APPENDIX 3.10

DERIVATION OF CUMULATIVE ANNUAL AVERAGE NO_X TO NO_2 CONVERSION EQUATION USING JENKIN METHOD

Derivation of Cumulative Annual Average NO_x to NO_2 Conversion Equation using Jenkin Method

Introduction

In order not to overestimate the NO_2 emissions during the conversion of NO_x to NO_2, besides OLM and DPM, an alternative method using the Jenkin method [1] is proposed. This method can estimate annual NO_2 based on a project-specific empirical relationship of NO_x to NO_2 derived from a fitted curve, making reference to annual NO_2 and NO_x monitoring data.

Jenkin Method

With reference to the *"Review of Methods for NO to NO_2 Conversion in plumes at short ranges" (EA UK, 2007)* [2], the annual NO_2 concentrations can be estimated by the Jenkin method with the derived project-specific empirical relationship of NO_x to NO_2 and the use of the latest available and representative data from EPD's air quality monitoring stations (AQMS). The empirical relationship can be described by selected annual NO_2 and NO_x monitoring data and a fitted curve [1]. The annual NO_2 concentrations can be determined from the functional form curve using the total NO_x concentrations. The functional form is presented below [1]:

$$NO2 = \frac{(\mathrm{NOx} + \mathrm{OX} + \frac{J}{k}) - \sqrt{\left(\mathrm{NOx} + \mathrm{OX} + \frac{J}{k}\right)^2 - 4 \times \mathrm{NOx} \times \mathrm{OX}]}}{2}$$

where
NO_2 is the NO_2 concentration
NO_x is the NO_x concentration
O_X is the sum of NO_2 and O_3 concentration (i.e. $O_X = NO_2 + O_3$)
J is the photolysis rate of NO_2
k is the rate coefficient for the reaction between NO and O_3

Derivation Process

Step 1: Obtain representative data from EPD's AQMS

Three AQMS are selected to analyse the annual NO_x to NO_2 relationship, including Tuen Mun General Station, Tap Mun General Station and Mong Kok Roadside Station. The recent five years (i.e. Year 2017 to 2021) annual mean data of NO_2, NO_x and O_3 are extracted from the reports "Air Quality in Hong Kong" published by EPD and presented in **Table 1** below. The annual mean OX (i.e. $NO_2 + O_3$) is also presented in **Table 1**.

Table 1. Annual Mean of NO_2, NO_x and O_3 Concentrations in Recent Five Years at Selected EPD AQMS

Year	Location	Annual Mean NO_2	Annual Mean NO_x	Annual Mean O_3	Annual Mean OX [$NO_2 + O_3$]
		(µg/m³)	(µg/m³)	(µg/m³)	(µg/m³)
2017	Mong Kok	81	164	24	105
2018	Mong Kok	79	163	27	106
2019	Mong Kok	78	154	32	110
2020	Mong Kok	74	162	30	104
2021	Mong Kok	70	139	32	102
2017	Tap Mun	10	12	74	84
2018	Tap Mun	11	13	72	83
2019	Tap Mun	10	12	80	90
2020	Tap Mun	9	11	71	80
2021	Tap Mun	10	12	75	85
2017	Tuen Mun	46	70	43	89
2018	Tuen Mun	47	68	46	93
2019	Tuen Mun	47	69	51	98
2020	Tuen Mun	40	55	48	88
2021	Tuen Mun	44	59	49	93

Step 2: Calculate and plot functional form curve

With the use of OX= 110µg/m^3 and J/k= 23.5µg/m^3, NO_2 concentrations can be calculated from the functional form based on the measured annual mean NO_x concentrations shown in **Table 1** above. The calculated NO_2 concentrations are shown in **Table 2**. The value of OX and J/k are considered reasonable as they are within typical value range for Hong Kong. The range of annual average OX from the selected AQMS is 80µg/m^3 to 110µg/m^3.

Table 2. Calculated NO_2 Concentrations using the Functional Form based on Annual NOx Concentrations Measured at Selected EPD AQMS

Year	Location	Calculated NO_2 (µg/m^3)
2017	Mong Kok	85
2018	Mong Kok	85
2019	Mong Kok	83
2020	Mong Kok	84
2021	Mong Kok	79
2017	Tap Mun	10
2018	Tap Mun	11
2019	Tap Mun	10
2020	Tap Mun	9
2021	Tap Mun	10
2017	Tuen Mun	50
2018	Tuen Mun	49
2019	Tuen Mun	50
2020	Tuen Mun	41
2021	Tuen Mun	44

A plot for annual means of NO_2 versus NO_x obtained from selected AQMS from the recent 5 years is created in **Figure 1** below. The functional form curve, adopting OX of 110µg/m^3 and J/k of 23.5µg/m^3, fits with all annual mean data from the selected AQMS. Underestimation of the annual average NO_2 concentration is not expected.

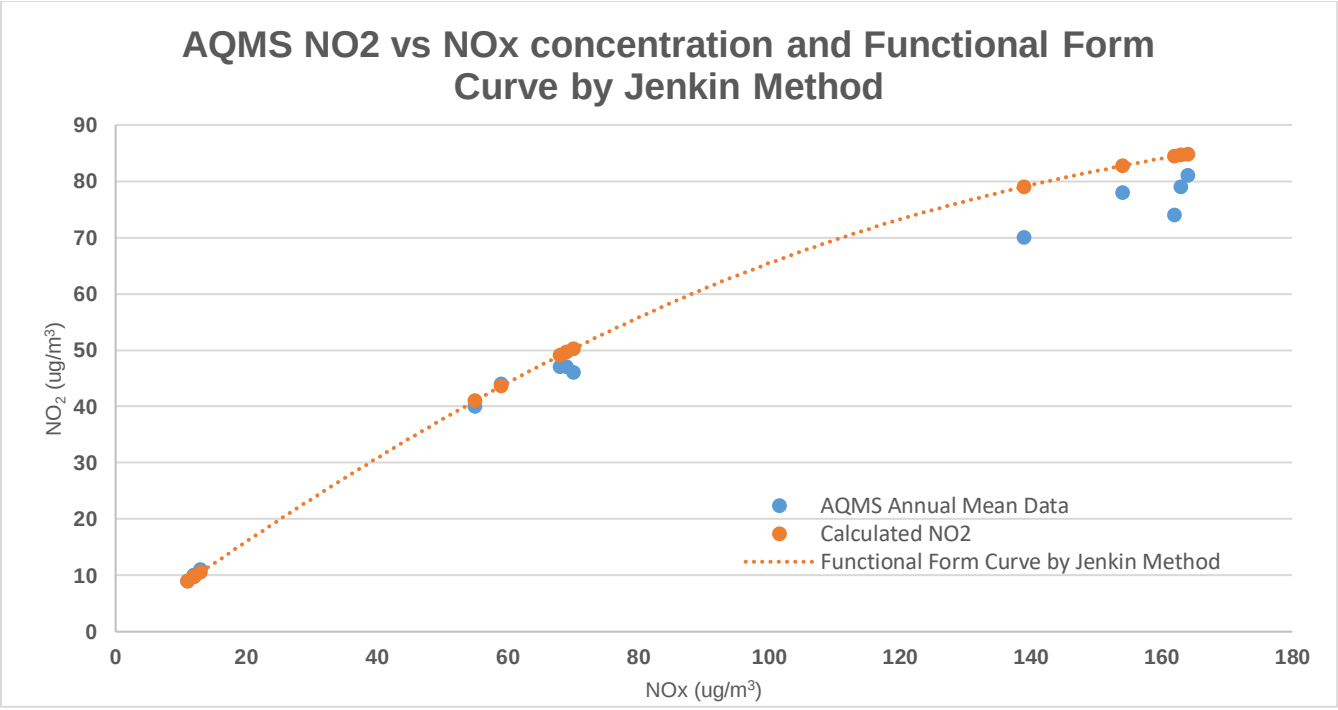

Figure 1. AQMS NO_2 vs NO_x concentration and Functional Form Curve by Jenkin Method

Step 3: Convert predicted cumulative annual NO_x results to cumulative annual NO_2 results

The functional form curve will be adopted for annual NO_2 assessment, where predicted cumulative annual NO_x results can be converted to predicted cumulative annual NO_2 results. The conversion equation for the annual NO_2 assessment is as follows:

$$NO2_c = \frac{(NOx_c + 110 + 23.5) - \sqrt{(NOx_c + 110 + 23.5)^2 - 4 \times NOx_c \times 110}}{2}$$

where
NO_{2c} is the predicted cumulative NO_2 concentration
NO_{xc} is the predicted cumulative NO_x concentration

References

[1] J. M. E, "Analysis of sources and partitioning of oxidant in the UK – Part 1: The NOx-dependence of annual mean concentrations of nitrogen dioxide and ozone.," Atmospheric Environment, 2004.

[2] Environment Agency UK, "Review of methods for NO to NO2 conversion in plumes at short ranges," Environment Agency UK, UK, 2007.