concentrations, be it measurements or regional model outputs.

To find the transformation, we define $PM2.5'_i$ as the i^{th} daily concentration of PM2.5, $PM10_i$ as the i^{th} daily concentration of PM10. We then seek a transformation of the form:

$$PM2.5'_i = A \times PM10_i + B$$

$$i = 1, 2, \dots, \dots, 3650 = N$$

where A and B are constants (A and B are spatially dependent, i.e., different for each site).

Let $\mu_{2.5}$ and μ_{10} be the observed annual averages of PM2.5 and PM10, respectively, and σ_{10} be their standard deviations. By equating the annual average of the transform (from PM10) with that of the observed PM2.5, one gets

$$\frac{1}{N} \sum_{i=1}^N (A \times PM10_i + B) = \mu_{2.5}$$

which gives

$$A\mu_{10} + B = \mu_{2.5}$$

Similarly, equating the standard deviation of the transformed PM2.5 (from PM10) with the observed PM2.5 gives

$$\frac{1}{N} \sum_{i=1}^N [(A \times PM10_i + B) - (A\mu_{10} + B)]^2 = \sigma_{2.5}^2$$

which gives

$$A^2 \sigma_{10}^2 = \sigma_{2.5}^2$$

From (2) and (3), we have:

$$A = \frac{\sigma_{2.5}}{\sigma_{10}}$$

and

$$B = \mu_{2.5} - \frac{\sigma_{2.5}}{\sigma_{10}} \mu_{10}$$

The transformation is illustrated in Figure 1 below.

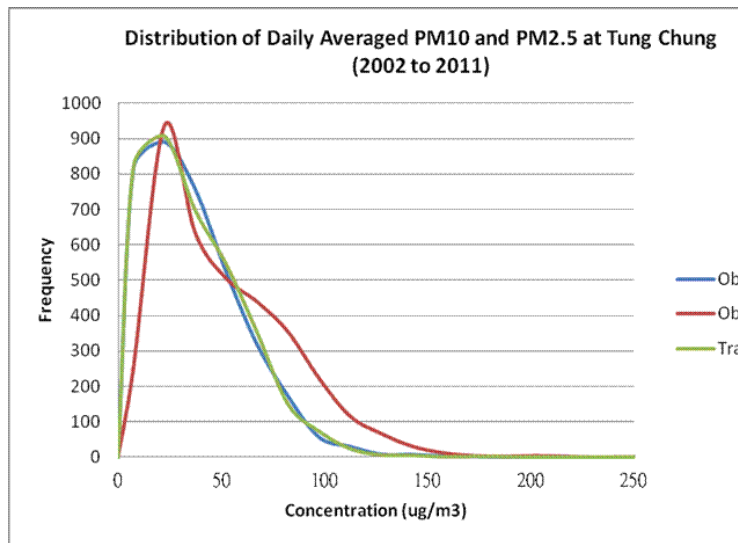


Figure 1 Distribution of daily averaged PM10 and PM2.5 at Tung Chung (2002 to 2011)

The proposed AQO for daily PM2.5 allows a number of exceedences per year. This number is dependent on the shape of the distribution. This is illustrated by the small discrepancy in the areas under the two curves in Figure 2 below. Since the observed PM2.5 distribution is further adjusted in the form of a small addition to "B" in equation (1) is made to ensure the transformed number of PM2.5 exceedences matches that of observation with a small margin built in. This is illustrated in Figure 3.

Among the five stations measuring PM2.5 between 2002 and 2011, Central station is excluded from consideration because of its roadside emission dominance, and Tap Mun station is excluded because of its remoteness from any meaningful sources. Since Tung Chung has the highest value of "A" among the three remaining stations, making the estimate of PM2.5 conservative, its data are used to come up with:

$$PM2.5 = 0.75 \times PM10 - 1.72.$$

To simplify the findings for EIA applications further and achieve an even more conservative estimate, we suggest using:

$$PM2.5 = 0.75 \times PM10.$$

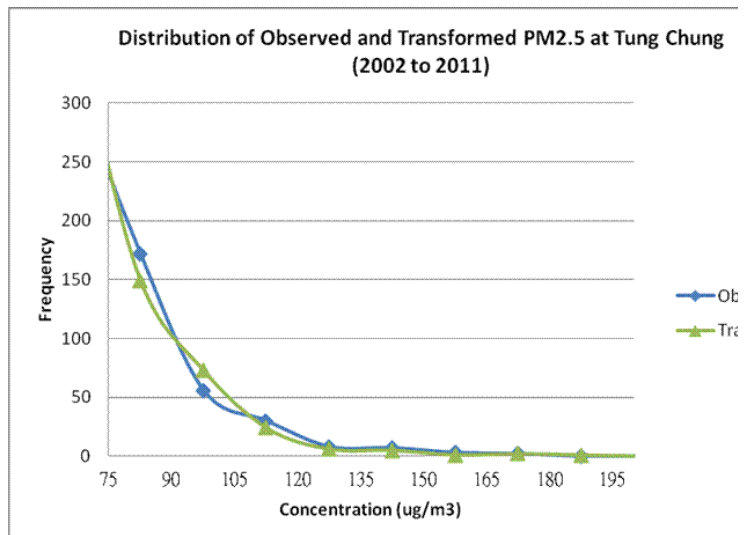


Figure 2 Distribution of observed and transformed PM2.5 at Tung Chung (2002 to 2011)

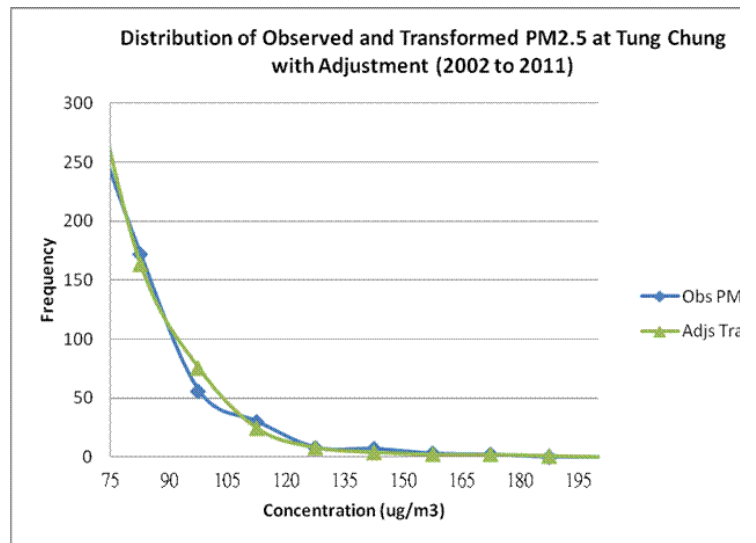


Figure 3 Distribution of observed and transformed PM2.5 at Tung Chung with adjustment (2002 to 2011)

References

1. Steve C. Smyth, Weimin Jiang, Dazhong Yin, Helmut Roth, Eric Giroux, "Evaluation of O3 and PM2.5 performance using Pacific 2001 measurement data", Atmospheric Environment, Volume 40, Issue 15, May 2006, Pages 735-2749.

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