



Study of Tracer Organic Species in Fine Particles of Hong Kong  
**EPD Final Report**

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**Appendix A**     **Final Project Report:** “*Hong Kong and the Pearl River Delta Pilot Air Monitoring Project: Pilot study on the use of atmospheric measurements to manage air quality in Hong Kong and the Pearl River Delta. Project 2: Fine Particulate Matter (PM2.5) in the Pearl River Delta*”.

## 1.0 Background

The Hong Kong Environmental Protection Department (EPD) carried out a 12-month monitoring programme for fine particles (that is PM<sub>2.5</sub>) at three strategic locations in Hong Kong for the period from November 2000 to October 2001. The filter samples were sent to various laboratories for gravimetric analysis and analysis of elements, ions, carbon, solvent extractable organics, water soluble organics, and tracer organic species. For tracer organic species, Dr Mike Bergin of Georgia Institute of Technology, USA (GIT) was engaged for the necessary analytical work.

Civic Exchange (also referred herein as “the Contractor”) of Hong Kong embarked on a Pilot Air Monitoring Project (the Pilot Project) on the use of atmospheric measurements for the management of air quality in Hong Kong and Pearl River Delta (PRD). In the Pilot Project, a fine particle speciation monitoring network was planned to be set up in the region for 12 months with an objective to quantify the sources that contribute to the atmospheric fine particle burden. GIT are also be involved in this Pilot Project to apply organic chemical tracer technique to differentiate between the contributions from the many different source types that emit carbon particles.

To build upon the finding of the first 12-month monitoring programme, the EPD saw the need to conduct another round of PM<sub>2.5</sub> speciation sampling. And in view of the development of Civic Exchange’s Pilot Project, the EPD seized the opportunity to synchronize the second round programme with the Pilot Project. The aim was then furthered to compare the local tracer organic species concentrations with relevant findings of the Pilot Project which has a distinct advantage of covering a much wider geographic terrain within the PRD region, thus enabling more insightful interpretation of data.

## 2.0 Introduction

The Pearl River Delta and adjoining Hong Kong metropolitan area, like virtually all other major urban-industrialized regions of the world, suffers from photochemical smog and the unhealthy concentrations of ozone and fine particles that it engenders. The characteristic of smog that is readily apparent to the unaided observer is the low visibility or haziness caused by the tiny

particles or fine particulate matter suspended within the smog. Less readily apparent but equally ubiquitous in smog is the high concentration of ground level ozone (O<sub>3</sub>) generated from photochemical reactions between gaseous pollutants. Both PM<sub>2.5</sub> and O<sub>3</sub> are toxic and their presence in photochemical smog represents a health risk to a significant segment of the exposed population, especially the elderly, the young, and the infirm.

To protect the health and to continue to improve the quality of life of its citizens and visitors, officials from the Pearl River Delta (PRD) region recognize that it must improve its air quality by reducing the severity of photochemical smog. However, the control of photochemical smog is complex and depends on a multitude of factors including meteorological conditions that foster smog formation (sea-breeze effects, winter monsoon circulations) and the transport and co-mingling of pollutants from distant and local sources.

The Pilot Project was initiated in May 2002 and was implemented over a 2-year period although the completion of final reports was not until August 2004. The Environmental Protection Department (EPD) project AS:02-011 (the EPD Project) is part of this larger Pilot Project conducted by Civic Exchange. The Pilot Project intended to build upon the useful work already done by the Hong Kong EPD, the universities in Hong Kong, and their counterparts in South China. This project was designed to explore the use of observation-based methods, analyses, and models based upon new measurements of NO<sub>x</sub>, VOC, ozone and the chemical compositions of the atmospheric fine particles to:

- (1) Fill in knowledge gaps in smog and visibility problems in Hong Kong and the PRD region;
- (2) Provide insight into policy relevant questions that could assist policy-makers in managing regional air quality in Hong Kong and South China;
- (3) Strengthen the ability of public sector agencies, private businesses, and the academic scientific community to develop policies to improve air quality management; and
- (4) Build long-term air quality management capacity in Hong Kong and Mainland China.

The Pilot Project was organized around two interrelated sub-projects: **Project 1** focused on ground-level ozone in Hong Kong and **Project 2** on fine particles in the PRD region. In this report we summarize the final results of our investigations related to fine particulate matter; here in referred to as Project 2.

### 3.0 Objectives

To characterize fine particles burden of Hong Kong by:

- a) conducting literature search for related studies, with particular emphasis on the PRD region and on Hong Kong EPD's 12-month fine particles data set mentioned in Section 1 above; and
- b) analyzing fine particles filter samples plus quality assurance samples presented by EPD for specific tracer organic species and other parameters.

To determine the contributions of different fine particles pollution sources, both in Hong Kong and in the neighbouring PRD areas, by comparing the results obtained in (b) above with that as available from the Pilot Study or other information on the PRD, under normal seasonal and episodic meteorological conditions.

Consistent with the EPD Project objectives above, Project 2 of the Pilot Project aimed to: (i) measure the concentrations and chemical composition of fine particulate matter (PM<sub>2.5</sub>) in the PRD region (including Hong Kong); (ii) determine the general sources of PM<sub>2.5</sub> across the PRD region; and (iii) assess the concentrations of sub-regions of the PRD to PM<sub>2.5</sub> in the PRD region.

### 4.0 Summary of Results

#### 4.1 Final Project Report

All results of the EPD Project (in relation to the requirements set out in tender reference AS 02-011) are included in the Final Project Report entitled “*Hong Kong and the Pearl River Delta Pilot Air Monitoring Project: Pilot study on the use of atmospheric measurements to manage air quality in Hong Kong and the Pearl River Delta. Project 2: Fine Particulate Matter (PM<sub>2.5</sub>) in the Pearl River Delta*”. This Final Project Report includes both the results and findings for

Project 2 of the Pilot Project (see further details in Sections 4.2 to 4.4) and specific detailed requirements under the EPD's Tender No. AS 02-011 (see further details in Section 4.5). A copy of the Final Project Report is included in Appendix A.

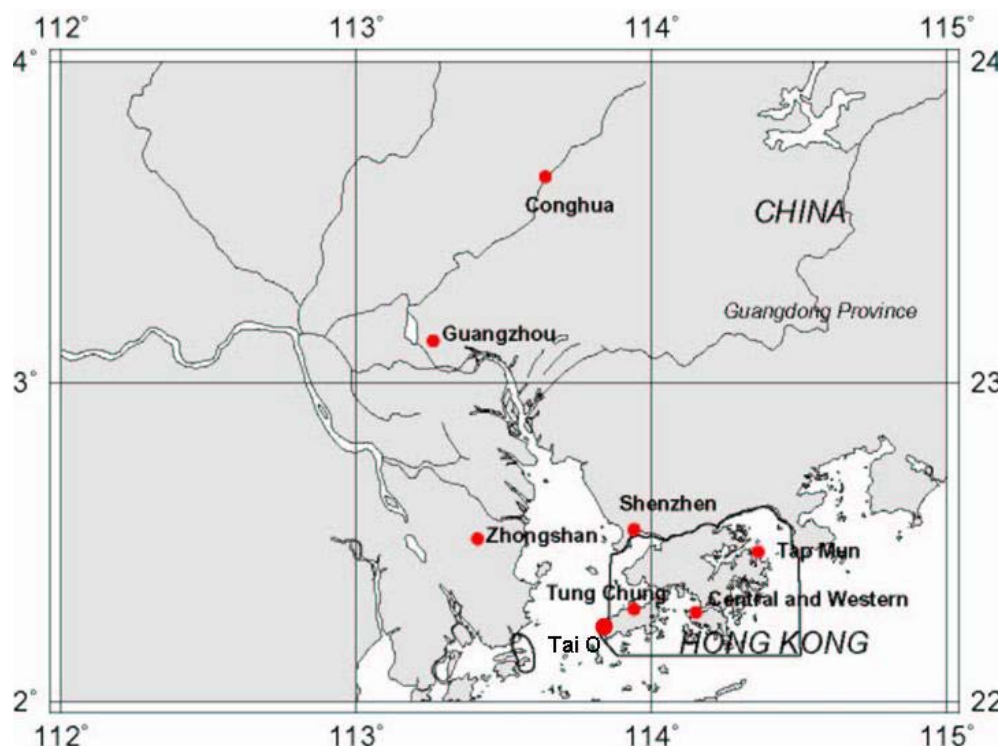
#### ***4.2 Literature review***

Literature review summary was included in the Interim Report submitted to EPD on 1 August 2003 and is further included in the Final Project Report in Section 3.0 (Background).

#### ***4.3 Overview of sampling***

Air sampling involved the collection of filters over 24-hr integrated time periods during a month of each season (from October 2002 to June 2003) at 7 sites including 4 in the Guangdong and 3 in Hong Kong (see Figure 1). Sampling sites in Guangdong were run by local air monitoring station personnel with the assistance of Peking University while sampling sites in Hong Kong were run by HKEPD forming a part of their regular network of air monitoring stations. Air monitoring equipment was sourced and installed by researchers from GIT and California Institute of Technology.

For a given month samples were collected every sixth day. The filters were used to determine the PM<sub>2.5</sub> concentration as well as the concentrations of a variety of ions, elemental and organic carbon, specific elements, and solvent extractable organic compounds. Related to specific pollution sources that contributed to PM<sub>2.5</sub>, chemical tracers for pollution source classes including coal combustion, wind-blown dust, biomass burning was used to infer local and sub-regional influences within the PRD. In addition, the relative concentrations of specific organic compounds were used to infer primary sources of carbonaceous aerosols using a Chemical Mass Balance (CMB) model.



**Figure 1.** Map showing locations of 7 sites used in Project 2. In China this includes: Conghua, Guangzhou, Zhongshan and Shenzhen. In Hong Kong this includes: Tung Chung, Tap Mun and Central and Western. The map also shows the Tai O Supersite used in Project 1 of the Pilot Project.

#### 4.4 Major findings

A summary of key findings is as follows:

- **Summary 1: Concentrations and chemical composition of fine particulate matter (PM<sub>2.5</sub>) in the PRD region**

Based on the gravimetric measurement data of PM<sub>2.5</sub> from the present study, the highest annual mean PM<sub>2.5</sub> concentration was observed in Guangzhou (71 ug m<sup>-3</sup>), followed by Shenzhen (47 ug m<sup>-3</sup>), Zhongshan (46 ug m<sup>-3</sup>), Conghua (37 ug m<sup>-3</sup>), Central & Western (34 ug m<sup>-3</sup>), Tung Chung (32 ug m<sup>-3</sup>), and Tap Mun (29 ug m<sup>-3</sup>). Speciation data of the PM<sub>2.5</sub> particulates revealed that

organic carbon and sulfate are the dominant fine particulate chemical species across the PRD region accounting for on average 24-53% and 21-32%, respectively of PM<sub>2.5</sub> mass.

Further details of this finding can be found in Sections 1, 5.1.1, 5.1.2, 5.1.3, 5.1.4, and 5.1.5 of the Final Project Report.

- **Summary 2: General sources of PM<sub>2.5</sub> across the PRD region**

Based on meteorological analyses as well as the spatial and temporal variation of fine particulate concentrations, it appears that the dominant source of sulfate aerosol in the PRD region is sulfur dioxide emissions from Guangdong province. The sources of organic carbon throughout the PRD region are dominated by mobile sources and biomass burning which are roughly estimated to account for from 15-27% and 14-22%, respectively

Further details of this finding can be found in Sections 5.2 of the Final Project Report.

- **Summary 3: Concentrations of sub-regions of the PRD to PM<sub>2.5</sub> in the PRD region**

Fine particulate concentrations in Hong Kong are influenced by both local and regional sources while Guangzhou is impacted by more local sources of fine particulate matter. Biomass burning sources throughout Guangdong province influence fine particulate concentrations across the PRD. Guangzhou appears to be more influenced by local gasoline vehicles and Hong Kong by diesel sources. In addition, Guangdong appears to be a source of wind blown dust in the PRD.

Further details of this finding can be found in Sections 5.2, 5.2.4, 5.2.5, 5.3.4.1, and 5.3.4.3 of the Final Project Report.

#### **4.5 EPD's detailed specifications**

As outlined in the EPD Tender AS 02-011 Special Conditions of Contract, EPD's Project was to include the detailed specifications outlined in the table below. The table also includes reference



to the completion of such specifications, which are included in the Final Project Report (copy of which is attached as Appendix A).

<b>EPD' Detailed Specification</b>	<b>Contractor's comments and Final Project Report Ref.</b>
The Contractor shall complete this study within TWENTY-FOUR (24) months upon confirmation of appointment.	The Contractor has fulfilled the requirements within the study period.
EPD will be responsible for taking samples for 24-hour periods at 6-day intervals for one month in each quarter of a 12-month period which is yet to be determined but will be as far as practicable synchronized with the sampling schedule in the Pilot Project. EPD will also concurrently carry out Hi-Vol/Parisol samplings at all locations.	Work completed by EPD.
The three sampling locations will tentatively be at the EPD Tung Chung, Tsuen Wan and Tap Mun air quality monitoring stations.	Final agreed sampling locations in Hong Kong were Tung Chung, Central & Western, and Tap Mun. Also, sampling schedule synchronized with CE's Pilot Project.
<p>The Contractor will be responsible for provision/installation/commissioning of the RAAS 2.5-400 Samplers from Andersen Instruments Inc. (or equivalent as agreed upon by the EPD) plus free supply of the filter samples (including pre- and post-treatment of filters) required for successful completion of this speciation sampling at the three selected locations in Hong Kong. At the end of this speciation sampling, the Contractor will have been provided with</p> <p>a) 120 nos. exposed 47mm QMA filter samples for</p>	<p>While CE provided the RAAS samplers for the project, HKUST completed the samplers installation and decommission work.</p> <p>Sampled filters were received and</p>

<p>OC/EC analysis, water soluble organic compounds, and tracer organic species analysis including n-alkanes, branched alkanes, cycloalkanes, n-alkanoic acids, n-alkenoic acids, PAH, oxy-PAH, hopanes, steranes, alkanedioic acids, resin acids, aromatic acids, levoglucosan, etc.;</p> <p>b) 120 nos. exposed 47mm Teflon filter samples for XRF and ions analyses; and</p> <p>c) a total of 48 nos. field blank 47mm QMA and Teflon filter samples for quality assurance purposes.</p>	<p>tracer organic species analysis performed (see section 5.3 of the Final Project Report for further details).</p> <p>Same as above</p> <p>Same as above</p>
<p>The Hong Kong EPD will be responsible for provision/installation/commissioning of the collocated Hi-Vol Samplers/Partisol Samplers at the three locations as well as supply of necessary filter samples throughout the sampling period. Filter samples collected on three separate days to be determined will be retrieved for episode analysis. The Contractor will be provided with a total of 9 nos. exposed 8" X 10" QMA samples, 9 nos. exposed 47mm Teflon filter samples, plus 4 nos. blank samples for the analysis.</p>	<p>Hi-vol sampling work completed by EPD.</p> <p>Hi-vol filters received and analysis completed.</p>
<p>At the end of each month of sampling in each quarter of the 12-month period, the Contractor will collect the exposed and blank filter samples of the RAAS 2.5-400 Samplers (stored at 40C or below in rigid containers) from the EPD offices in Wanchai, for shipment of these filters to Dr. Mike Bergin of GIT for gravimetric and other laboratory analysis. These filter samples shall reach GIT within FIVE calendar days from the day of collection at</p>	<p>Shipping of sampled filters was completed in accordance with agreed schedule.</p>

the EPD offices	
Contractor will work out a proposal for the endorsement of EPD on how to group the exposed filters into four (seasonal) composites spanning the 12-month sampling period for each of the sampling sites. For episodic days with exceptionally high fine particle loading, those filters collected by the collocated Hi-Vol Samplers/Partisol Samplers will be retrieved and analysed separately to gain insight into possible transboundary movement of dirty air mass, etc. under certain meteorological conditions. These filter samples will be analyzed and reported in the same manner as Dr. Mike Bergin of GIT would have done for the current study by the EPD.	Analytical strategy agreed with EPD and findings incorporated in the Final Project Report. For further information, please refer to sections 5.3, 5.3.3 and Appendix F of the Final Project Report.
Following extraction of these composite/episodic samples or organic tracer analysis, the Contractor will conduct chemical mass balance receptor modelling calculations to assess the sources that contribute to the fine particles burden at these sites. The Contractor will interpret these results in the context of Hong Kong and other data available for the PRD region.	See results and findings presented in Sections 5.3 and 5.3.4 of the Final Project Report.
The Contractor will prepare a report that documents the analysis results of organic tracer species and other parameters, analysis of episode(s), and conclusions on the nature and sources of the fine particle burden in Hong Kong.	See results and findings presented in Sections 5.3. 5.3.2, 5.3.3, 5.3.4, Appendix F of the Final Project Report.

#### ***4.6 Suggested further work in this area***

Based on the results of the EPD Project, the Contractor suggests that further work should be conducted in the following areas:

- Locate the source of sulfate and the industries they are associated with;

- Further understand where and when biomass burning is taking place and what is being burned;
- Determine the true source profiles of primary OC emissions in the PRD;
- Evaluate the effect of continued economic growth of the PRD region and its influence on air quality;
- Consider how anthropogenic (man made) emissions and climate change impact air quality in PRD region.

## 5.0 Conclusion

Through the use of an observation based model and scientific analytical modeling techniques such as Chemical Mass Balancing, EPD's Project has both confirmed previous research and produced new and interesting results. The project has also provided a much needed list of focus areas, which highlight the areas of further study required to enable definitive conclusions to be drawn on the most effective and efficient pollution control strategies in Hong Kong and the PRD Region. Equally importantly the project has formed a model for cross-boarder multi-stakeholder collaboration, which has proven able in setting the foundation for increased capacity in areas of human, financial and information resources. With political support from EPD, the key task ahead is to deepen that support and extend it to the PRD authorities, then to transfer this knowledge gained to the creation of policy review and change.

The Contractor thanks EPD for the opportunity to work on this project and hopes it will lead to further and deepened collaboration in the future.

# APPENDIX A

## **Final Project Report:**

*“Hong Kong and the Pearl River Delta Pilot Air Monitoring Project: Pilot study on the use of atmospheric measurements to manage air quality in Hong Kong and the Pearl River Delta. Project 2: Fine Particulate Matter (PM<sub>2.5</sub>) in the Pearl River Delta”.*