FINAL REPORT

Agreement No. CE 106/98

Study of Air Quality in the Pearl River Delta Region

Reference	**:**	**R0355.01**
Client	**:**	**Environmental Protection Department** **Hong Kong Special Administrative Region Government**
Date	**:**	**April 2002**

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1. INTRODUCTION

1.1 Background

1.1.1 CH2M HILL (China) Limited (formerly known as EHS Consultants Limited) was commissioned by the Environmental Protection Department (EPD) of the Hong Kong Special Administrative Region (HKSAR) Government to undertake this consultancy study according to "Agreement No. CE: 106/98 Study of Air Quality in the Pearl River Delta Region" (the Study).

1.1.2 HKSAR is facing two air pollution problems. One is the street level pollution mainly caused by the large number of motor vehicles, especially diesel vehicles, on Hong Kong streets. The Government has been tackling this problem for many years. Unleaded petrol was introduced in April 1991 and cleaner diesel of 0.2% sulphur content in April 1995. To combat the air pollution problem, in 1999, the Government introduced a new comprehensive programme to reduce motor vehicle emissions. The programme when fully implemented will reduce the particulate and nitrogen oxides emissions from motor vehicles by 80% and 30% respectively by end of 2005. A sum of $1.4 billion has been earmarked for implementing this programme which includes providing grants to owners of diesel taxis for the purpose of encouraging them to switch over to taxis that are run on liquefied petroleum gas (LPG), and providing financial assistance to owners of pre-Euro light diesel vehicles for the installation of particulate traps or diesel catalytic converters. A duty concession was also introduced in July 2000 to make the price of ultra low sulphur diesel (ULSD) competitive with regular motor diesel. ULSD became the only motor diesel available at petrol filling stations by September 2000. The Government has also proposed to provide incentives to encourage owners of diesel light buses to switch to LPG or electric light buses and to retrofit pre-Euro heavy vehicles with particulate removal devices.

1.1.3 Another air pollution problem that HKSAR is facing is regional air quality pollution. This is exemplified by a gradual deterioration in visibility degradation and occasional episodes of high respirable suspended particulates and ozone pollution throughout HKSAR. Contrary to the first acute street level pollution, which stems mainly from local vehicle emissions, the deteriorating air pollution problem is caused by both the local air pollution sources and the regional air quality problem in the Pearl River Delta Region (the Region) – a problem to which HKSAR is also accountable.

1.1.4 The regional air quality problem is the focus of this Study. The main root of the problems lies with unprecedented economic growth and urbanisation in the Region in the past decades. Under certain meteorological conditions, regional air pollutant concentrations can reach levels that threaten public health. The HKSAR Government has therefore given high priority to developing measures to improve air quality to safeguard public health.

1.1.5 As air pollution is a trans-boundary issue, the EPD of HKSAR Government and the Guangdong Province Environmental Protection Bureau (GDEPB) have agreed to join forces to study the regional air pollution problem with a view to developing effective control strategies. This Study is an initiative that comes out of this regional collaborative effort.

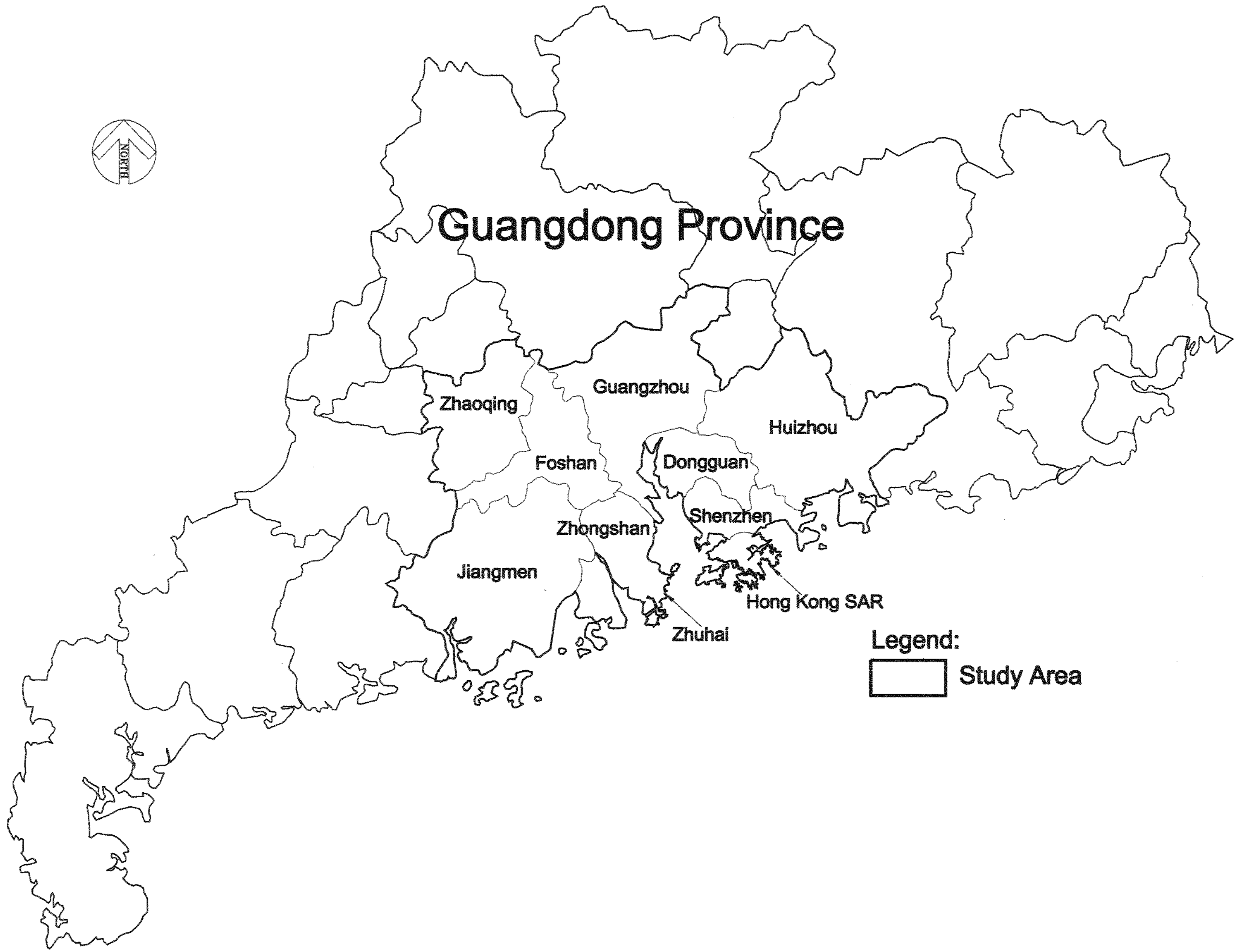
1.2 The Study Area

1.2.1 The study area covers the whole territory of HKSAR and the Pearl River Delta Economic Zone (PRDEZ). PRDEZ includes Guangzhou, Shenzhen, Zhuhai, Dongguan, Zhongshan, Foshan, Jiangmen, Huizhou (Huicheng, Huiyang, Huidong and Boluo), and Zhaoqing (Duanzhou, Dinghu, Gaoyao and Sihui). Figure 1-1 illustrates the boundary of the Region for this Study. The demographics and land areas of HKSAR and PRDEZ are listed in Table 1-1.

Table 1-1 Population and Land Area of the Region in 1997

	Population (million)	Land Area (km^2)	Population/Area ($person/km^2$)
HKSAR	6.5	1,096	5,909
PRDEZ	32.2	41,698	772
Region Total	38.7	42,794	904

Sources: Statistical Yearbook of Guangdong 1998, Hong Kong Annual Digest of Statistics 1999



CH2M HILL (China) Limited	Project:	Agreement No. CE106/98 Study of Air Quality in the Pearl River Delta Region				Environmental Protection Department
	Title:	Final Report Boundary of the Region for this Study				
	Figure:	1-1	Scale:	NTS	Page No: Chapter1-2	

1.3 Objectives of the Study

1.3.1 The Study primarily investigates the levels of ozone (O_3), respirable suspended particules (RSP) and nitrogen dioxide (NO_2) in the Region. However, sulphur dioxide (SO_2) and volatile organic compounds (VOC) also need to be considered in addition to O_3, RSP and NO_2, as they take part directly or indirectly in the formation of regional pollutants. The formation of regional pollutants and its relationship to air quality will be further elaborated in Chapter 2 of this report.

1.3.2 The main objective of the Study is to investigate the air pollution problems in the Region related to the above pollutants with a view to identifying possible measures to improve regional air quality.

1.4 Study Methodology

1.4.1 The Study consists of 5 components, and Figure 1-2 depicts their inter-relationships:

- Data Collection and Analysis
- Air Quality Monitoring Exercise
- Base and Future Emission Inventory Development
- Air Quality Modelling
- Control Measures and Strategy Formulation

1.4.2 Data Collection and Analysis

This task involved the collection of historical and current data on air quality in the Region through EPD and the Guangdong Environmental Protection Monitoring Centre of the GDEPB. These data were reviewed for completeness and adequacy for use in this project, and organised into a suitable format for emission inventory development and air quality modelling. An understanding of the existing air quality with respect to O_3, RSP and NO_2 was established. Historical air pollution trends were developed and meteorological conditions responsible for regional air pollution episodes were identified.

1.4.3 Air Quality Monitoring Exercise

The study included an additional air quality monitoring exercise to fill in data gaps where existing air quality data were not adequate. VOC and RSP samples were collected at various locations within the PRDEZ and HKSAR. VOC data were analysed to understand the composition of ozone precursors while RSP data were analysed to understand the RSP concentrations in the Region. The monitoring locations were selected to reflect sites potentially influenced by industrial, urban, motor vehicle, agricultural and biogenic emissions. The consultant team members, who possess a valid Category A Environmental Impact Assessment Certificate issued by the State Environmental Protection Administration, followed the Mainland and the HKEPD, as well as the United States Environmental Protection Agency standard methodologies as far as technically feasible and practicable, throughout the monitoring exercise.

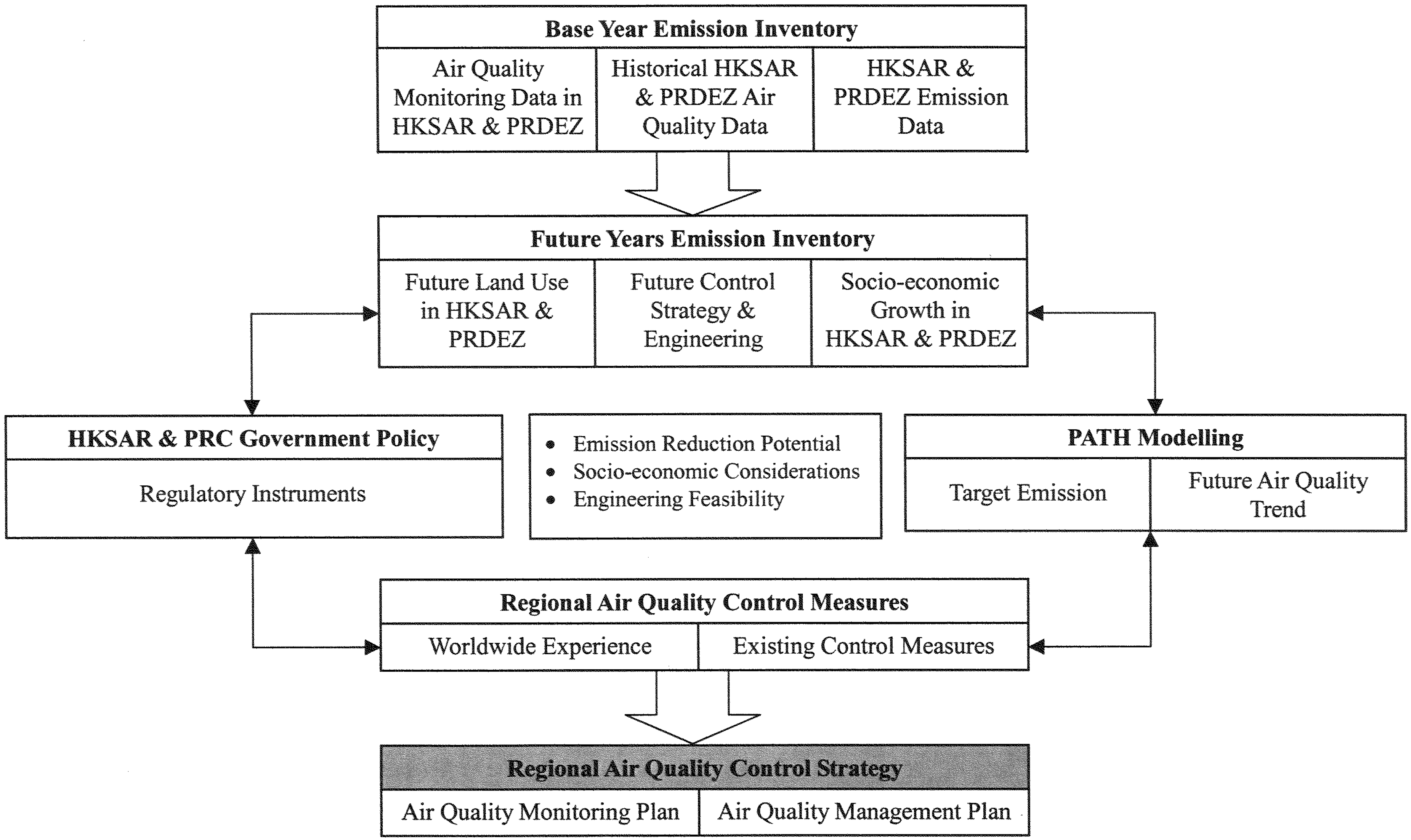
1.4.4 Base and Future Years Emission Inventories Development

A base year (1997) air emission inventory for PRDEZ was developed for the pollutants of concern based on information supplied by the GDEPB, site surveys, and Government published reports. Together with the 1997 emission inventory for HKSAR, a regional base year emission inventory was set up. The major air emission contributors were identified. From this base year inventory, future projections were made for years (2000, 2005, 2010 and 2015) based on recognised methodologies and assumptions on economic and development growth in the Region.

1.4.5 Air Quality Modelling

The PATH modelling system of EPD was used to predict future air quality in the Region based upon the predicted emissions inventory and the base year (1997) ambient air quality. The effectiveness of control measures and their reduction potential in the Region were evaluated using the model.

Figure 1-2 Process Flow Diagram for Various Technical Components of the Study



1.4.6 Control Measures and Strategy Formulation

Options of practicable engineering control measures to improve air quality were identified through discussions with the HKSAR and Guangdong Provincial governments as well as other stakeholders through workshops and interviews. These measures took into consideration their emission reduction potential, technical applicability, economic feasibility, ease of enforcement, and general acceptability. The control measures under the control scenario enabled compliance with air quality standards in the future. The total emission derived from such scenario would serve as target for the Region.

1.5 Consultancy Management

<u>Structure of the Study Team</u>

1.5.1 The Study was directed and managed by CH2M HILL (China) Limited with a team of sub-consultants including ENSR International, Inc. (ENSR), Rowan Williams Davies & Irwin, Inc. (RWDI), Guangdong Province Environment Protection Monitoring Centre (GPEMC), Guangzhou Research Institute of Environment Protection (GRIEP), and the South China Institute for Environmental Sciences; and project advisors and independent air quality experts from Peking University.

<u>Management of the Project</u>

1.5.2 A Project Steering Group was set up for this study. Membership of the Steering Group consisted of the following bureaux and departments:

- Environment and Food Bureau
- Transport Bureau
- Economic Services Bureau
- Environmental Protection Department
- Hong Kong Observatory
- Planning Department
- Transport Department

1.5.3 The terms of reference of the Project Steering Group were: -

(i) Provide guidance to the Study regarding major technical and policy issues;
(ii) Monitor general progress and receive reports from the Consultants;
(iii) Review, comment on and endorse the Consultants' study results, reports and recommendations;
(iv) Facilitate liaison among Government bureaux, departments, relevant parties and the Consultants to support the Study;
(v) Recommend action as a result of findings throughout the course of the Study; and
(vi) Set up working groups as required and receive and consider reports from the Consultants.

1.5.4 During the course of the Study, technical workshops were organised to exchange views on important technical issues in the Study among the Consultants, HKSAR and PRDEZ officials, and other professionals related to the Study.

1.5.5 Throughout the study period, informal meetings were also arranged with representatives from EPD and other relevant parties in HKSAR and Guangdong to exchange views and to ensure effective co-ordination. A web site with regularly updated project information, plans, and papers was set up to provide the authorities, consultants and sub-consultants with easy access to study materials.

1.6 Structure of the Study Final Report

1.6.1 In addition to this Introductory Chapter which gives the background, objective and management structure of the study, the report consists of the following chapters: -

1.6.2 Chapter 2: Existing Air Quality in the Region

This chapter presents the formation processes of regional air pollutants and the air quality standards in place. The existing air quality in the Region with respect to O_3, RSP, and NO_2, and the historical trends of these pollutants are presented. Meteorological conditions leading to elevated pollution levels in the Region are also identified.

1.6.3 Chapter 3: Pollution Sources in the Region

This chapter presents the emission inventory of the Region for the base year (1997) for substances contributing to regional pollution. These substances include VOC, RSP, NO_X, SO_2, and ammonia (NH_3). The emission inventory helps to identify the key sources that potentially contribute to regional air pollution. These key emission sectors include the Energy, Industry, Motor Vehicle, and VOC Containing Product sectors.

1.6.4 Chapter 4: Predicted Future Air Quality in the Region

This chapter presents future year emission inventories for 2000, 2005, 2010, 2015 for substances contributing to regional pollution, taking into consideration future economic development and emission control measures already in place. The chapter also presents the likely air quality in 2010 relative to 1997.

1.6.5 Chapter 5: Additional Control Measures for the Region

This chapter presents practicable engineering control measures proposed for the Region and the emission reductions necessary to bring about improvements in regional air quality. The reduction potential of the proposed control measures was assessed and further reflected in modelling results to show their cumulative impact on future air quality trends. Recommendations were made on target emission standards.

1.6.6 Chapter 6: Regional Air Quality Management and Cooperative Programme

This chapter suggests the approach to develop an effective management plan to resolve regional air quality issues. Continual cooperation between the two Governments is believed to be a prerequisite to bring about air quality improvements in HKSAR and PRDEZ.

1.6.7 Chapter 7: Conclusion and Recommendations

This chapter presents key findings of the study and recommendations for future actions to improve regional air quality in the Region.

1.6.8 Chapter 8: Reference

This chapter presents the list of references that were used in the compilation of this report.

1.6.9 To supplement the report, technical details and eight Technical Annexes have been prepared in a separate volume to provide further understanding of individual topics covered in this study. The Annexes include:

- Air quality monitoring exercise
- Meteorological analysis
- Base year emission inventory and future development trends
- Selection of air quality control measures
- Air quality modelling
- Suggested air quality monitoring network

Chapter Summary

- A regional air quality study has been carried out in view of deteriorating regional air quality.
- The objective of the study is to understand current air quality and identify possible measures to improve regional air quality.
- This chapter explains the overall approach of the study and the layout of this report.

2. EXISTING AIR QUALITY IN THE REGION

2.1 Regional Pollutants and Air Quality Standards

2.1.1 Certain air pollutants can impact locations far from their sources and contribute to air pollution over geographically large areas like the Region. Some of these pollutants such as fine particles, by their nature, can be transported over long distances. Others, like ozone, are formed as their precursors and are emitted and transported downwind. The focus of this study is on pollutants that have an impact on a regional scale and for which standards or objectives have been established for the protection of public health. The pollutants of concern in this study include ozone (O_3), respirable suspended particle (RSP) and nitrogen dioxide (NO_2). Regional air quality objectives and standards for these pollutants are presented in Table 2-1. The Mainland Class 2 National Ambient Air Quality Standard (NAAQS) is applicable to residential, urban, commercial, industrial, and village areas, while the Mainland Class 3 NAAQS is applicable to designated industrial zones in PRDEZ.

Table 2-1 Ambient Air Quality Standards in the Region

Region		Averaging Time ($\mu g/m^3$)		
	Pollutant	1 hr	24 hr	1 yr
HKSAR	O_3	240$^{(1)}$	-	-
Air Quality Objective	RSP	-	180$^{(2)}$	55
(AQO)	NO_2	300$^{(1)}$	150$^{(2)}$	80
PRDEZ	O_3	200	-	-
Mainland Class 2	RSP	-	150	100
NAAQS	NO_2	240	120	80
PRDEZ	O_3	200	-	-
Mainland Class 3	RSP	-	250	150
NAAQS	NO_2	240	120	80

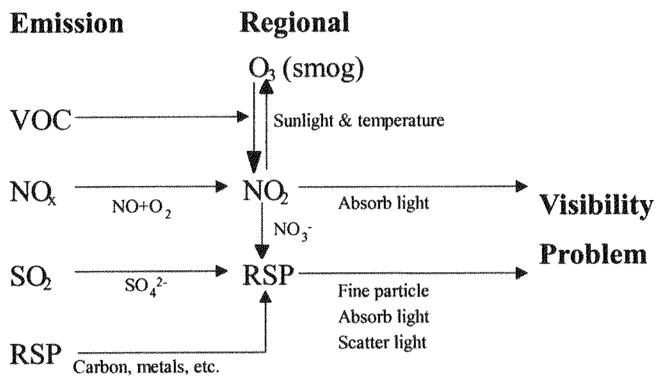
Notes: $^{(1)}$ *1-hr objectives are not to be exceeded more than three times per year in HKSAR*
$^{(2)}$ *24-hr objectives are not to be exceeded more than once per year in HKSAR*

2.1.2 Ozone is a photochemical oxidant formed from a complex chain of chemical reactions in the presence of sunlight and warm temperatures which involves a host of precursors, the key ones being oxygen, nitrogen oxides and reactive volatile organic compounds. RSP comprises particles with a nominal aerodynamic diameter of 10 micrometers or less. Some of these particles, such as carbon particles, are emitted from combustion sources and can be suspended and transported for long distances. Others, such as sulphates and nitrates, are formed from sulphur dioxide and nitrogen oxides following chemical reactions in the atmosphere. Nitrogen dioxide is formed primarily from nitric oxide emitted from combustion sources. It is also a product of photochemical smog.

2.1.3 Figure 2-1 is a simple schematic diagram showing the relationships of man-made emissions and the regional pollutants. In very simple terms, sunlight, in the range of 3,000-4,600 Å, decomposes NO_2 into NO and an O radical. This O radical combines with O_2 and subsequently, VOCs to form O_3. As mentioned in the last paragraph, photochemical smog formation is a very complex phenomenon. For example, after O_3 is formed, it can recombine with NO to generate NO_2 and O_2. Furthermore, the vast number of VOCs, each with a different reactivity and each involved in a multitude of chain reaction steps which have to conform thermodynamically and kinetically, make it very difficult to formulate a precise mechanism for photochemical formation. In contrast, the formation of NO_2 from NO_X emissions as a result of photochemical reactions is a relatively simple reaction. As shown in Figure 2-1, RSP results from combination of processes including the transformation of gaseous nitrogen and sulphur compounds to nitrates and sulphates, as well as emissions of carbonaceous particles from combustion process, metallic particles from manufacturing, mining or metallurgical processes, and crustal particles and particles from sea sprays.

2.1.4 Because of the nature of these regional pollutants, reducing their atmospheric concentrations requires the reduction in emissions of the pollutants themselves, such as carbon particles, or of their precursors, such as reactive organic compounds and nitrogen oxides for ozone and sulphur dioxide for sulphates. Furthermore, because of the non-linear nature of the chemical reactions in the atmosphere, sophisticated chemical and numerical mathematical models are required to ascertain the necessary reduction in emissions to bring about the required reduction in levels of these. In this study, the PATH air quality model was employed. Details of the model methodology are presented in Technical Annex 7 of this report.

Figure 2-1 Formation Processes of the Regional Air Pollution



2.2 Regional Air Quality

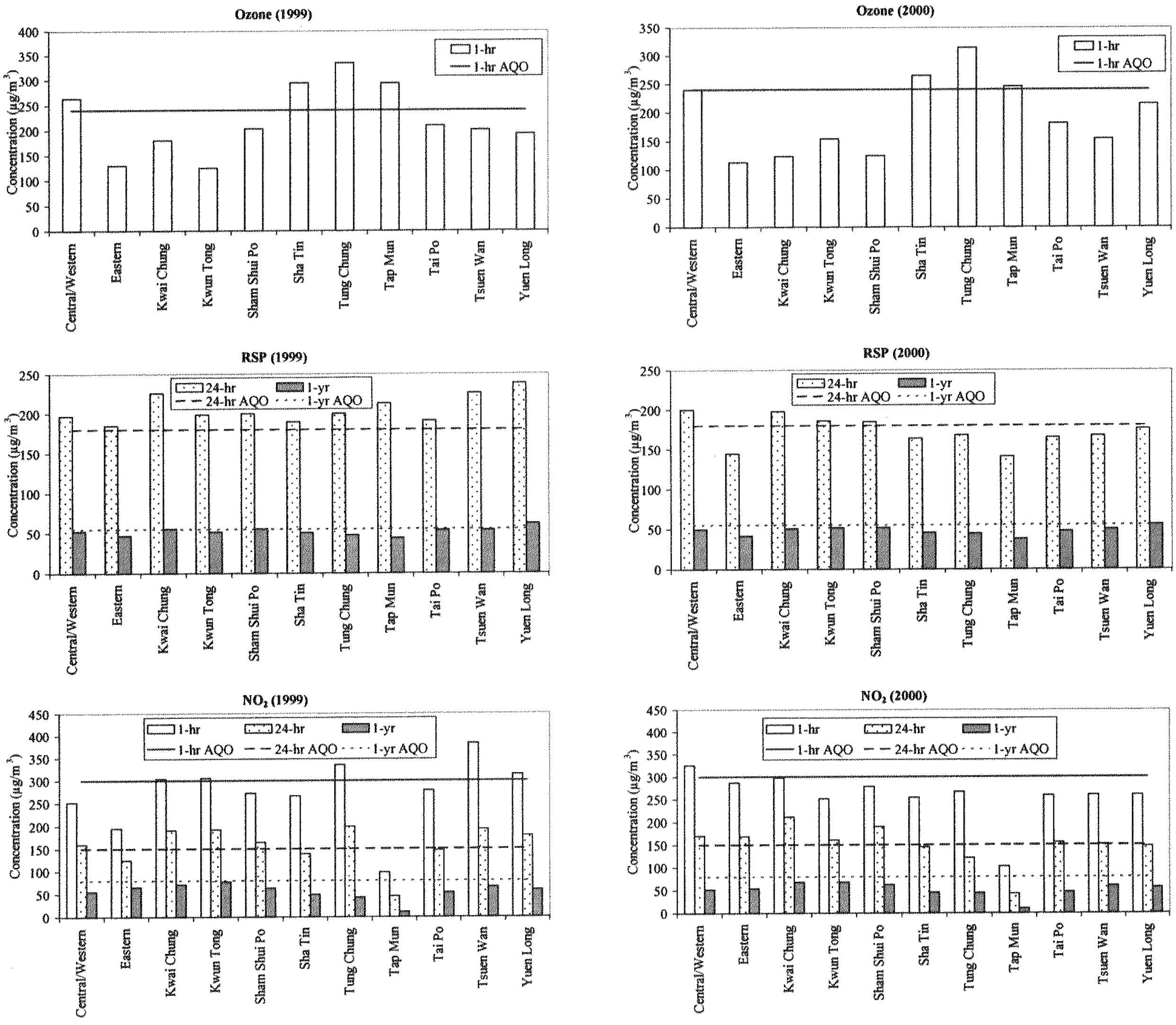
2.2.1 To understand the existing air quality in the Region, all routinely monitored representative (exclusive of roadside sites) O_3, RSP and NO_2 data in the Region for the period 1999 through 2000 were used. In HKSAR, O_3, RSP and NO_2 data were available at 11 sites for the entire period. For the rest of the Region, comparable O_3 data were available at 9 sites and at each site, for durations varying from two months to the entire twenty-four months. RSP data were not collected routinely outside HKSAR. For this study, collection of RSP data was conducted at eight sites in the PRDEZ between January and April 2000 as part of the monitoring exercise. Details of the monitoring exercise were described in Technical Annex 2. NO_2 hourly data outside HKSAR consisted of three months of data (January to March, 2000) at six sites in Shenzhen. In addition, there were 12 other sites in Guangzhou, Zhongshan, and Foshan where daily NO_2 data were collected over a period of 241 to 272 days in year 2000.

2.2.2 Figure 2-2 presents the maximum O_3, RSP and NO_2 concentrations for various averaging times in HKSAR during the study period. This shows occasional exceedences of the hourly and 24-hour air quality monitoring standards. In 1999, the maximum O_3 concentrations at 4 of the 11 sites exceeded the Hong Kong Air Quality Objectives (AQO) 1-hour limit. The highest concentration of 335 $\mu g/m^3$ was recorded at Tung Chung. The 24-hour AQO limit for RSP was exceeded at all sites while the annual limit was exceeded at 3 sites. The highest daily and annual RSP concentrations were 238 $\mu g/m^3$ and 62 $\mu g/m^3$ respectively at Yuen Long. The maximum 1-hour AQO limit for NO_2 was exceeded at 5 sites. The highest concentration of 383 $\mu g/m^3$ was recorded at Tsuen Wan. The highest 24-hour AQO for NO_2 hourly was exceeded at 7 sites. The highest concentration of 199 $\mu g/m^3$ was recorded at Kwai Chung.

2.2.3 In 2000, the maximum O_3 concentrations at 3 of the 11 sites exceeded the AQO 1-hour limit. The highest concentration of 314 $\mu g/m^3$ was recorded at Tung Chung. The 24-hour AQO limit for RSP was exceeded at 4 sites. The highest daily RSP concentration of 200 $\mu g/m^3$ was recorded at Central/Western. The maximum 1-hour AQO limit for NO_2 was exceeded at Central/Western with the highest concentration of 326 $\mu g/m^3$. The highest 24-hour AQO for NO_2 hourly was exceeded at 7 sites. The highest concentration of 211 $\mu g/m^3$ was recorded at Kwai Chung.

2.2.4 In general, an exceedance of the 1-hour or 24-hour objective limit at a monitoring site does not necessarily mean non-compliance with the corresponding AQO, since the objective allows a number of exceedances within a calendar year. However, even taking this into consideration, air quality still fails to comply with the necessary standards. For example, in 1999, the 1-hour O_3 AQO was not complied with at three sites, namely Sha Tin, Tung Chung, and Tap Mun. The 24-hour RSP AQO was not complied with at four sites, namely Central/Western, Sham Shui Po, Tung Chung, and Yuen Long. The 1-year RSP AQO was not complied with at three sites, namely Kwai Chung, Sham Shui Po, and Yuen Long. The 1-hour NO_2 AQO was not complied with at only one site, Tsuen Wan. The 24-hour NO_2 AQO was not complied with at six sites, namely Kwai Chung, Kwun Tong, Sham Shui Po, Tsuen Wan, Tung Chung and Yuen Long. The 1-year NO_2 AQO was complied with at all sites.

Figure 2-2 Maximum Hong Kong Air Quality Concentrations from 1999 to 2000



2.2.5 In 2000, the hourly O_3 AQO was not complied with at 1 site. Non-compliance of the daily and annual RSP objectives were observed at 2 sites and 1 site respectively. The hourly, daily, and annual NO_2 objectives were achieved at all sites. Table 2-2 summarizes the compliance of the HKAQO within 1999 to 2000.

Table 2-2 Number of Violations of the HKAQO Limit for the Ambient Monitoring Stations

No. of hour/day Violation of AOQ	O_3 1-hr		NO_2 1-hr	NO_2 24-hr	NO_2 1-yr	NO_2 1-hr	NO_2 24-hr	NO_2 1-yr	RSP 24-hr	RSP 1-yr	RSP 24-hr	RSP 1-yr
Period (1999 to 2000)	1999	2000	1999			2000			1999		2000	
Central/Western	2	0	0	1	0	3	1	0	**2**	0	**3**	0
Eastern	0	0	0	0	0	0	1	0	1	0	0	0
Kwai Chung	0	0	2	**4**	0	0	1	0	1	**1**	**2**	0
Kwun Tong	0	0	1	**4**	0	0	1	0	1	0	1	0
Sham Shui Po	0	0	0	**2**	0	0	1	0	**2**	**1**	1	0
Tsuen Wan	0	0	**5**	**4**	0	0	1	0	1	0	0	0
Sha Tin	**4**	2	0	0	0	0	0	0	1	0	0	0
Tai Po	0	0	0	0	0	0	1	0	1	0	0	0
Tung Chung	**6**	**7**	3	**2**	0	0	0	0	**3**	0	0	0
Yuen Long	0	0	2	**3**	0	0	0	0	**2**	**1**	0	**1**
Tap Mun	**8**	1	0	0	0	0	0	0	1	0	0	0

Note: For 1-yr compliance, "1" denotes violation of the HKAQO, "0" denotes compliance with HKAQO
Bold and shaded value indicates violation of the HKAQO

2.2.6 The maximum concentrations and the number of exceedances of Class 2 NAAQS for the available data in the PRDEZ are presented in Table 2-3. Exceedances of all short-term (1-hour and 24-hour) Class 2 NAAQS were recorded at those sites where data were available in discrete periods. No comparison could be made for the annual standard since annual data were not available.

2.2.7 The highest 1-hour O_3 concentration of 457 $\mu g/m^3$ (more than 2 times the corresponding standard) was recorded at Chengxi in Foshan. The highest 1-hour NO_2 concentration of 334 $\mu g/m^3$ (1.4 times the corresponding Class 2 NAAQS) was recorded at Lixiang in Shenzhen and the highest 24-hour NO_2 concentration of 307 $\mu g/m^3$ (2.6 times the corresponding Class 2 NAAQS) was recorded at the Guangya Secondary School station in Guangzhou. From the result of the RSP monitoring exercise in PRDEZ as presented in Figure 2-3, the highest 24-hour RSP concentration of 608 $\mu g/m^3$ (4 times Class 2 NAAQS) was recorded at Xiancun in Guangzhou.

Figure 2-3 Results of the RSP Monitoring Exercise for the Study from December 1999 to May 2000

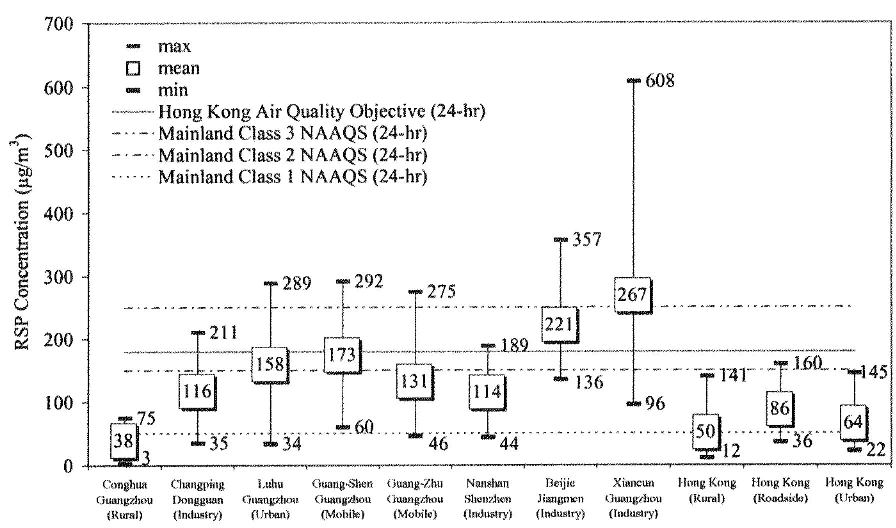


Table 2-3 Maximum PRDEZ Air Pollutant Concentrations from Various Records in 2000

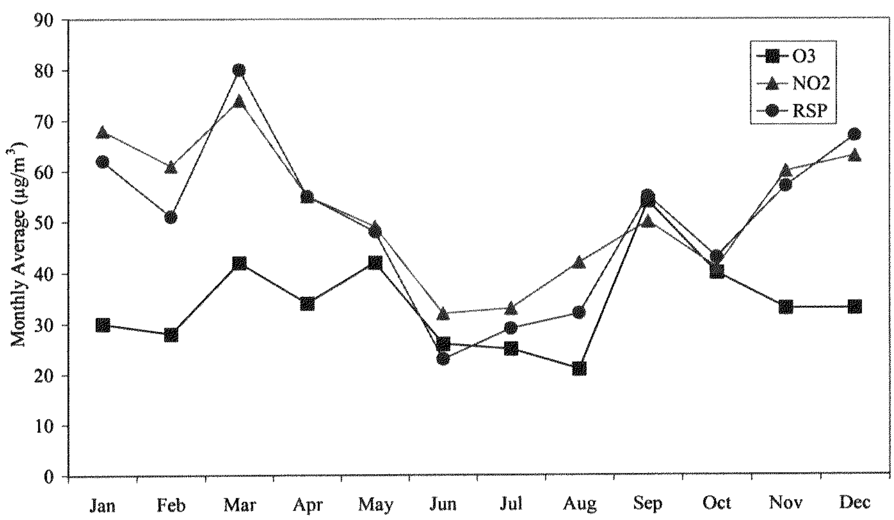
O_3	Chengnan Foshan	Chengxi Foshan	Laocheng Foshan	Nanhu Shenzhen	Nanyou Shenzhen	Honghu Shenzhen	Huaqiao Shenzhen	Liyuan Shenzhen	Lixiang Shenzhen
Hourly Maximum (μg/m³)	254	457	271	270	315	243	305	264	316
Hourly Exceedances (% of hours)	0.5%	0.9%	1.1%	0.2%	1.4%	0.2%	0.6%	0.2%	1.2%
Number of Hour Exceeded	24	26	20	13	80	10	31	12	67
Number of Sampled Hours	4401	2749	1764	5545	5566	5334	5152	4963	5529
Sampling Period	Feb – Aug	Mar – Aug	Mar – Aug	Jan – Aug	Jan – Aug	Jan – Aug	Jan – Aug	Jan – Aug	Jan – Aug
NO_2	Honghu Shenzhen	Huaqiao City Shenzhen	Liyuan Shenzhen	Lixiang Shenzhen	Nanhu Shenzhen	Nanyou Shenzhen	Zhongshan 1	Zhongshan 2	Zhongshan 3
Hourly Maximum (μg/m³)	261	270	248	334	267	257	-	-	-
Hourly Exceedances (% of hours)	0.1%	0.1%	0.1%	0.2%	0.0%	0.1%	-	-	-
Number of Hour Exceeded	1	2	1	4	1	2	-	-	-
Number of Sampled Hours	1884	1900	1997	2059	2013	1970	-	-	-
Sampling Period	Jan – Mar	Jan – Mar	Jan – Mar	Jan – Mar	Jan – Mar	Jan – Mar	-	-	-
Daily Maximum (μg/m³)	128	183	183	101	92	114	108	82	103
Daily Exceedances (% of days)	0.5%	0.5%	0.5%	0.0%	0.0%	0.0%	0%	0%	0%
Number of Day Exceeded	1	1	1	0	0	0	0	0	0
Number of Sampled Days	183	202	183	183	183	183	259	265	261
Sampling Period	Apr – Sep	Apr – Sep	Apr – Sep	Apr – Sep	Apr – Sep	Apr – Sep	Jan – Sep	Jan – Sep	Jan – Sep
NO_2	Foshan City 1	Foshan City 2	Foshan City 3	GRIEP Guangzhou	Guangya Secondary School Guangzhou	Haizhu Monitoring Station Guangzhou	Luhu Park Guangzhou	Urban Environmental Monitoring Station Guangzhou	Xilaixi Primary School Guangzhou
Daily Maximum (μg/m³)	113	112	140	237	307	132	153	231	141
Daily Exceedances (% of days)	0%	0%	0.8%	4.8%	9.0%	1.1%	1.9%	8.9%	2.2%
Number of Day Exceeded	0	0	2	13	24	3	5	24	6
Number of Sampled Days	241	251	245	272	268	266	270	269	270
Sampling Period	Jan – Sep	Jan – Sep	Jan – Sep	Jan – Sep	Jan – Sep	Jan – Sep	Jan – Sep	Jan – Sep	Jan – Sep
RSP	Changping Dongguan	Conghua Guangzhou	Guang-Shen Guangzhou	Luhu Guangzhou	Xiancun Guangzhou	Beijie Jiangmen	Nanshan Shenzhen	Guang-Zhu Zhuhai	
Daily Maximum (μg/m³)	211	75	292	289	608	357	189	275	
Daily Exceedances (% of days)	33%	0%	67%	40%	73%	87%	27%	31%	
Number of Day Exceeded	5	0	10	6	11	13	4	5	
Number of Sampled Days	15	15	15	15	15	15	15	16	
Sampling Period	Jan – Apr	Jan – Apr	Jan – Apr	Jan – Apr	Jan – Apr	Jan – Apr	Jan – Apr	Jan – Apr	

Note: The number of exceedances is with respect to the PRDEZ Mainland Class 2 NAAQS which is designed to protect public health in urban, residential, commercial, industrial, and village areas. The Mainland Class 2 NAAQS are:

1-hr O_3 200μg/m³
1-hr NO_2 240μg/m³
24-hr NO_2 120μg/m³
24-hr RSP 150μg/m³

2.2.8 Figure 2-4 shows a plot of seasonal variability of these three pollutants at Central/Western in HKSAR from Jan 2000 to Dec 2000. O_3 levels were high in spring and autumn while NO_2 and RSP levels were high in winter. In general, elevated regional air pollution levels are associated with stagnating high-pressure systems. For ozone, however, there are two other ingredients, sunshine and warm temperature. The lower pollution levels for all three pollutants in summer are attributed to the strong convective instability in summer months and high rainfall associated with the summer monsoon. On occasions, O_3 levels can be high in summer days when stagnation occurs as a result of the buildup of a high-pressure system over Mainland China or when a typhoon approaches the continent from the Pacific Ocean. When this happens, peak O_3 levels can be even higher than those normally occurring in late spring and early summer because of the higher temperature. This seasonal variability is expected to be similar for all sites in the Region since the entire region is influenced by the same meteorological systems.

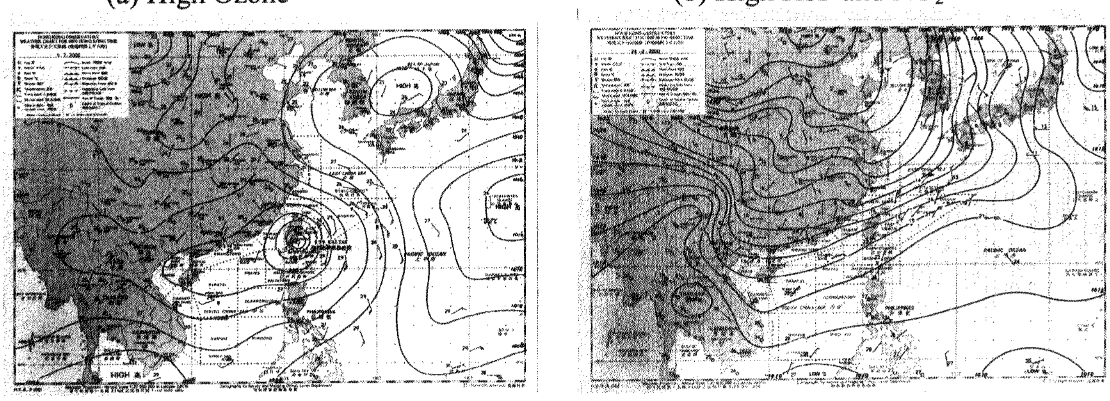
Figure 2-4 Seasonal Variability of O_3, RSP and NO_2 at Central/Western Monitoring Station in 2000



2.2.9 A typical meteorological weather pattern leading to high O_3 levels is shown in Figure 2-5a. In this case, a tropical cyclone is approaching Hong Kong. The slack pressure gradients over Southern China and the subsiding air ahead of the tropical system produce light wind speeds and pollutant stagnation. The weather is generally fine and the weather is warm. A typical meteorological weather pattern leading to high NO_2 and RSP levels is shown in Figure 2-5b. A broad area of high pressure dominates over the south China Coast. This brings about subsiding air over southern China with an inversion in the lower part of the atmosphere which causes pollutants difficult to disperse. This occurs in the wintertime and thus does not lead to elevated O_3 levels due to the low temperature.

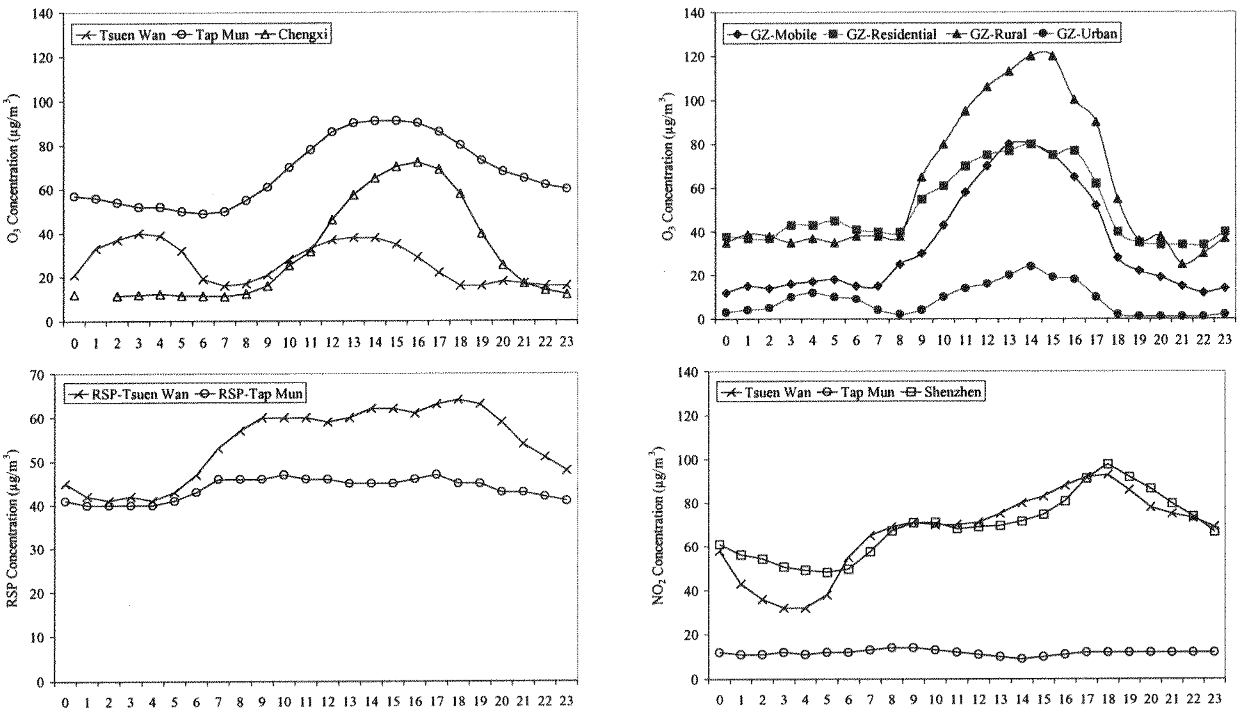
Figure 2-5 Meteorological Weather Patterns Conducive to High Levels of Regional Air Pollution

(a) High Ozone (b) High RSP and NO_2



2.2.10 Diurnal variations of the pollutants (ozone, RSP and NO_2) in 1999 are shown in Figure 2-6 for Tap Mun, a rural site, and Tsuen Wan, an urban site in HKSAR. In addition, diurnal variations of O_3 are shown for Chengxi of Foshan and NO_2 at Shenzhen for the study period when data were available. A special ozone study was carried out in Guangzhou in 1998 (UNDP 2001), and diurnal variations of ozone concentrations obtained during that study are also presented in Figure 2-6. RSP data collected in PRDEZ were 24-hour composite samples and therefore the diurnal variations are not presented. Figure 2-6 shows the differences in diurnal patterns between a rural site and urban sites. For O_3, the plot for Tap Mun and the rural sites in Guangzhou showed that O_3 levels peak in the early afternoon when solar radiation is strongest and this peak lags slightly behind that of urban sites. It also shows that O_3 concentrations decrease steadily from late afternoon to early morning before solar activity picks up again. The plot for Tap Mun typifies the O_3 profile at a site with few anthropogenic sources downwind of O_3 precursor sources. In an urban site (Tsuen Wan), there are some troughs during morning and evening rush hours when large amounts of NO, an O_3 scavenger, are emitted. Because of the presence of O_3 scavengers in an urban area, which reduce the concentration of O_3 in the atmosphere, and the time it takes to generate O_3 from precursors emitted in an urban area, the peak is less than that of a rural site downwind. This also shows that O_3 is a regional pollutant and any location downwind of an urban or industrial setting with O_3 precursor emissions is likely to experience high O_3 concentrations. It also shows that if the downwind location is itself an urban or industrial area with emissions of O_3 scavengers, like NO, then the peak would be less than a rural site and there would be valleys coinciding with the peak emissions of NO, such as during early and evening rush hours.

Figure 2-6 1999 Diurnal Variation in Tap Mun, Tsuen Wan, Chengxi, 1998 for Guangzhou, and 2000 for Shenzhen



2.2.11 For both RSP and NO_2 plots, the concentrations at the urban site show an increase in concentrations during daytime corresponding to emissions from traffic and other anthropogenic sources. However, the concentrations at Tap Mun, a rural site, do not vary much with the time of day. Since this is a rural site without much anthropogenic emission from local sources, the plots show that there is a background RSP concentration of around 40 $\mu g/m^3$ and a background NO_2 concentration of around 12 $\mu g/m^3$. The plots also show that NO_2 and RSP at locations where NO_2 and constituents of RSP are emitted contain a component attributable to local sources in addition to a regional background concentration. More importantly, the local component of NO_2 is significant since the background NO_2 concentration represents only about 10% of the average daily peaks at the urban sites in Hong Kong and Shenzhen. Thus, for these average peaks, 90% of the concentrations are attributable to local sources.

2.2.12 Since there are no significant anthropogenic sources at Tap Mun, the RSP concentration is attributable to the regional background concentration and is a testimony that secondary pollutants such as O_3, NO_2, and RSP are regional in nature. The annual average background RSP concentration is about 70% of the 1-year objective of 55 $\mu g/m^3$ and about 40% of the Class 2 1-year NAAQS of 100 $\mu g/m^3$.

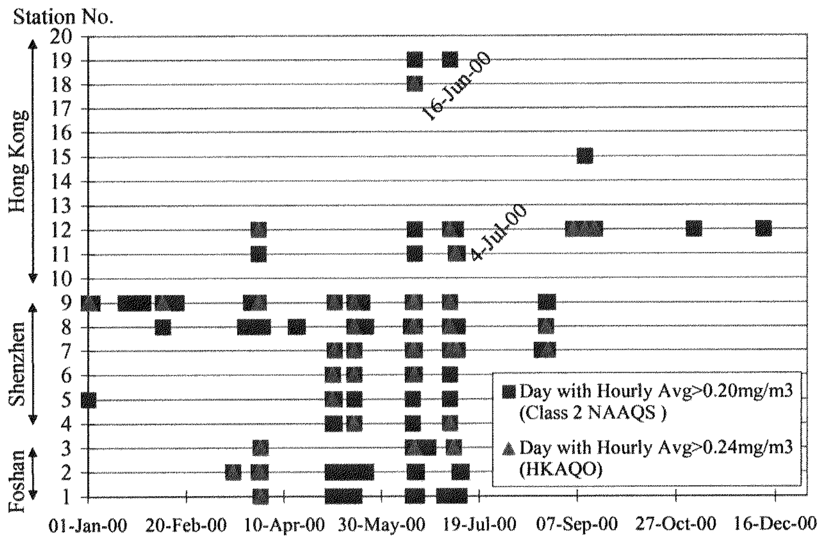
2.2.13 A background RSP site (Conghua) was established in the Mainland for this study. The average concentration over the monitoring period was 38 $\mu g/m^3$. The average concentration at Conghua compares well with the average concentration at Tap Mun of 50 $\mu g/m^3$ during the same sampling period. The average concentrations over the same period at 7 other sites all in the Mainland, varied from 114 $\mu g/m^3$ to 267 $\mu g/m^3$ (see Figure 2-3). This is further evidence that regional RSP concentrations are elevated compared to natural background levels.

2.2.14 The secondary particles of RSP comprise sulphate, nitrate, ammonium and constitute the fine particulate component of RSP subject to long distance transport. Sulphate and nitrate are formed in the atmosphere from SO_2 and NO_x emissions while ammonium is formed from urea and ammonia emissions. Secondary particles, by nature of the atmospheric chemical reactions that form them, are regional in nature. In this Study, RSP composition had been analyzed with monitoring data available at various sites within the Region. It was found that secondary particles represented approximately 32-33% of RSP at the two rural sites of the Region, namely Tap Mun in HKSAR and Conghua in PRDEZ. At urban sites, the fraction of secondary particles in RSP is relatively less significant, with an average of 28% and 22% in HKSAR and PRDEZ respectively. Appendix 2-B shows a comparison of the constituents of RSP at Conghua, Tap Mun and Tsuen Wan (an example of urban site) based on mass balance approach (Chow 2000).

2.2.15 The regional nature of O_3 and the occurrence of O_3 episodes in the Region are analyzed with monitoring data at HKSAR, Shenzhen, and Foshan sites as illustrated in Figure 2-7. This figure shows when in the year 2000, ozone concentrations exceeding 200 $\mu g/m^3$ (equivalent to 1-hour Class 2 NAAQS) or 240 $\mu g/m^3$ (equivalent to 1-hour HKAQO) are identified. Elevated O_3 concentrations were observed at most sites on certain days and demonstrated the regional nature of O_3. Regional ozone episodes in 2000 are clearly identified on two days, June 16 and July 4.

2.2.16 On 16th June 2000, there was a weak trough off the coast of Mainland China. Pressure gradients were very slack throughout the Region. This resulted in calm or very light and variable wind conditions. Subsiding air led to clear skies. Calm and light wind conditions (or the lack of dispersion), clear skies (sunlight) and June temperatures combined to give rise to high O_3 levels throughout the entire Region. On July 4, Typhoon Kirogi over the western North Pacific and a tropical depression over the northern part of the South China Sea. Ahead of these tropical systems, there were slack pressure gradients and clear skies throughout the Region, caused by descending air ahead of the arrival of these low-pressure systems. Winds in Hong Kong and Shenzhen were light and from the northeast. The conditions for a regional O_3 episode were again present: light winds (low dispersion), clear skies (sunlight) and July (warm) temperatures. Ozone concentrations at all sites on these two days were high again highlighting the regional nature of these poor air quality episodes. Appendix 2-C shows synoptic weather maps for these two days.

Figure 2-7 *Days with High O_3 in HKSAR, Shenzhen, and Foshan*



2.2.17 The background RSP concentrations at Tap Mun and Conghua, the composition of the RSP concentrations at Tap Mun and Conghua, the background NO_2 concentrations at Tap Mun, the differences between the diurnal variation of NO_2 at urban and rural sites illustrate that both RSP and NO_2 have a regional and a local component. In addition, the local component of NO_2 is significant. For O_3, the regional nature of this pollutant is clearly illustrated by the O_3 episodes of June 16 and July 4, 2000.

2.2.18 Figure 2-8 presents the trends in annual O_3, NO_2, and RSP concentrations in HKSAR for the period from 1991-2000. Ozone levels have increased by approximately 39% and NO_2 by about 26%. RSP, on the other hand, shows a declining trend of about 8% over this period.

2.2.19 Pollution trends in the Region can also be illustrated by using visibility as a surrogate for the fine particulate component of RSP as well as photochemical smog. Figure 2-9 highlights the worsening trend in visibility for Guangzhou, Shenzhen, and Hong Kong (EPD, 2000).

Figure 2-8 *1991 to 2000 Annual Average of Pollutants Concentration for HKSAR*

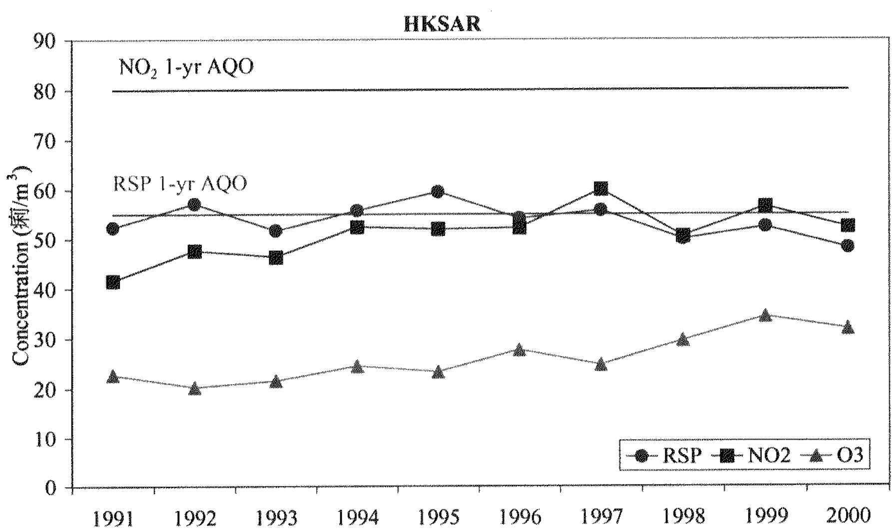
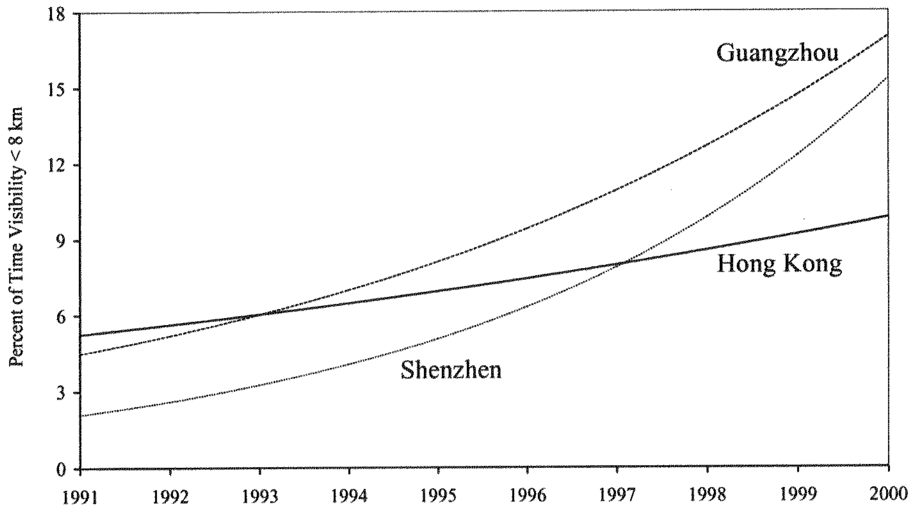


Figure 2-9 1991 to 2000 Trends in Visibility Impairments in the Region

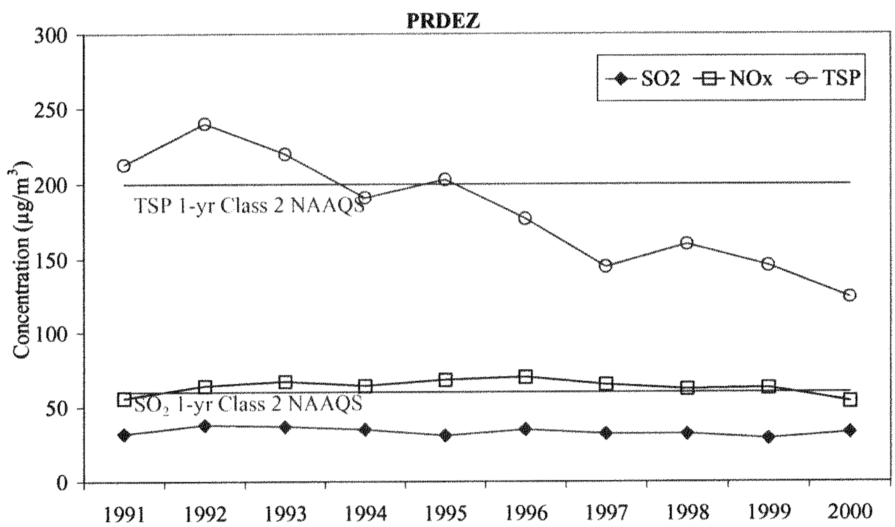


Note: Relative Humidity is less than or equal to 80%
For Hong Kong, the visibility was measured at the Hong Kong Observatory headquarters

2.2.20 All cities showed deterioration in visibility between 1991-2000 with an upward trend in the percent of time when visibility was less than 8 kilometers. It is of interest to note that among the three cities, the percent of time with poor visibility was highest for Hong Kong in 1991 but least in 2000. This might be attributable to the air quality control measures that were implemented and the gradual reduction in manufacturing activities in Hong Kong during this period. The most significant increase in visibility impairment has occurred in Shenzhen, where the percentage of time with visibility less than 8 km in the late 1990s has increased ninefold compared to that of 1991. Over the same period, the number of hours with visibility impairment has increased fivefold in Guangzhou.

2.2.21 Figure 2-10 shows the trend in air quality in the PRDEZ. Air quality in terms of total suspended particulate (TSP, of which RSP is a subset) has improved over the past decade by 50% while primary pollutant concentrations of NO_x (of which NO_2 is a subset) and SO_2 have remained pretty constant in this period. Tabulated data are shown in Appendix 2-A. From the deteriorating visibility trend and the O_3 trend in Hong Kong, it can be surmised that the O_3 trend in PRDEZ has worsened during this period.

Figure 2-10 1991 to 2000 Annual Average of Pollutants Concentration for PRDEZ



2.3 Summary of the Air Quality in the Region

2.3.1 In summary, regional air pollutants of concern are O_3, NO_2 and RSP. Non-compliance of the HKAQO and exceedances of the NAAQS in cities under the corresponding jurisdiction are recorded in individual monitoring stations in discrete periods. High O_3 concentrations occur in spring and autumn while high NO_2 and RSP concentrations in winter; all associated with stagnate air conditions. However, O_3 production also requires the presence of sunlight and warm weather and thus does not peak in winter. These pollutants are regional in nature as they, as well as their precursors, are transported over long distances. For all three pollutants, there is also a local component due to local emissions sources.

2.3.2 Long-term trends indicate a worsening of regional air pollution, therefore there is a need to ameliorate the worsening regional air pollution trend in order to protect public health. Furthermore, improvement in air quality with respect to these regional pollutants will require a concerted regional effort to bring the overall level of pollution down to within acceptable limits.

Chapter Summary

- Non-compliance of the HKSAR Air Quality Objectives and exceedances of the Mainland National Ambient Air Quality Standards are recorded in the Region.
- High O_3 concentrations occur in spring and autumn, and high NO_2 and RSP concentrations in winter.
- O_3, RSP and NO_2 are regional pollutants but all have a local component.
- Regional air quality has been deteriorating in the past decade.

3. POLLUTION SOURCES IN THE REGION

3.1 Introduction

3.1.1 The emission inventory is a tool to help identify air pollution sources in the Region. In this Study, emission inventories were prepared for HKSAR and PRDEZ, in accordance with methodologies widely accepted by developed countries and international organisations such as the United States Environmental Protection Agency (USEPA 1998), United Nations Development Programme (UNDP 2000), Intergovernmental Panel of Climate Change (IPCC 1996) and European Environmental Agency (CORINAIR 1999). The study focused on the analysis of anthropogenic emissions.

3.1.2 The base year of the emission inventory was chosen to be 1997 to take account of the availability of data. For HKSAR, the emission inventory was primarily based on the 1995 emission inventory as data were available from a study which developed the PATH modelling system and contained emission inventory data for the territory which are regularly updated by EPD. For the PRDEZ, data were primarily provided by the Guangdong Province Environmental Protection Monitoring Center (GPEMC) of the Guangdong Environmental Protection Bureau (GDEPB) and reviewed by a Guangdong expert team. Supplementary data were obtained from relevant government departments, annual statistical yearbooks published by individual cities or municipalities, annual reports of public companies, etc. A detailed summary of the data used in the emission inventory is presented in Appendix 3-A to 3-C.

3.1.3 Key substances emitted into the atmosphere that contribute towards the formation of O_3 are nitrogen oxides (NO_X) and volatile organic compounds (VOC). Some of RSP are emitted from combustion sources. Others, such as sulphates, nitrates and ammonium are formed from sulphur dioxide (SO_2), NO_X, and ammonia (NH_3) respectively as they get involved in chemical reactions in the atmosphere. NO_2 is formed primarily from NO_X emitted from combustion sources. Thus, substances included in the inventory are VOC, RSP, NO_X, SO_2, and NH_3. Among these, the first four substances are more important as control strategies are available to reduce atmospheric emissions. These four substances are therefore discussed more extensively in this report.

3.1.4 Since data for HKSAR and PRDEZ were obtained from different information sources, they are subjected to different classification systems and levels of details. Emission source types were grouped into four major sectors: energy, industry, transportation, and transportation. Each of these has distinct emission characteristics and specific approaches to implementation and enforcement of control measures. Efforts had been made to reconcile information obtained from HKSAR and PRDEZ such that emission source types included in each major sector are largely comparable. Table 3-1 shows the different source types within each sector.

3.1.5 The emission inventory was complied using the best available information. However, as this is the first regional emission inventory of this scale, a certain level of uncertainties is expected. Higher confidence could be obtained through further refinement of the inventory in future studies if undertaken.

3.1.6 The base year emission inventory served as part of the input to the PATH modelling system for simulating the regional air quality in terms of pollutant concentrations. The methodology of PATH modelling is presented in Technical Annex 7 of the report. Furthermore, the base year emission inventory will be applied as the foundation of future year projection in the next chapter.

Table 3-1 Classifications of the Emission Inventory in this Study

(a) HKSAR emission sources

Sector	**Sub-Sector**	**HKSAR Source Category**
Energy	Power Generation	Power Generation
	Others	Other Fuel Combustion
Industry		Cement Production
		Paint Manufacture
		Printing
		Service Station Refuelling
		Textile manufacturing
Transportation	Motor Vehicle	Motor Cycle
		Taxi
		Private Car
		Pass. Van
		PLB
		LGV
		HGV
		Non Fr. Bus
		SD Fr. Bus
		DD Fr. Bus
	Marine	Marine Vessels-Harbour Area
		Marine Vessels-SAR Waters
	Others	Airport
		Diesel Locomotives
VOC Containing Product		Domestic Product
		Paint
Others		Animal Waste Ammonia
		Dry Cleaning
		Fuel Terminals
		Human Sweat & Exhalation
		Nitrogen Fertilizer Usage
		Other Services
		Quarries
		Transportable Construction Dust
		Transportable Paved Road Dust
		Transportable Unpaved Road Dust
		Waste Incineration

Note: Pass. Van denotes Passenger Van
PLB denotes Public Light Bu
LGV denotes Light Goods Vehicle
HGV denotes Heavy Goods Vehicle
Non Fr. Bus denotes Non Franchised Bus
SD Fr. Bus denotes Single Deck Franchised Bus
DD Fr. Bus denotes Double Deck Franchised Bus

Table 3-1 Classifications of the Emission Inventory in this Study (cont'd)

(b) PRDEZ emission sources

Sector	**Sub-Sector**	**PRDEZ Source Category**
Energy	Power Generation	Power Generation
	Others	Commercial Fuel Use
		Domestic Coal Consumption
		Domestic LPG Consumption
		Domestic Other Fuel Consumption
Industry		Alcoholic Beverage Production
		Chemicals/Rubber/Plastic
		Construction
		Electronic Manufacture
		Food and Beverage
		Gas, Water & Sanitary Works
		Manufacture-Heavy
		Manufacture-Light/Medium
		Mining/Mineral Extraction
		Non-Metallic Mineral Products
		Oil Refinery
		Petrol Distribution & Handling
		Printing
		Pulp and Paper Industries
		Transportation
Transportation	Motor Vehicle	Motor Cycle
		Small Petrol Vehicle
		Large Petrol Vehicle
		Diesel Goods Vehicle
	Marine	Ports
		Waters
	Others	Guangzhou Airport
		Shenzhen Airport
		Zhuhai Airport
		Railway
VOC Containing Product		Domestic Product
		Paint
Others		Agricultural Waste Burning
		Agriculture
		Ammonia Production
		Animal Waste Ammonia
		Dry Cleaning
		Grain Drying
		Human Sweat & Exhalation
		Human Waste Rural Households
		Human Waste Urban without Sanitary Facilities
		Industrial Waste Incineration
		Medical Waste Incineration
		Nitrogen Fertilizer Production
		Nitrogen Fertilizer Usage
		Pesticide Application
		Transportable Construction Dust
		Transportable Paved Road Dust
		Transportable Unpaved Road Dust

3.2 Summary of Data Used in the HKSAR Base Year Emission Inventory

Energy

3.2.1 Emission sources within this sector include power generation, commercial and domestic fuel combustion. Industrial fuel combustion is classified under Industry sector. A table summarising the classification of emissions is presented in Table 3-1.

3.2.2 The power generation data, including the 1997 activity information, emissions, fuel usage, and stack monitoring data of each operating power plant are provided by the Hongkong Electric Company Limited (HEC) and CLP Power HK Limited (CLP). Other fuel combustion emissions were based on 1997 fuel consumption statistics. Detailed summaries of the data collected for the calculation of the emission inventory from this sector are presented in Appendix 3-A.

Industry

3.2.3 The activities within an industry resulting in significant pollutant emissions are industrial fuel consumption and the production process. The emission data for cement production was obtained from a continuous emission monitoring system. Emissions from textile manufacturing and printing industry emissions were projected from the 1995 inventory based on employment statistics. The growth of car registration from 1995 was used as a surrogate to project the emissions from petrol filling stations. Detailed data summaries of the data collected for the calculation of the emission inventory from this sector are presented in Appendix 3-A.

Transportation

3.2.4 Annual vehicle-kilometres-travelled (VKT) for motor vehicles were estimated with reference to the Strategic Environmental Assessment (SEA) of the Third Comprehensive Transport Study (CTS3) (Transport Department 1999). For marine emissions, 1997 shipping activity data for the Victoria Harbour and within Hong Kong waters were collected from the Hong Kong Marine Department, Hong Kong Port and Maritime Board, port related organisations and the Hong Kong Annual Digest of Statistics. The 1997 Hong Kong Kai Tak International Airport landing and take off data, together with the helicopter movement data from Central Heliport and Shun Tak Heliport were obtained from the Civil Aviation Department. Emissions from the limited number of maintenance diesel locomotives were computed using diesel fuel consumption information provided by the Kowloon-Canton Railway Corporation (KCRC) and the MTR Corporation Limited. Detailed data summaries for the calculation of the emission inventory for this sector are presented in Appendix 3-B.

VOC Containing Product

3.2.5 The 1997 emissions from VOC containing products were primarily projected from 1995 PATH value to 1997 using the growth in population in Hong Kong between the two years. Detailed data summary for the calculation of the emission inventory from this sector are presented in Appendix 3-C.

Others

3.2.6 The lengths of paved and unpaved roads within the territory were estimated in CTS3. In 1997, there were no ammonia or fertiliser production facilities in Hong Kong. The primary sources of ammonia emissions were fertiliser usage, followed by human sweat and exhalation.

3.3 Summary of Data Used in the PRDEZ Base Year Emission Inventory

Energy

3.3.1 The major source categories are power generation, commercial and domestic fuel consumption. Data for the emission calculations for the power plants were extracted from the 1995 comprehensive emission survey and the 1996 update conducted by the Guangdong Province Environmental Protection Bureau. The comprehensive survey covered approximately 11,000 emission premises of the energy and industry sectors in the PRDEZ.

Industry

3.3.2 Emissions from this sector include the fuel usage and the emissions from industrial processes. Data for the emission calculations were based on the 1995 and 1996 surveys conducted by the Guangdong Province Environmental Protection Bureau. In addition, the inventoried data on industrial fuel use in PRDEZ, official government statistics on fuel use, and data in the Guangdong Province Statistical Yearbook were used.

Transportation

3.3.3 Annual VKT for each vehicle class were provided by traffic police and statistical bureau of each individual city and verified by GPEMC. Data on shipping tonnage and vessel traffic at each of the ports were obtained from the annual transportation statistical yearbooks, port authority web sites and the Mainland shipping information network. In PRDEZ, there are 3 dominant civil airports, the Shenzhen International Airport, Zhuhai Airport and Guangzhou Baiyun International Airport. Landing and take off data for each of these airports were obtained from either business traffic planners or through direct communication with the airports. Rail emissions were computed from 1997 tonne-km freight statistics and fuel consumption per tonne-km for four PRDEZ railway companies, viz Yangcheng Company, Guangzhou, Meizhou-Shantou Company, Pinghu-Nantou Joint Stock Company and Shanshui-Maoming Company, for which data are available in the statistical yearbook.

VOC Containing Product

3.3.4 Consumption and product usage data were obtained from trade associations together with GPEMC. Other data, such as population data, were obtained from the Guangdong Province and City statistical yearbooks.

Others

3.3.5 Paved and unpaved road dust emissions were estimated using VKT data for the PRDEZ. Data for computing ammonia emissions and emissions from agricultural waste burning were obtained from the GPEMC, and from the Guangdong Province, City, and China agricultural statistical yearbooks.

3.4 Analysis of the Base Year Emission Inventory

3.4.1 Table 3-2 and Figure 3-1 present an overall summary of the emission inventory for HKSAR and Guangdong, excluding the biogenic VOC emissions in the Region. Emissions from PRDEZ, contributing 88%, 95%, 80% and 87% of the total respectively, dominated the regional emissions of VOC, RSP, NO_X and SO_2.

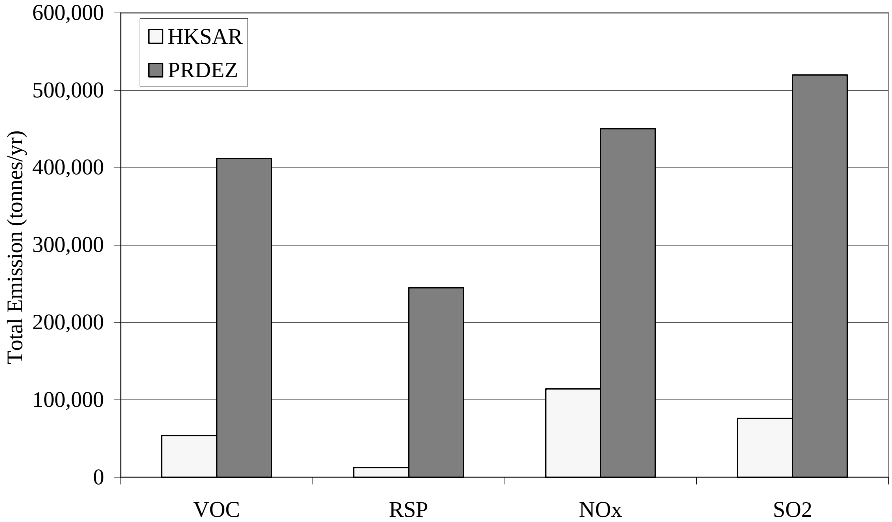
3.4.2 Further breakdowns of individual VOC, RSP, NO_x, and SO_2 emissions by major source types are presented in Appendix 3-D to 3-G. A summary of the complete base year emission inventory is in Appendix 3-H.

Table 3-2 Summary of the 1997 Base Year Emission Inventory in the Region

Entity	Emissions (kilo tonnes/year)				Population (million people)	Population Density (people/km^2)
	VOC	RSP	NOx	SO_2		
HKSAR	54 (12%)	13 (5%)	114 (20%)	76 (13%)	6.5 (17%)	5,909
PRDEZ	412 (88%)	245 (95%)	450 (80%)	520 (87%)	32.2 (83%)	772
Region	466	258	564	596	38.7	904

Note: Figure in bracket indicates contribution to the regional total

Figure 3-1 Base Year Emission Summary for the Region



3.5 Major Sources of Emissions in the Region

3.5.1 Table 3-3 summarises the contribution of major emission sources in the Region. Emissions from the four major sectors contributed at least 90% of the regional emission. Control measures for the attainment and maintenance of the air quality standards will therefore be suggested for these major sources and are discussed in Sections 4 and 5. Controlling the major emitters in the region does not necessarily mean that there is no control over other minor sources. Continual review of the emission inventory, however, is recommended to take note of the changes in future emission characteristics.

Table 3-3 Contributions of the Major Sectors to the Regional Base Year Emission Inventory

Emission		VOC	RSP	NO_x	SO_2
Contributions by Major Sectors, broken down to individual entities:					
Energy	HKSAR	-	2%	11%	11%
	PRDEZ	1%	13%	31%	43%
	Subtotal	1%	15%	42%	54%
Industry	HKSAR	2%	-	1%	1%
	PRDEZ	9%	60%	12%	38%
	Subtotal	11%	60%	13%	39%
Transportation	HKSAR	3%	2%	9%	1%
	PRDEZ	52%	13%	35%	6%
	Subtotal	55%	15%	44%	7%
VOC Containing Product	HKSAR	6%	-	-	-
	PRDEZ	17%	-	-	-
	Subtotal	23%	-	-	-
Total		90%	90%	99%	100%

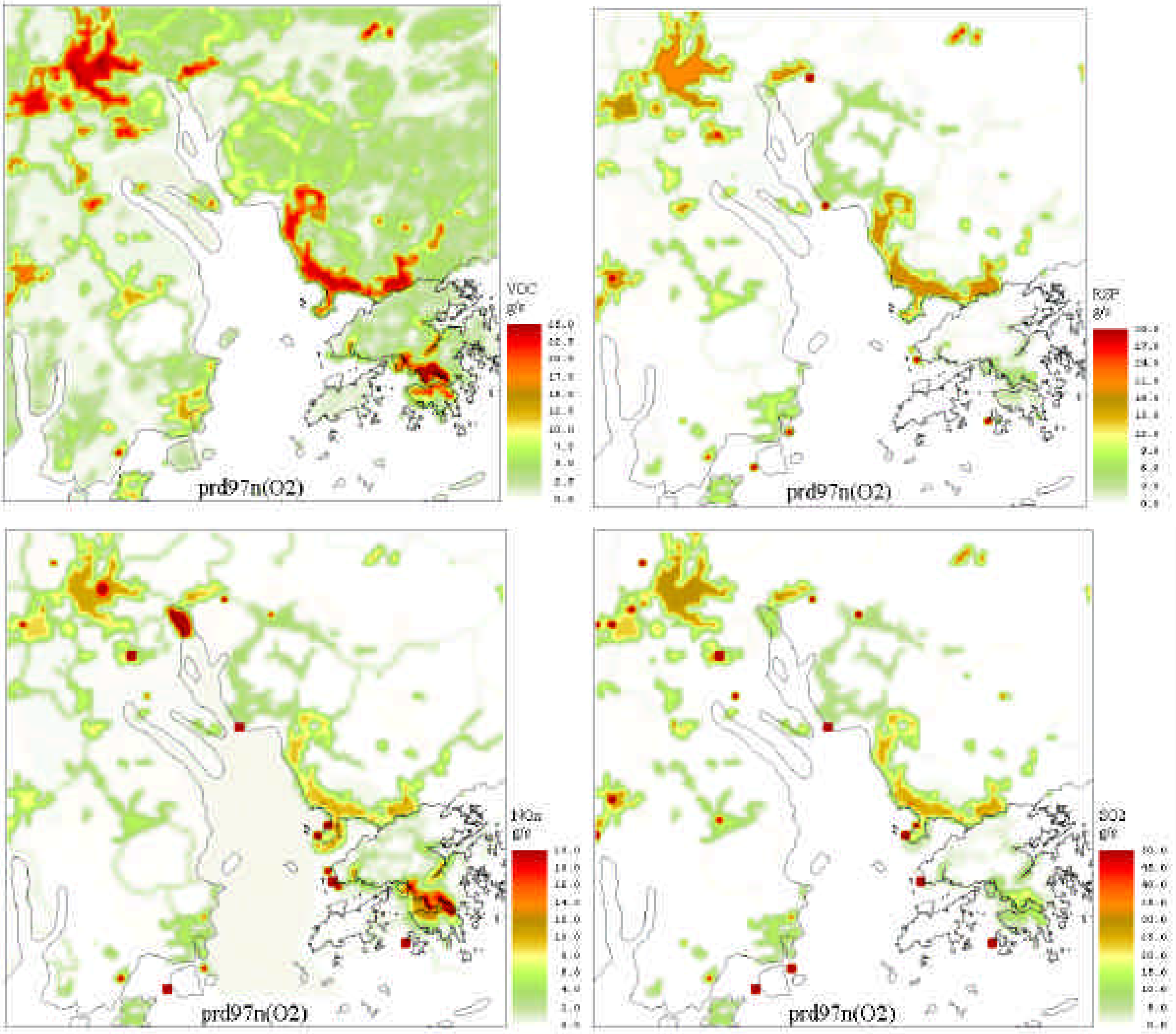
3.5.2 The regional emissions for all the concerned pollutants are dominated by PRDEZ. Nevertheless, the emissions per capita and per unit area for the Region as presented in Table 3-4 may provide indicative representation of emission quantities for HKSAR and PRDEZ.

Table 3-4 Pollutant Emissions per Capita and per unit Area in the Region

	VOC	RSP	NO_x	SO_2
Pollutant emission per capita (kg/person)				
HKSAR	8	2	18	12
PRDEZ	13	8	14	16
Region	12	7	15	15
Pollutant emission per unit area (tonnes/km^2)				
HKSAR	49	11	104	70
PRDEZ	10	6	11	12
Region	11	6	13	14

3.5.3 The spatial distribution of emissions across the region is illustrated in Figure 3-2. It can be seen from the model results that the spread of emission densities is very similar for different pollutants throughout the Region. As expected, the emissions are generally more concentrated in urban areas. The red spots on the figures indicate large point sources or dense area sources in the Region. The high levels of emissions from motor vehicles resulted as a visible road network across the Region.

Figure 3-2 Spatial Distribution of Emissions in the Region

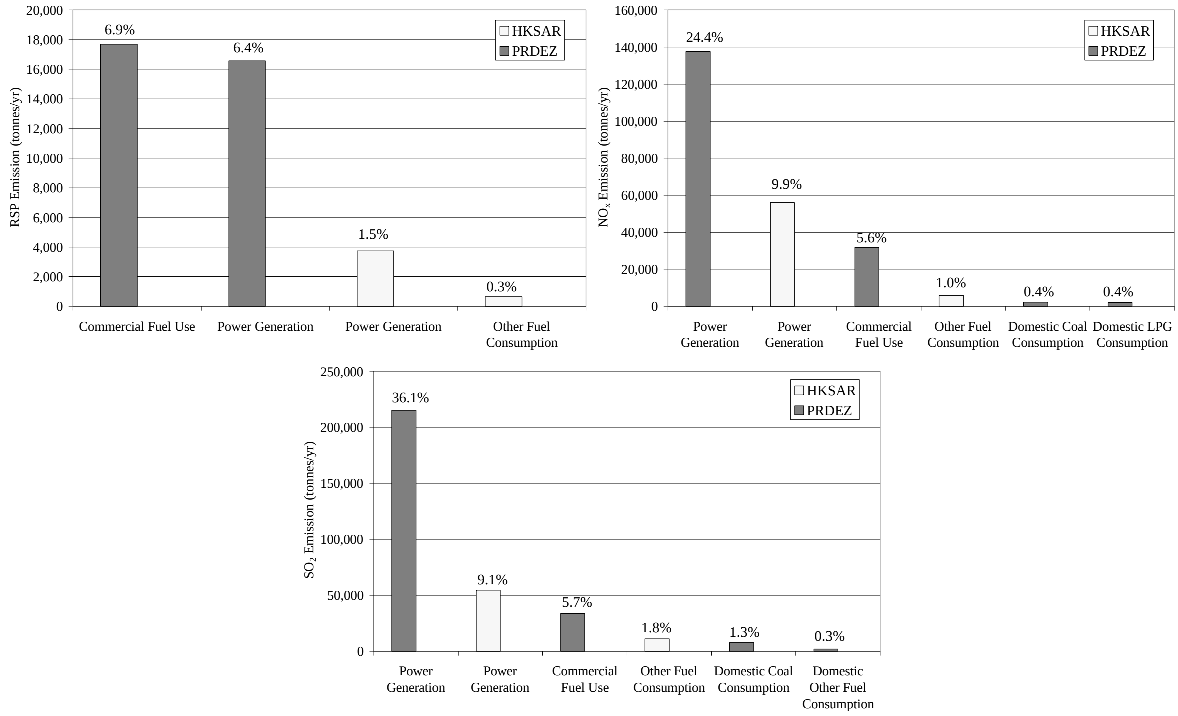


3.6 Emission Profiles of the Major Sectors

<u>Energy Sector</u>

3.6.1 Emissions from the energy sector account for 54%, 42%, and 15% of the regional SO_2, NO_x, and RSP emissions respectively. For SO_2 and NO_x, power plants are the dominant source types. For RSP, emissions from commercial fuel use and power generation in PRDEZ are the most significant source types within this sector (See Figure 3-3).

Figure 3-3 Emissions from the Energy Sector and their Contribution to the Region



<u>Industry Sector</u>

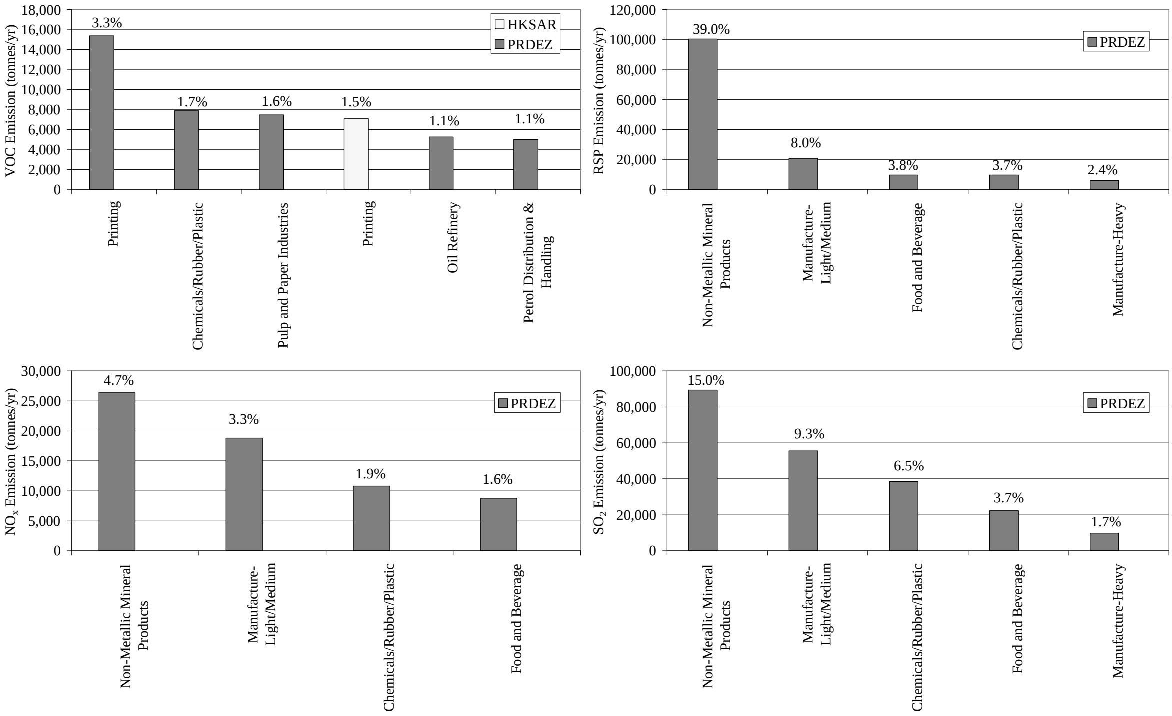
3.6.2 The emissions from the industry sector consisted of SO_2, NO_x, RSP and VOC emitted from industrial fuel consumption and production processes. Figure 3-4 presents emissions from major sources within this sector in HKSAR and PRDEZ.

3.6.3 Industrial NO_x and SO_2 emissions contribute 13% and 39% respectively to the regional totals. The most important source type in this sector is fuel combustion by the top four fuel users, i.e. non-metallic mineral products, the light/medium manufacture, chemical/rubber/plastic processes and food and beverage industries, are the most important source types in this sector.

3.6.4 Industrial RSP emissions from PRDEZ account for 60% of regional emissions. Non-metallic products manufacturing in PRDEZ including cement production and brick production is the dominant source, with an annual emission of around 100,000 tonnes, approximately 39% of the regional total.

3.6.5 Industrial VOC emissions account for 11% of the total regional VOC emissions, in which about 9% was sourced from PRDEZ (with printing being the most significant source) and less than 2% from HKSAR.

Figure 3-4 Base Year VOC, RSP, NO_x and SO_2 Emissions from the Industry Sector



<u>Transportation Sector</u>

3.6.6 Transportation sector is the largest contributor to VOC and NO_x emissions, and the second largest producer of RSP regional base year emissions. Emitting 99%, 69% and 95% of sectoral VOC, NO_X and RSP emissions respectively, motor vehicles are the most important source in this sector (See Table 3-5). Therefore further discussion related to transportation will only be focused on motor vehicles for the purpose of this report.

Table 3-5 Base Year Emissions (kilo tonnes/yr) from the Transportation Sector in the Region

Sub-Sector	Region	VOC	RSP	NO_x	SO_2
Motor Vehicle	Region Sub-Sector Total	254.1	37.0	172.2	22.6
	HKSAR	13.4	5.5	31.4	1.5
	PRDEZ	240.7	31.5	140.8	21.1
Marine Vessel	Region Sub-Sector Total	0.9	1.9	70.3	17.2
	HKSAR	0.4	0.5	14.4	3.2
	PRDEZ	0.5	1.4	55.9	14.0
Railway	Region Sub-Sector Total	-	-	0.3	-
	HKSAR	-	-	0.1	-
	PRDEZ	-	-	0.1	-
Airport	Region Sub-Sector Total	1.0	-	5.0	0.4
	HKSAR	0.7	-	2.8	0.3
	PRDEZ	0.3	-	2.2	0.1
Total Regional Emission from Transportation Sector		256.0	38.8	247.8	40.3

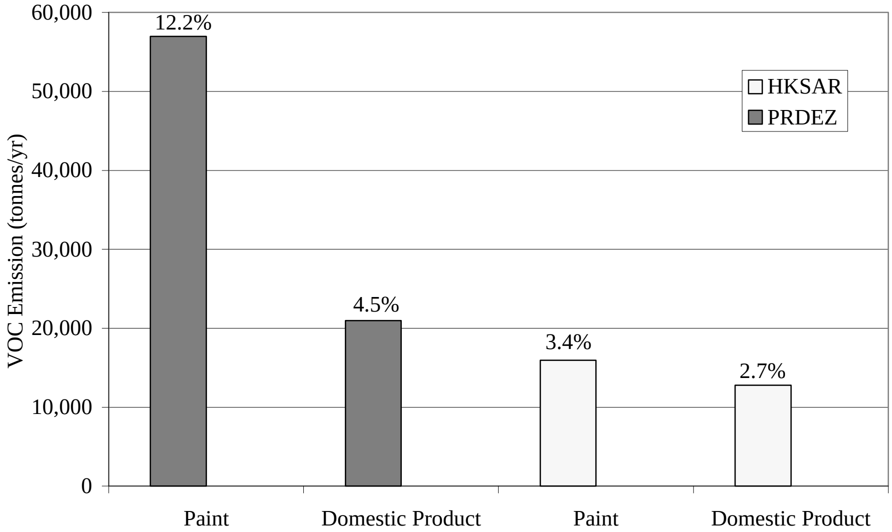
Note: "-" denotes an emission of less than 0.1 kilo tonne/yr

3.6.7 Petrol vehicles (including motor cycles) are a major contributor to motor vehicle NO_X and VOC emissions while diesel goods vehicles accounts for about 46% of motor vehicle RSP emissions in PRDEZ. In HKSAR, goods vehicles are the most significant motor vehicle source of NO_X and RSP, with private cars, motorcycle and heavy goods vehicles emitting most VOC compounds.

VOC Containing Product

3.6.8 VOC compounds are the primary emission from this sector. The two main sources within this sector are paint application and domestic solvent use. VOC emissions in this sector in PRDEZ and in HKSAR account for 17% and 6% of the regional VOC emissions, respectively. Figure 3-5 illustrates the VOC emissions from VOC containing products.

Figure 3-5 Emission of VOC from VOC Containing Product and their Contribution to the Region



3.7 Base Year Air Quality

3.7.1 Using the base year emission inventory, the base year air quality was simulated by PATH modelling system. Figure 3-6 illustrates the estimated base year air quality on a scale of 1 to 10 at different averaging times for O_3, RSP, and NO_X. Level 1 is relatively good air quality, and Level 10 represents a relatively poor air quality in terms of pollutant concentrations. The plots represent the overall existing regional air quality in 1997 against which the future year air quality presented in subsequent chapters will be compared with.

3.7.2 The estimated air quality indicated that there were large spatial coverage of exceedance of the standards in HKSAR and PRDEZ in 1997 for all the three pollutants under different averaging time periods. Similar air quality levels were recorded in HKSAR EPD's general air quality stations. The air quality for annual RSP and hourly ozone was particularly serious due to recent industrialisation in the Region. The highest level of the daily RSP was predicted in all the urban cities in the Region due to emissions from fuel combustion and transportation sectors.

Chapter Summary

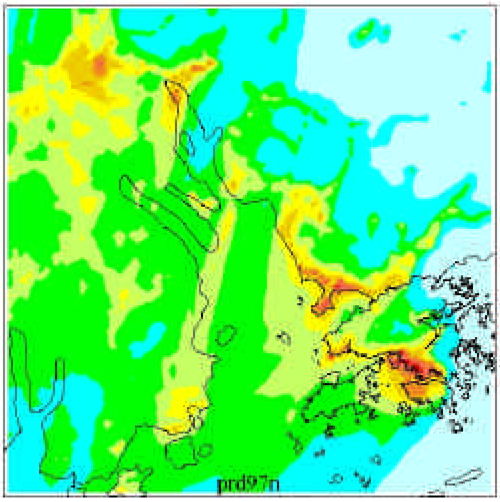
- Energy, industry process, motor vehicle and VOC containing product were the four major emission source sectors identified in the Region.
- In summary, the total contributions by target sources are:

Emission	VOC	RSP	NO_x	SO_2
Energy	1%	15%	42%	54%
Industry	11%	60%	13%	39%
Motor Vehicle	55%	14%	31%	4%
VOC Containing Product	23%	-	-	-
Total	90%	89%	86%	97%

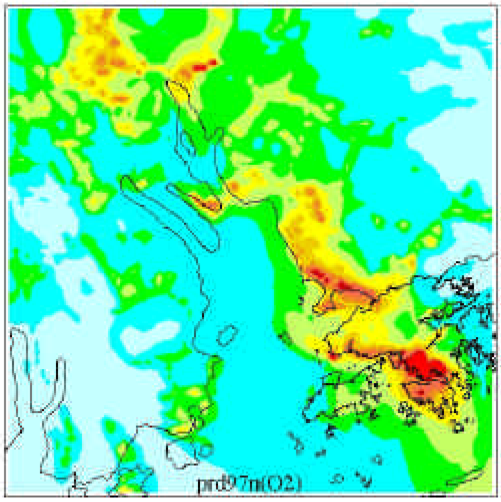
- PRDEZ dominates the regional emissions, however, the per capita emissions of HKSAR and PRDEZ are comparable.

Figure 3-6 Estimated Base Year Air Quality

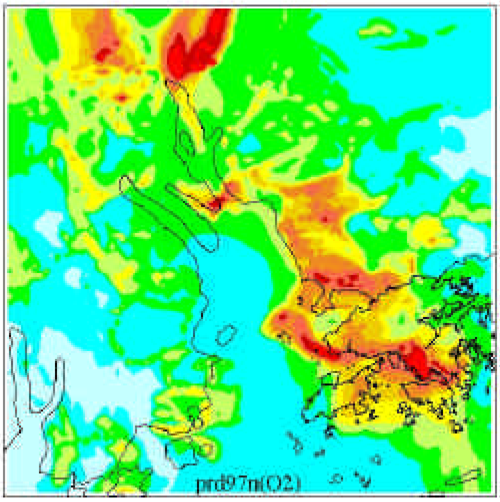
(a) NO_2 Annual



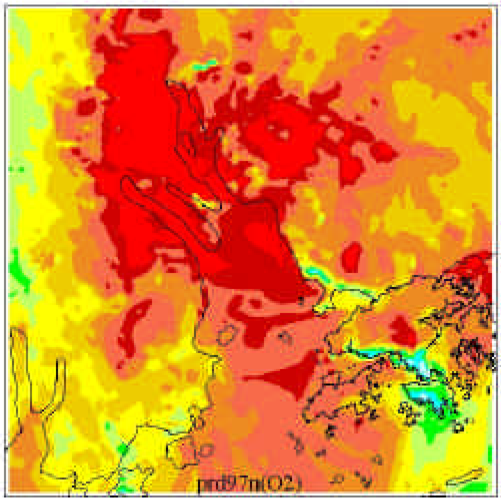
(b) NO_2 Daily



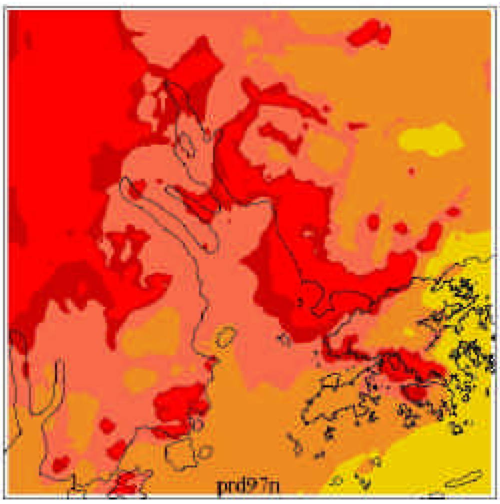
(c) NO_2 Hourly



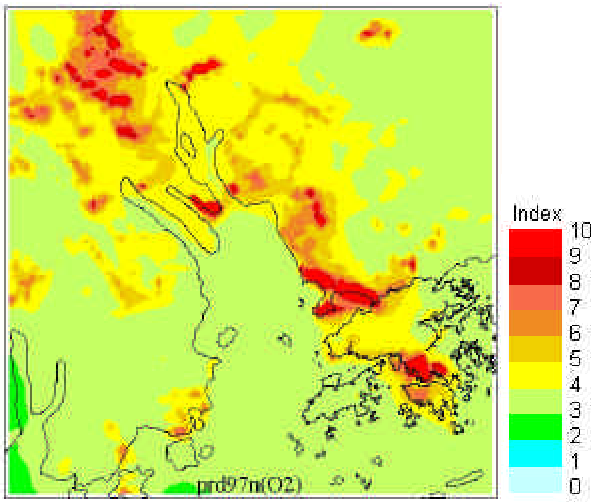
(d) O_3 Hourly



(e) RSP Annual



(f) RSP Daily



Note: Index>9 implies incompliance with HKAQO

4. PREDICTED FUTURE AIR QUALITY IN THE REGION

4.1 Introduction

4.1.1 Future air quality in the Region was assessed using the projected emission inventories in combination with the PATH air quality modelling system developed by EPD. The emission inventories for the years 2000, 2005, 2010, and 2015 were projected from the emission inventory for base year of 1997. The projections took into account predicted economic growth in the Region and the effects of emission control measures already committed by the two governments in the Region.

4.1.2 Estimates of economic growth in the Region were based on data obtained from relevant authorities and historic trends. These include Gross Domestic Product (GDP), population, landuse pattern, infrastructure development, the number of motor vehicles, vehicle kilometres travelled (VKT), airport landing and take-off cycles (LTOs), marine freight and passenger volume, and energy generation. More details on the future development trends and emissions in the Region are presented in Technical Annex 5 of this report

4.1.3 The air pollution control measures that have been accounted for in the compilation of future emission inventories were referenced to the legislations and announcements by the governments in the Region before June 2000.

4.1.4 With the economic growth and development in the Region, future year emissions are expected to increase significantly. Future air quality as a result of increased emissions will be predicted with PATH.

4.2 Future Development in the Region

Economic Characteristics

4.2.1 In 1997, the total GDP in HKSAR and PRDEZ was about HK$1,800 billion (Yearbook of HKSAR, Statistical Yearbook of Guangdong 1998), with contributions of approximately 70% and 30% for HKSAR and PRDEZ respectively.

4.2.2 Over the past 20 years, HKSAR's annual GDP growth rate has been about 5% in real terms. The growth is expected to slow down to 4.5% in the medium term and further reduce to 4% in the long term when the economy approaches maturation. As a result, GDP in HKSAR will grow by about 111% in the period of 1997-2015, as shown in Table 4-1.

Table 4-1 Projection of Annual GDP in the Region

Classification		Base year	Projected years			
		1997	2000	2005	2010	2015
GDP (HK$ billion)	HKSAR	1318	1440	1838	2291	2787
	PRDEZ	481	694	1223	2156	3632
	Region	1799	2134	3061	4447	6419
GDP Growth from 1997	HKSAR	-	9%	39%	74%	111%
	PRDEZ	-	44%	154%	348%	655%
	Region		19%	70%	147%	257%

4.2.3 In the mainland, the economic reform strategy over the last two decades has centred on the agriculture and manufacturing sectors. The service sector is expected to undergo reform and resultant growth in the medium to long term as a result of the Mainland's entry into the World Trade Organization (WTO). It is also anticipated PRDEZ would remain a focus of economic development in the Mainland. According to Guangdong's strategies for the coming decade, Guangzhou, Shenzhen, Zhuhai, Foshan, Dongguan and Zhongzhan will be developed into commercial, trade and hi-tech manufacturing centre, Huizhou will become a key production centre, and Zhaoqing will focus on the development of tourism (GDPD 1995). Based on official forecasts, PRDEZ's economy is expected to grow continuously at a rate of 12% over the short to medium term and 11% over the long term. The overall growth of GDP in PRDEZ is expected to be about 655% in the period of 1997-2015.

4.2.4 With these projected levels of GDP growth, by the year 2002/3, the GDP per capita for the PRDEZ is expected to reach about US$3,500 per annum, which will place the PRDEZ at about the level of development that Shanghai stands today. By 2007/8 the figure may reach about US$5,000 per annum (similar to Bangkok today), and by 2012/3 the figure will reach approximately US$7,500 per annum (similar to Kuala Lumpur today) (GDPD, 1995).

Population

4.2.5 Based on actual figures and population projected from 1996 bi-census, the population in HKSAR is expected to grow by 25%, from 6.5 million in 1997 to 8.1 million in 2015 (C&SD, 1997 and PD, 1998).

4.2.6 Future population in PRDEZ was estimated from existing data and the historical trend in Guangdong Province. It is expected that the total population, viz. the sum of permanent residents and transients, will grow by 27% from 32 million in 1997 to 41 million in 2015 (Table 4-2).

Table 4-2 Estimated Total Population in Future Years for the Region

Classification		**Base year**	**Projected years**			
		1997	**2000**	**2005**	**2010**	**2015**
Population (million people)	HKSAR	6.5*	6.9	7.3	7.7	8.1
	PRDEZ	32.2	33.3	35.7	38.2	40.9
	Region	38.7	40.2	43.0	45.9	49.0
Population Growth from 1997	HKSAR	-	6%	12%	18%	25%
	PRDEZ	-	3%	11%	19%	27%
	Region	-	4%	11%	19%	27%

**Source: C&SD 1997*

Electricity Supply

4.2.7 Electricity supply is expected to grow to support the increase in population and economic growth in the Region. The total electricity supply is expected to grow by 31% and 223% in HKSAR and PRDEZ respectively during the 1997-2015 period. However the fuel sources for generating electricity are expected to grow at different rates in PRDEZ based on the forecast by Guangdong Province (GDPD, 1995). Coal/oil, and gas are the dominant fuel sources for electricity generation in the Region. These three fuel types contributed to over 76% and 87% of the electricity generation in HKSAR and PRDEZ respectively, as shown in Table 4-3.

Table 4-3 Fuel sources of Electricity Consumption in the Region

Classification		**Fuel Type**	**Base year**	**Projected years**			
			1997	**2000**	**2005**	**2010**	**2015**
Electricity Consumption (100 million kWh)	HKSAR	Coal/Oil	148	165	175	184	194
		Gas	95	105	112	118	124
		*Nuclear	75	83	89	93	98
		Subtotal	318	353	376	395	417
	PRDEZ	Coal/Oil	674	931	991	1,050	1,110
		Gas	26	51	238	425	612
		Nuclear	38	38	38	295	295
		Hydroelectricity	10	10	10	10	10
		Western Provinces	52	75	235	394	554
		Subtotal	799	1,105	1,511	2,174	2,580
	Region	Coal/Oil	822	1,096	1,165	1,234	1,304
		Gas	121	156	350	543	736
		Nuclear	113	121	127	388	393
		Hydroelectricity	10	10	10	10	10
		Western Provinces	52	75	235	394	554
		Total	1,117	1,458	1,887	2,569	2,997
Electricity Consumption Growth from 1997	HKSAR		-	11%	18%	24%	31%
	PRDEZ		-	38%	89%	172%	223%
	Region		-	31%	69%	130%	168%

** Nuclear power is not generated in HKSAR*
Remark:
(1) For HKSAR, it is understood that there is a general trend towards clean electricity generation using gas, however, there is no tangible plan on the future fuel mix. Therefore the current projection has assumed the proportion of fuel mix constant throughout the study years.
(2) Assume no export of electricity from the Region

Road Traffic

4.2.8 Traffic growth can be expressed in terms of the vehicle kilometres travelled (VKT). Based on a medium growth scenario in the Third Comprehensive Transport Study (CTS-3), the total VKT in HKSAR is expected to grow by 107% from 10,812 million km in 1997 to 22,422 million km in 2015, while private car usage is expected to undergo the highest growth among all vehicle types (Table 4-4).

Table 4-4 Estimated Annual VKT in the Region (100 million kilometres)

Vehicle Type		Base year	Projected year			
		1997	2000	2005	2010	2015
HKSAR	Taxi	17	22	27	31	35
	Motorcycle	3	4	5	6	6
	Private Car	42	59	75	87	98
	Light Duty Vehicle (1)	28	35	36	40	44
	Heavy Duty Vehicle (2)	18	24	30	36	41
	HKSAR Total	108	144	173	200	224
PRDEZ	Motorcycle	273	383	617	787	787
	Small Petrol Vehicle (3)	180	265	488	860	1384
	Large Petrol Vehicle (4)	67	80	102	125	144
	Diesel Goods Vehicle	104	107	112	118	124
	PRDEZ Total	624	835	1319	1890	2439
Regional Total		732	979	1492	2090	2663

(1) Include Pass. Van, PLB and LGV; (2) Include HGV, Non Fr Bus, SD Fr Bus, DD Fr. Bus
(3) Include passenger vehicles up to 20 seats; (4) Include passenger vehicles with more than 20 seats

4.2.9 Based on historical trends of the number of registered vehicles and the information on the VKT for each vehicle type in individual PRDEZ cities, it is estimated that the total VKT in PRDEZ may grow by 291%, from 62,388 million km in 1997 to 243,944 million km in 2015. Small petrol vehicles are expected to undergo the highest growth among all vehicle types (Table 4-5).

Marine Traffic

4.2.10 Based on the CTS-3 estimation and the Hong Kong Port Cargo Forecast (Hong Kong Port and Maritime Board 1998/99), the activities of marine traffic in HKSAR except domestic ferry, are expected to grow by 47-151% in the period of year 1997-2015 (Table 4-6).

Table 4-5 Estimated Marine Activities in HKSAR from 1997 to 2015

Class of Vessel	Base year	Projected years			
	1997	2000	2005	2010	2015
Ocean-Going Vessels Freight Carried (million tonnes)	135	158	201	251	300
River Traffic Vessels Freight Carried (million tonnes)	34	45	63	79	87
Container Vessels Freight Carried (million TEUs)	12	14	17	21	25
Domestic Ferry (daily 1000 one-way person trips)	114	97	97	97	97
International Ferry (daily 1000 one-way person trips)	49	54	64	58	73

4.2.11 Based on a review of the historical trends in marine traffic and predicted GDP for each of the nine cities in PRDEZ, the growth in marine traffic was forecasted in terms of passenger and freight volume as in Table 4-7.

Table 4-6 Marine Traffic Forecasts for the PRDEZ

Classification	Base year	Projected years			
	1997	2000	2005	2010	2015
Passenger (thousand people)	12,230	9,845	6,667	4,515	3,141
Freight (million tonnes)	150	164	192	225	261

4.3 Committed Control Measures in the Region

4.3.1 The effects of existing air pollution control measures or those committed by the Guangdong Government and HKSAR Government have been taken into consideration when predicting future emission inventories. Those measures used have quantifiable effects on emissions and have been either legislated in the Region or announced officially by the Guangdong Provincial Government and the HKSAR Government before June 2000.

HKSAR

4.3.2 In HKSAR, the principal legislation governing emissions from air pollution sources is the Air Pollution Control Ordinance (APCO). Appendix 4-A lists the legislation in force as at June 2000 for controlling air pollution from energy, industry, and transportation sectors in HKSAR.

4.3.3 Apart from legislation, there are Government programmes to reduce emissions from various sources, for example:

- retrofitting pre-Euro light diesel vehicles with particulate traps or diesel catalytic converters;
- limiting the sulphur content of diesel to 0.035%; making Ultra Low Sulphur Diesel (ULSD) (0.005% Sulphur) available in the market;
- implementing emission standards for motor vehicles to match with the Euro requirement (Euro III in 2000, Euro IV in 2006 (proposed));
- offering incentives for the replacement of diesel taxis with ones that are run on liquefied petroleum gas (LPG); completing the replacement of diesel fuelled taxis by end of 2005;
- adopting more advanced smoke tests (dynamometer);
- raising fixed penalty for smoky vehicles;
- installing Stage I vapour recovery system for petrol refuelling stations;
- limiting the sulphur content in fuels and setting emissions limits for sulphur dioxide and nitrogen oxides for coal fired power generation units;
- requiring new power generation plants to run on gas.

PRDEZ

4.3.4 Different levels of government in PRDEZ have issued air pollution control legislation. The State Environmental Protection Administration (SEPA) is responsible for the nation-wide air pollution control policy. The Provincial Government is empowered to issue regulations that are at least as good as the SEPA regulation and best fit the local situation for environmental protection. Appendix 4-B summarises the air pollution regulations that were in force as at June 2000.

4.3.5 In addition, there are programmes for controlling air pollution announced by the SEPA and Guangdong Provincial Government. The "Blue Sky" project announced by the Guangdong Provincial Government in February 2000 stipulated a provincial limit for SO_2 discharged from power generation industry of 550,000 tonnes, 480,000 tonnes, and 450,000 tonnes by the year 2000, 2005, and 2015, respectively. According to the project, no new coal-fired and oil-fired power plants will be allowed within PRDEZ. Electricity will be conveyed to PRDEZ from western provinces in the Mainland, such as Yuannan and Guizhou, or will be generated from gas-fired power plants in PRDEZ.

4.3.6 Furthermore, under the "Blue Sky" project, there will be progressive closure of fifteen types of industries in small village and townships which are heavy air polluters such as cement and brick manufacturers.

4.3.7 According to the announcement (No. 134) by SEPA in 1999, the emission standards for motor vehicles as set out in Table 4-8 would be implemented.

Table 4-7 Existing Proposed Emission Standards for Motor Vehicles in the PRDEZ

(Year of commencement)	1997	2000	2001	2004	2005	2010
Motorcycle	Pre-Euro		Euro 1		Euro 2	Euro 3
Small Petrol Vehicle	Pre-Euro	Euro 1		Euro 2		Euro 3
Large Petrol Vehicle	Pre-Euro		Euro 1		Euro 2	Euro 3
Diesel Goods Vehicle	Pre-Euro	Euro 1		Euro 2		Euro 3

4.4 Future Emission Inventories

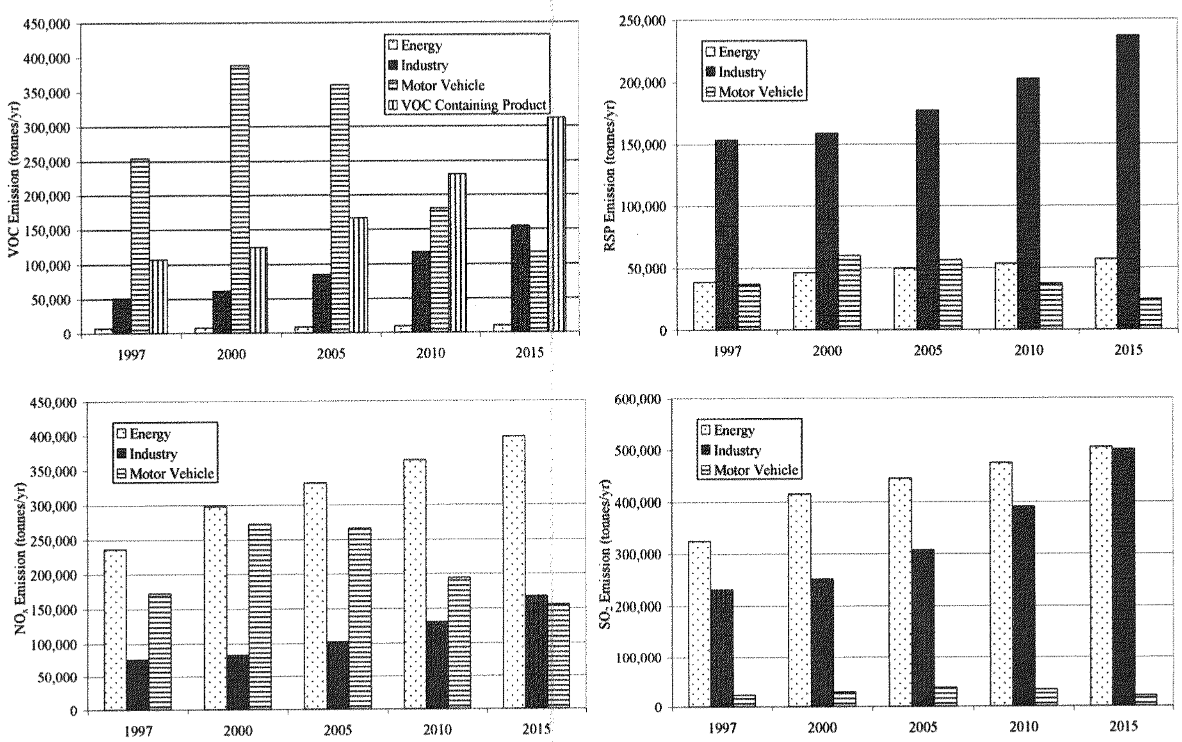
4.4.1 By taking into account predicted economic growth and committed control measures discussed in the preceding sections, emission inventories for future years were projected from the 1997 base year. The emission inventory is summarised in Table 4-9 and illustrated in Figure 4-1.

Table 4-8 Emissions of Major Pollutants in Future Years

Classification		Pollutant	1997	2000	2005	2010	2015
Emission (kilo tonnes per year)	HKSAR	VOC	54	57	67	79	95
		RSP	13	13	12	12	13
		NO_x	114	122	127	132	146
		SO_2	76	82	88	96	106
	PRDEZ	VOC	412	574	603	504	537
		RSP	245	286	315	333	359
		NO_x	450	606	641	624	646
		SO_2	520	630	715	816	935
	Region	VOC	465	631	671	583	632
		RSP	257	299	327	345	372
		NO_x	565	727	768	756	792
		SO_2	596	712	803	912	1041
Emission Growth from 1997	Region	VOC	-	36%	44%	25%	36%
		RSP	-	16%	27%	34%	45%
		NO_x	-	29%	36%	34%	40%
		SO_2	-	20%	35%	53%	75%

4.4.2 These predictions indicate that emissions will increase in both HKSAR and PRDEZ during the 1997-2015 period. Regional emissions of the four pollutants are expected to grow by 36-75%, with emissions from sources in HKSAR increasing by 5-76%, and emissions from PRDEZ rising by 30-80%. By 2015, PRDEZ's share in regional emissions will increase slightly from 80-95% to 82-96%.

Figure 4-1 VOC, RSP, NO_x and SO_2 Emission Trends in the Region



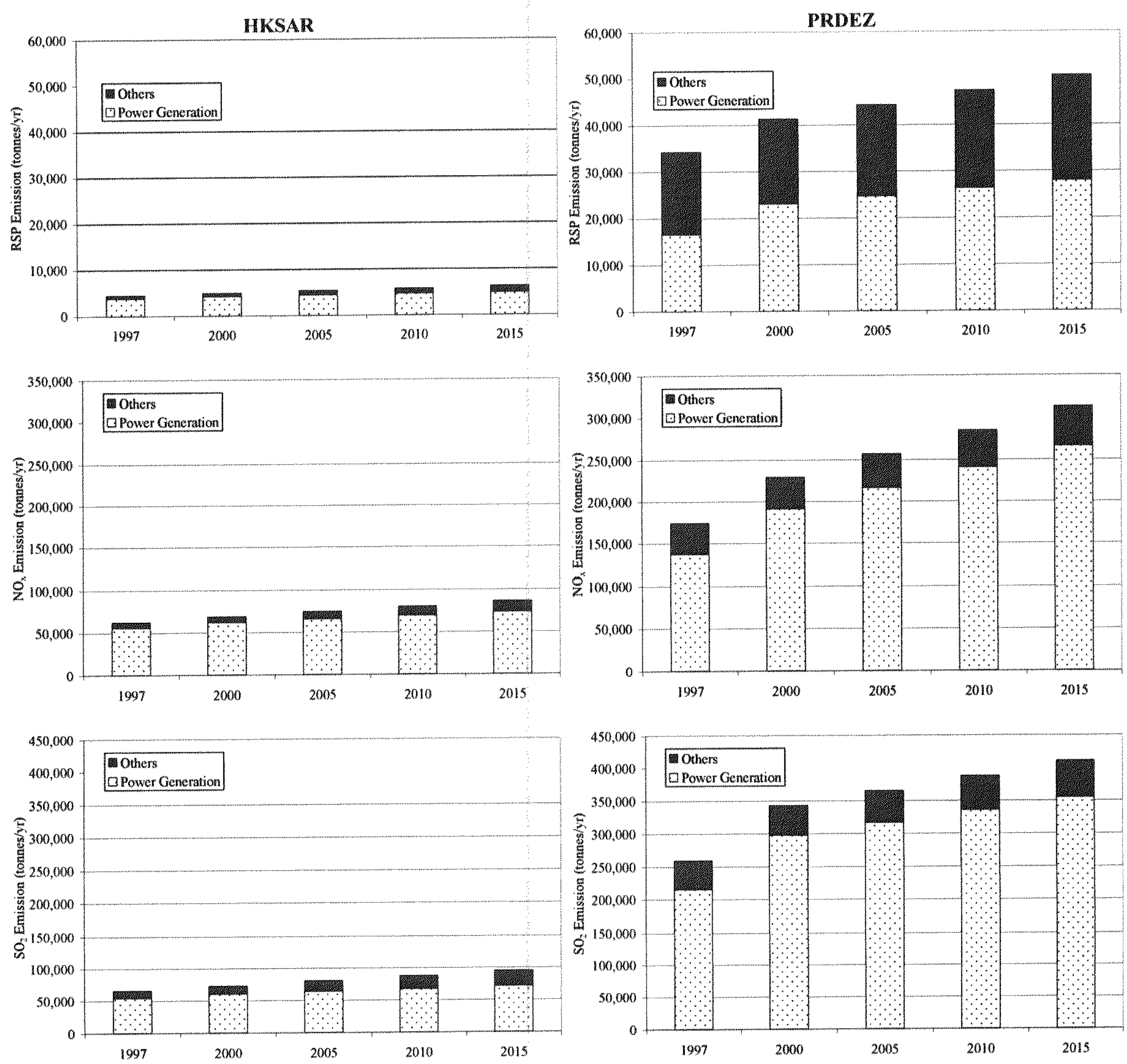
4.5 Emission Profiles of the Major Sectors in the future

Energy Sector

4.5.1 Power plant emissions in HKSAR are projected to increase in proportion to the increase in power consumption. Emissions from other fuel burning sources including commercial and domestic fuel uses are projected to increase in proportion to the GDP. Figure 4-2 presents predicted SO_2, NO_x and RSP emissions from the energy sector.

4.5.2 Power plant emissions in PRDEZ are projected to increase up to 65% for SO_2 and 93% for NO_x between 1997 to 2015. However, the increase in emissions is much smaller than the predicted 223% growth in power consumption because of the trend towards using cleaner fuels in the future. As already shown in Table 4-3, the percentage of electricity generated from polluting fuels such as coal will decrease from 84% in 1997 to 43% in 2015, while the percentage of electricity generated from clean fuels such as natural gas will increase from 3% in 1997 to 24% in 2015. In general, the emissions from this sector will increase but not as fast as the growth in GDP.

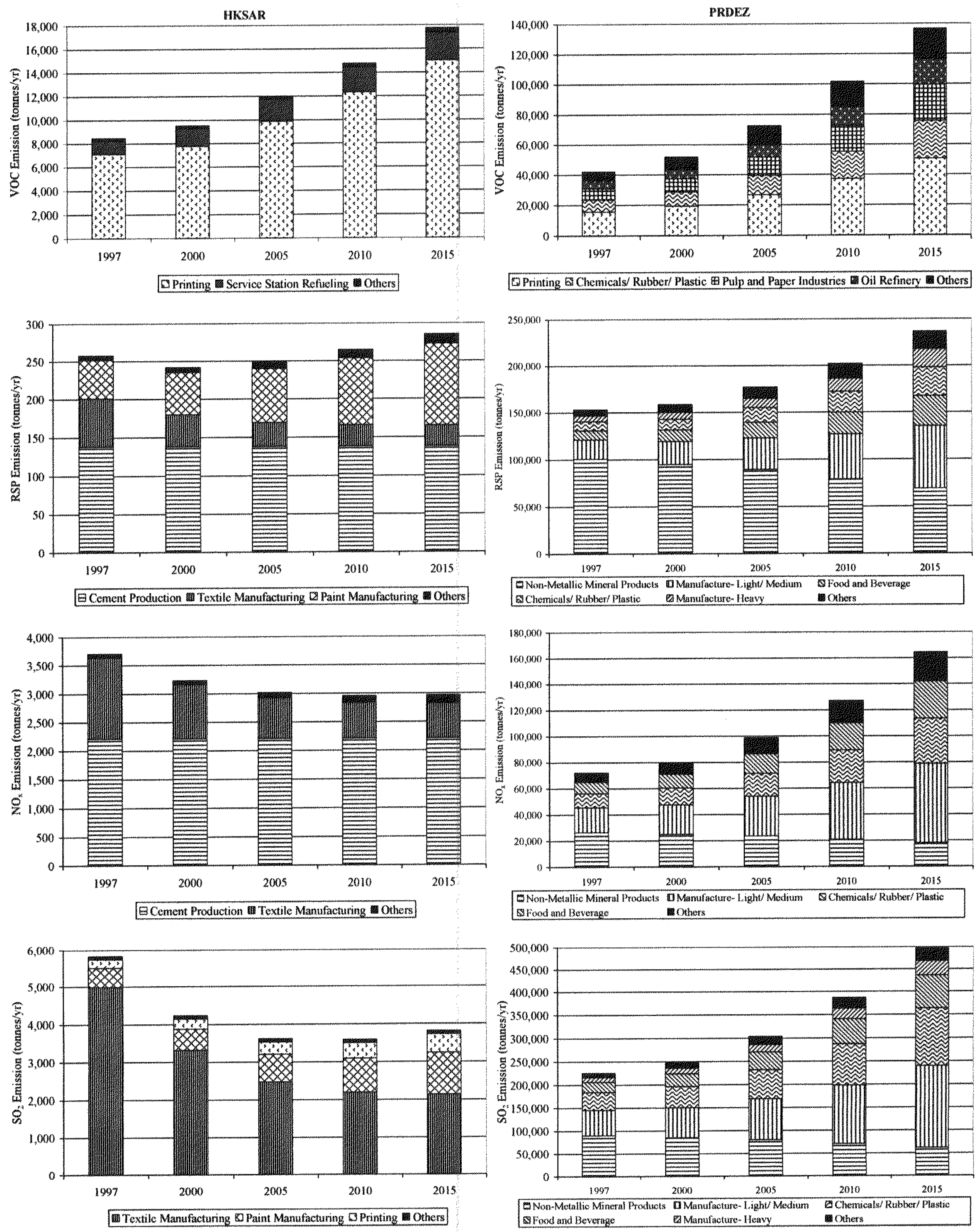
Figure 4-2 Predicted Emissions from the Energy Sector in the Region



Industry Sector

4.5.3 Emissions from industry sectors were projected using the GDP growth rate and the elasticity coefficient of energy consumption for particular sectors, to reflect the growth in activities and the expected improvement in energy efficiency of production processes. Figure 4-3 shows future emissions from the industry sector. It was stated in Section 3 that the non-metallic mineral product manufacturer is the largest emitter among all industries. Emissions from this manufacturing process are projected to decrease by about 32% from 1997 to 2015 due to reduced production of non-metallic mineral products (SEPA, 1999; SEPA, 2000). Nevertheless, emissions from other manufacturing sources are projected to increase in proportion to the GDP and the result is an overall net growth in industrial emissions in the future.

Figure 4-3 Emissions from the Major Industries in the Region

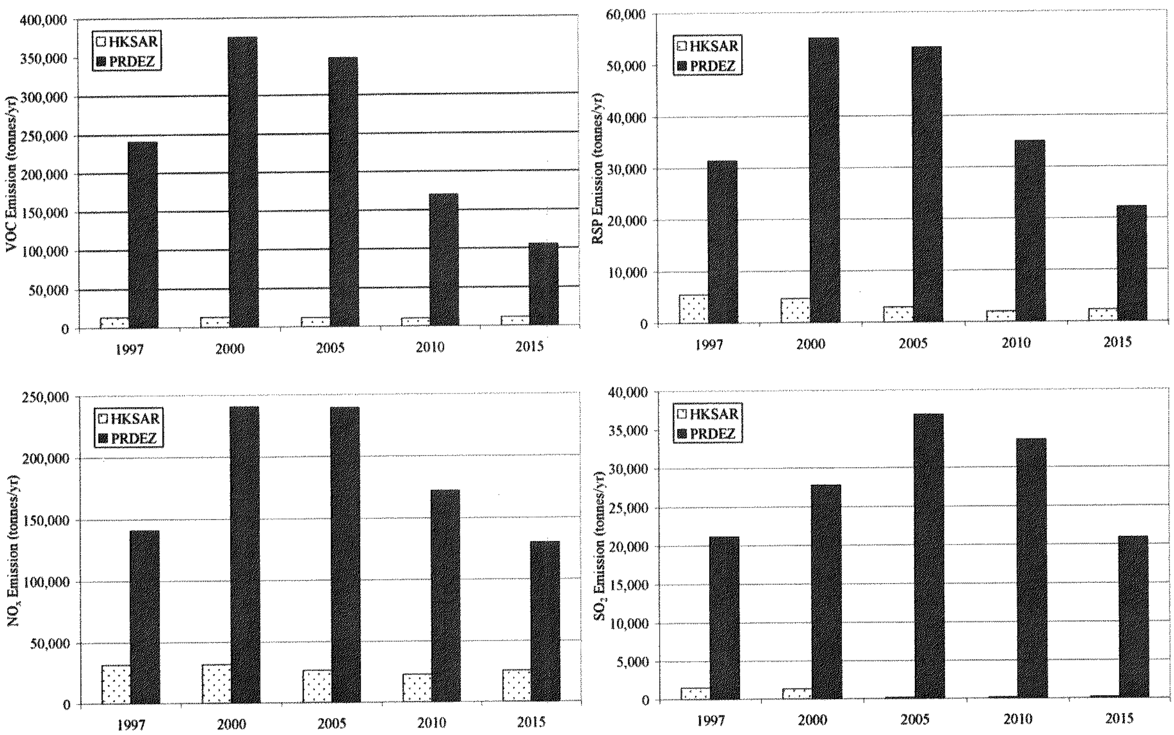


Motor Vehicle

4.5.4 Emissions associated with the increase in vehicle kilometre travelled (VKT) are presented in Figure 4-4. Despite the steady growth in VKT, vehicular emissions in the Region are expected to decrease by 2015. In PRDEZ, emissions of VOC, NO_X, and RSP are predicted to increase up until 2000 and then decrease. By 2015, it is estimated that emissions that will have been reduced by as much as 30% (RSP) relative to 1997. For SO_2, vehicular emissions are expected to increase from 1997 to 2005 and decrease thereafter. The percent reduction of SO_2 in PRDEZ between 1997 and 2015 is estimated to be about 1%.

4.5.5 This reduction in vehicular emissions is a result of the implementation of air pollution control measures for motor vehicles by both the Guangdong Provincial and the HKSAR governments. The emission trends in Figure 4-4 reflect the phase out of old vehicles together with the implementation of more stringent emission standards with time.

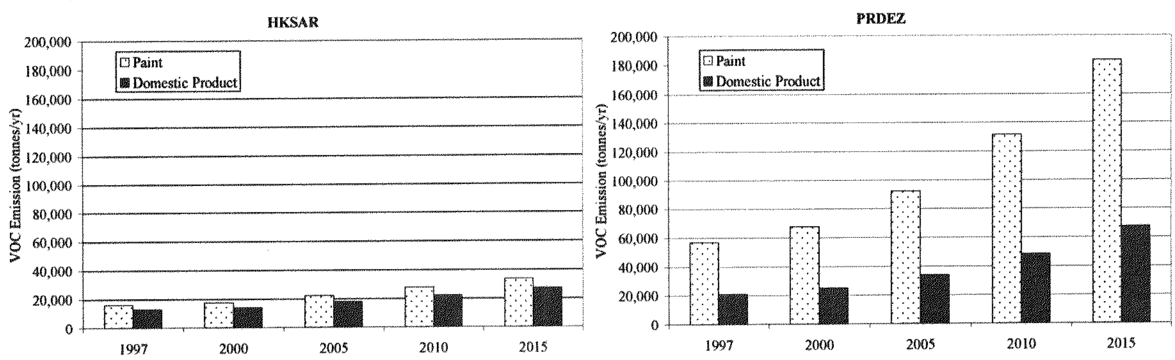
Figure 4-4 Motor Vehicles Emissions in the Region



VOC Containing Product

4.5.6 Figure 4-5 shows the predicted emissions from VOC containing product. The future VOC emissions are directly related to the economic and population growth in the Region since no controls have been committed for this sector.

Figure 4-5 Predicted Emissions from the VOC Containing Product Sector in the Region



Summary of the Future Emission Inventory

4.5.7 In general, emissions tend to increase as the activity of the emitter (or its projection surrogate) grows unless additional control measures are implemented. As demonstrated in Table 4-10 with the improvement in technology and implementation of control measures already committed to by the two governments in the Region, emissions from energy, industry, and motor vehicles are not expected to grow as quickly as the growth rates of the underlying economic activities. In particular, emissions from vehicles will decouple from the predicted growth in the traffic and fall in the range of 7-54% by 2015 if the control measures committed by both governments are effectively carried out as planned.

4.5.8 In HKSAR by 2015, emissions from VOC containing products will be the dominant source of VOC emissions, while emissions from energy sector will dominate the NO_x and SO_2 emissions in HKSAR. In PRDEZ, all four major sectors identified will continue to be significant sources of emissions, with energy sector being the predominant source of SO_2 and NO_x, and VOC containing products being the predominant source of VOC in the atmosphere.

Table 4-9 Summary of the Emission Inventory in 2015

	Growth in 2015 relative to 1997					Percent emission relative to local emissions in 2015			
	Activity	Emissions							
		VOC	RSP	NO_x	SO_2	VOC	RSP	NO_x	SO_2
HKSAR									
Energy	31%/111%*	58%	43%	39%	45%	1%	48%	59%	90%
Industry	111%	110%	11%	-20%	-35%	19%	2%	2%	4%
Motor Vehicle	107%	-15%	-58%	-19%	-89%	12%	18%	17%	-
VOC Containing Product	111%	111%	-	-	-	64%	-	-	-
PRDEZ									
Energy	223%	45%	47%	79%	59%	2%	14%	48%	44%
Industry	221%	225%	55%	128%	120%	25%	66%	25%	53%
Motor Vehicle	291%	-56%	-30%	-8%	-1%	20%	6%	20%	2%
VOC Containing Product	221%	221%	-	-	-	47%	-	-	-

** 31% refers to the estimated growth in power generation; while 111% refers to the estimated growth in other fuel combustion*

4.6 Likely Air Quality in 2010

4.6.1 While emissions are projected to be dampened slightly by control measures already committed to, it is unlikely that the regional air quality will be improved. In fact, regional VOC, RSP, NO_X, and SO_2 emissions are estimated to increase from the base year 1997 to future year 2015 by 36%, 45%, 40%, and 75% respectively. Even though air quality is related to emissions, this relationship is not linear, especially for regional pollutants that are formed under complex chemical reactions. Future air quality was thus predicted by using the PATH modelling system.

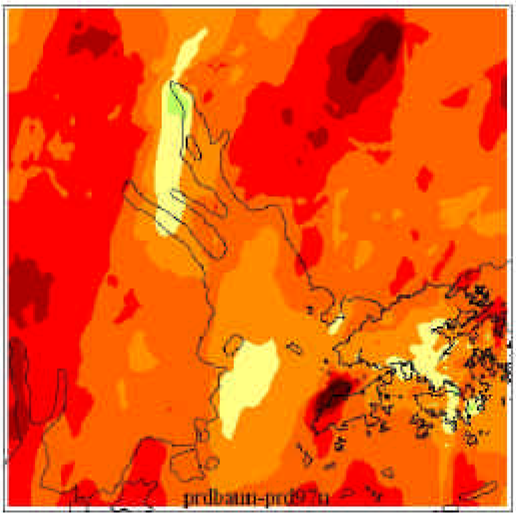
4.6.2 For the purpose of this study, 2010 was chosen as the assessment year for future air quality modelling. By 2010, all committed control measures should have come into effect and resulted in noticeable changes in emissions and air quality on a local and regional scale. Extending the modelling year further out would add uncertainty to the predictions. Therefore the year 2010 was considered more preferable than 2015 for the input for the air quality modelling.

4.6.3 The change in air quality in 2010 relative to 1997 is illustrated in Figure 4-6. Air quality in terms of average pollutant concentrations in HKSAR is predicted to have deteriorated slightly, but by less than 8%, from 1997 to 2010. Considering the economic growth in HKSAR, the predicted air quality might imply that the committed control measures had achieved positive results in curbing emissions. However the emission reductions from committed control measures might not be sufficient to improve the air quality from the 1997 level. Therefore, further effort is required by HKSAR and additional control measures will be necessary.

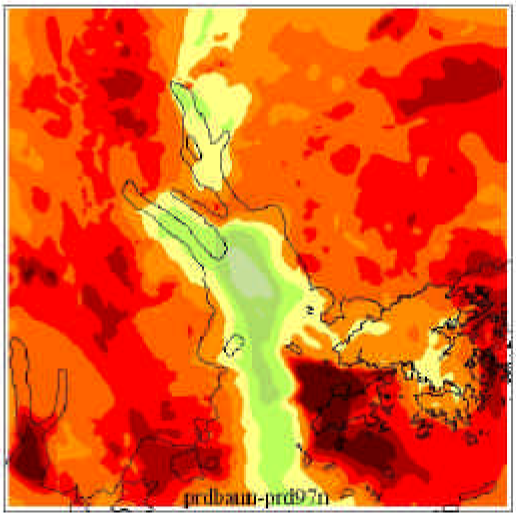
4.6.4 The air quality in terms of average pollutant concentrations in PRDEZ major cities is predicted to deteriorate up to 28%. This is not unexpected as PRDEZ is currently and will continue to develop rapidly in the next ten years. The air quality in the Region is summarised in Table 4-11.

Figure 4-6 Air Quality in 2010 with reference to 1997

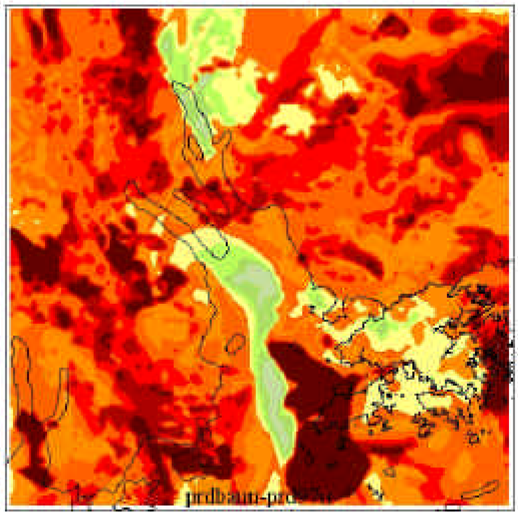
(a) Annual NO_2



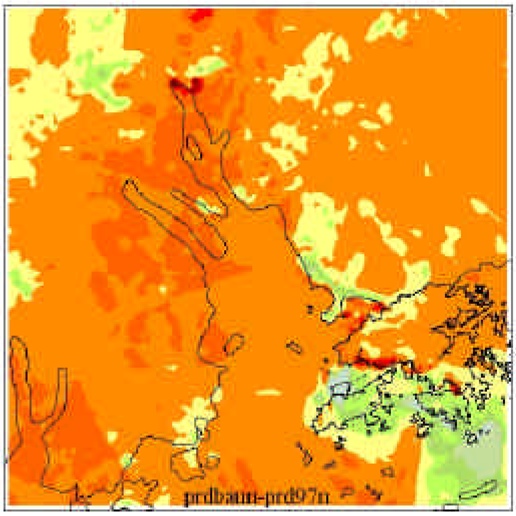
(b) Daily Average NO_2



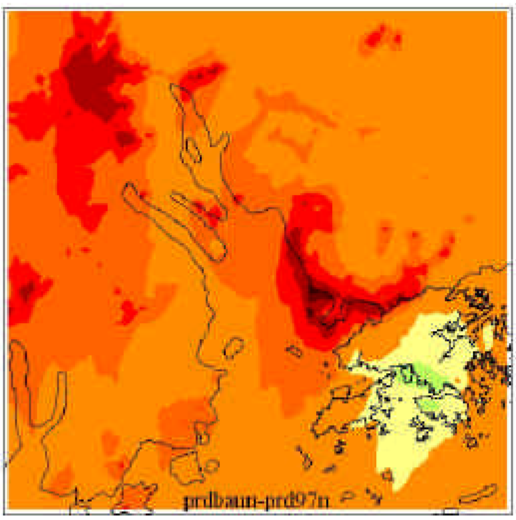
(c) Hourly NO_2



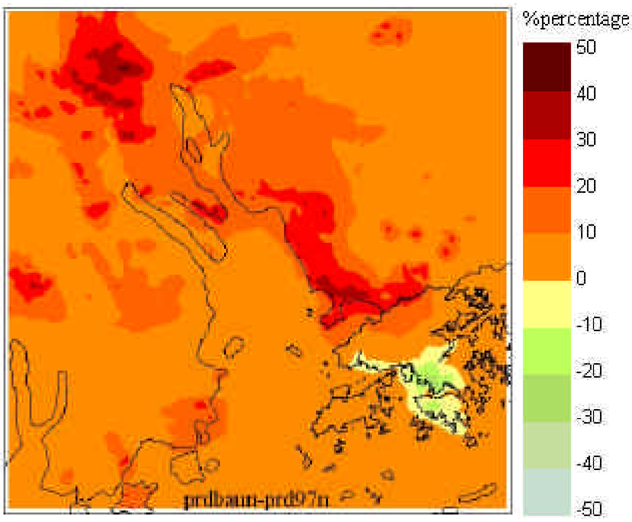
(d) Hourly Ozone



(e) Annual RSP



(f) Daily Average RSP



Note: A positive percentage denotes an increase in pollutant concentration
A negative percentage denotes a decrease in pollutant concentration

Table 4-10 Percentage Change in Pollutant Concentration in 2010 relative to 1997

City	NO_2			O_3	RSP		NO_2			O_3	RSP	
	Annual	Daily	Hourly	Hourly	Annual	Daily	Annual	Daily	Hourly	Hourly	Annual	Daily
	% change in average concentration						% change in maximum concentration					
Hong Kong	7%	8%	7%	0%	-1%	0%	-1%	-3%	-9%	2%	-19%	-22%
Shenzhen	15%	16%	11%	0%	16%	16%	12%	13%	23%	1%	32%	27%
Dongguan	22%	19%	17%	1%	7%	8%	18%	23%	53%	5%	30%	30%
Guangzhou	14%	14%	10%	1%	16%	16%	19%	22%	23%	3%	30%	31%
Zhuhai	17%	17%	15%	-3%	10%	9%	19%	14%	16%	3%	19%	20%
Zhongshan	16%	16%	12%	0%	12%	11%	23%	36%	22%	11%	26%	20%
Foshan	21%	21%	15%	-1%	20%	18%	24%	21%	11%	8%	38%	25%
Jiangmen	28%	28%	20%	-3%	17%	15%	32%	49%	23%	0%	34%	33%
Huizhou	25%	24%	25%	2%	4%	4%	48%	28%	35%	-1%	28%	25%

Note: A positive percentage denotes an increase in pollutant concentration; A negative percentage denotes a decrease in pollutant concentration

4.6.5 From the analysis of modelling results, it is observed that the number of days, based on model episodic events, with poor air quality in HKSAR has not changed significantly between 1997-2010. HKSAR is likely to suffer from poor air quality for less than 4% time of the year when special meteorological condition occurs. For PRDEZ, the number of days with poor air quality is anticipated to increase by about 21% for hourly NO_2, and 11.5% for daily RSP between 1997-2010, while no significant changes in terms of daily NO_2 were predicted. Ozone was modelled with respect to a special meteorological condition that occurs at limited times of the year, and the area coverage and the intensity of elevated concentrations were predicted to rise significantly by 2010.

Chapter Summary

- Regional emission increases as the regional economy continues to grow rapidly.
- Pollutant emissions are predicted to increase between 36-75% during the period of 1997-2015.
- The results of computer modelling have predicted deterioration in future air quality in the Region.

5 ADDITIONAL CONTROL MEASURES FOR THE REGION

5.1 Introduction

5.1.1 In the last two chapters the sources of emissions in the Region have been identified. Those sources responsible for the majority of the VOC, RSP, NO_x, and SO_2 emissions are shown in Table 5-1. As pointed out in the last chapter, even though the governments in the Region have imposed air quality control measures to reduce emissions in view of the worsening air quality, the measures are not sufficient to curb the growth of emissions. Therefore, additional control measures are needed to stop future air quality from deterioration.

Table 5-1 Most Significant Emission Sources in the Region in future

	HKSAR	PRDEZ
VOC	• Industrial processes (printing and petrol filling stations) • Motor vehicles • Application of VOC containing products (paint, architectural coating and domestic products)	• Industrial processes (printing, petrol filling stations, petrochemical works, oil depots) • Motor vehicles • Application of VOC containing products (paint, architectural coating and domestic products)
RSP	• Electricity generation (power plants) • Fuel usage (fuel consumption for industrial, commercial and domestic use) • Motor vehicles	• Electricity generation (power plants) • Fuel usage (fuel consumption for industrial, commercial and domestic use) • Manufacturing of non-metallic mineral products • Motor vehicles
NO_2	• Electricity generation (power plants) • Fuel usage (fuel consumption for industrial, commercial and domestic use) • Motor vehicles	• Electricity generation (power plants) • Fuel usage (fuel consumption for industrial, commercial and domestic use) • Motor vehicles
SO_2	• Electricity generation (power plants) • Fuel usage (fuel consumption for industrial, commercial and domestic use)	• Electricity generation (power plants) • Fuel usage (fuel consumption for industrial, commercial and domestic use)

5.1.2 The additional control measures discussed here are based on control measures that are currently implemented elsewhere and are technically practicable for the Region. The implementation of some of these measures might require a long preparation time, yet technically speaking, is achievable by 2010. Other preliminary factors considered in the selection of additional control measures include economic viability, legislative requirement, public acceptability and cost-benefit. The selection process and criteria for the additional control measures for this study are presented in Technical Annex 6 of this report.

5.1.3 Although the control measures presented here are comprehensive, they are by no means exhaustive. In addition, continual review of innovative technologies in overseas as well as local markets will be essential for the Region to take advantage of new technology that could bring about significant improvement in air quality at lower cost and with greater public acceptance.

5.1.4 Additional control measures for the four major source categories (energy, industry, motor vehicle, and VOC containing product) are presented in the following sections. It is suggested that an in-depth investigation of individual control measures in terms of implementation planning and resource allocation should be executed based on the finding of this report in order to determine the optimal control measures for the Region. Apart from engineering feasibility and cost-benefit of the control measures, good public awareness and education programme are equally important for successful implementation of these measures.

5.1.5 The estimated emission reduction potential for individual control measures in subsequent sections are for demonstration purpose and are based on implementation of control measures within the study years. The reduction potential of a control measure represents the quantity of emissions that could possibly be reduced by the effect of the control measure in the future. The indicative costs for individual control technologies are referenced from overseas research that might not be applicable to local situations within the Region. Therefore the recommended additional control measures are packaged as a demonstration of engineering feasibility and further socio-economic studies on individual control measures are highly recommended prior to actual implementation.

5.2 Proposed Control Measures for the Energy Sector

5.2.1 The selection of additional possible control measures for the energy sector involves a systematic approach to research into the availability of control technology options and their potential effects on regional emissions. The selected control techniques are commonly available worldwide with substantial practical experience for at least five years on record. The estimated reduction potential of a control measure in reducing RSP, NO_x, and SO_2 is based on official documentation on the emission control technologies.

5.2.2 Table 5-2 lists the major emission sources in the energy sector. Additional control measures recommended for these sources can be broadly divided into three categories as listed below:

- Diversification towards Cleaner Fuel Mix
- Combustion and Emission Processes Modification
- Tightening of Emission Standards

Table 5-2 Major Emission Sources from the Energy Sector in the Region

Classification	Process Category	Purpose of Usage
Power Generation	Power Plants	Public power supply
Commercial Fuel Usage	Hotel, restaurant, institutional community facilities: Boiler and combustion engine	Power supply, heating, hot water
Domestic Fuel Usage	Household : domestic heater, stove	Cooking and heating

Diversification towards Cleaner Fuel Mix

Power Generation

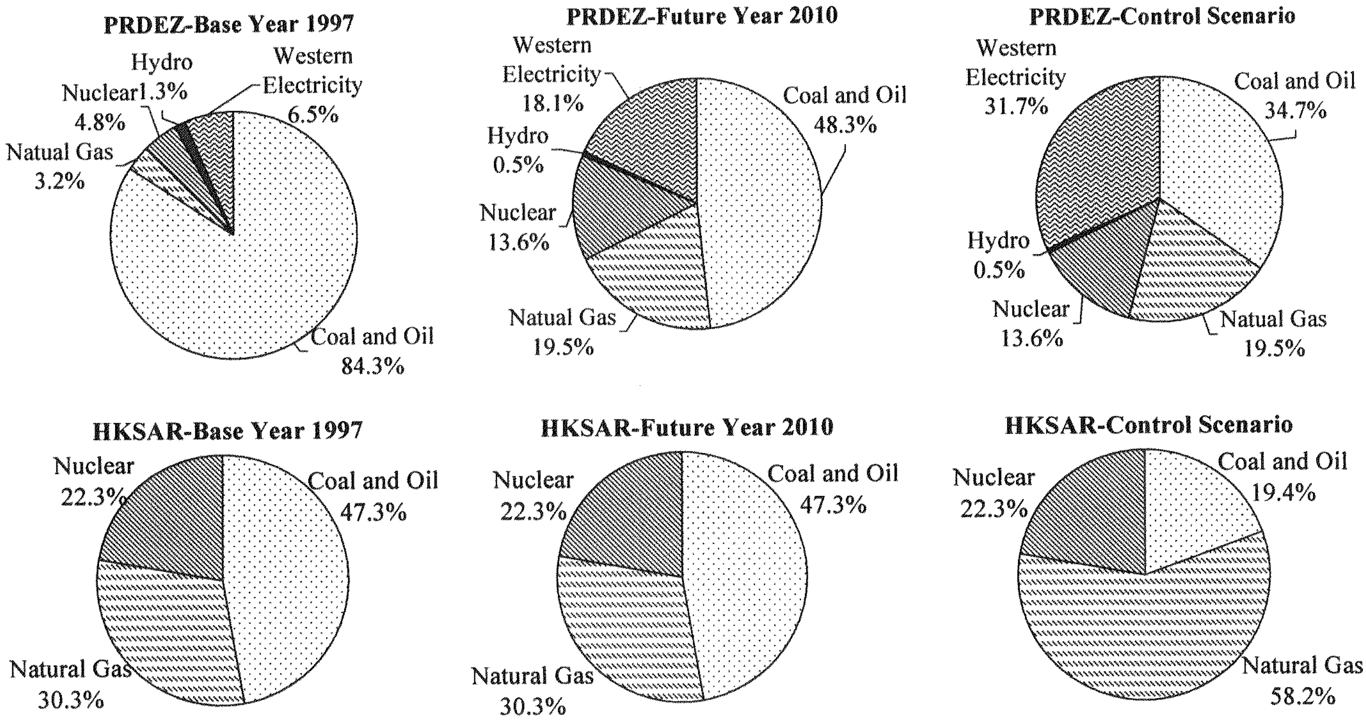
5.2.3 Throughout the Region, the majority of power plants use coal for fuel. In 1997, approximately 84% of power generated in PRDEZ was from coal-fired and oil-fired power plants while 47% of power generated in HKSAR was from coal-fired units. Reducing reliance on coal in power generation is expected to be the most effective way to reduce pollution from coal burning.

5.2.4 In HKSAR, newly established generating units are gas-fired. Reducing the reliance on coal-fired power plants would be one of the effective ways to achieve a reduction of RSP, NO_x, and SO_2 emissions with both environmental and engineering benefits. Another option is to import more electricity from cleaner sources (e.g. nuclear, natural gas plants) in the Mainland.

5.2.5 A State Electricity Board research study found that the average sulphur content of coal consumed by the power plants (>6MW in capacity) in the Mainland from 1994 to 1996 is on average about 1.1% (SEB, 1999). However, about 20% of the power plants consume coal with a sulphur content >1.5%. Therefore improving the fuel quality is considered one of the priorities for significantly reducing emissions from power generation in PRDEZ.

5.2.6 Investigating cleaner fuels and adopting them extensively is a way to reduce the use of coal as fuel in the future. Clean fuel options for PRDEZ include hydroelectricity, natural gas, nuclear power, and utilisation of electricity generated in the western provinces (referred to here as western electricity"). Considering its capacity and practicality, western electricity is recommended as a preferred energy source for PRDEZ among all possible clean fuel options. More extensive utilisation of electricity conveyed from the western provinces will not only benefit Guangdong in terms of air quality improvement, but also benefit the western provinces economically. Figure 5-1 demonstrates the possible change from coal and oil fired power generation to importation of western electricity as an additional control measure. Apart from importing electricity, other clean alternatives include banning the construction of new coal and oil-fired plants, introducing natural gas and increasing the proportion of electricity generated by hydroelectricity and nuclear power production plants.

Figure 5-1 Transition of the Fuel Mix in the Future for Power Generation in the Region



Remark:
(1) For HKSAR, it is understood that there is a general trend towards clean electricity generation using gas, however, there is no tangible plan on the future fuel mix. Therefore the current projection has assumed the proportion of fuel mix constant throughout the study years.
(2) Assume no export of electricity from the Region

Other Fuel Combustion

5.2.7 There are a number of domestic, commercial, and miscellaneous industrial facilities in HKSAR which consume fuels as energy source. The major types of fuels used by these facilities are gas oil, kerosene, LPG, and Towngas. Compared with liquid fuels, the gaseous ones have relatively lower RSP, NO_x, and SO_2 emissions. Switching domestic and commercial fuel combustion in HKSAR to gas combustion will be an effective control measure. It is noted that the HK Planning Standards and Guidelines already makes it clear that piped gas supply would be provided for new domestic, commercial and industrial developments. It is suggested that HKSAR should continue to extend the use of piped gas.

5.2.8 There are currently over 2,600 commercial fuel usage premises including hotels and restaurants in the PRDEZ that are expected to emit about 40,000 tonnes of SO_2 and 40,000 tonnes of NO_x in the future. Switching to piped gas or electricity would be the most cost-effective control measures for emission reduction without imposing major socio-economic impact on the operations of these businesses.

5.2.9 For domestic fuel uses within PRDEZ, the provision of piped gas and grid electricity is also a cost-effective way to eliminate combustion pollutants. Another option is to make bottled LPG widely and conveniently available in areas not currently covered by gas pipelines and electricity grids.

<u>Combustion and Emission Process Modification</u>

Power Generation and Commercial Fuel Usage

5.2.10 Technological control options for end-of-pipe flue gas treatments are well established and readily available for implementation in the Region. Indeed, they are already widely used in coal-fired plants in HKSAR but not so in PRDEZ.

5.2.11 Commercially available engineering solutions for post-combustion flue gas desulphurization (FGD) include additive injection, wet scrubbing and spray dry absorption. Overall, these methods have a SO_2 removal efficiency of 60-95% (UNECE, 1994). The cost of a typical desulphurisation system is about RMB500-4,500 per ton of SO_2 removed (Air Quality Management and Planning System for Guangzhou, 2000). A United Nation Development Program (UNDP) funded study by the State Electricity Bureau in 1999 proved a practical SO_2 efficiency of 85% on large-scale power plants (>200MW) through 10 demonstration projects the Mainland. The power companies in HKSAR have also achieved a comparable SO_2 reduction efficiency (HEC, 1999).

5.2.12 The control technologies for NO_x are divided into two fundamental streams, namely combustion control and post combustion control. Combustion control reduces the formation of NO_x during combustion. Post combustion control treats NO_x after it has been formed. It is common commercial practice to have combustion control including low-NO_x burner (LNB), overfire air (OFA), and low excess air biased burner firing systems to be installed at fuel consuming facilities for the reduction of NO_x formation. Post combustion control includes selective noncatalytic reduction and selective catalytic reduction (SCR) (USEPA, 1998).

5.2.13 Low NO_x burners are commercially available in the Mainland. Preliminary small-scale pilot tests on the efficiency of such control equipment have been carried out by the State Electricity Board (SEB, 1999). The applicability of this technology in small industries, however, is still uncertain until full scale testing is complete.

5.2.14 Emissions from new boilers with LNB may be less than half (45%) of the emissions from a new boiler with a conventional burner (SEB 1999). To retrofit LNB on an old coal fire boiler, the NO_x emission may be reduced by 30-40%. CLP Power Hong Kong Limited recorded an overall NO_x reduction of about 40% with the application of low NO_x burners in their processes (CLP 1997). LNB may be applied alone or in combination with over fire air. The principle of over fire air is simply forcing air into the top of a boiler to fan the flames. The combined LNB and overfire air option may reduce NO_x emissions by 40-60%, and if used in conjunction with reburn control, the highest possible reduction is up to 50 to 60% (SEB, 1999 & USEPA, 1998). Utilising LNB, OFA and SCR technologies could achieve the maximum benefit of post-combustion and combustion control technologies and reduce NO_x by 95% (USEPA, 1998). The cost for applying LNB ranges from RMB3,000 to RMB5,000 per ton of pollutant reduced (AQMPSG, 2000).

5.2.15 Control of post-combustion RSP emissions can be accomplished by the installation a selection of devices, such as electrostatic precipitators (EP), fabric filters, wet scrubbers or cyclones. As electrostatic precipitators have no adverse effect on the combustion system performance, they can be applied to systems over a wide size range (USEPA, 1998). A reduction efficiency of 99% on particles with diameters between 0.1 to 10μm could be achievable by applying EP to coal-fired plant (USEPA, 1998). The cost of EP installation is approximately RMB100-3,000 per ton RSP reduced (AQMPSG, 2000).

<u>Tightening of Emission Standards and Enhancement Programme</u>

Commercial Fuel Usage

5.2.16 In HKSAR, under Section 12 of the Air Pollution Control Ordinance, the owner of a premise conducting specified process shall use the best practicable means (BPM) for preventing the emission of noxious or offensive emissions from the premise. The HKEPD has prepared a series of guidance notes on the BPM requirements for various types of specified processes. The BPMs are reviewed periodically in light of new development of advanced control technology.

5.2.17 In PRDEZ, there are national emission discharge standards (GB) for fuel consumption processes in thermal power plants (GB13223-1996). Nevertheless comparing the Mainland emission standards for power plant with established emission standards overseas regardless of the operating capacity indicates that there is still potential for further tightening of the standards in PRDEZ. The effect on SO_2 emission is particularly significant, as shown in Table 5-3, when compared with the emission standard drafted by the United Nation for long-range transportation under the Convention on Long-range Transboundary Air Pollution (UNECE, 1999).

Table 5-3 Existing Emission Standards for Fuel Consumption Processes

Fuel Type	Pollutant	Emission Standards (mg/m^3)	
		PRDEZ	European Countries
Solid fuels	SO_2	900	200 – 850
Gaseous fuels		100	35
Liquid fuels	NO_2	400	200 – 400
Gaseous fuels		400	100 – 200

5.2.18 To ensure that the proposed fuel switching and end of pipe control technologies discussed above are implemented, tightening of emission standards and enforcement of these standards through legislation will be necessary.

<u>Emission Reduction Potential of the Additional Control Measures for the Energy Sector</u>

5.2.19 The emission reduction potential of the proposed additional control measures which could be quantified are presented in Table 5-4 and Table 5-5. The reduction potential is estimated for demonstration purposes on the assumption that the recommended control measures would be implemented within the study years. Based on these reduction potentials, the potential future emission reductions were calculated with respect to both local and regional emissions. Reduction of emissions from base year 1997 is also presented in the two tables.

Table 5-4 Reduction Potential and Effectiveness of the Quantifiable Control Measures for the Energy Sector in HKSAR

Source	Pollutant	Control Measure	Reduction potential of control measure (kilo tonnes)	Effects of additional and committed control measures on total emissions relative to 1997	
				Local	Regional
Power plants	VOC	Reduce reliance on coal-fired power plants and assume a future coal:gas ratio of 1:3	-0.2	-0.2%	0.0%
	RSP		-2.6	-13.2%	-0.6%
	NO_x		-3.5	-18.8%	-3.8%
	SO_2		-39.1	-34.2%	-4.4%
Other fuel combustion	VOC	Continue to extend the use of piped gas	-0.2	-0.2%	0.0%
	RSP		-0.8	-2.4%	-0.1%
	NO_x		-8.2	-3.4%	-0.7%
	SO_2		-15.3	-9.4%	-1.2%

Table 5-5 Reduction Potential and Effectiveness of the Quantifiable Control Measures for the Energy Sector in PRDEZ

Source	Pollutant	Control Measure	Reduction potential of control measure (kilo tonnes)	Effects of additional and committed control measures on total emissions relative to 1997	
				Local	Regional
Power plants	VOC	Extensive utilisation of western electricity	-0.5	0.2%	0.1%
	RSP	Extensive utilisation of western electricity	-7.3	-6.0%	-5.7%
		Process control equipment (e.g. EP)	-17.1		
	NO_x	Extensive utilisation of western electricity	-59.7	-10.4%	-8.3%
		Process modification (Low NO_x burner)	-90.7		
	SO_2	Extensive utilisation of western electricity	-94.5	-34.5%	-30.0%
		Process control equipment (e.g. flue gas desulphurisation	-205.0		
Commercial/ domestic combustion	VOC	Fuel improvement (Application of cleaner fuels)	-5.9	-1.2%	-1.1%
	RSP		-10.5	-2.9%	-2.8%
	NO_x		-21.5	-3.3%	-2.6%
	SO_2		-29.0	-4.0%	-3.5%

5.3 Proposed Control Measures for the Industry Sector

5.3.1 Table 5-6 lists the major emission sources from industry. The criteria in selecting the additional control measures for this sector were similar to those for energy sector. The control techniques must be well established worldwide based on substantial practical experience for at least five years with its reduction potential officially recorded.

Table 5-6 Major Regional Emission Sources from the Industry Sector

Emission Source	Process Description	Pollutant Involved
Industrial Fuel Use	Boiler, combustion engine, turbine and process heater, processing heating, hot water, stream	SO_2, NO_x & RSP
Non-Metallic Mineral Products Operations	Cement works, brick works and ceramic works	RSP
Organic chemical processes	Oil depots and terminal, fuel storage, handling, distribution Manufacturing of organic chemicals and petrochemical works	VOC
Printing and graphic art	Application of ink, thinner, coating or adhesive material for impressing or transferring an image onto a substrate	VOC
Process evaporative loss	Dry cleaning, organic solvent cleaning and surface coating	VOC

5.3.2 A number of considerations were taken into account in determining the additional control measures for this sector. These considerations include but are not limited to the regulation mechanisms in the Region, the availability of the control measures locally, the potential to shift to other emission points, existing in-plant operational conditions of the sources, local economic circumstances, and the cost-benefit of the control techniques.

5.3.3 At present, the number of industrial facilities in HKSAR is very small, as most of them have moved elsewhere because of relatively higher labour and operational costs in Hong Kong. The gains in the implementation of these control measures are expected to be primarily in PRDEZ because of the large number of industrial operations compared to that in HKSAR.

5.3.4 The basic and commonly available control equipment in the market for reducing industrial emissions in the Region are mechanical collectors, wet scrubbers, bag house, electrostatic precipitators, combustion systems, condensers, absorbers, and adsorbers. These technologies have been used extensively worldwide to control emissions from a variety of industrial process operations. The final choice in equipment is usually heavily dependent on its capability to achieve the required statutory compliance level of a particular pollutant at the lowest possible capital and operational costs.

SO_2, NO_x & RSP Control for Fuel Combustion Processes

5.3.5 In many industrial estates within PRDEZ, centralised co-generation power facilities or an extended electricity grid could be alternatives to the generation of electricity by individual facilities using fuel combustion systems. Small and medium sized enterprises in an industrial estate could share a central system delivering electricity, process heat or steam as well as treating waste gas. The cost shared by the users (enterprises) would be much less than that required if each facility were to undertake energy production and waste gas treatment individually.

5.3.6 Cleaner energy sources could be provided for all newly planned industrial areas to avoid the unnecessary combustion of high sulphur fuels such as coal and oil. In areas where the electricity grid, piped natural gas and low-sulphur fuel are available, the use of private fossil-fuelled electricity generating equipment should be prohibited.

5.3.7 Post-combustion end-of-pipe technological control options, as mentioned for the power plants, are equally applicable to reduce emissions of industrial processes. With the advancement of energy-efficient appliances and innovative equipment installed in industrial facilities through governmental incentive programme, the amount of energy demanded would not be as great and thus would decrease the demand for new power plants in the Region in the long run.

5.3.8 As mentioned earlier, most facilities will only apply control technology in order to meet emission standards or when they are required to do so by legislation. Tightening of emission standards in PRDEZ will have a positive effect on the use of the proposed control technologies.

5.3.9 In setting emission standard, due consideration should be given to the plant operation size and discharge pattern, existing combustion technology and the type of fuel used. An alternative approach could be the implementation of an emission target in a fixed time frame for a group of individual sources, allowing a flexible choice of technology options to be implemented to achieve the necessary reduction.

RSP Control for Non-Metallic Mineral Products Operations

5.3.10 The manufacturing process of non-metallic mineral products in HKSAR is controlled under the Air Pollution Control Ordinance. The Guidance Notes on the Best Practicable Means issued by the HKEPD requires that a fabric filtering system with at least 95% control efficiency must be used for treating non-combustion exhausts from a plant.

5.3.11 Many premises in the PRDEZ are operating without any kind of emission control equipment, thus resulting in high RSP emissions in the Region. Control techniques of a dust control system similar to HKSAR with an assumed RSP reduction of at least 90% is recommended for non-metallic mineral product operations in the PRDEZ.

5.3.12 It has been observed that towards the end of the year 2000, the installation of dust collection systems in non-metallic mineral production facilities was initiated to control RSP emissions in PRDEZ. However, the observation was made after the compilation of the emission inventory and thus the emission improvement resulted from the installation of end of pipe equipment in this sector was not accounted for in the future air quality predictive scenarios but only in the control scenario.

VOC Control

5.3.13 Besides SO_2, NO_x and RSP, VOC is a common pollutant found in industrial emissions that contributes to regional air pollution as an ozone precursor. Control options specific for VOC emitting operations and activities within the industry sector are not common in the Region. In view of the limited local experience in implementing VOC control measures and regulations, it is recommended that both Governments should further explore the technologies for cost-effective VOC reduction and mirror worldwide practices where practicable. The following paragraphs present possible control measures for selected VOC emitting operations within the industry sector that are potentially applicable for HKSAR and PRDEZ.

VOC Control for Organic Chemical Processes

5.3.14 VOC emissions from the storage of petroleum products are affected by the size and type of the tanks, the vapour pressure of the liquid inside the tank, and the atmospheric conditions. The rates of VOC emission from various tank designs are different and the floating roof technology with an effective sealing and fitting system is the most effective control measure. Vapour control systems such as incinerator or refrigerated condensers are usually employed as an add-on control technique to reduce emission. Moreover, sensors for internal pressure have to be installed to monitor potential leakage of the tank and to provide early warning thereof.

5.3.15 VOC vapour displaces the vapour space of the container and is released during the transfer of petroleum products from the bulk storage terminals to the consumers, through the pipelines, road tankers, filling station dispensers and the motor vehicle refuelling process. The USEPA enacted a regulation (USEPA 1983) to limit the outlet emission of no more than 35mg/L or a recovery rate of about 95% for fuel terminals and fuel tankers. The close-circuit vapour recovery/balancing system has been widely used to control the VOC emissions from the handling of petroleum products in North America and Western European Countries for over 10 years.

5.3.16 The HKSAR government is investigating options to further control the vapour emission arising from the refuelling of motor vehicles. These options include a vapour recovery nozzle or hose that could effectively collect the displaced vapour (Stage II design), or an onboard carbon absorber installed on the motor vehicle itself. Stage II design had been tested by the California Air Resources Board and found to achieve a reduction in displaced vapour of at least 95% when compared with uncontrolled systems, and the cost to implement such control measures is as low as USD1.6 per driver per year. (SCAQMD, 2000) This inexpensive and simple technology applicable for both HKSAR and PRDEZ should be pursued.

VOC Control for Printing and Graphic Arts Operations

5.3.17 Printing ink, coating materials, fountain solution additives, platemaking and press cleaning solvents are the main sources of VOC emission from the printing and graphic art processes. The type and level of VOC emitted from each individual process depends on the scale of operation of the business and specific job requirements. The most common processes of the printing and graphic art include:

- Non-heat and heat web printing
- Flexography
- Sheetfed offset printing
- Gravure printing
- Screen print

5.3.18 The key to controlling VOC emissions from the printing industry is to set up a process emission limit. Industry may then choose from a wide range of commonly available means, such as applying solvent recovery techniques and using low VOC ink to achieve a satisfactory emission level within the limit.

5.3.19 Solvent recovery using engineering control techniques including thermal incineration, catalytic incineration, adsorption by activated carbon filters, adsorption by waste gas washing and condensation as well as the use of low-solvent inks, pigments and fountain solutions are commonly employed to reduce emission for compliance with the stringent VOC emission control limits in the United States. Under Rule 1130 implemented in January 2000 by the South Coast Air Quality Management District (SCAQMD) of California, all operations related to graphic arts shall have an emission control system to be used in conjunction with low-VOC emitting materials in order to achieve an overall control efficiency of at least 90%. It is suggested that further research in the cost for reducing VOC in the Region be carried out in future studies as such information is quite limited at present.

VOC Control for Process Evaporative Loss

5.3.20 Process evaporative loss collectively refers to process emission from organic solvent cleaning and surface coating. Organic solvent cleaning refers to the process in which organic solvents are used to remove oil, grease, waxes from metals, plastic and printed circuit boards. It is a pre-process to printing, coating and plating.

5.3.21 Designs that enclose the process have a reduction potential of around 50% achievable by completely enclosing all emission points apart from a minimum sized single entrance and exit point for the enclosure. U-bend designs could be utilised to minimise the VOC diffusion throughout the process.

5.3.22 There is legislation in the south coast of California, USA, limiting both the VOC content of coatings, and the emissions from assembly lines for the application of coatings in order to reduce the level of VOC discharged into the ambient air. (http://www.aqmd.gov/rules/html/tofc11.html). Various European countries and the United States have also produced a set of emission values for the control of VOC process evaporative loss from industrial processes (http://www.unece.org/env/lrtap/) (UNECE, 1999).

5.3.23 Control measures recommended in the legislation for these coating operations generally fall into three areas: low-VOC coatings, higher transfer efficiency equipment, and installation of air pollution control equipment.

5.3.24 The application of powder, high-solid, and water based coatings for assembly line applications is proven effective and does not result in loss of transfer efficiency. By replacing the VOC containing coatings with these low-VOC coatings, a reduction potential of 70 – 90% by volume or weight is achievable. Control equipment in the form of carbon adsorber, thermal incinerator and catalytic incinerator are commonly available in the commercial market. Testing was performed by the USEPA in a full-scale commercial operation of VOC control devices, and the results indicated an average control efficiency of 91 to 96% based on the method used and the device tested. (USEPA, 1999)

Emission Reduction Potential of the Additional Control Measures for the Industry Sector

5.3.25 The reduction potentials for each of the proposed additional control measures which could be quantified are presented in Table 5-7 and Table 5-8. The reduction potential is estimated for demonstration purposes on the assumption that the control measures would be implemented within the study years. Based on these reduction potentials, the effectiveness on emission reductions for the future was calculated with respect to both local and regional emissions. Reduction of emissions from base year 1997 is also presented in the two tables.

Table 5-7 Reduction Potential and Effectiveness of the Quantifiable Control Measures for the Industry Sector in HKSAR

Source	Pollutant	Control Measure	Reduction potential of control measure (kilo tonnes)	Effects of additional and committed control measures on total emissions relative to 1997	
				Local	Regional
Service station refuelling	VOC	Stage II vapour recovery	-2.0	-1.9%	-0.2%
Printing		Process emission limit	-11.1	-10.9%	-1.3%

Table 5-8 Reduction Potential and Effectiveness of the Quantifiable Control Measures for the Industry Sector in PRDEZ

Source	Pollutant	Control Measure	Reduction potential of control measure (kilo tonnes)	Effects of additional and committed control measures on total emissions relative to 1997	
				Local	Regional
Chemical operations	VOC	Process emission limit	-44.0	-3.9%	-3.4%
Fuel handling		Process control equipment	-14.1	-1.0%	-0.9%
Printing		Process emission limit	-33.3	-2.8%	-2.5%
Non-metallic mineral production	RSP	Process control equipment	-70.8	-37.8%	-36.0%
Industrial fuel combustion	RSP	Process control equipment	-110.7	-16.4%	-15.6%
	NO_x	Process modification	-63.4	-1.9%	-1.5%
	SO_2	Process emission limit	-154.6	1.3%	1.1%

5.4 Proposed Control Measures for Motor Vehicles

5.4.1 The two principal power sources for motor vehicles, namely petrol and diesel fuelled internal combustion engines, are projected to remain in use in the foreseeable future. It is necessary not only to reduce vehicle kilometres travelled, but also to tighten exhaust emission standards in order to improve air quality.

5.4.2 The vehicular emission control measures recommended for HKSAR and the PRDEZ will be examined, including the following components:

- Motor Vehicle Emission Control;
- Comprehensive Inspection/Maintenance (I/M) Programme;
- Environmentally Friendly Transportation Plan;
- Application of Alternative Fuel Vehicle;

Motor Vehicle Emission Control

5.4.3 While a number of emission control measures have been committed to by both governments, further reduction of emissions from motor vehicles needs a multi-pronged approach with the following proposed elements:

- to speed up the tightening of emission standards for new vehicles
- to ensure fuel quality to be inline with emission standards

5.4.4 In HKSAR, the implementation schedule of vehicular emission standards is in line with Euro standards, supported by advance emission control equipment and improved fuel quality. It is recommended that HKSAR should continue to update the standards in line with action by the European Union.

5.4.5 In PRDEZ, existing motor vehicles are designed to meet pre-Euro standards, which are equivalent to the European ECE15-03 standards of the 1970's and 1980's. The State Environmental Protection Administration (SEPA) has proposed a schedule to tighten emission standards to Euro III by year 2010 (Table 5-9). As emission standard forms the core elements of control over emissions from motor vehicles, it is suggested that the emission standards should be tightened as fast as practicable.

Table 5-9 Existing SEPA Proposed Emission Standards for Motor Vehicles in the PRDEZ

(Year of commencement)	1997	2000	2001	2004	2005	2010
Motorcycle	Pre-Euro		Euro 1		Euro 2	Euro 3
Small Petrol Vehicle	Pre-Euro	Euro 1		Euro 2		Euro 3
Large Petrol Vehicle	Pre-Euro		Euro 1		Euro 2	Euro 3
Diesel Goods Vehicle	Pre-Euro	Euro 1		Euro 2		Euro 3

5.4.6 If the emission standards are tightened in advance of the existing plan to Euro IV by 2010 as in the proposed timetable in Table 5-10, it is estimated that the emissions of most pollutants from motor vehicles would be reduced by about 20% of the projected emission in the future.

Table 5-10 Proposed Emission Standards for Motor Vehicles in the PRDEZ

(Year of commencement)	1997	2000	2001	2004	2005	2006	2010
Motorcycle	Pre-Euro		Euro 1		Euro 3		Euro 4
Small Petrol Vehicle	Pre-Euro	Euro 1		Euro 2		Euro 3	Euro 4
Large Petrol Vehicle	Pre-Euro		Euro 1		Euro 3		Euro 4
Diesel Goods Vehicle	Pre-Euro	Euro 1		Euro 2		Euro 3	Euro 4

5.4.7 For motor vehicles to meet more stringent emission standards, vehicle production technology (particularly engine technology) would have to be improved. Production cost and prices are likely to increase due to the improved technology. The cost for adopting Euro 1 and Euro 2 emission standards for new vehicles would be about RMB7,000 per tonne of NO_x reduced while substituting Euro 2 with Euro 3 standard diesel and gasoline vehicles would cost about RMB6,000 per tonne of NO_x removed. (AQMPSG, 2000)

5.4.8 To ensure that the environmental benefits of tightening emission standards are achieved, it is necessary to make fuel of appropriate quality available in line with the implementation of emission standards. Table 5-11 shows the maximum allowable sulphur content in fuel stipulated for different Euro emission standards.

Table 5-11 Maximum Allowable Sulphur Content in Motor Vehicle Fuel for different EURO standards

Euro Standard	Petrol	Diesel
Pre-Euro	0.1%	0.5%
EURO I	0.1%	0.2%
EURO II	0.05%	0.05%
EURO III	0.015%	0.035%
EURO IV	0.005%	0.005%

5.4.9 In addition to the advancement of emission standards and fuel quality, emission control could also be achieved by limiting the number of licenses for polluting motor vehicles. In PRDEZ for instance, the number of motorcycles constitutes a larger portion of the total number of motor vehicles. It is also observed that motorcycles have significant contributions to vehicular emissions. Therefore, capping the number of motorcycles at 2005 level could be an option to control emissions from motor vehicles. Such control measure should be regularly reviewed and reassessed, as motor vehicles with better performance in terms of emission control become available in the market.

Comprehensive Inspection/Maintenance (I/M) Petrol Programme

5.4.10 An effective I/M programme can yield a maximum 28% reduction in emissions (USEPA, 1996) through identifying mechanical problems that cause high emission levels. It is also an integrated element in a motor vehicle emission control programme to ensure the benefits of tightening emission standard are fully materialised. It is recommended that comprehensive inspection/maintenance programmes in the Region be considered with the following factors:

- I/M emission cutoff points for different age group of the in-use vehicles;
- Management and certification of the emission testing facilities and personnel;
- Establishment of inspection frequencies according to the various types and age of the vehicles;
- Emission tests should be extended to include other pollutants such as NO_x by dynamometer loaded test.

5.4.11 The programme should also involve the creation of an emission inventory database system and public education to promote the awareness of the need for vehicle maintenance.

5.4.12 In HKSAR the vehicle test requirement was last revised in 2000. All petrol vehicles over 6 years old have to undergo emission tests during the annual examination. All diesel vehicles are tested under an enhanced smoke test procedure in their annual roadworthiness examination. Major franchised bus operators regularly carry out emissions tests on their fleets. Nevertheless the continual upgrade of an I/M programme to match that with advancement of vehicle technologies in HKSAR is considered important.

5.4.13 In PRDEZ, vehicles operating on the road are checked randomly and any vehicles that fail the check are penalised and undergo mandatory repair. The vehicles that fail the random road check have to be re-checked after repair. In addition to the random road check, five percent of the vehicles from large transportation companies are also required to be tested. It is recommended that a more comprehensive I/M programme be implemented so as to be compatible with further tightening of emission standards. This would help to achieve the integrated emission reduction for this sector.

Environmentally Friendly Transportation Plan

5.4.14 Environmentally friendly transportation plans for the urban centres in the Region provide the possibility to meet the needs of transportation with less reliance on motor vehicles. The plan, in an approach similar to other studies such as CTS-3 and the Second Railway Development Study (RDS-2) of HKSAR, may cover a number of transport planning and traffic management elements. It is proposed to plan environmentally friendly transportation networks for areas within urban centres and provide linkages among urban centres.

Transport planning elements:

- preparation of a long term transportation plan with emphasis on railway system;
- integration of transport planning with land use and pedestrian traffic planning;
- giving priorities to providing mass transportation systems;
- the study and mitigation of the environmental impact of transport infrastructure projects.

Traffic management elements:

- designation of permanent and temporary traffic restricted zones in congested areas during busy periods;
- giving priorities to public transport modes in the use of roads, e.g. to designate dedicated bus lanes;
- provision and promotion of public transport services;
- development of electronic road pricing (ERP) systems.

5.4.15 A feasibility study on ERP commissioned by TD with the objective of examining the practicability of implementing ERP system in Hong Kong and assessing the need for such a system to meet transport objectives was completed in early 2001. The Study revealed that there were no transport grounds for applying drastic restraint measures like ERP in Hong Kong at this stage and that there were equally effective measures to discourage the use of private cars, increase the use of public transport services and reduce traffic congestion, if necessary. The applicability of ERP to achieve environmental objectives was also considered by the HKSAR government. The findings of ERP indicate that the impact would mainly be on roadside air quality. Therefore, ERP may not be a direct solution for the regional air quality problems. Given these circumstances, ERP was not considered a priority for Hong Kong but the development of its technology and the need for additional restraint measures in future would be closely monitored.

<u>Application of Alternative Fuel Vehicles</u>

5.4.16 The use of alternative fuel vehicles has been explored in many countries with a view to reducing vehicular emissions. The Clean Fleet Project carried out by the Battelle Memorial Institute in 1995 showed that alternative fuels had fewer emissions than regular gasoline. Compressed natural gas was shown to generate 68-77% less carbon monoxide and 90-95% less ozone precursors; while liquefied petroleum gas, 48% carbon monoxide and 68-70% less ozone precursors; and methanol, 50% and 59%, respectively. Electric vehicles, without combustion engines, were shown to have the lowest emission rates. However, they still contribute to regional air pollution through the use of electricity that has to be produced by power plants.

5.4.17 Gaseous fuels such as CNG (compressed natural gas) and LPG (liquefied petroleum gas) are the most popular alternative fuels at present. Emission tests on cars with CNG and LPG aftermarket conversions indicate that these conversions are generally less satisfactory when compared to engine designed to use these fuels. Other options such as alcohol and biofuels are considered to be uneconomical in most circumstances. The use of electricity is limited by present battery technology. Hybrid vehicles, which are vehicles running on two or more sources of power (e.g. power from electric motors and gasoline engine), are already frequently used in the US and the cost of a salon car is about US$20,000. Fuel cell vehicles are also under development. It is suggested that development in alternative fuel vehicles be monitored and the necessary studies and tests be conducted on their feasibility within the Region.

5.4.18 HKSAR has been exploring the feasibility of alternative fuel vehicles. Since August 2000, HKSAR has been offering one-off grants to provide an incentive for the replacement of diesel taxis with ones running on LPG. It has enacted legislation to require newly registered taxis to use LPG or petrol only. All new taxis now use LPG.

5.4.19 HKSAR has also conducted studies of LPG light buses, electric light buses, trolley buses and biodiesel. For instance, a 6-month trial scheme for LPG light buses was completed in early 2001 and factors such as the refuelling network, tank size and costs have been reviewed. An incentive scheme to encourage early replacement of diesel light buses with LPG or electric ones has been announced. The findings of a feasibility study on trolleybus system in HKSAR indicated that trolleybus operation in urban areas would involve important technical and operational difficulties. It was concluded that there was not a strong case for introducing trolleybus in existing built-up areas in Hong Kong. The Government would however further explore the merits of introducing trolleybuses vis-à-vis other environmentally friendly transport modes in new development areas.

5.4.20 In PRDEZ (Guangzhou), emission tests were performed on gasoline vehicles that were retrofitted to operate on alternative fuels such as compressed natural gas. The test results showed that the emissions were not low enough to be comparable to the emissions from vehicles designed to use the same alternative fuel, (UNDP, 2001). Although retrofitting the existing gasoline vehicles is unlikely to be practicable in Guangzhou, the effectiveness of the introduction of new alternative fuel vehicles is under investigation in other cities, e.g. Beijing. The study in Beijing showed a significant cut in emissions with the use of alternative fuel vehicles, however, the actual effects of alternative fuel vehicles in PRDEZ cannot be quantified without going through further studies and trial applications. It is recommended that the use of alternative fuel vehicles be vigorously examined by PRDEZ.

Emission Reduction Potential of the Additional Control Measures for the Motor Vehicles

5.4.21 The emission reduction potential for each of the proposed additional control measures which could be quantified is presented in Table 5-12. The reduction potential is estimated for demonstration purpose on the assumption that the control measures would be implemented within the study years. Based on these reduction potentials, the effectiveness on emission reduction for the future was calculated with respect to both local and regional emissions. Reduction of emissions from base year 1997 is also presented in the following table.

Table 5-12 Reduction Potential and Effectiveness of the Quantifiable Control Measures for the Motor Vehicles in PRDEZ

Source	Pollutant	Control Measure	Reduction potential of control measure* (kilo tonnes)	Effects of additional and committed control measures on total emissions relative to 1997	
				Local	Regional
Motor cycle Small petrol vehicle Large petrol vehicle Diesel good vehicle	VOC	Advance implementation of Euro standards; Control the number of motor cycle licenses at 2005 level	-28.1	-24.0%	-21.3%
	RSP		-8.2	-1.9%	-1.8%
	NO_x		-24.9	1.3%	1.0%
	SO_2		-9.2	0.6%	0.5%

* *A composite estimate based on continual improvement of motor vehicles (upgraded Euro standards) at a normal phase in/out rate.*

5.5 Proposed Control Measures for the VOC Containing Product Sector

5.5.1 VOC emissions from the VOC containing product sector are expected to increase over time. As identified in the emission inventories, the products identified in Table 5-13 contributed heavily to the regional VOC level. Effective control strategy based on existing worldwide experiences is recommended for consideration in HKSAR and PRDEZ.

Table 5-13 Major Emission Sources from the VOC Containing Product in the Region

Emission Sources	Products	Usage/Application
Paint	Architectural coating, paint, varnish, thinner, lacquer, latex and cleaning agents	Surface coating
Domestic Product	Domestic aerosols products, household cleaning products, toiletries and adhesive	Personal purpose, general housekeeping and office work

5.5.2 The long-term management plan shall consider the following three items for necessary action in HKSAR and PRDEZ.

- VOC Product Survey: The purpose of a product survey is to research on the types of VOC containing products in the market and to understand their emission characteristics so as to facilitate the smooth progress of implementing VOC control strategy on VOC containing products;
- Labelling of VOC Containing Products: To provide the general public a scheme on the VOC content of these products and promote the public awareness on the impact of the VOC containing products; and

- Establishment of VOC Content Limit for products: The purpose of this control measure is to reduce the emission by controlling the content of VOC in a product, either on voluntary or mandatory basis. The VOC portion of the product is substituted by a material with lower VOC emission level or re-formulated to contain less VOC.

5.5.3 Since there is currently no local provision on VOC containing products, the combined effects of the control measure are expected to be substantial for the Region. The three components should be implemented as a package. However, the actual schedule and timeline for implementing the suggested components would require more intensive investigations and have to be in line with future policy direction of the governments.

VOC Product Survey

5.5.4 Product survey is a tool to collect critical technical information for developing source specific classification of the VOC containing products in the commercial market. Technical information includes sales volume of individual products and classification, product applications and emissions, product ingredients and speciation profile. The result of the survey would help to develop the overall management plan and also provide enhanced activity data to fill in gaps in the compilation of emission inventory for the Region. Similar survey had been regularly conducted in the United States (http://www.arb.ca.gov/coatings/arch/Survey/results/Final.htm) and EU countries.

5.5.5 For this Region, product surveys for both architectural coatings and domestic products could be carried out in parallel. Key technical information and results could assist the governments in formulating future comprehensive package of VOC control measures.

Labelling of VOC Containing Products

5.5.6 A general awareness programme to educate the public on the impact of VOC on air quality is necessary. Programmes should be launched in the Region to promote the use of low VOC content products in the near future.

5.5.7 A scheme for the labelling of VOC containing products should be set up to provide consumers with sufficient information to choose low VOC products. Displaying maximum VOC content, together with other application notice on containers is a regulatory requirement for some categories of paints in parts of the US. Experiences in other product labelling programmes such as food labelling scheme and energy efficiency labelling scheme in HKSAR and green labelling system overseas can help devise the labelling system for VOC containing products in the Region.

5.5.8 To raise awareness amongst the general public, information centre providing technical and educational information could be set up. This will enable the public of all ages to understand the environmental impact of VOC and to learn how to identify low VOC products through product labelling. Publication materials could be made available at the centre to educate the public about the impact of VOC on ambient ozone and smog.

Establishment of VOC Content Limit for products

5.5.9 Setting limits on VOC content is the usual practice used by foreign jurisdictions in controlling VOC emissions from this category. This approach drives technological development and provides incentives to encourage manufacturing industries to 1) modify their product formulation to reduce VOC contents; 2) adopt alternative or innovative packaging or application method; and 3) reduce the overall use of VOC in their products.

5.5.10 Conventional solvent paint contains 40-70% of VOC by weight. For most applications, low solvent or solvent-free paints are commercially available or are under development. These alternative paints contain no VOC (as in powder paint) to less than 20% VOC content (as in waterborne paint). Decrease in average VOC content in paints due to increasing penetration of these alternative paints is observed in e.g. California, USA where stringent regulations on VOC limits are set. In South Coast Air Quality Management District, California, USA, more stringent VOC content limits are intended to be implemented by year 2008.The VOC content in some most widely used categories of paints can be further reduced from the uncontrolled level (CARB websites).

5.5.11 The California Air Resources Board began controlling VOC content in consumer products in 1990 and is phasing in near, medium and long term measures and plans. The Board uses only technologically and commercially feasible measures to limit VOC emissions from consumer products and does not eliminate a product form. It should however be noted that ambitious targeted values of VOC limits are usually set years ahead of the effective dates. To ensure that the anticipated VOC limits are actually technically and commercially feasible, further consultation and public hearings will be held when approaching the effective dates. Limits of VOC content in 28 product categories are already in place and those for an additional 18 product categories were recently adopted for implementation in 2005. The Board expects that these measures can reduce 55% of VOC emissions from the 1990 levels. With the help of further technological development and possibly market incentives, the Board intends to reduce 85% of VOC from consumer products from its 1990 level by 2010.

5.5.12 Since controlling VOC content of VOC containing products overseas has only a short enforcement history, the effectiveness of reducing VOC emissions by this measure should be carefully evaluated and monitored after its implementation. Availability of low or zero VOC substitutes, local application practice and technological development in the Region should also be taken into account. Continuous surveillance on technical and policy development in other jurisdictions is important in developing this measure in the Region.

<u>Emission Reduction Potential of the Additional Control Measure for the VOC Containing Products</u>

5.5.13 The emission reduction potentials for the proposed additional control measures which could be quantified are presented in Table 5-14 and Table 5-15. The reduction potential is estimated for illustration purpose only on the assumption that the control measures would be implemented within the study years, and assuming that they are technically and commercially feasible in the Region. Based on these reduction potentials, the effectiveness on emission reduction for the future was calculated with respect to both local and regional levels. Emission reduction for the base year 1997 is also presented in the two tables.

Table 5-14 Reduction Potential and Effectiveness of the Quantifiable Control Measure for the VOC Containing Product in HKSAR

Source	Pollutant	Control Measure	Reduction potential of control measure (kilo tonnes)	Effects of additional and committed control measures on total emissions relative to 1997	
				Local	Regional
Domestic product	VOC	Product emission limit	-20.0	-19.6%	-2.3%
Paint		Product emission limit	-24.9	-24.5%	-2.8%

Table 5-15 Reduction Potential and Effectiveness of the Quantifiable Control Measure for the VOC Containing Product in PRDEZ

Source	Pollutant	Control Measure	Reduction potential of control measure (kilo tonnes)	Effects of additional and committed control measures on total emissions relative to 1997	
				Local	Regional
Domestic product	VOC	Product emission limit	-43.6	-3.9%	-3.5%
Paint		Product emission limit	-118.2	-10.6%	-9.4%

5.6 Reduction Potential of all the Recommended Additional Control Measures

5.6.1 With the implementation of the recommended additional control measures for the major emission sectors, the reduction potential of the emissions in the Region were studied and are presented in Table 5-16. Appendix 5-B presents the emission inventory for the Region after the implementation of the recommended additional control measures. However, only those air quality control measures with quantifiable effects are accounted for in the compilation of the emission inventory and further applied in the modelling exercise.

Table 5-16 Overall Reduction Potential of the Recommended Control Measures on the Emission

Emission Sector	Pollutant	Change in Control scenario relative to 1997
Energy	VOC	-66%
	RSP	-62%
	NO_x	-37%
	SO_2	-72%
Industry	VOC	-77%
	RSP	-87%
	NO_x	-12%
	SO_2	2%
Motor Vehicle	VOC	-40%
	RSP	-22%
	NO_x	-2%
	SO_2	8%
VOC Containing Product	VOC	-78%
Overall	VOC	-54%
	RSP	-55%
	NO_x	-20%
	SO_2	-39%

5.6.2 As seen from the above result, there is a predicted overall reduction in future emissions resulting from the effects of additional control measures. The future air quality based upon implementation of the control scenario was compared with base year and future year scenarios to draw a more comprehensive conclusion on future air quality and to further assess whether additional control measures will be necessary.

5.7 Likely Future Air Quality in the Region with the Implementation of the Recommended Control Measures

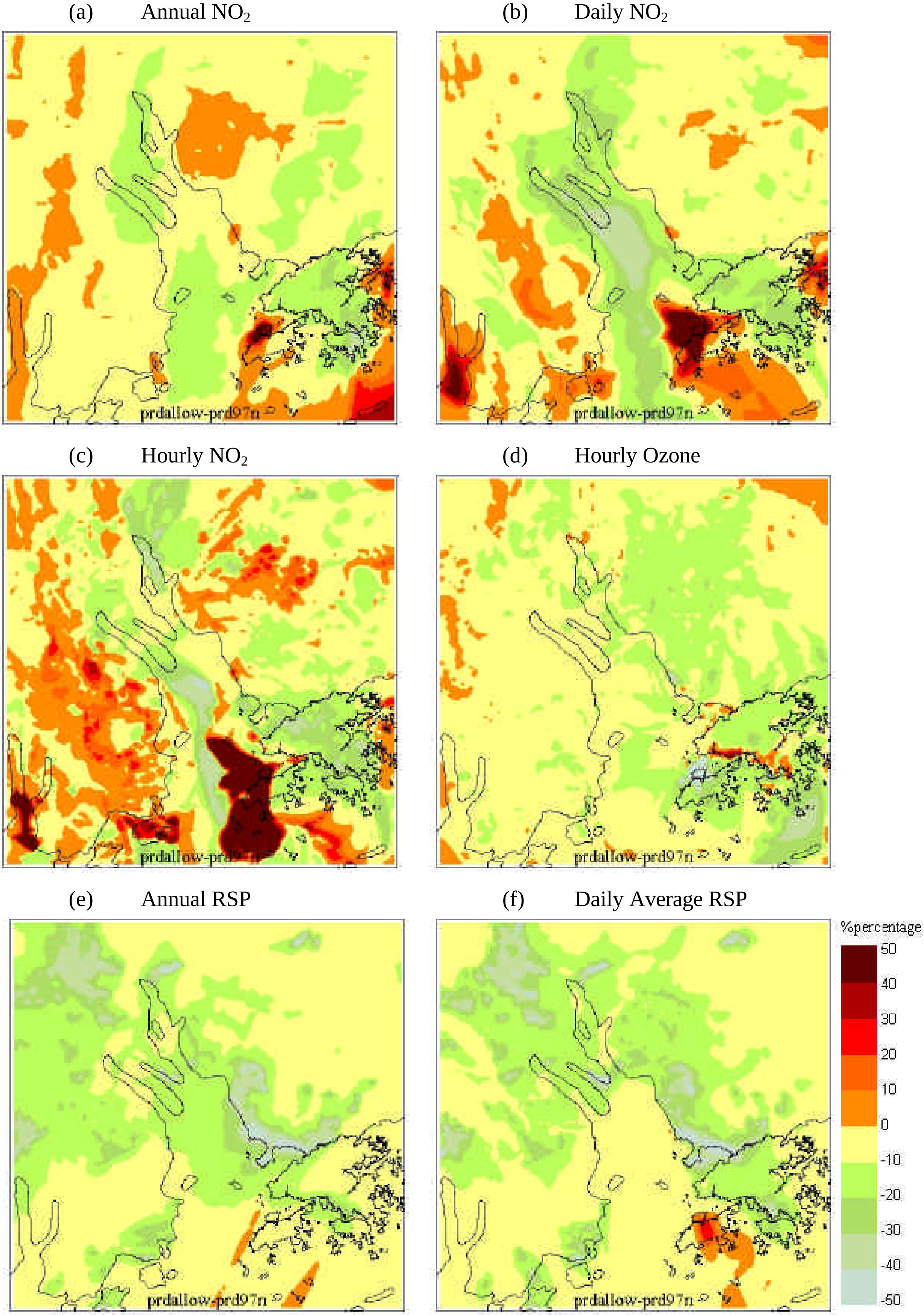
5.7.1 The likely future year air quality in the Region incorporating the implementation of the recommended additional control measures was predicted by the PATH model under the same methodology as applied before for the base year. Table 5-17 presents the air quality in 9 urban areas of the Region under the future year control scenario. Figure 5-2 shows the air quality plot under the same scenario. The positive scale of the presented figures should read as air quality deterioration and the negative scale as air quality improvement.

Table 5-17 Percentage Change in Air Pollutant Concentration relative to 1997

City	NO_2			O_3	RSP		NO_2			O_3	RSP	
	Annual	Daily	Hourly	Hourly	Annual	Daily	Annual	Daily	Hourly	Hourly	Annual	Daily
	% change in mean concentration						% change in maximum concentration					
Hong Kong	-12%	-12%	-10%	-4%	-8%	-9%	-16%	-27%	-28%	-12%	-24%	-35%
Shenzhen	-7%	-7%	-8%	-5%	-23%	-22%	-8%	-9%	-10%	-15%	-58%	-62%
Dongguan	-2%	-3%	-2%	-4%	-9%	-10%	-5%	-13%	-8%	-20%	-52%	-59%
Guangzhou	-6%	-7%	-6%	-3%	-18%	-18%	3%	-11%	-23%	-15%	-57%	-60%
Zhuhai	-4%	-5%	-4%	-6%	-11%	-11%	-4%	-7%	-5%	-16%	-31%	-39%
Zhongshan	-5%	-5%	-3%	-4%	-12%	-12%	0%	1%	1%	-7%	-31%	-31%
Foshan	-1%	-2%	0%	-4%	-19%	-18%	0%	-3%	-7%	-6%	-36%	-37%
Jiangmen	-1%	-2%	-1%	-4%	-17%	-17%	-3%	-7%	-4%	-12%	-40%	-43%
Huizhou	-6%	-6%	-6%	-3%	-6%	-6%	-3%	-8%	-18%	4%	-46%	-50%

Note: A positive percentage denotes an increase in pollutant concentration; A negative percentage denotes a decrease in pollutant concentration

Figure 5-2 *Improvement/deterioration of Air Quality in 2010 with the effects of Additional Controls*



Note: A positive percentage denotes an increase in pollutant concentration
A negative percentage denotes a decrease in pollutant concentration

5.7.2 Although the modelling of air quality involves an array of variables in which uncertainties could not be avoided, the study result should provide a reasonable representation of the actual scenario. As presented in the tables and plots, an overall improvement in air quality is predicted in the Region after the implementation of additional controls.

5.7.3 The modelling results showed that satisfactory air quality in terms of NO_2 concentration would be achievable in the Region under the control scenario. The average annual NO_2 concentration would be reduced by 1-12% relative to 1997 situations. Based on the air quality monitoring data obtained in 1997, this level of improvement would lead to compliance of HKAQO and the Class 2 NAAQS in HKSAR and PRDEZ, respectively.

5.7.4 Improvement in RSP concentration in the Region under the control scenario is expected to be even greater. The average annual RSP concentrations in the Region would be reduced by 7-23% from their 1997 levels. With these predicted levels of improvement, the measurement made in 1997 suggested that the HKAQO and the Class 2 NAAQS would be complied with in HKSAR and cities in PRDEZ respectively.

5.7.5 The modelling results also suggested that O_3 would still be a problem in the Region but at a lesser scale with respect to 1997 situation. Under the control scenario, the maximum hourly O_3 concentrations in the most cities of the Region would be reduced by 6-20% from their 1997 levels. Although this level of improvement would lead to compliance of HKAQO in HKSAR, it is not enough for the cities in the PRDEZ to comply with the Class 2 NAAQS for O_3. However, the coverage of area in the Region with elevated hourly O_3 concentration is expected to reduce by 40% when compared to 1997.

5.7.6 Occurrence of adverse meteorological conditions has been identified as an important factor of elevated pollutant concentration in the Region. By reducing the emissions of precursor pollutants, formation of ozone will be suppressed and elevated concentration will be less likely to occur even under unfavourable meteorological conditions.

5.7.7 Although the maximum hourly O_3 concentrations in the PRDEZ could not be lowered to levels below the Class 2 NAAQS under the control scenario, exceedances of the Class 2 NAAQS under adverse meteorological conditions would be largely reduced. Modelling results suggested that exceedances of the Class 2 NAAQS under meteorological conditions made up approximately 38% of time (or about 138 days) in 1997. Under the control scenario, exceedances would only constitute approximately 4% of time (or about 15 days) in a year.

Chapter Summary

- Control measures that best suit the Region have been evaluated.
- The implementation of the recommended additional control measures, technically achievable by 2010, would enable significant improvement of regional air quality and allow general compliance with corresponding air quality standards and objectives of the Region.
- Air pollution is regional in nature and both governments in HKSAR and Guangdong will need to carry out control measures for the mutual benefit of improved air quality.

6 REGIONAL AIR QUALITY MANAGEMENT PLAN

6.1 Objectives

6.1.1 In view of the present and future trend of air quality in the Region, it is evident that a solution to the air pollution problems of RSP, NO_2 and O_3 need the concerted efforts of both the HKSAR Government and Guangdong Provincial Government. The HKSAR and PRDEZ have different characteristics in political structure, societal development and economic growth, but they do influence each other in terms of the regional air quality under the ever-changing meteorological conditions.

6.1.2 To enable more effective management of the regional air quality, it is important for the two governments to set out common objectives. This can be achieved by establishing a management programme with which the two governments can ensure the effective implementation of regional control strategies. Additionally, this programme will enable the two governments to continually exchange information, which will facilitate decision making.

6.2 Air Quality Management Plan

6.2.1 The air quality management plan requires concerted efforts and support from both Hong Kong and Guangdong authorities. In fact, the cooperation between Hong Kong and Guangdong is not new to the Region. There have been a number of special panels set up for various specific areas under the Hong Kong-Guangdong Joint Working Group on Sustainable Development and Environmental Protection, namely:

- Pearl River Delta Region Air Quality Special Panel;
- Hong Kong-Guangdong Motor Diesel Fuel Specification Special Panel;
- Hong Kong-Guangdong Afforestation and Conservation Special Panel;
- Hong Kong-Guangdong Marine Resources and Conservation Special Panel;
- Pearl River Delta Water Quality Protection Special Panel;
- Hong Kong-Guangdong Town Planning Special Panel;
- Mirs Bay and Deep Bay (Shenzhen Bay) Areas Environmental Management Special Panel;
- Dongjiang Water Quality Protection Special Panel.

6.2.2 A management team, which will oversee the regional air quality management programme and be required to report to high level officials of the two governments regularly should be established and should be composed of officials from the HKSAR and Guangdong Province Governments to oversee the development of the air quality management plan. Its responsibility should include:

- to establish goals for the improvement of regional air quality
- to identify specific control measures for the Region
- to verify the effect of control measures and air quality management plan
- to improve and update the regional air quality emission inventory
- to establish a regional air quality monitoring network
- to track new technology and options for controlling air pollution.

Major components of the air quality management plan are presented in the following sections.

6.3 Verification of Control Measures and Air Quality Management Plan

6.3.1 With the implementation of the regional air quality monitoring exercise, the emission inventory improvement programme and the air quality control measures, there shall be a separate evaluation mechanism to oversee the benefit of these works on the air quality. Furthermore, the recommended regional control measures will be carried out in a long time frame. A continuous effort is needed to identify any further necessary studies and the appropriateness as well as the suitability for any modification needed for the control measures.

6.3.2 The independent evaluation programme will examine the technical side of the co-operative programmes and provide recommendations to improve the management side of the co-operative programmes with respect to the programme structures, communications among members at various levels as well as the management effectiveness among the sub-programmes. The reviewers of this programme shall give opinions on the overall progress of the programmes and the tasks that have been accomplished.

6.3.3 For the regional air quality monitoring programme, the evaluation programme will include independent audits to ensure quality of the monitored data from the regional network is comparable with international standards. There will be examination of data records, calibration audits on laboratory and field sampling equipment of the monitoring network, field and laboratory system and performance audit programme as well as laboratory inter-comparison exercises.

6.3.4 Furthermore, the independent audit programme should review the reduction potential effectiveness of the recommended measures implemented in the Region. In addition, this programme should review the suitability and practicability of the implemented control measures in various cities throughout the Region. The independent audit should also assess the rates of penetration of various control measures. All these facts would assist the decision-makers in handling short and long term regional control measures effectively.

6.4 Regional Emission Inventory Improvement and Update

6.4.1 An emission inventory of pollution sources in the Region is essential to help decision-making by identifying major contributors to regional air quality problems. In this Study, the best available information has been utilised for the compilation of the base year and future year emission inventories. Nevertheless continuous improvement to the emission inventories is still important. Verification of the inventories is necessary but was not always possible due to the absence of some fundamental activity data. This study has verified information as much as possible through obtaining data from multiple sources such as fuel consumption, past official publications and on-site observations. In general, the guidelines on compilation of emission inventories provided by international institutes, e.g. UNDP, USEPA, etc were followed as far as technically practicable.

6.4.2 However, there were gaps in the data as well as a lack of local validated parameters for calculations. To improve the quality of the emission information in the Region and to maintain consistency among emission inventories, a continuous effort is needed to prepare regular updates to the emission inventory through a compatible protocol for collecting information, compiling emission inventories, and conducting quality control on data.

6.5 Regional Air Quality Monitoring Network

6.5.1 A regional network of air quality monitoring stations across the Region is necessary to record the effectiveness of the control measures as well as the long-range transportation of the secondary pollutants emitted within the Region. Proposed locations of these regional air quality monitoring stations, each of which is strategically located, are presented in Figure 6-1. The air quality monitoring exercise has to be carried out by qualified institutions with local experience using measuring equipment that is comparable to international standards as far as technically feasible.

6.5.2 Tap Mun and Conghua stations will serve as the background monitoring stations as both of them are located at the remote location in the Study area, and are not being influenced by any local man-made emissions. Other monitoring locations should be deployed along two air pollution axis within the Region : the North-Easterly South-Westerly direction to capture emissions from major stationary sources in the Region and the North-Westerly South-Easterly direction to capture air movement along the prevailing wind direction across the Region.

6.5.3 The proposed monitoring network should be designed to specifically target regional air pollutants and their precursors including SO_2, NO_x, RSP, VOC and ozone, with possible extension to visibility as this may serve as a surrogate for the regional air quality problem.

6.5.4 Final decision on the exact locations of these regional air quality monitoring network can only be made after detailed surveys in the local environs of the proposed monitoring stations. It is important for the survey to include photographic and written evaluation for final site selection as well as the priority for operation of the monitoring network.

6.5.5 Air quality monitoring practitioners in HKSAR and PRDEZ are currently employing different monitoring and quality control/quality assurance procedures. It is necessary to formulate a set of protocols compatible with international established procedures for operations of this regional network to ensure comparability of air quality data collected. Training and technical exchanges among the practitioners, including discussion with local and overseas monitoring experts may be necessary to build up local capability and to familiarise the operators with the functioning of such a network.

6.6 Tracking of Latest Control Technology and Information Exchange

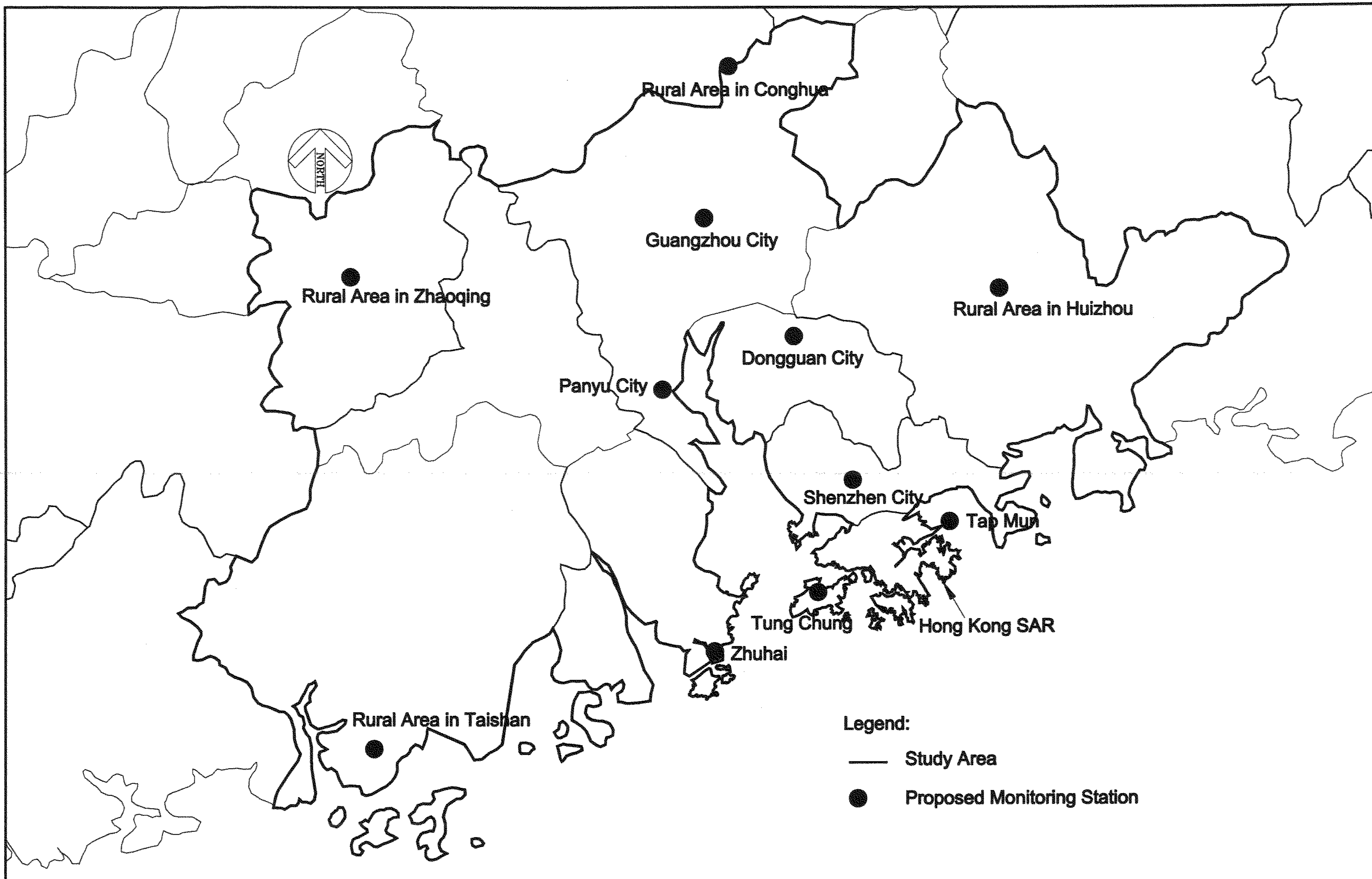
6.6.1 In order to build up local capability in dealing with the regional air quality issues, more extensive interactions among practitioners in the Region and with worldwide experts to share the experiences on the latest technologies are needed. Technical meetings, workshops, conferences and study group visits are suggested for practitioners in HKSAR and PRDEZ with possible participations of local and international experts from worldwide organisations, academia and governments.

6.6.2 Potential topics of these information sharing sessions include emission source characterisation, regional air quality network design and implementation, monitoring data processing and database management, data validation and analysis, compilation of emission inventories, low and zero emission technologies and regional air quality modelling.

6.6.3 In addition, information sharing sessions aimed at the general public can also be included for education purposes. These programmes will provide the public with an understanding of the causes and controls of the air pollution so that direct community support actions on regional air quality management can be built up.

Chapter Summary

- For effective management of air quality, the two governments have to work together with the same vision for the mutual benefit of both areas.
- The air quality management programme should include planning and implementation of a regional air quality monitoring network, regional emission inventory improvement, information sharing, and independent evaluation.



CH2M HILL (China) Limited	Project:	Agreement No. CE106/98 Study of Air Quality in the Pearl River Delta Region				Environmental Protection Department
	Title:	Final Report Locations of the Proposed Regional Air Quality Monitoring Network				
	Figure:	6-1	Scale:	NTS	Page No: Chapter6-4	

7. CONCLUSION AND RECOMMENDATIONS

7.1 Study Conclusion

7.1.1 The Study of Air Quality in the Region is the first joint effort between the HKSAR government and the Guangdong Provincial government to tackle regional air pollution with respect to the regulated air pollutants of ozone (O_3), nitrogen dioxide (NO_2), and respirable suspended particulate (RSP). This study recommends that continual co-operation be maintained and that a Regional Air Quality Management Plan with distinct objectives for air quality improvement be jointly established.

7.1.2 The main objective of the Study was to assess the air pollution problems in the Region related to the above three pollutants with a view to identifying possible measures benefiting the regional air quality.

7.1.3 The study achieved its objectives through evaluating regularly monitored air quality data, performing additional air quality monitoring, collating a comprehensive inventory of air emissions in the Region, conducting computer air quality modelling, and compiling a list of practicable regional air quality control measures.

Existing Air Quality in the Region

7.1.4 To understand the existing air quality in the Region, O_3, RSP and NO_2 data from existing, regularly monitored locations were used. Additional sampling and analyses were performed for RSP and VOC at fifteen sites in PRDEZ and a couple of locations in HKSAR to fill in gaps where existing air quality data were not adequate.

7.1.5 There are altogether 11 general monitoring stations in HKSAR operated by EPD. In 2000, the hourly O_3 air quality objective was not complied with at 1 station. Non-compliance of the daily and annual RSP objectives was observed at 2 stations and 1 station respectively. The hourly, daily, and annual NO_2 objectives were achieved in 2000.

7.1.6 Exceedances of the Mainland Class 2 National Ambient Air Quality Standards (NAAQS) were recorded at discrete periods in 2000 in PRDEZ cities where air quality data were available. Exceedances of hourly O_3, hourly NO_2, and daily RSP standards were recorded. At Nanyou in Shenzhen, exceedances were recorded on a total of 80 hours in 2000. At urban areas of Chengxi in Foshan, the maximum-recorded hourly O_3 concentration was 457 $\mu g/m^3$, 2.3 times the Class 2 NAAQS of 200 $\mu g/m^3$. The daily NO_2 standard was exceeded at Foshan, Guangzhou, and Shenzhen. At Beijie, Jiangmen, exceedances were recorded at 87% of the monitored days and the maximum daily average of 357 $\mu g/m^3$ was 2.4 times the Class 2 NAAQS of 150$\mu g/m^3$.

Regional Air Pollution in the Study Area

7.1.7 Both RSP and NO_2 concentrations have a regional component and a local component. The annual regional background RSP and NO_2 concentrations are about 40$\mu g/m^3$ and 12$\mu g/m^3$ respectively. The regional background RSP concentration is about 70% of the Hong Kong 1-year objective and about 40% of the Mainland 1-year Class 2 NAAQS.

7.1.8 Daily peak 1-hour O_3 concentrations are highly correlated at sites in Hong Kong, Foshan and Shenzhen. Since correlations indicated that high O_3 episodes in the Region are usually associated with stagnation of air in Southern China, these cities are affected by the same air mass, which is also responsible for transporting O_3 and O_3 precursors throughout the Region.

7.1.9 In general, O_3 values are high in late spring and early autumn while RSP and NO_2 concentrations are high in winter. Elevated regional air pollution levels are associated with stagnation of air. For O_3, however, there are two other ingredients, sunshine and warm temperatures. The generally lower levels of all three pollutants in the summer are attributed to the strong convective instability in summer months and high rainfall associated with the summer monsoon. On occasions, O_3 levels can be high in summer days when stagnation occurs with a high-pressure system built up over the Mainland or typhoon approaching the Region. When this happens, the peak O_3 levels can be even higher than those in the late spring and early autumn high O_3 days because of the higher temperature.

7.1.10 In HKSAR, O_3 levels have increased by approximately 39% from 1991. The trend in NO_2 has steadily increased by 26% since 1991. RSP concentrations have decreased over the same period by about 8%. Long-term data needed to compute regional pollutant trends in the PRDEZ were not available. Visibility, however, can be used as a surrogate for regional air pollution. In HKSAR, Shenzhen and Guangzhou, the percentage of time with poor visibility in the late 1990s was 3 times, 9 times and 5 times of those in 1991 respectively.

Emission Sources in the Region

7.1.11 An emission inventory was developed in order to understand the pollution sources and their future trends in the Region. Based on the availability of data, 1997 was chosen as the base year. Emission projections were made to 2000, 2005, 2010 and 2015. The inventory comprised, in the main, manmade emissions of VOC, NO_X, RSP, and SO_2. VOC and NO_X are involved in the formation of photochemical pollutants of NO_2 and O_3. NO_X, RSP, and SO_2 are involved in the formation of RSP.

7.1.12 Four major emission sources represent about 90% of the regional emissions. They include:

- Power plants and domestic and commercial fuel use;
- Industrial fuel combustion and process emissions;
- Motor vehicles;
- VOC containing products such as domestic products (personal products, sprayed aerosols) and paints.

7.1.13 Table 7-1 shows emissions in the base year and predicted future emissions. Even though HKSAR's contribution to the regional total emissions in 1997 is about 14%, its emission per capita (0.04 tonne/person) is comparable with that of PRDEZ (0.05 tonne/person). Thus, both HKSAR and PRDEZ should put in efforts to implementing control measures for improved regional air quality.

Table 7-1 Base year and Predicted Future Emissions

Emissions	Entity	VOC	RSP	NO_X	SO_2
1997 base year emissions (kilo tonnes)	HKSAR	54	13	114	76
	PRDEZ	412	245	450	520
	Region	466	258	564	596
2010 predicted emissions (kilo tonnes)	HKSAR	79	12	132	96
	PRDEZ	504	333	624	816
	Region	583	345	756	912
2015 predicted emissions (kilo tonnes)	HKSAR	95	13	146	106
	PRDEZ	537	359	646	935
	Region	632	372	792	1041
% increase in regional emissions from 1997 to 2010		25%	34%	34%	53%
% increase in regional emissions from 1997 to 2015		36%	45%	40%	75%

Likely Future Emissions in the Region

7.1.14 Emissions of regional pollutants are expected to increase from the base year to 2015 by 36% to 75% even with the many control measures that both the Guangdong government and the HKSAR government have committed to implement. In the Mainland, there will be significant control in power plant emissions through the importation of energy from western provinces, and the prohibition of new construction of coal-fired or oil-fired power plants. In the industrial sector, there will be progressive closure of fifteen types of polluting village and township businesses. Presently, motor vehicles are operating at pre-EURO emission standards. By 2010, EURO III emission standard will be adopted. No controls have been planned for the VOC containing product sector. HKSAR already has stringent emission controls on both the energy sector and the industrial sector. Similar to the Mainland, there are no controls on the VOC containing product sector. For motor vehicles, emission control will be in line with the implementation programme of the EURO standards in European countries with Euro IV emission standard to be adopted by 2006.

7.1.15 Committed control measures by both governments are needed in order to be effective in preventing emissions from growing in line with economic growth in the Region. Even though electricity generation is expected to increase in the PRDEZ by 223%, emissions of combustion pollutants are projected to increase by only 45-79%. Similarly, industrial production is expected to increase by 221% while emissions of various pollutants are projected to increase by 55-225%. Most significantly, while motor vehicle activities are expected to increase by 291%, emissions of various pollutants are projected to decrease by 1% to 56%. In HKSAR similar situation will occur. Unfortunately, these measures would not be sufficient to prevent emissions from increasing from present levels. Consequently, air quality is expected to get worse in the future.

Proposed Practicable Control Measures for the Region

7.1.16 To prevent regional air quality from deteriorating, emissions would need to be maintained at or even improved from present levels. To improve regional air quality from existing levels, additional control measures beyond those committed by both governments would be necessary. Table 7-2 presents those considered technically practicable within the four emission sectors for PRDEZ and HKSAR. Many control measures were considered in this study but not all control measures' effectiveness were quantifiable. Therefore only measures with quantifiable effects before the end of the study period were accounted in the emission inventory and the modelling exercise. For a measure with a reduction potential that is not individually quantifiable but was considered complementary for another measure, the added effect will be accounted as an integrated reduction potential. Table 7-3 shows emissions under a control scenario that will enable HKSAR to meet its current AQO for O_3, RSP and NO_x except for a small number of hot spots which will still be subject to occasional exceedance under certain meteorological conditions, and that will enable PRDEZ to meet its current NAAQS for RSP and NO_x. The NAAQS for O_3 will still not be achieved under certain meteorological conditions. But overall the improvement would be significant. The additional control measures suggested for the Region are technically achievable by 2010 the earliest and the emission reduction for regional pollutants over 1997 are as follows: SO_2 by 39%, NO_X by 20%, RSP by 55%, and VOC by 54%.

Table 7-2 Proposed Additional Control Measures for the Region

HKSAR	Possible Controls
Energy	▪ Acquire energy from cleaner fuels; Reduce reliance on coal-fired power plants ▪ Continue to extend the use of piped gas for other fuel combustion
Industry	Reduce VOC emissions from printing industry and service station refueling process
Motor Vehicle	▪ Develop environmentally friendly transportation plan ▪ Continue to explore the use of alternate fuelled vehicles
VOC containing product	Impose VOC content limit and implement product labeling system
PRDEZ	**Possible Controls**
Energy	▪ Diversify the use of cleaner fuels; increase the utilization of electricity from western provinces ▪ Reduce emissions by installing control equipment (such as flue gas desulpurisation, low-NO_x burner and EP) in power plants ▪ Improve the fuels employed by commercial and domestic users ▪ Tightening of emission standards
Industry	▪ Install end of pipe process control equipment (e.g. bag filter, cyclones, wet scrubbers, etc.) ▪ Process modification on combustion technology to reduce emission (e.g. low- low-NO_x burner) ▪ Install VOC control at chemical work facilities, fuel handling and printing processes ▪ Strengthen the enforcement of emission regulations
Motor Vehicle	▪ Implement motor vehicle emission standards with an advance schedule, EURO III by 2005/06, EURO IV by 2010; improve fuel quality to cope with the higher Euro standards. ▪ Limit the growth of polluting motor vehicle ▪ Introduce advance inspection and maintenance techniques ▪ Develop environmentally friendly transportation plan ▪ Explore the use of alternate fuelled vehicles
VOC containing product	Impose VOC content limit and implement product labeling system

Table 7-3 Predicted Emissions under the Control Scenario

Emission		VOC	RSP	NO_X	SO_2
Base year 1997 emissions (tons)	HKSAR	53,719	12,542	114,317	76,301
	PRDEZ	411,773	244,912	450,332	519,532
Emissions under control scenario (tons)	HKSAR	19,158	8,515	89,141	41,927
	PRDEZ	195,262	106,275	363,752	323,535
% change in emissions in control scenario	HKSAR	-64%	-32%	-22%	-45%
	PRDEZ	-53%	-57%	-19%	-38%
	Overall	-54%	-55%	-20%	-39%

7.2 Recommendations

7.2.1 To ensure that regional air quality will improve and not continue to deteriorate, it is recommended that a Regional Air Quality Management Plan be developed and implemented under a joint cooperative effort between the HKSAR government and the Guangdong government. Components of this plan should include:

- The establishment of goals for the improvement of regional air quality: This study pointed out the severity of regional air pollution in the Region and listed practicable control measures for improving regional air quality. The implementation of some of these measures might require a longer preparation time. The plan should allow flexibility in implementation. The establishment of goals specifying the desired level of improvement in a practicable timeframe is important.
- Identification of specific control measures: Further evaluation of the list of proposed control measures based on economic viability, legislative requirement, public acceptability, time required for implementation, and their effectiveness should be carried out. The selected control measures should be identified in the plan with a timetable for their implementation that matches the goals established in the plan.
- Verification of control measures: Once a control measure is selected, its implementation schedule and the adherence to the measure need to be regularly verified to ensure that the desired effect of the control measure can be realized. The plan should address how this is to be accomplished.

- Establishment of a system to update the regional air quality emission inventory: As air pollution control measures are implemented, the emission inventory developed under this study needs to be updated to reflect the effect of the control measures. This inventory will also serve as a guide for determining whether the control measures implemented are adequate for achieving the goals in the plan and changes in circumstances in future.
- Establishment of a regional air quality monitoring network: The network helps to fill in the gaps that currently exist in the understanding of the spatial and temporal variability of regional air quality, as well as the meteorological conditions affecting regional air quality. This will also allow the tracking of the effect of air pollution control measures that will be implemented by the HKSAR and Guangdong governments.
- Establishment of a system to track new technology and options for controlling air pollution: As pointed out in this study, the implementation of all additional practicable control measures would not be sufficient for the attainment of the O_3 standard in PRDEZ. Achieving the standard would require additional measures that might become feasible and practicable in the future. As control technology evolves, other control measures that are more cost effective than those currently available might be worth considering. Furthermore, the principles of emission offset or trading should be considered, with collaborations between the two governments to allow more effective use of resources and enforcement of regional control system.

Chapter Summary

- A Regional air quality problem exists and air quality is deteriorating.
- The currently committed air pollution control measures in the Region are not adequate to curb the growth of emissions.
- With the implementation of a right mix of recommended control measures, emissions will be significantly reduced and, correspondingly, air quality will significantly improve. The current air quality objectives could be largely met. Technically, this level of reduction can be achieved by 2010 the earliest.
- It is recommended that a Regional Air Quality Management Plan be developed and implemented under a joint cooperative effort between the HKSAR and Guangdong governments to ensure continued improvement in regional air quality.

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Appendices

Appendix 2-A Long term SO_2, NO_x, and TSP data for PRDEZ

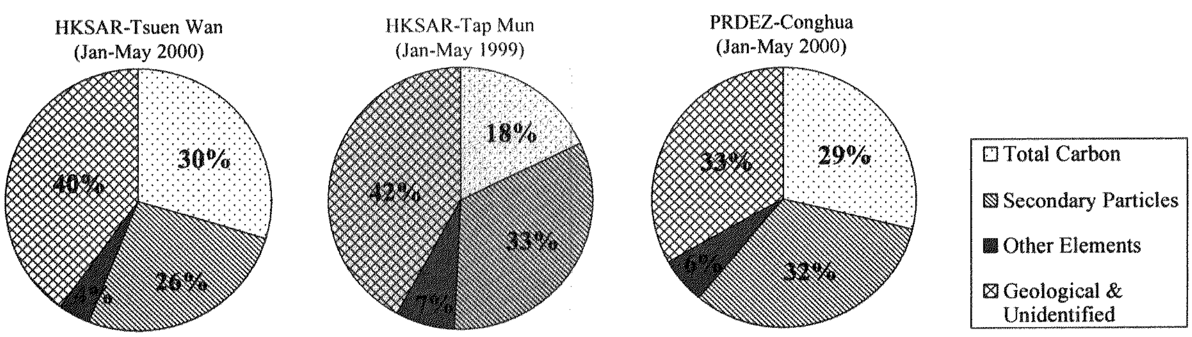
SO_2 (μg/m³)										
Region	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Guangzhou	71	59	47	56	57	65	70	61	54	44
Foshan	50	62	63	67	49	53	52	64	62	59
Zhongshan	32	32	44	57	47	56	30	22	21	34
Jiangmen	24	44	47	24	26	42	46	45	36	33
Zhaoqing	35	47	50	37	38	30	34	20	2	2
Dongguan	26	48	37	30	26	32	21	21	30	32
Zhuhai	12	17	15	19	16	16	11	24	33	31
Huizhou	15	15	15	15	11	9	14	18	10	10
Shenzhen	19	15	18	6	8	13	8	9	13	26
PRDEZ	32	38	37	35	31	35	32	32	29	33

NO_x (μg/m³)										
Region	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Guangzhou	111	107	116	117	124	151	139	124	112	118
Foshan	69	82	62	71	81	70	78	70	79	54
Shenzhen	108	118	121	67	73	64	53	61	52	60
Zhuhai	45	48	61	70	55	82	66	54	60	48
Dongguan	49	57	53	57	61	55	63	61	71	48
Zhongshan	36	45	54	69	75	49	45	56	52	56
Huizhou	32	47	59	49	45	53	50	48	63	27
Jiangmen	29	44	41	34	50	61	52	50	45	46
Zhaoqing	21	30	39	41	50	44	36	36	30	27
PRDEZ	56	64	67	64	68	70	65	62	63	54

TSP (μg/m³)										
Region	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Dongguan	303	364	305	355	305	219	155	158	141	105
Foshan	236	320	285	314	255	245	199	216	192	185
Guangzhou	260	279	280	306	295	265	217	204	180	148
Jiangmen	-	-	-	133	181	245	162	237	193	161
Zhaoqing	-	184	247	59	304	148	164	148	117	98
Huizhou	-	-	200	196	155	135	99	125	107	85
Zhongshan	133	218	110	95	168	148	142	140	150	135
Shenzhen	161	206	156	143	130	135	103	92	87	97
Zhuhai	185	109	180	115	38	57	64	118	147	110
PRDEZ	213	240	220	191	203	177	145	160	146	125

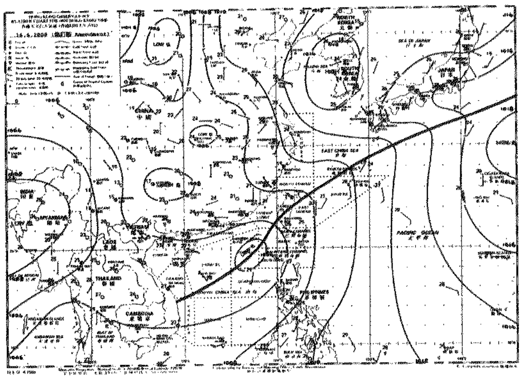
Source: GDEPB

Appendix 2-B RSP Composition at sites in the Region

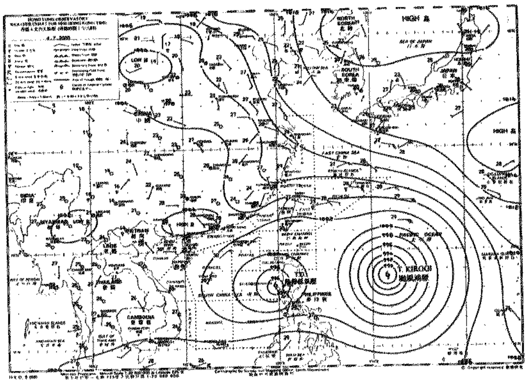


Appendix 2-C Synoptic Weather Maps for June 16 and July 4 of 2000

(a) June 16, 2000



(b) July 4, 2000



Appendix 3-A Summary Methodology for the Computation of the Energy and Industrial Source Emissions in the Region

Sector	Sub-Sector	Activity Data Collection[#]	Emission Estimation Techniques
Industry Processes	31 types of specified process in HKSAR including acrylates works, aluminium works, cement works, ceramic works, chlorine works, copper works, electricity works, gas works, iron and steel works, metal recovery works, mineral works, incinerators, petrochemical works, sulphuric acid works, tar and bitumen works, frit works, lead works, amines works, asbestos works, chemical incineration works, hydrochloric acid works, hydrogen cyanide works, sulphide works, pathological waste incinerators, organic chemical works, petroleum works, zinc galvanising works, rendering works, non-ferrous metallurgical works, glass works and *paint works Various types of industrial operations in PRDEZ using solid, liquid and gaseous fuel including electricity works, processing plants, product assemble plants, mining petrochemical works municipal waste incinerators, chemical incineration works and printing	Name, location and capacity of the facility Facility type in accordance with the Hong Kong Standard Industrial Classification Predominant fuel type and consumption Maximum pollutant emission and emission rate Chimney height Minimum efflux velocity Stack diameter Exhaust temperature Information on control equipment Operation hours Reference key of every industrial emission source Total volume of gaseous emission Emission volume of gaseous emission	Activity-based direct calculation with fuel consumption data for combustion sources
Energy use	Different type of fuel: Coal, kerosene, oil, gas, naphtha, petrol, hydroelectricity, nuclear & LPG	Hong Kong Annual Digest of Statistics, Hong Kong Energy Statistics, GPEMC, energy yearbook and provincial and city statistical yearbooks • Fuel type and quantity of import and export • Location of fuel terminals	Direct computation from fuel use.

Note: **not yet enforced*
[#]where data is available and applicable

Appendix 3-B Summary Methodology for the Computation of Mobile Source Emissions in the Region

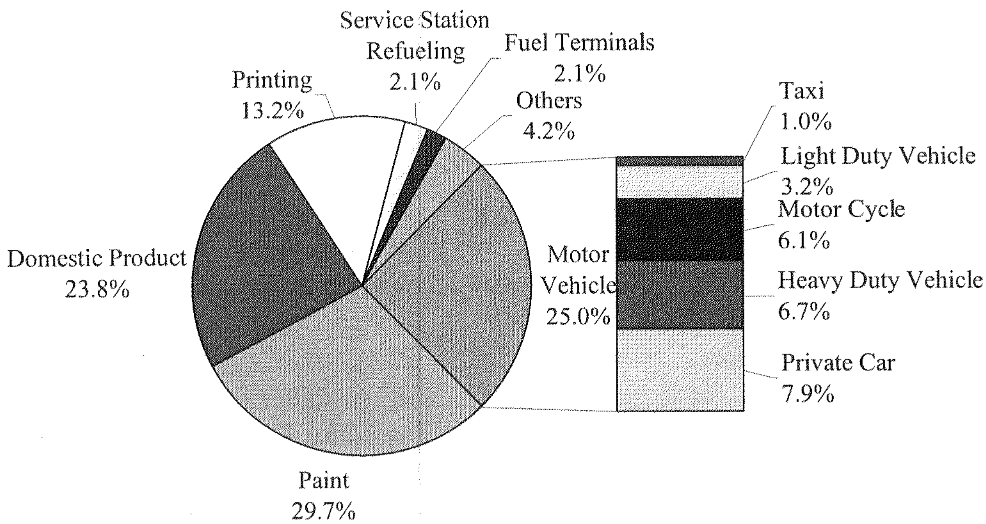
Sector	Sub-Sector	Activity Data Collection	Emission Factor Estimation Techniques
On-Road (HKSAR)	Motor vehicle movement characteristics for 18 districts	Strategic Environmental Assessment (SEA) report of the Third Comprehensive Transport Study (CTS3) of the Transport Department: • 10 vehicle classification • Average-day vehicle-kilometre-travelled (VKT) with the above motor classification • Average-day to annual average VKT conversion factor for above motor classification • Average fuel economy (km/l) for above motor classification	CTS3 and EPD fleet average emission factor for various type of pollutants for different vehicle types
	Territory wide road network	Traffic Census and Third Comprehensive Transport Study (CTS3): • Traffic count of above motor classifications movement for top 50 links • Fleet age distribution • Length of paved and unpaved road	
On-Road (PRDEZ)	Motor vehicle movement characteristics for 9 cities (Guangzhou, Shenzhen, Zhuhai, Zhongshan, Foshan, Jiangmen, Zhaoqing, Huizhou, Dongguan)	GPEMC, province, city and transportation statistical yearbooks, traffic research institutes, city traffic police, city statistical bureaux: • Classification – motorcycle, passenger cars, taxi, public buses, light-diesel goods vehicle and heavy goods diesel vehicles • Annual vehicle-kilometre-travelled (VKT) for at least motor cycles, diesel goods vehicles, large petrol vehicles (20 seaters or above) and small petrol vehicles (<20 seaters)	Published emission factors from technical seminars and conferences for various type of pollutants for different vehicle types
	PRDEZ road network National superhighway, highway and link roads	GPEMC, province, city and transportation statistical yearbooks, traffic research institutes, city traffic police, city statistical bureaux: • Length and daily traffic flow for above motor classifications • Length of paved and unpaved road	
	Fuel Type	Energy statistical yearbooks and GB standards for 1995: • Motor vehicle fuel type and the product specifications • Implementation schedules of the GB standards for different fuel types as well as tail pipe emission standards	
Off-Road	Marine	Marine Department (MD), Hong Kong Port and Maritime Board, Port Development Board, Hong Kong Annual Digest of Statistics, annual PRDEZ transportation statistical yearbooks, individual port authority web sites, Hong Kong company web sites and China shipping information network and port related organisations: • Shipping lanes for marine traffic • Port call statistics for various vessel GRT classifications • Activity data for the major hub, river and coastal ports in terms of vessels type	By using 1997 port related activity data referenced to Corinair report for vessel engine size. Emission calculation based on USEPA document "Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data" (EPA420-R-00-002 dated February 2000).
	Railway	Kowloon-Canton Railway Corporation (KCRC) and Mass Transit Railway Corporation (MTRC) and PRDEZ transportation, provincial and city statistical yearbooks: • Diesel fuel usage for locomotives • Engine type and configuration for diesel fuelled locomotives	Activity-based projection using PATH effective emission factor and 1997 activity data.
	Aviation for Kai Tak Airport, Central Heliport, Shun Tak Heliport and Shenzhen, Zhuhai and Guangzhou Baiyun Airports	Civil Aviation Department and business travel planner, airport web sites: • Airport diurnal profiles, runway usage, civil international traffic by movement type, aircraft analysis by aircraft type by movement type, airport instrument guidance for landing and taking off • Helicopter movement data from the Central Heliport and Shun Tak Heliport • Run length, airport diurnal profiles, runway usage, movement by aircraft type for landing and taking off	Activity-based projection. Emission factors from USFAA Aircraft Engine Emissions Database (FAEED) Version 2.1 (Nov 95). Time in Mode is taken from the PATH Project.

Appendix 3-C Summary Methodology for the Computation of Others Sources Emissions in the Region

Sector	Sub-Sector	Activity Data Collection	Emission Factor Estimation Techniques
Population	Population by district board boundary and the major cities, municipalities and districts within the study area	Census and Statistic Department, Hong Kong Annual Digest of Statistics and provincial and city statistical yearbooks in PRDEZ • 1997 population By-census for population and household statistic for HKSAR • Population and household figure for PRDEZ	Used to project emissions from 1995 to 1997 for certain source categories.
Construction activity	Active construction site and government projects	Hong Kong Review and Buildings Department, provincial and city statistical yearbooks and China construction yearbooks • Number of construction site/building/infrastructure project	Projection from 1995 PATH Inventory
Sewage treatment plants	Operating plants	Drainage Services Department, EPD published information, GPEMC and city environmental bureau: • Location and size, operation hours and capacity • Daily sewage handle	Projection from 1995 PATH Inventory
Quarries	Active sites	EPD Specified Process Registration, provincial and city statistical yearbooks and China construction yearbooks: • Location and size, operation hours and capacity, pollution control equipment employed	Projection from 1995 PATH Inventory
Domestic Solvent Use (e.g. Cosmetics & toiletries) & Paint Application (e.g. paints & varnishes)		Hong Kong Annual Digest of Statistics, trade journals, GPEMC and provincial and city statistical yearbooks • Data including population and car registration figures • Paint manufacture and consumption rate • Solvent type and quantity of import and export	Activity based estimation methodology based upon 1995 and 1998 data and effective emission factor from 1995 PATH inventory.
Dry cleaning		Modification, compliance checking & surveys of existing dry-cleaning machines, final report from Hong Kong Productivity Council, GPEMC and provincial and city statistical yearbooks • Number of dry cleaning shops • Amount of Perchloroethylene used • Dry cleaning machine type	Direct computation from amount of Perchloroethylene used.
Road surfacing	District board boundary	CTS3 Report, Transport and Highway Department, GPEMC and provincial and city statistical yearbooks • Length of paved and unpaved road	Insignificant source. Not considered.
Agriculture		Hong Kong Annual Digest of Statistics, GPEMC, city environmental bureaux and provincial and city statistical yearbooks • Type and quantity of crop produced	Used to estimate fertiliser usage.
Fertiliser		Hong Kong Annual Digest of Statistics, AFCD, GPEMC, city environmental bureau and provincial and city statistical yearbooks • Type and quantity of import and export	Direct computation from 1997 activity data and IPCC Table 4-19.
Livestock	Pigs, cattle, chicken, duck, geese and quails	Hong Kong Annual Digest of Statistics, GPEMC, city environmental bureau and provincial and city statistical yearbooks • Type and quantity of livestock produced	Direct computation of ammonia emissions from animal waste and IPCC Table 4-19.

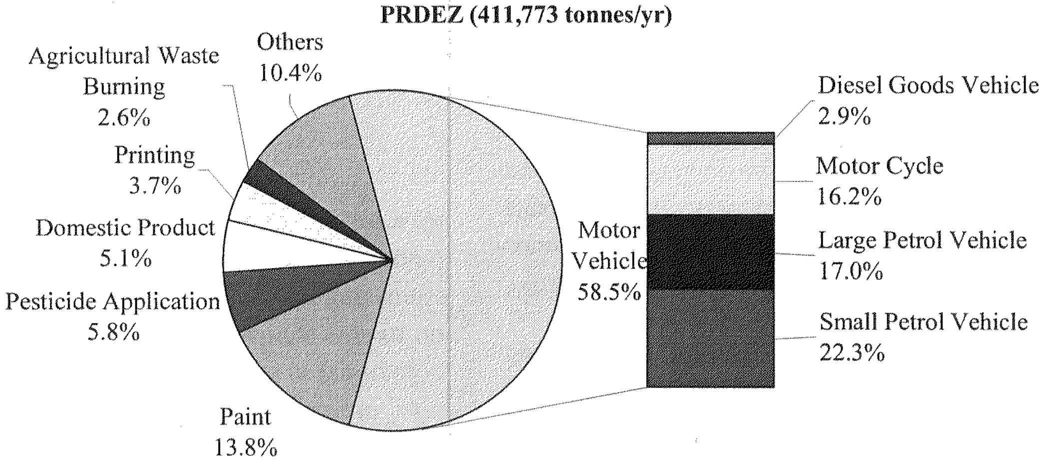
Appendix 3-D Manmade VOC Emission Sources in the Region

HKSAR (53,719 tonnes/yr)



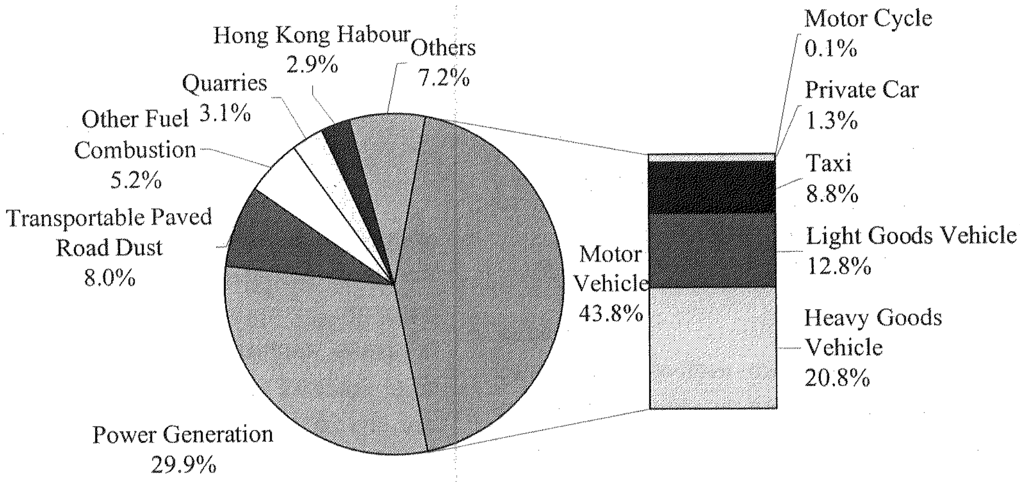
Light Duty Vehicle includes Pass Van, PLB & LGV
Heavy Duty Vehicle includes HGV, Non Fr Bus, SD Fr Bus & DD Fr Bus

PRDEZ (411,773 tonnes/yr)



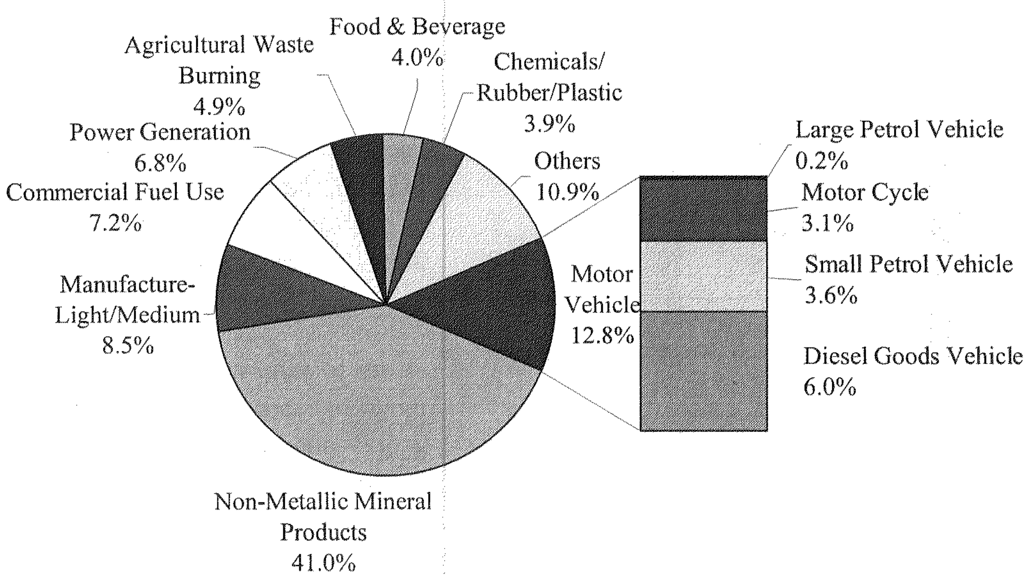
Appendix 3-E RSP Emission Sources in the Region

HKSAR (12,542 tonnes/yr)

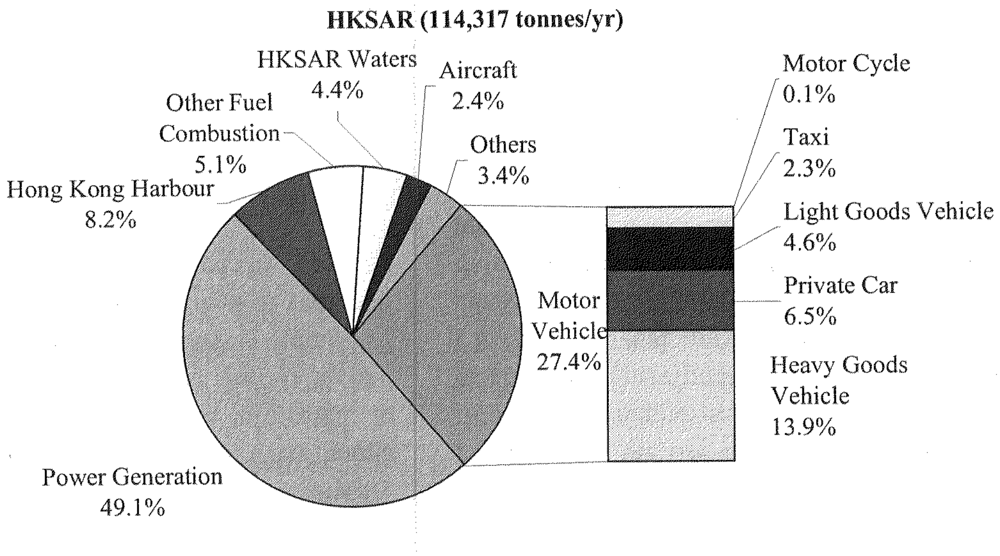


Light Duty Vehicle includes Pass Van, PLB & LGV
Heavy Duty Vehicle includes HGV, Non Fr Bus, SD Fr Bus & DD Fr Bus

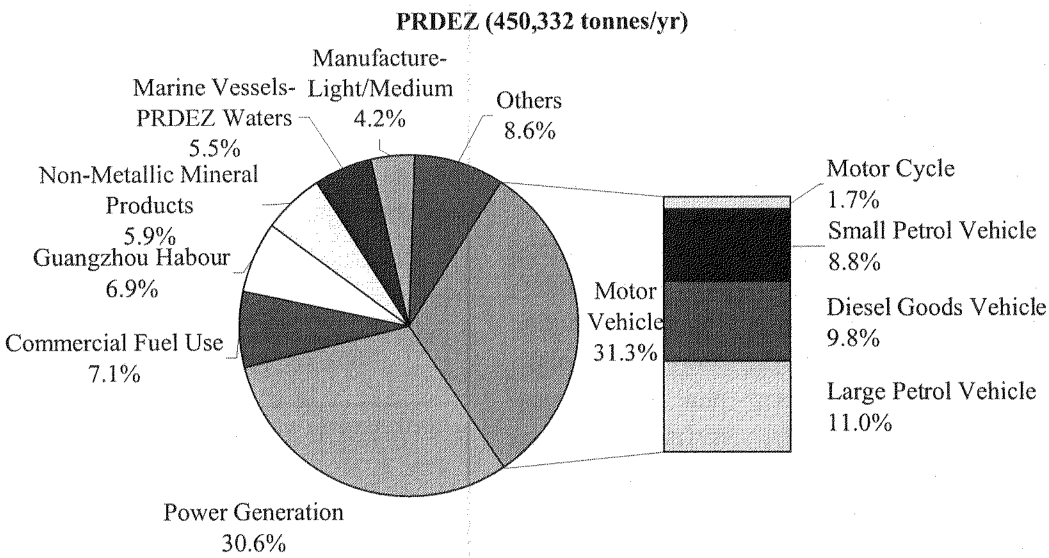
PRDEZ (244,912 tonnes/yr)



Appendix 3-F NO_x Emission Sources in the Region

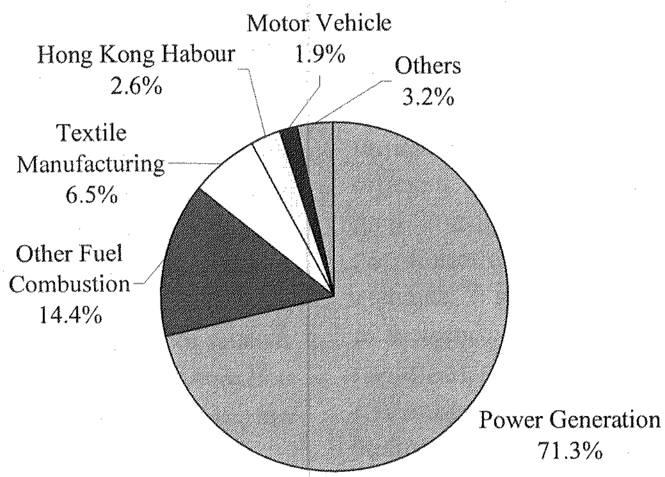


Light Duty Vehicle includes Pass Van, PLB & LGV
Heavy Duty Vehicle includes HGV, Non Fr Bus, SD Fr Bus & DD Fr Bus

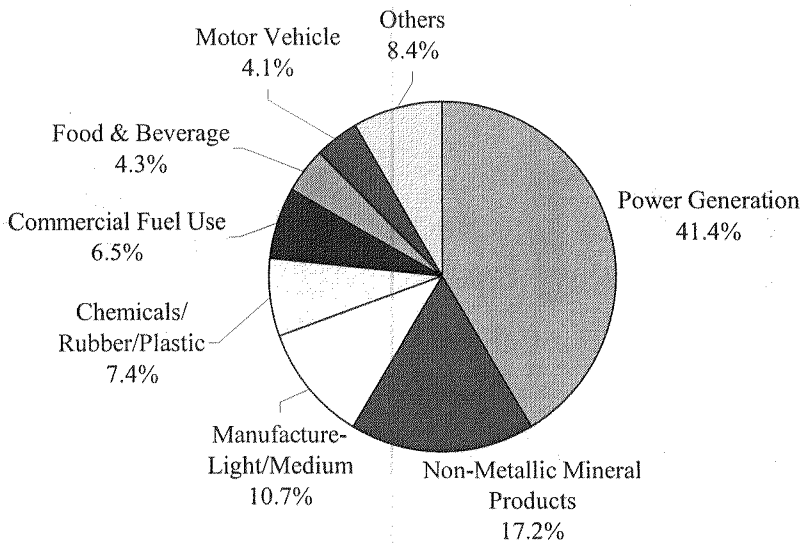


Appendix 3-G SO_2 Emission Sources in the Region

HKSAR (76,301 tonnes/yr)



PRDEZ (519,532 tonnes/yr)



Appendix 3-H Base Year Emission Inventory of the Region

HKSAR 1997	1997 Base Year Annual Emissions (tonnes/yr)				
	VOC	RSP	NO_x	SO_2	NH_3
Energy					
HKSAR Power Generation	296	3,747	56,084	54,434	-
HKSAR Other Fuel Combustion	145	646	5,844	11,008	-
Industry					
HKSAR Cement Production	89	138	2,212	90	-
HKSAR Paint Manufacture	135	51	-	522	-
HKSAR Printing	7,083	6	65	230	-
HKSAR Service Station Refueling	1,145	-	-	-	-
HKSAR Textile Manufacturing	9	63	1,423	4,983	-
Transportation					
HKSAR Motor Cycle	3,264	8	150	6	1
HKSAR Taxi	539	1,106	2,638	151	2
HKSAR Private Car	4,268	169	7,396	284	9
HKSAR Pass. Van	115	131	419	31	0
HKSAR PLB	197	224	705	55	0
HKSAR LGV	1,423	1,247	4,112	409	3
HKSAR HGV	2,726	1,981	10,828	412	2
HKSAR Non Fr. Bus	263	195	1,584	37	0
HKSAR SD Fr. Bus	37	27	216	5	0
HKSAR DD Fr. Bus	563	409	3,314	81	0
HKSAR Marine Vessels - Harbour Area	368	360	9,404	1,961	-
HKSAR Marine Vessels - SAR Waters	75	125	4,991	1,273	-
HKSAR Airport	677	-	2,787	288	-
HKSAR Diesel Locomotives	25	4	122	11	-
VOC Containing Product					
HKSAR Domestic Product	12,771	-	-	-	-
HKSAR Paint	15,935	-	-	-	-
Others					
HKSAR Animal Waste Ammonia	-	-	-	-	11,200
HKSAR Dry Cleaning	360	-	-	-	-
HKSAR Fuel Terminals	1,142	-	-	-	-
HKSAR Human Sweat & Exhalation	-	-	-	-	1,626
HKSAR Nitrogen Fertiliser Usage	-	-	-	-	85
HKSAR Other Services	52	337	-	-	-
HKSAR Quarries	-	393	-	-	-
HKSAR Transportable Construction Dust	-	73	-	-	-
HKSAR Transportable Paved Road Dust	-	1,000	-	-	-
HKSAR Transportable Unpaved Road Dust	-	68	-	-	-
HKSAR Waste Incineration	17	35	25	31	-
HKSAR Biogenic	5,833	-	-	-	-
Total HKSAR	59,552	12,542	114,317	76,301	12,928

Notes:
1. All emissions are rounded to the nearest whole tonne.
2. A value of "0" indicates emissions of greater than zero but less than 0.5 tonnes/year.
3. A value of "-" indicates emissions not quantified or no emissions.
4. Emission totals are not accurate to more than two significant figures.

Key:
Pass. Van denotes Passenger Van,
PLB denotes Public Light Bus
LGV denotes Light Goods Vehicle
HGV denotes Heavy Goods Vehicle
Non Fr. Bus denotes Non Franchised Bus
SD Fr. Bus denotes Single Deck Franchised Bus
DD Fr. Bus denotes Double Deck Franchised Bus

PRDEZ 1997	1997 Base Year Annual Emissions (tonnes/yr)				
	VOC	RSP	NO_x	SO_2	NH_3
Energy					
PRDEZ Power Generation	1,150	16,580	137,642	215,169	-
PRDEZ Commercial Fuel Use	20	17,697	31,871	33,806	-
PRDEZ Domestic Coal Consumption	5,049	1	2,244	7,661	-
PRDEZ Domestic LPG Consumption	148	2	2,005	152	-
PRDEZ Domestic Other Fuel Consumption	11	0	267	1,942	-
Industry					
PRDEZ Alcoholic Beverage Production	578	-	-	-	-
PRDEZ Chemicals/Rubber/Plastic	7,889	9,603	10,819	38,551	-
PRDEZ Construction	17	2,112	651	2,661	-
PRDEZ Electronic Manufacture	3	710	695	1,991	-
PRDEZ Food & Beverage	101	9,697	8,758	22,234	-
PRDEZ Gas, Water & Sanitary Works	7	562	107	1,948	-
PRDEZ Manufacture - Heavy	47	6,087	4,711	9,933	-
PRDEZ Manufacture - Light/Medium	106	20,697	18,824	55,531	-
PRDEZ Mining/Mineral Extraction	-	1,854	93	200	-
PRDEZ Non-Metallic Mineral Products	179	100,450	26,452	89,438	-
PRDEZ Oil Refinery	5,261	-	-	-	-
PRDEZ Petrol Distribution & Handling	4,992	-	-	-	-
PRDEZ Printing	15,400	331	39	144	-
PRDEZ Pulp and Paper Industries	7,476	-	-	-	-
PRDEZ Transportation	9	817	813	2,526	-
Transportation					
PRDEZ Motor Cycle	66,886	7,601	7,601	1,450	55
PRDEZ Small Petrol Vehicle	91,892	8,794	39,571	6,108	11
PRDEZ Large Petrol Vehicle	69,885	487	49,560	3,875	15
PRDEZ Diesel Goods Vehicle	12,063	14,589	44,060	9,710	48
PRDEZ Ports	256	770	31,065	7,761	-
PRDEZ Waters	228	617	24,860	6,227	-
PRDEZ Guangzhou Airport	193	-	1,804	75	-
PRDEZ Shenzhen Airport	82	-	362	27	-
PRDEZ Zhuhai Airport	12	-	72	6	-
PRDEZ Railway	5	4	142	17	-
VOC Containing Product					
PRDEZ Domestic Product	21,000	-	-	-	-
PRDEZ Paint	56,980	-	-	-	-
Others					
PRDEZ Agricultural Waste Burning	10,813	12,082	4,835	-	4,819
PRDEZ Agriculture	-	16	4	19	-
PRDEZ Ammonia Production	-	-	-	-	842
PRDEZ Animal Waste Ammonia	-	-	-	-	67,683
PRDEZ Dry Cleaning	87	-	-	-	-
PRDEZ Grain Drying	9,018	-	-	-	-
PRDEZ Human Sweat & Exhalation	-	-	-	-	4,559
PRDEZ Human Waste Rural Households	-	-	-	-	31,411
PRDEZ Human Waste Urban without Sanitary Facilities	-	-	-	-	1,250
PRDEZ Industrial Waste Incineration	-	-	-	-	-
PRDEZ Medical Waste Incineration	51	1,784	407	370	-
PRDEZ Nitrogen Fertiliser Production	-	-	-	-	12,265
PRDEZ Nitrogen Fertiliser Usage	-	-	-	-	90,541
PRDEZ Pesticide Application	23,880	-	-	-	-
PRDEZ Transportable Construction Dust	-	3,281	-	-	-
PRDEZ Transportable Paved Road Dust	-	4,004	-	-	-
PRDEZ Transportable Unpaved Road Dust	-	3,684	-	-	-
PRDEZ Biogenic	257,370	-	-	-	-
Total PRDEZ	669,143	244,912	450,332	519,532	213,501

Notes:
1. All emissions are rounded to the nearest whole tonne.
2. A value of "0" indicates emissions of greater than zero but less than 0.5 tonnes/year.
3. A value of "-" indicates emissions not quantified or no emissions.
4. Emission totals are not accurate to more than two significant figures.

Appendix 4-A Summary of the Air Pollution Legislation in HKSAR

Summary of the Air Pollution Legislation in Effect for the Energy Sector

Legislation	Description of Control
Environmental Impact Assessment Ordinance	Provides for the control of air pollution from industrial operations
Air Pollution Control Ordinance (Cap. 311)	Provides for the control of air pollution from stationary sources
Air Pollution Control (Air Control Zones) (Declaration) (Consolidation) Order	Provides for consolidated declaration of Air Control Zones.
Air Pollution Control (Dust and Grit Emission) Regulations	Stipulates the emission standards, assessment procedures and requirements for particulate emissions from stationary combustion sources.
Air Pollution Control (Fuel Restriction) Regulations	Prohibits the use of high sulphur content solid and liquid fuel (>0.5%) for commercial and industrial appliances.
Air Pollution Control (Furnaces, Ovens and Chimneys) (Installation and Alteration) Regulations	Requires prior approval to ensure suitable design for the installation and alteration of furnaces, ovens and chimneys.
Air Pollution Control (Smoke) Regulations	Restricts emissions of dark smoke from stationary combustion sources.
Air Pollution Control (Specified Processes) Regulations	Provides the administrative framework for the licensing of Specified Processes.

Summary of the Legislation in Effect for the Industry Sector

Legislation*	Description of Control
Air Pollution Control (Open Burning) Regulation	Prohibits open burning of construction waste, tyres and cables for metal salvage, and controls other open burning activities by permit system.
Air Pollution Control (Petrol Filling Stations) (Vapour Recovery) Regulation	Requires petrol filling stations and petrol delivery vehicles to be equipped with effective stage I vapour recovery systems and to observe good practice during petrol unloading.
Building (Demolition Works) Regulations	Regulates building demolition, including prevention of nuisance.
Air Pollution Control (Construction Dust) Regulation	Requires constructors to take dust reduction measures when construction work is being carried out.

** The recently implemented Dry Cleaning Regulation is neither included in the above list nor accounted in this Study as it is announced after the cutoff date for information collection*

Summary of the Air Pollution Legislation in Effect for Motor Vehicle Sector

Legislation	Description of Control
Air Pollution Control Ordinance (Cap. 311)	Provides for the control of air pollution from mobile sources
Air Pollution Control (Motor Vehicle Fuel) Regulation	Limit the benzene in petrol to not more than 1% and sulphur content of motor diesel to not more than 0.035%
Air Pollution Control (Vehicle Design Standards) (Emission) Regulations	Sets out the EURO III emission standards for newly registered vehicles in line with European countries, the United States and Japan in 2001
Air Pollution Control (Vehicle Design Standards) (Emission) Regulations	Control on emissions from diesel vehicles to the latest standards of EU new taxis will be required to use LPG
Road Traffic Ordinance (Cap. 374)	Regulates road traffic, vehicles and users of roads and related matters; includes provisions to limit pollution from vehicles
Road Traffic (Construction and Maintenance of Vehicles) Regulations	Specifies smoke levels for in-service vehicles

Summary of other Air Pollution Legislation in Effect

Legislation	Description of Control
Ozone Layer Protection Ordinance (Cap.403)	Gives effects to HK's international obligations under the 1985 Vienna Convention, the 1987 Montreal Protocol and any amendments to control the manufacture, import, and export of ozone depleting substances.
Shipping and Port Control Ordinance (Cap.313)	Regulates and controls ports, vessels and navigation, including control of smoke emissions.

Appendix 4-B Summary of the Air Pollution Legislation in PRDEZ

Summary of the Air Pollution Legislation in Effect for the Energy Sector and Industry Sector

Legislation	Description of Control
State Ambient Air Pollution Control Regulation	Provides for the frame work fort he control of air pollution from all emission sources, including stationary and fuel consumption sectors
State Ambient Air Quality Standard (GB3095-1996)	Specify the maximum emission concentration of air pollutants in different time period for various land use
Integrated Emission Standard of Air Pollution (GB16297-1996)	The regulation specifies the emission concentration for 33 types of pollutants from industrial operations
Emission Standard of Air Pollution for Coal-burning, Oil-burning, Gas-fired Boiler (GWPB 3-1999)	For the control of soot, SO_2, and NO_2 emission from boilers with a capacity of >45.5MW in the three different land use.
Emission Standard of Air Pollutants for Cement Plant (GB4915-1996)	For the control of soot, SO_2, and NO_2 emission from cement plant in the three different land use.
Emission Standard of Air Pollutants for Industrial Kiln and Furnace (GB9078-1996)	For the control of 6 air pollutants from 19 types of industrial kilns in the three different land use.
Emission Standard of Air Pollutants for Coke Oven 1997	For the control of air pollutants from oven in the three different land use.
Emission Standard of Air Pollutants for Thermal Power Plants (GB13223-1996)	For the control of soot, SO_2, and NO_2 emission from thermal power plant with a capacity of >65t/hr in the three different land use
Emission Standards for Odour Pollutants (GB14554-1993)	For the control of 8 odorous pollutants in the three different land use.
Guangzhou Ambient Air Pollution Control Regulation 1991	Based on the State Ambient Air Pollution Control Regulation, established by the Guangdong Province Government for the control of air pollution
State Environmental Protection Agency Announcement No: 74, 91and 151 of 1999 and 35 of 2000 Guangdong Province People Government Announcement No 57 of 1999 and 15 of 2000	Close down of the 15 small industrial operation, including coal-fired power plant with a capacity of less than 50KW
State Environmental Protection Agency Announcement No: 74 and 91of 1999 and 7 of 2000	Implementation of the "一控" major pollutants total emission control and "雙達標" compliance of the air quality standard and industrial emission standard.
State Environmental Protection Agency Announcement No: 9 of 2000	Promote the use of cleaner production in urban areas, improve the quality fuel for industrial, commercial and domestic use and advance the control techniques for boilers
Guangdong Province People Government Announcement No 7 of 2000	The Blue Sky Project specified the target emission reduction programme and the control measures that are to be implemented in the Guangdong Province

Summary of the Air Pollution Legislation in Effect for the Motor Vehicle Sector

Legislation	Description of Control
State Ambient Air Pollution Control Regulation 2000	Provides for the framework for the control of air pollution from mobile sources
State Environmental Protection Agency Announcement No 134 of 1999	Provides framework for the structure of the inspection and maintenance programme in mainland and specifies the time frame for the implementation of vehicular emission standard.
Emission Standard for Pollutants from Light-Duty Vehicle (GWPB1 -1999)	Establishes the emission standard and testing procedures for passenger cars, small passenger vehicles, and light goods vehicles
Limits and Measurement Methods for Emissions of Pollution from Motor Vehicles (GB14761-1999)	Establishes the emission standards for petrol and diesel vehicles
Guangzhou Ambient Air Pollution Control Regulation 1991	Based on the State Ambient Air Pollution Control Regulation, established by the Guangdong Provincial Government for the control of air pollution from mobile sources
Guangzhou Motor Vehicle Exhaust Supervision and Management Regulation 1994	Regulates the local manufacturing of motor vehicles, which must comply with the State emission standard. All imported vehicles must also comply with the same State standard

Appendix 4-C Future Year Emission Inventories for 2000, 2005, 2010 & 2015

HKSAR 2000	2000 Annual Projected Emissions (tonnes/yr)				
	VOC	RSP	NO_x	SO_2	NH_3
Energy					
HKSAR Power Generation	329	4,159	62,253	60,422	-
HKSAR Other Fuel Combustion	158	706	6,386	12,029	-
Industry					
HKSAR Cement Production	89	138	2,212	90	-
HKSAR Paint Manufacture	148	56	-	570	-
HKSAR Printing	7,740	7	71	251	-
HKSAR Service Station Refueling	1,525	-	-	-	-
HKSAR Textile Manufacturing	6	42	946	3,310	-
Transportation					
HKSAR Motor Cycle	3,724	10	176	-	1
HKSAR Taxi	455	732	2,623	158	2
HKSAR Private Car	3,268	198	6,733	-	11
HKSAR Pass. Van	108	105	431	35	0
HKSAR PLB	163	145	647	54	0
HKSAR LGV	1,343	936	4,087	436	3
HKSAR HGV	2,962	2,003	11,511	485	2
HKSAR Non Fr. Bus	266	175	1,546	41	0
HKSAR SD Fr. Bus	38	25	217	6	0
HKSAR DD Fr. Bus	588	381	3,338	89	0
HKSAR Marine Vessels - Harbour Area	335	350	9,784	2,121	-
HKSAR Marine Vessels - SAR Waters	93	155	6,168	1,573	-
HKSAR Airport	189	-	2,561	298	-
HKSAR Diesel Locomotives	25	4	122	11	-
VOC Containing Product					
HKSAR Domestic Product	13,955	-	-	-	-
HKSAR Paint	17,413	-	-	-	-
Others					
HKSAR Animal Waste Ammonia	-	-	-	-	11,200
HKSAR Dry Cleaning	393	-	-	-	-
HKSAR Fuel Terminals	1,248	-	-	-	-
HKSAR Human Sweat & Exhalation	-	-	-	-	1,719
HKSAR Nitrogen Fertiliser Usage	-	-	-	-	85
HKSAR Other Services	57	368	-	-	-
HKSAR Quarries	-	393	-	-	-
HKSAR Transportable Construction Dust	-	80	-	-	-
HKSAR Transportable Paved Road Dust	-	1,332	-	-	-
HKSAR Transportable Unpaved Road Dust	-	90	-	-	-
HKSAR Waste Incineration	17	35	25	31	-
HKSAR Biogenic	5,833	-	-	-	-
Total HKSAR	62,470	12,623	121,837	82,008	13,024

Notes:
1. All emissions are rounded to the nearest whole tonne.
2. A value of "0" indicates emissions of greater than zero but less than 0.5 tonnes/year.
3. A value of "-" indicates emissions not quantified or no emissions.
4. Emission totals are not accurate to more than two significant figures.

Key:
Pass. Van denotes Passenger Van,
PLB denotes Public Light Bus
LGV denotes Light Goods Vehicle
HGV denotes Heavy Goods Vehicle
Non Fr. Bus denotes Non Franchised Bus
SD Fr. Bus denotes Single Deck Franchised Bus
DD Fr. Bus denotes Double Deck Franchised Bus

PRDEZ 2000	2000 Annual Projected Emissions (tonnes/yr)				
	VOC	RSP	NO_x	SO_2	NH_3
Energy					
PRDEZ Power Generation	1,577	22,971	191,355	297,462	-
PRDEZ Commercial Fuel Use	21	18,318	32,991	34,993	-
PRDEZ Domestic Coal Consumption	5,227	1	2,323	7,930	-
PRDEZ Domestic LPG Consumption	154	2	2,075	157	-
PRDEZ Domestic Other Fuel Consumption	12	0	277	2,010	-
Industry					
PRDEZ Alcoholic Beverage Production	686	-	-	-	-
PRDEZ Chemicals/Rubber/Plastic	9,355	11,387	12,828	45,712	-
PRDEZ Construction	24	3,073	947	3,873	-
PRDEZ Electronic Manufacture	3	842	824	2,361	-
PRDEZ Food & Beverage	125	12,009	10,847	27,536	-
PRDEZ Gas, Water & Sanitary Works	8	666	127	2,310	-
PRDEZ Manufacture - Heavy	55	7,217	5,586	11,778	-
PRDEZ Manufacture - Light/Medium	126	24,542	22,320	65,845	-
PRDEZ Mining/Mineral Extraction	-	2,198	110	237	-
PRDEZ Non-Metallic Mineral Products	168	94,645	24,923	84,269	-
PRDEZ Oil Refinery	6,238	-	-	-	-
PRDEZ Petrol Distribution & Handling	6,860	-	-	-	-
PRDEZ Printing	19,072	409	48	178	-
PRDEZ Pulp and Paper Industries	8,864	-	-	-	-
PRDEZ Transportation	11	1,011	1,006	3,128	-
Transportation					
PRDEZ Motor Cycle	137,503	16,701	16,701	3,340	122
PRDEZ Small Petrol Vehicle	110,496	13,302	59,805	10,178	80
PRDEZ Large Petrol Vehicle	103,761	869	88,371	6,951	27
PRDEZ Diesel Goods Vehicle	23,355	24,211	75,704	7,280	20
PRDEZ Ports	220	659	26,595	6,645	-
PRDEZ Waters	195	528	21,283	5,331	-
PRDEZ Guangzhou Airport	236	-	2,212	92	-
PRDEZ Shenzhen Airport	109	-	482	36	-
PRDEZ Zhuhai Airport	13	-	78	6	-
PRDEZ Railway	5	4	142	17	-
VOC Containing Product					
PRDEZ Domestic Product	24,901	-	-	-	-
PRDEZ Paint	67,564	-	-	-	-
Others					
PRDEZ Agricultural Waste Burning	11,639	13,005	5,204	-	5,188
PRDEZ Agriculture	-	17	4	21	-
PRDEZ Ammonia Production	-	-	-	-	906
PRDEZ Animal Waste Ammonia	-	-	-	-	72,855
PRDEZ Dry Cleaning	103	-	-	-	-
PRDEZ Grain Drying	9,707	-	-	-	-
PRDEZ Human Sweat & Exhalation	-	-	-	-	4,719
PRDEZ Human Waste Rural Households	-	-	-	-	32,514
PRDEZ Human Waste Urban without Sanitary Facilities	-	-	-	-	1,294
PRDEZ Industrial Waste Incineration	-	-	-	-	-
PRDEZ Medical Waste Incineration	52	1,847	421	383	-
PRDEZ Nitrogen Fertiliser Production	-	-	-	-	13,202
PRDEZ Nitrogen Fertiliser Usage	-	-	-	-	97,460
PRDEZ Pesticide Application	25,705	-	-	-	-
PRDEZ Transportable Construction Dust	-	4,964	-	-	-
PRDEZ Transportable Paved Road Dust	-	5,504	-	-	-
PRDEZ Transportable Unpaved Road Dust	-	5,063	-	-	-
PRDEZ Biogenic	257,370	-	-	-	-
Total PRDEZ	831,521	285,967	605,590	630,057	228,386

Notes:
1. All emissions are rounded to the nearest whole tonne.
2. A value of "0" indicates emissions of greater than zero but less than 0.5 tonnes/year.
3. A value of "-" indicates emissions not quantified or no emissions.
4. Emission totals are not accurate to more than two significant figures.

HKSAR 2005	2005 Annual Projected Emissions (tonnes/yr)				
	VOC	RSP	NO_x	SO_2	NH_3
Energy					
HKSAR Power Generation	350	4,421	66,179	64,232	-
HKSAR Other Fuel Combustion	202	901	8,150	15,352	-
Industry					
HKSAR Cement Production	89	138	2,212	90	-
HKSAR Paint Manufacture	189	71	-	728	-
HKSAR Printing	9,878	8	91	321	-
HKSAR Service Station Refueling	1,824	-	-	-	-
HKSAR Textile Manufacturing	4	31	707	2,474	-
Transportation					
HKSAR Motor Cycle	3,719	10	203	-	1
HKSAR Taxi	444	29	1,559	-	3
HKSAR Private Car	2,629	194	4,694	-	14
HKSAR Pass. Van	113	71	437	5	0
HKSAR PLB	142	72	565	6	0
HKSAR LGV	1,190	443	3,271	42	3
HKSAR HGV	2,936	1,688	10,578	58	2
HKSAR Non Fr. Bus	256	141	1,366	6	0
HKSAR SD Fr. Bus	21	18	213	1	0
HKSAR DD Fr. Bus	315	278	3,271	11	0
HKSAR Marine Vessels - Harbour Area	340	370	10,591	2,321	-
HKSAR Marine Vessels - SAR Waters	137	227	9,027	2,302	-
HKSAR Airport	240	-	3,286	383	-
HKSAR Diesel Locomotives	25	4	122	11	-
VOC Containing Product					
HKSAR Domestic Product	17,811	-	-	-	-
HKSAR Paint	22,223	-	-	-	-
Others					
HKSAR Animal Waste Ammonia	-	-	-	-	11,200
HKSAR Dry Cleaning	502	-	-	-	-
HKSAR Fuel Terminals	1,593	-	-	-	-
HKSAR Human Sweat & Exhalation	-	-	-	-	1,829
HKSAR Nitrogen Fertiliser Usage	-	-	-	-	85
HKSAR Other Services	73	470	-	-	-
HKSAR Quarries	-	393	-	-	-
HKSAR Transportable Construction Dust	-	102	-	-	-
HKSAR Transportable Paved Road Dust	-	1,593	-	-	-
HKSAR Transportable Unpaved Road Dust	-	108	-	-	-
HKSAR Waste Incineration	17	35	25	31	-
HKSAR Biogenic	5,833	-	-	-	-
Total HKSAR	73,095	11,814	126,546	88,373	13,138

Notes:
1. All emissions are rounded to the nearest whole tonne.
2. A value of "0" indicates emissions of greater than zero but less than 0.5 tonnes/year.
3. A value of "-" indicates emissions not quantified or no emissions.
4. Emission totals are not accurate to more than two significant figures.

Key:
Pass. Van denotes Passenger Van,
PLB denotes Public Light Bus
LGV denotes Light Goods Vehicle
HGV denotes Heavy Goods Vehicle
Non Fr. Bus denotes Non Franchised Bus
SD Fr. Bus denotes Single Deck Franchised Bus
DD Fr. Bus denotes Double Deck Franchised Bus

PRDEZ 2005	2005 Annual Projected Emissions (tonnes/yr)				
	VOC	RSP	NO_x	SO_2	NH_3
Energy					
PRDEZ Power Generation	1,926	24,627	216,185	316,569	-
PRDEZ Commercial Fuel Use	22	19,599	35,298	37,440	-
PRDEZ Domestic Coal Consumption	5,592	1	2,485	8,485	-
PRDEZ Domestic LPG Consumption	164	2	2,220	168	-
PRDEZ Domestic Other Fuel Consumption	13	0	296	2,150	-
Industry					
PRDEZ Alcoholic Beverage Production	935	-	-	-	-
PRDEZ Chemicals/Rubber/Plastic	12,755	15,525	17,491	62,325	-
PRDEZ Construction	39	4,925	1,519	6,208	-
PRDEZ Electronic Manufacture	4	1,148	1,123	3,219	-
PRDEZ Food & Beverage	175	16,735	15,115	38,371	-
PRDEZ Gas, Water & Sanitary Works	11	909	173	3,149	-
PRDEZ Manufacture - Heavy	75	9,841	7,617	16,058	-
PRDEZ Manufacture - Light/Medium	172	33,461	30,432	89,775	-
PRDEZ Mining/Mineral Extraction	-	2,997	150	323	-
PRDEZ Non-Metallic Mineral Products	158	89,054	23,451	79,292	-
PRDEZ Oil Refinery	8,505	-	-	-	-
PRDEZ Petrol Distribution & Handling	10,972	-	-	-	-
PRDEZ Printing	26,576	570	67	248	-
PRDEZ Pulp and Paper Industries	12,086	-	-	-	-
PRDEZ Transportation	15	1,409	1,403	4,359	-
Transportation					
PRDEZ Motor Cycle	129,401	21,023	20,175	5,015	191
PRDEZ Small Petrol Vehicle	106,301	13,990	60,587	16,744	146
PRDEZ Large Petrol Vehicle	90,082	871	84,702	8,324	34
PRDEZ Diesel Goods Vehicle	22,037	17,318	74,039	6,804	21
PRDEZ Ports	173	520	20,983	5,243	-
PRDEZ Waters	154	417	16,792	4,206	-
PRDEZ Guangzhou Airport	256	-	2,396	100	-
PRDEZ Shenzhen Airport	156	-	692	52	-
PRDEZ Zhuhai Airport	15	-	90	7	-
PRDEZ Railway	5	4	142	17	-
VOC Containing Product					
PRDEZ Domestic Product	33,950	-	-	-	-
PRDEZ Paint	92,119	-	-	-	-
Others					
PRDEZ Agricultural Waste Burning	11,932	13,332	5,335	-	5,318
PRDEZ Agriculture	-	18	4	21	-
PRDEZ Ammonia Production	-	-	-	-	929
PRDEZ Animal Waste Ammonia	-	-	-	-	74,686
PRDEZ Dry Cleaning	141	-	-	-	-
PRDEZ Grain Drying	9,950	-	-	-	-
PRDEZ Human Sweat & Exhalation	-	-	-	-	5,049
PRDEZ Human Waste Rural Households	-	-	-	-	34,788
PRDEZ Human Waste Urban without Sanitary Facilities	-	-	-	-	1,384
PRDEZ Industrial Waste Incineration	-	-	-	-	-
PRDEZ Medical Waste Incineration	56	1,976	450	409	-
PRDEZ Nitrogen Fertiliser Production	-	-	-	-	13,534
PRDEZ Nitrogen Fertiliser Usage	-	-	-	-	99,909
PRDEZ Pesticide Application	26,351	-	-	-	-
PRDEZ Transportable Construction Dust	-	8,287	-	-	-
PRDEZ Transportable Paved Road Dust	-	8,802	-	-	-
PRDEZ Transportable Unpaved Road Dust	-	8,098	-	-	-
PRDEZ Biogenic	257,370	-	-	-	-
Total PRDEZ	860,645	315,459	641,411	715,082	235,989

Notes:
1. All emissions are rounded to the nearest whole tonne.
2. A value of "0" indicates emissions of greater than zero but less than 0.5 tonnes/year.
3. A value of "-" indicates emissions not quantified or no emissions.
4. Emission totals are not accurate to more than two significant figures.

HKSAR 2010	2010 Annual Projected Emissions (tonnes/yr)				
	VOC	RSP	NO_x	SO_2	NH_3
Energy					
HKSAR Power Generation	367	4,646	69,544	67,498	-
HKSAR Other Fuel Combustion	252	1,123	10,157	19,131	-
Industry					
HKSAR Cement Production	89	138	2,212	90	-
HKSAR Paint Manufacture	235	88	-	907	-
HKSAR Printing	12,310	10	113	400	-
HKSAR Service Station Refueling	2,108	-	-	-	-
HKSAR Textile Manufacturing	4	28	625	2,187	-
Transportation					
HKSAR Motor Cycle	2,271	12	183	-	1
HKSAR Taxi	513	33	1,800	-	3
HKSAR Private Car	2,749	210	4,051	-	16
HKSAR Pass. Van	109	44	402	6	0
HKSAR PLB	136	37	498	7	0
HKSAR LGV	1,189	276	2,867	47	3
HKSAR HGV	2,543	1,111	8,842	71	3
HKSAR Non Fr. Bus	209	85	1,068	6	0
HKSAR SD Fr. Bus	23	13	163	1	0
HKSAR DD Fr. Bus	355	207	2,509	11	0
HKSAR Marine Vessels - Harbour Area	358	406	12,027	2,684	-
HKSAR Marine Vessels - SAR Waters	171	278	11,066	2,823	-
HKSAR Airport	287	-	3,963	463	-
HKSAR Diesel Locomotives	25	4	122	11	-
VOC Containing Product					
HKSAR Domestic Product	22,195	-	-	-	-
HKSAR Paint	27,694	-	-	-	-
Others					
HKSAR Animal Waste Ammonia	-	-	-	-	11,200
HKSAR Dry Cleaning	626	-	-	-	-
HKSAR Fuel Terminals	1,985	-	-	-	-
HKSAR Human Sweat & Exhalation	-	-	-	-	1,933
HKSAR Nitrogen Fertiliser Usage	-	-	-	-	85
HKSAR Other Services	90	586	-	-	-
HKSAR Quarries	-	393	-	-	-
HKSAR Transportable Construction Dust	-	127	-	-	-
HKSAR Transportable Paved Road Dust	-	1,841	-	-	-
HKSAR Transportable Unpaved Road Dust	-	124	-	-	-
HKSAR Waste Incineration	17	35	25	31	-
HKSAR Biogenic	5,833	-	-	-	-
Total HKSAR	84,744	11,855	132,236	96,374	13,246

Notes:

1. All emissions are rounded to the nearest whole tonne.
2. A value of "0" indicates emissions of greater than zero but less than 0.5 tonnes/year.
3. A value of "-" indicates emissions not quantified or no emissions.
4. Emission totals are not accurate to more than two significant figures.

Key:
Pass. Van denotes Passenger Van,
PLB denotes Public Light Bus
LGV denotes Light Goods Vehicle
HGV denotes Heavy Goods Vehicle
Non Fr. Bus denotes Non Franchised Bus
SD Fr. Bus denotes Single Deck Franchised Bus
DD Fr. Bus denotes Double Deck Franchised Bus

PRDEZ 2010	2010 Annual Projected Emissions (tonnes/yr)				
	VOC	RSP	NO_x	SO_2	NH_3
Energy					
PRDEZ Power Generation	2,275	26,284	241,015	335,677	-
PRDEZ Commercial Fuel Use	24	20,990	37,803	40,097	-
PRDEZ Domestic Coal Consumption	5,989	2	2,662	9,087	-
PRDEZ Domestic LPG Consumption	176	3	2,378	180	-
PRDEZ Domestic Other Fuel Consumption	13	0	317	2,303	-
Industry					
PRDEZ Alcoholic Beverage Production	1,333	-	-	-	-
PRDEZ Chemicals/Rubber/Plastic	18,184	22,133	24,936	88,855	-
PRDEZ Construction	46	5,837	1,800	7,356	-
PRDEZ Electronic Manufacture	6	1,637	1,601	4,589	-
PRDEZ Food & Beverage	243	23,319	21,062	53,469	-
PRDEZ Gas, Water & Sanitary Works	16	1,295	247	4,490	-
PRDEZ Manufacture - Heavy	107	14,029	10,859	22,894	-
PRDEZ Manufacture - Light/Medium	245	47,704	43,386	127,989	-
PRDEZ Mining/Mineral Extraction	-	4,272	214	460	-
PRDEZ Non-Metallic Mineral Products	140	78,629	20,706	70,009	-
PRDEZ Oil Refinery	12,126	-	-	-	-
PRDEZ Petrol Distribution & Handling	14,842	-	-	-	-
PRDEZ Printing	37,034	795	93	345	-
PRDEZ Pulp and Paper Industries	17,230	-	-	-	-
PRDEZ Transportation	21	1,964	1,954	6,073	-
Transportation					
PRDEZ Motor Cycle	74,791	18,017	17,882	4,917	258
PRDEZ Small Petrol Vehicle	39,301	10,122	32,399	16,486	251
PRDEZ Large Petrol Vehicle	35,804	672	54,508	7,788	43
PRDEZ Diesel Goods Vehicle	20,001	6,199	66,775	4,383	22
PRDEZ Ports	146	439	17,698	4,422	-
PRDEZ Waters	130	351	14,163	3,548	-
PRDEZ Guangzhou Airport	354	-	3,313	138	-
PRDEZ Shenzhen Airport	200	-	887	66	-
PRDEZ Zhuhai Airport	18	-	105	9	-
PRDEZ Railway	5	4	142	17	-
VOC Containing Product					
PRDEZ Domestic Product	48,402	-	-	-	-
PRDEZ Paint	131,330	-	-	-	-
Others					
PRDEZ Agricultural Waste Burning	10,784	12,049	4,822	-	4,806
PRDEZ Agriculture	-	16	4	19	-
PRDEZ Ammonia Production	-	-	-	-	839
PRDEZ Animal Waste Ammonia	-	-	-	-	67,501
PRDEZ Dry Cleaning	201	-	-	-	-
PRDEZ Grain Drying	8,993	-	-	-	-
PRDEZ Human Sweat & Exhalation	-	-	-	-	5,407
PRDEZ Human Waste Rural Households	-	-	-	-	37,257
PRDEZ Human Waste Urban without Sanitary Facilities	-	-	-	-	1,483
PRDEZ Industrial Waste Incineration	-	-	-	-	-
PRDEZ Medical Waste Incineration	60	2,116	482	438	-
PRDEZ Nitrogen Fertiliser Production	-	-	-	-	12,232
PRDEZ Nitrogen Fertiliser Usage	-	-	-	-	90,298
PRDEZ Pesticide Application	23,816	-	-	-	-
PRDEZ Transportable Construction Dust	-	10,980	-	-	-
PRDEZ Transportable Paved Road Dust	-	11,907	-	-	-
PRDEZ Transportable Unpaved Road Dust	-	10,954	-	-	-
PRDEZ Biogenic	257,370	-	-	-	-
Total PRDEZ	761,756	332,718	624,212	816,104	220,397

Notes:
1. All emissions are rounded to the nearest whole tonne.
2. A value of "0" indicates emissions of greater than zero but less than 0.5 tonnes/year.
3. A value of "-" indicates emissions not quantified or no emissions.
4. Emission totals are not accurate to more than two significant figures.

HKSAR 2015	2015 Annual Projected Emissions (tonnes/yr)				
	VOC	RSP	NO_x	SO_2	NH_3
Energy					
HKSAR Power Generation	388	4,908	73,470	71,308	-
HKSAR Other Fuel Combustion	306	1,366	12,357	23,276	-
Industry					
HKSAR Cement Production	89	138	2,212	90	-
HKSAR Paint Manufacture	286	107	-	1,103	-
HKSAR Printing	14,977	13	137	486	-
HKSAR Service Station Refueling	2,375	-	-	-	-
HKSAR Textile Manufacturing	4	27	610	2,136	-
Transportation					
HKSAR Motor Cycle	2,552	13	205	-	1
HKSAR Taxi	576	37	2,022	-	3
HKSAR Private Car	3,089	236	4,552	-	18
HKSAR Pass. Van	120	49	445	6	0
HKSAR PLB	148	40	541	8	0
HKSAR LGV	1,325	307	3,196	52	4
HKSAR HGV	2,988	1,306	10,388	83	3
HKSAR Non Fr. Bus	231	94	1,182	7	0
HKSAR SD Fr. Bus	24	14	172	1	0
HKSAR DD Fr. Bus	375	219	2,650	12	0
HKSAR Marine Vessels - Harbour Area	379	448	13,687	3,105	-
HKSAR Marine Vessels - SAR Waters	200	321	12,791	3,264	-
HKSAR Airport	327	-	5,091	526	-
HKSAR Diesel Locomotives	25	4	122	11	-
VOC Containing Product					
HKSAR Domestic Product	27,004	-	-	-	-
HKSAR Paint	33,694	-	-	-	-
Others					
HKSAR Animal Waste Ammonia	-	-	-	-	11,200
HKSAR Dry Cleaning	761	-	-	-	-
HKSAR Fuel Terminals	2,415	-	-	-	-
HKSAR Human Sweat & Exhalation	-	-	-	-	2,036
HKSAR Nitrogen Fertiliser Usage	-	-	-	-	-
HKSAR Other Services	110	713	-	-	-
HKSAR Quarries	-	393	-	-	-
HKSAR Transportable Construction Dust	-	155	-	-	-
HKSAR Transportable Paved Road Dust	-	2,074	-	-	-
HKSAR Transportable Unpaved Road Dust	-	140	-	-	-
HKSAR Waste Incineration	17	35	25	31	-
HKSAR Biogenic	5,833	-	-	-	-
Total HKSAR	**100,619**	**13,156**	**145,856**	**105,506**	**13,267**

Notes:

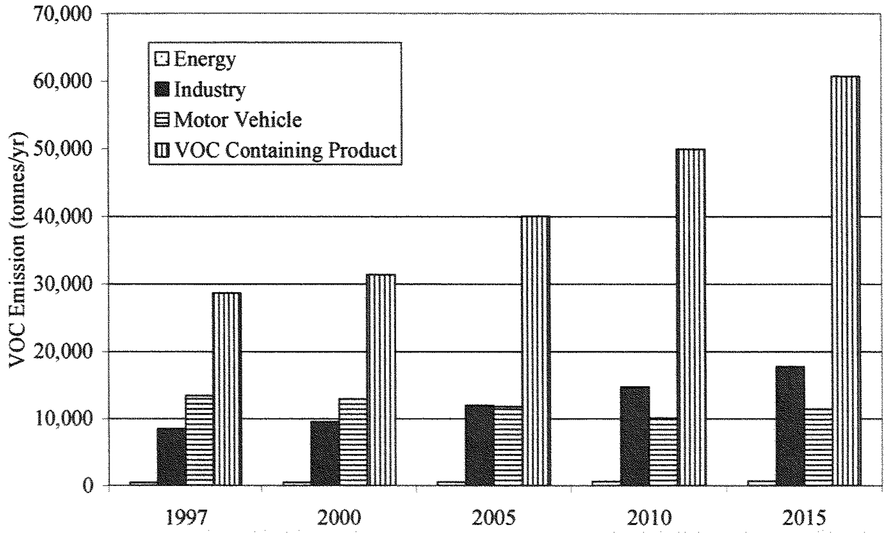
1. All emissions are rounded to the nearest whole tonne.
2. A value of "0" indicates emissions of greater than zero but less than 0.5 tonnes/year.
3. A value of "-" indicates emissions not quantified or no emissions.
4. Emission totals are not accurate to more than two significant figures.

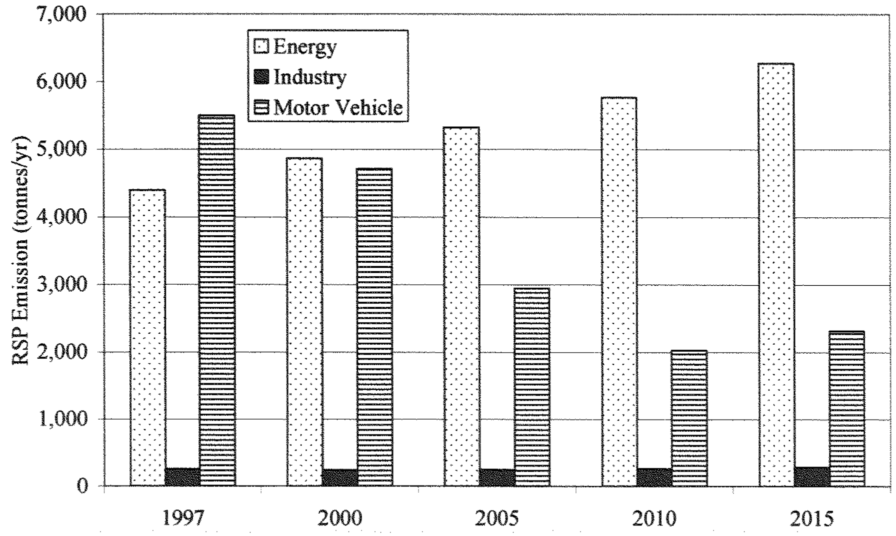
Key:
Pass. Van denotes Passenger Van,
PLB denotes Public Light Bus
LGV denotes Light Goods Vehicle
HGV denotes Heavy Goods Vehicle
Non Fr. Bus denotes Non Franchised Bus
SD Fr. Bus denotes Single Deck Franchised Bus
DD Fr. Bus denotes Double Deck Franchised Bus

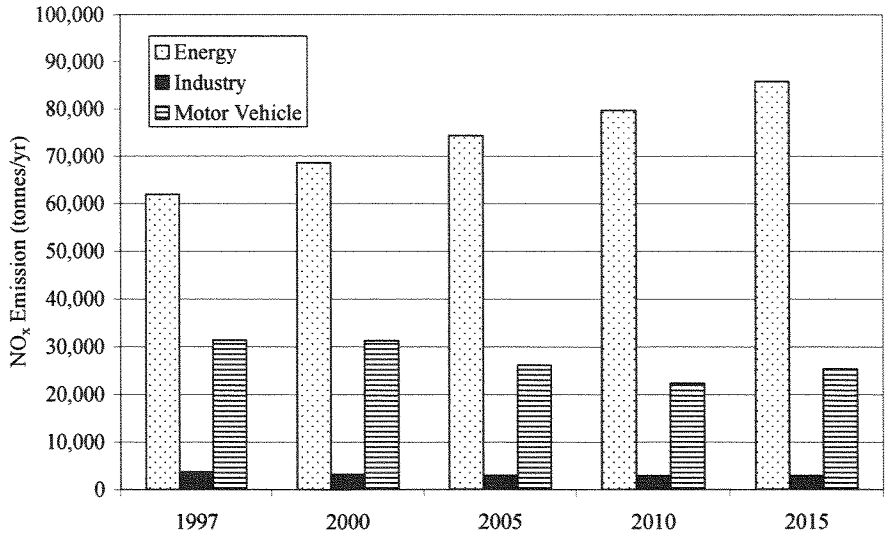
PRDEZ 2015	2015 Annual Projected Emissions (tonnes/yr)				
	VOC	RSP	NO_x	SO_2	NH_3
Energy					
PRDEZ Power Generation	2,624	27,940	265,846	354,784	-
PRDEZ Commercial Fuel Use	26	22,502	40,526	42,985	-
PRDEZ Domestic Coal Consumption	6,420	2	2,854	9,742	-
PRDEZ Domestic LPG Consumption	189	3	2,549	193	-
PRDEZ Domestic Other Fuel Consumption	14	0	340	2,469	-
Industry					
PRDEZ Alcoholic Beverage Production	1,855	-	-	-	-
PRDEZ Chemicals/Rubber/Plastic	25,314	30,811	34,713	123,694	-
PRDEZ Construction	42	5,353	1,651	6,747	-
PRDEZ Electronic Manufacture	8	2,279	2,229	6,388	-
PRDEZ Food & Beverage	331	31,700	28,632	72,685	-
PRDEZ Gas, Water & Sanitary Works	22	1,803	343	6,250	-
PRDEZ Manufacture - Heavy	150	19,530	15,116	31,870	-
PRDEZ Manufacture - Light/Medium	342	66,409	60,397	178,172	-
PRDEZ Mining/Mineral Extraction	-	5,948	298	640	-
PRDEZ Non-Metallic Mineral Products	122	68,687	18,088	61,158	-
PRDEZ Oil Refinery	16,880	-	-	-	-
PRDEZ Petrol Distribution & Handling	17,057	-	-	-	-
PRDEZ Printing	50,343	1,080	126	469	-
PRDEZ Pulp and Paper Industries	23,986	-	-	-	-
PRDEZ Transportation	29	2,669	2,657	8,256	-
Transportation					
PRDEZ Motor Cycle	49,467	8,040	14,262	2,114	260
PRDEZ Small Petrol Vehicle	31,233	11,111	32,283	13,155	417
PRDEZ Large Petrol Vehicle	7,153	564	30,902	3,839	49
PRDEZ Diesel Goods Vehicle	17,113	2,432	52,393	1,778	23
PRDEZ Ports	133	400	16,149	4,035	-
PRDEZ Waters	118	321	12,924	3,237	-
PRDEZ Guangzhou Airport	511	-	4,783	199	-
PRDEZ Shenzhen Airport	237	-	1,050	78	-
PRDEZ Zhuhai Airport	20	-	121	10	-
PRDEZ Railway	5	4	142	17	-
VOC Containing Product					
PRDEZ Domestic Product	67,379	-	-	-	-
PRDEZ Paint	182,823	-	-	-	-
Others					
PRDEZ Agricultural Waste Burning	8,565	9,570	3,830	-	3,818
PRDEZ Agriculture	-	13	3	15	-
PRDEZ Ammonia Production	-	-	-	-	667
PRDEZ Animal Waste Ammonia	-	-	-	-	53,613
PRDEZ Dry Cleaning	279	-	-	-	-
PRDEZ Grain Drying	7,143	-	-	-	-
PRDEZ Human Sweat & Exhalation	-	-	-	-	5,797
PRDEZ Human Waste Rural Households	-	-	-	-	39,940
PRDEZ Human Waste Urban without Sanitary Facilities	-	-	-	-	1,589
PRDEZ Industrial Waste Incineration	-	-	-	-	-
PRDEZ Medical Waste Incineration	64	2,269	517	470	-
PRDEZ Nitrogen Fertiliser Production	-	-	-	-	9,715
PRDEZ Nitrogen Fertiliser Usage	-	-	-	-	71,719
PRDEZ Pesticide Application	18,916	-	-	-	-
PRDEZ Transportable Construction Dust	-	11,421	-	-	-
PRDEZ Transportable Paved Road Dust	-	13,684	-	-	-
PRDEZ Transportable Unpaved Road Dust	-	12,589	-	-	-
PRDEZ Biogenic	257,370	-	-	-	-
Total PRDEZ	794,285	359,133	645,722	935,452	187,606

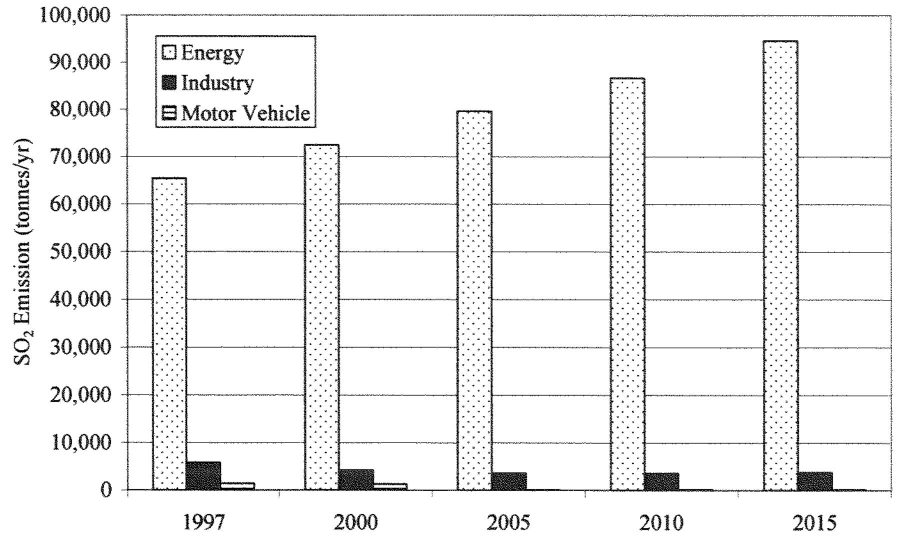
Notes:
1. All emissions are rounded to the nearest whole tonne.
2. A value of "0" indicates emissions of greater than zero but less than 0.5 tonnes/year.
3. A value of "-" indicates emissions not quantified or no emissions.
4. Emission totals are not accurate to more than two significant figures.

Appendix 4-D VOC, RSP, NO_x and SO_2 Emission Trends in the HKSAR

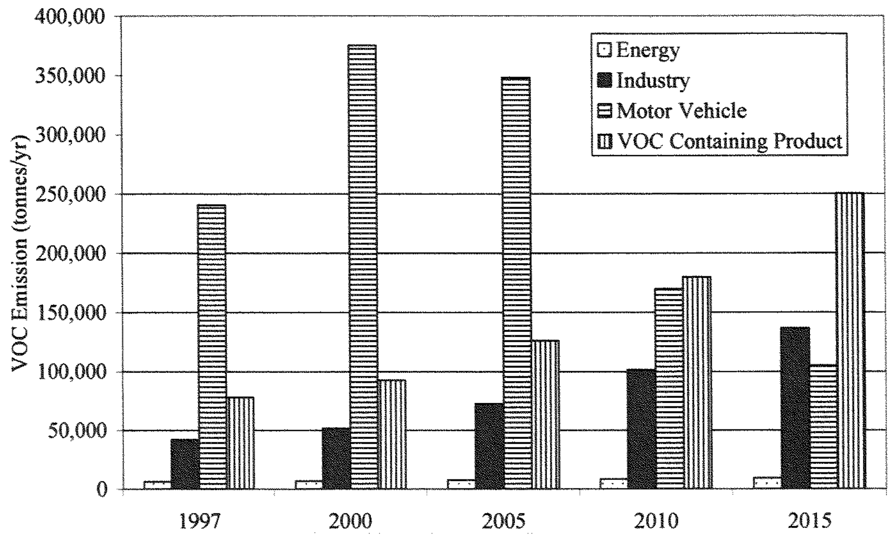


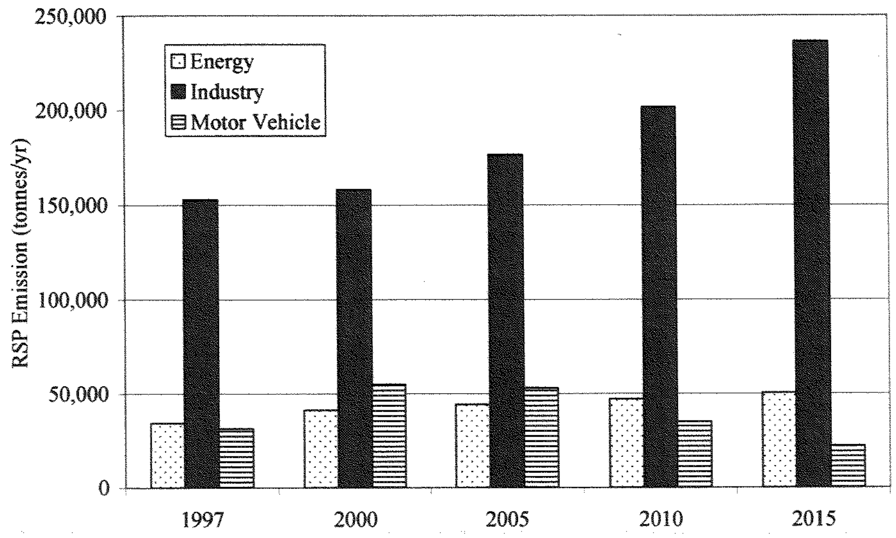


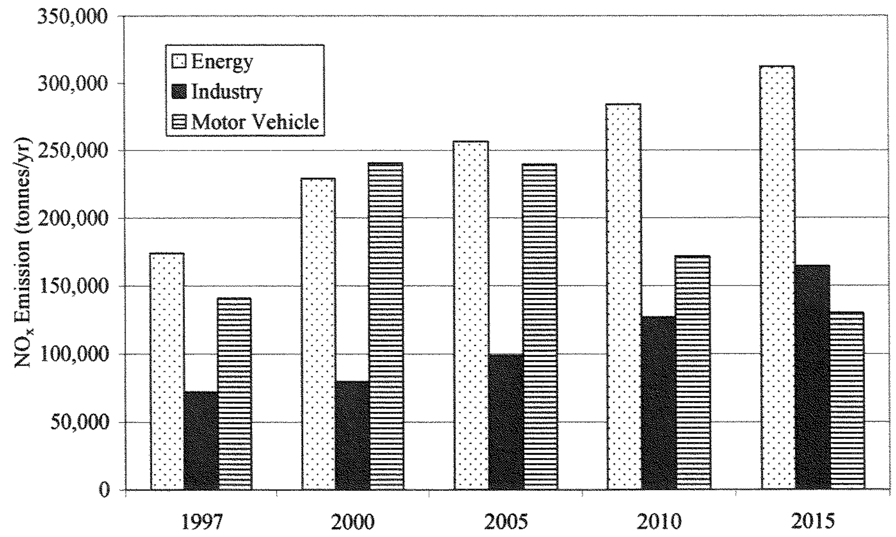


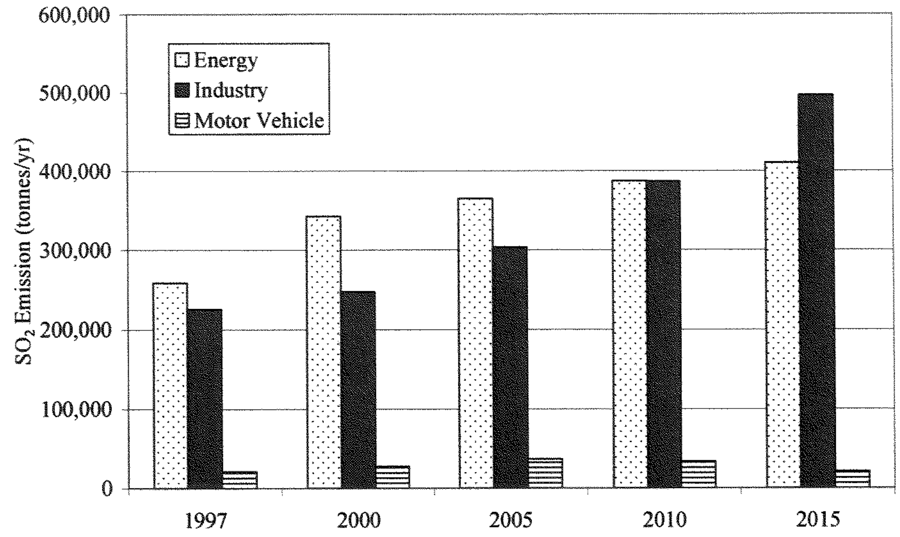


Appendix 4-E VOC, RSP, NO_x and SO_2 Emission Trends in the PRDEZ



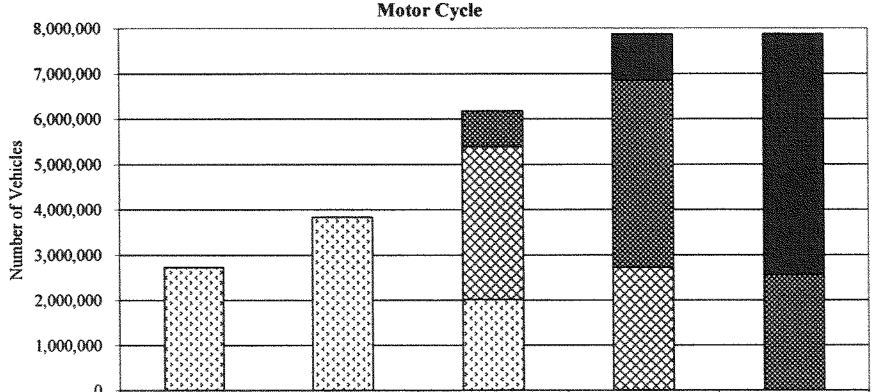






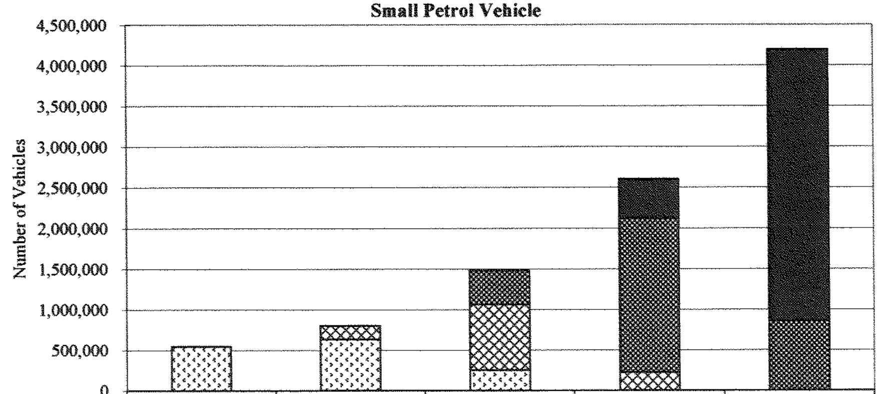
Appendix 4-F Emission Standard Distribution of Motor Vehicles in the PRDEZ

Motor Cycle



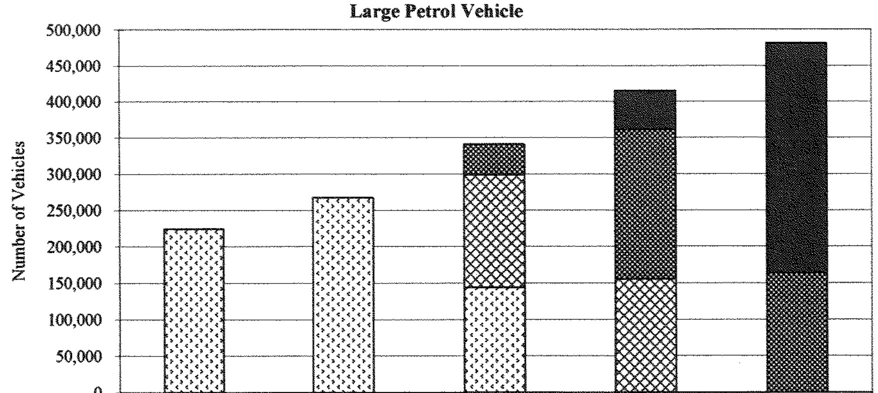
	1997	2000	2005	2010	2015
Euro 3				1,026,952	5,312,266
Euro 2			784,843	4,125,729	2,559,734
Euro 1			3,371,434	2,719,320	
Pre-Euro	2,726,000	3,830,000	2,011,723		

Small Petrol Vehicle



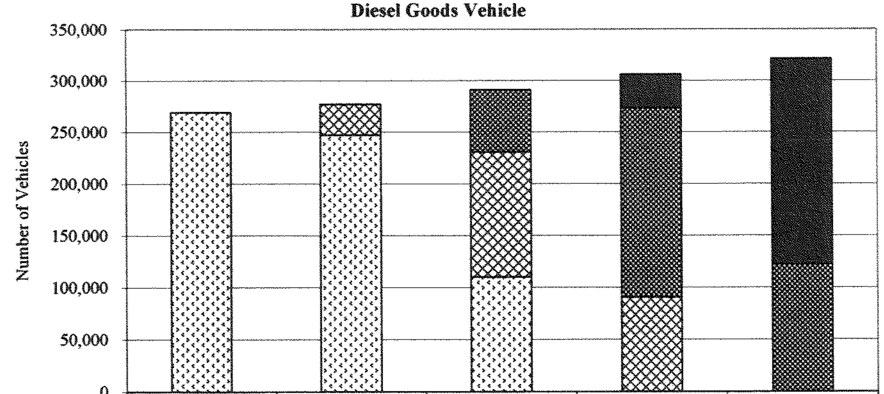
	1997	2000	2005	2010	2015
Euro 3				483,015	3,336,270
Euro 2			414,416	1,899,388	858,730
Euro 1		170,421	813,420	222,597	
Pre-Euro	547,000	631,579	250,164		

Large Petrol Vehicle



	1997	2000	2005	2010	2015
Euro 3				53,736	317,310
Euro 2			42,595	206,285	163,690
Euro 1			154,979	154,979	
Pre-Euro	224,000	267,000	143,426		

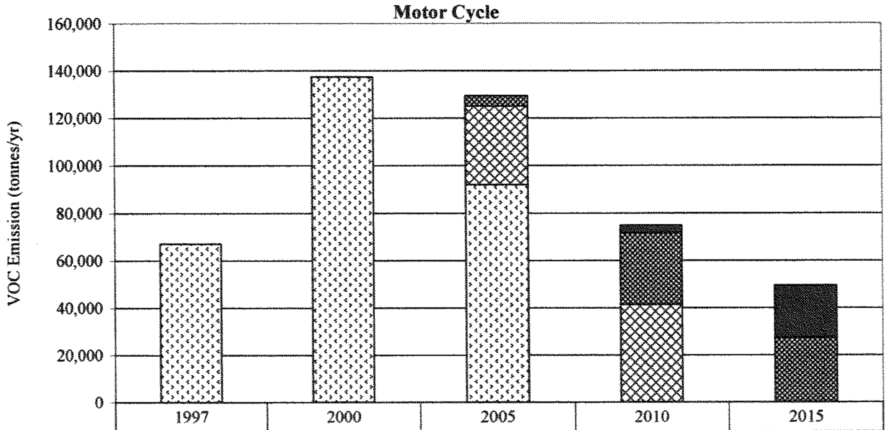
Diesel Goods Vehicle



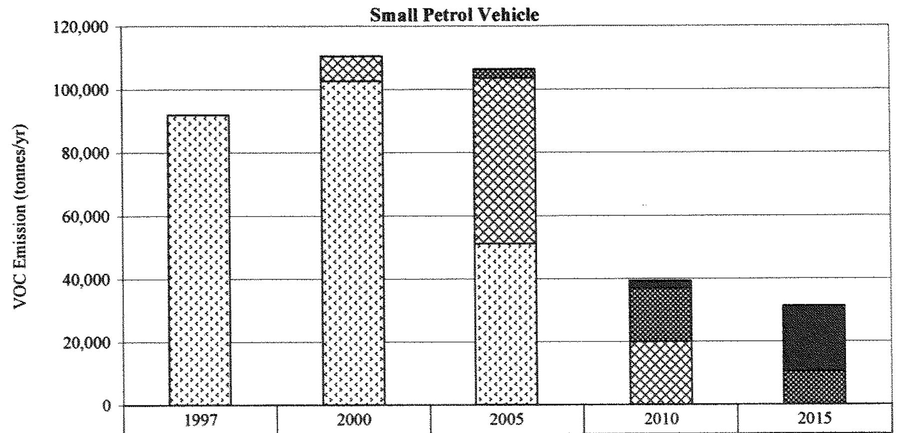
	1997	2000	2005	2010	2015
Euro 3				33,079	199,086
Euro 2			60,562	182,476	121,914
Euro 1		30,019	120,463	90,445	
Pre-Euro	269,000	246,981	109,974		

Small Petrol Vehicle includes passenger vehicles up to 20 seats; Large Petrol Vehicle includes passenger vehicles with more than 20 seats

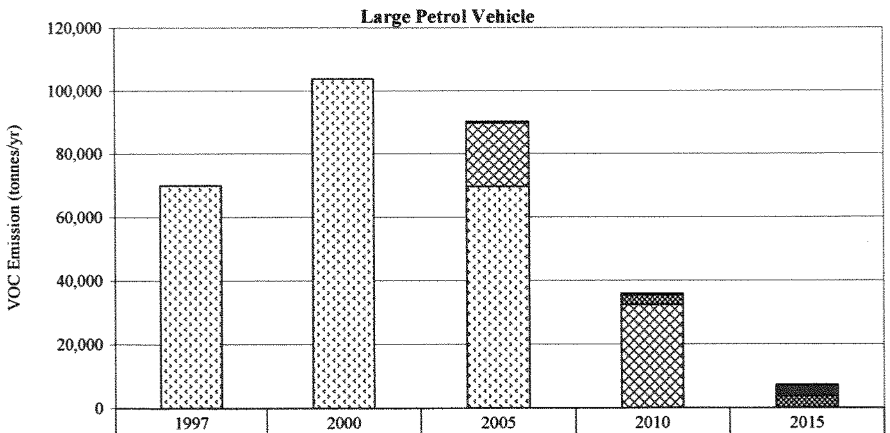
Appendix 4-G VOC Emission Distribution of Motor Vehicles in the PRDEZ



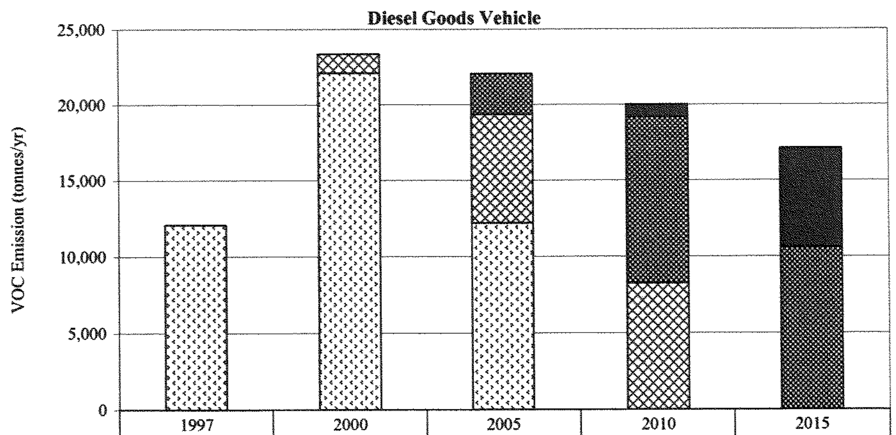
	1997	2000	2005	2010	2015
Euro 3				3,286	22,123
Euro 2			4,317	30,221	27,344
Euro 1			33,081	41,284	
Pre-Euro	66,886	137,503	92,003		



	1997	2000	2005	2010	2015
Euro 3				2,391	20,733
Euro 2			2,850	16,870	10,500
Euro 1		7,873	52,307	20,041	
Pre-Euro	91,892	102,623	51,144		



	1997	2000	2005	2010	2015
Euro 3				468	3,534
Euro 2			460	2,988	3,620
Euro 1			20,085	32,348	
Pre-Euro	69,885	103,761	69,536		

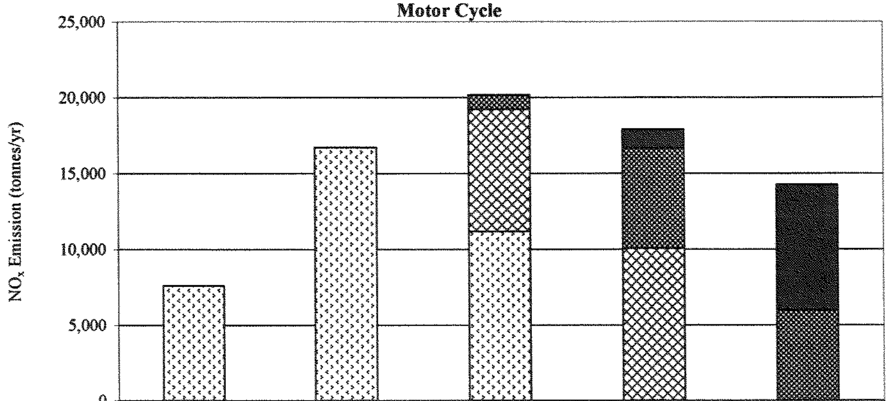


	1997	2000	2005	2010	2015
Euro 3				841	6,502
Euro 2			2,693	10,926	10,611
Euro 1		1,271	7,160	8,235	
Pre-Euro	12,063	22,084	12,184		

Small Petrol Vehicle includes passenger vehicles up to 20 seats; Large Petrol Vehicle includes passenger vehicles with more than 20 seats

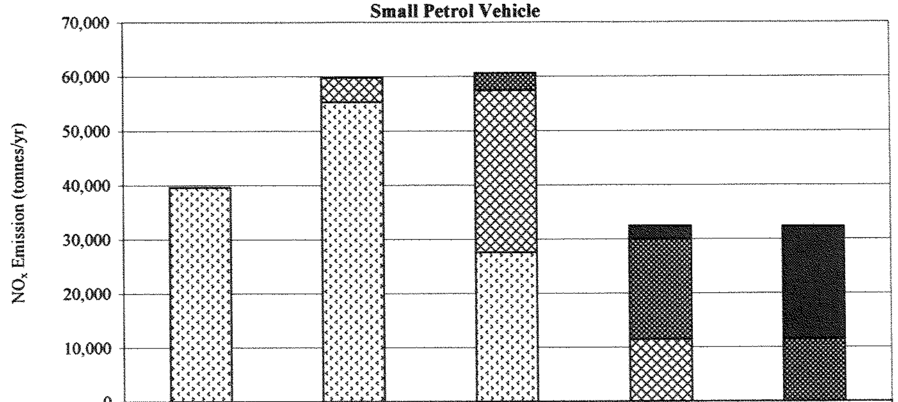
Appendix 4-H NO_x Emission Distribution of Motor Vehicles in the PRDEZ

Motor Cycle



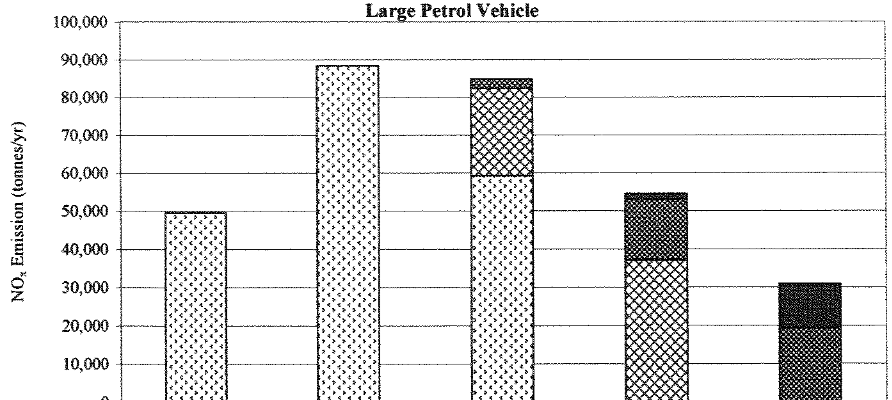
	1997	2000	2005	2010	2015
Euro 3				1,232	8,296
Euro 2			942	6,594	5,966
Euro 1			8,058	10,056	
Pre-Euro	7,601	16,701	11,174		

Small Petrol Vehicle



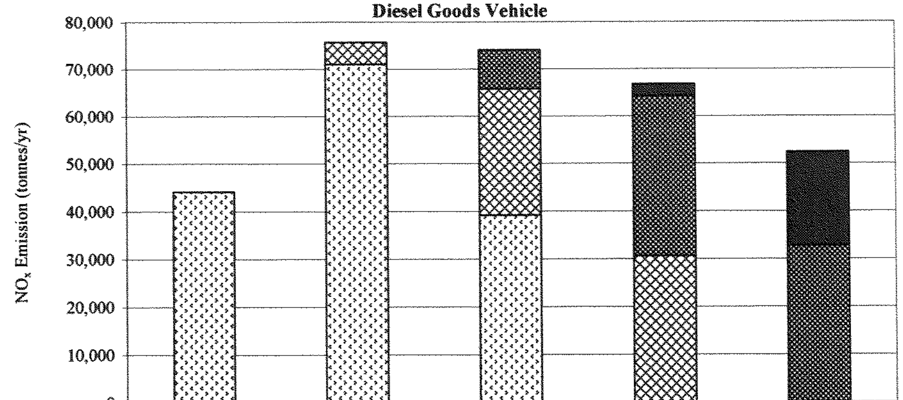
	1997	2000	2005	2010	2015
Euro 3				2,391	20,733
Euro 2			3,135	18,557	11,550
Euro 1		4,499	29,890	11,452	
Pre-Euro	39,571	55,306	27,563		

Large Petrol Vehicle



	1997	2000	2005	2010	2015
Euro 3				1,548	11,698
Euro 2			2,441	15,855	19,204
Euro 1			23,039	37,105	
Pre-Euro	49,560	88,371	59,222		

Diesel Goods Vehicle



	1997	2000	2005	2010	2015
Euro 3				2,547	19,703
Euro 2			8,296	33,659	32,690
Euro 1		4,719	26,581	30,568	
Pre-Euro	44,060	70,985	39,162		

Small Petrol Vehicle includes passenger vehicles up to 20 seats; Large Petrol Vehicle includes passenger vehicles with more than 20 seats

Appendix 5-A Maximum Acceptable VOC Levels in Paints for the US Army Pilot Project

Type of Paints	VOC Emission Levels (gram/litre)
Interior Architectural	
Flat	50
Non-flat	100
Exterior Architectural	
Flat	100
Non-flat	200
Anticorrosive	
Flat	250
Semi-gloss	250
Gloss	250

Appendix 5-B Emission Inventory of the Control Scenario for the Region

HKSAR Control Scenario	Control Scenario Emissions (tonnes/yr)				
	VOC	RSP	NO_x	SO_2	NH_3
Energy					
HKSAR Power Generation	204	2,088	34,616	28,362	-
HKSAR Other Fuel Combustion	34	341	1,989	3,821	-
Industry					
HKSAR Cement Production	89	138	2,212	90	-
HKSAR Paint Manufacture	235	88	-	907	-
HKSAR Printing	1,231	10	113	400	-
HKSAR Service Station Refueling	105	-	-	-	-
HKSAR Textile Manufacturing	4	28	625	2,187	-
Transportation					
HKSAR Motor Cycle	2,271	12	183	-	1
HKSAR Taxi	513	33	1,800	-	3
HKSAR Private Car	2,749	210	4,051	-	16
HKSAR Pass. Van	109	44	402	6	0
HKSAR PLB	136	37	498	7	0
HKSAR LGV	1,189	276	2,867	47	3
HKSAR HGV	2,543	1,111	8,842	71	3
HKSAR Non Fr. Bus	209	85	1,068	6	0
HKSAR SD Fr. Bus	23	13	163	1	0
HKSAR DD Fr. Bus	355	207	2,509	11	0
HKSAR Marine Vessels - Harbour Area	358	406	12,027	2,684	-
HKSAR Marine Vessels - SAR Waters	171	278	11,066	2,823	-
HKSAR Airport	287	-	3,963	463	-
HKSAR Diesel Locomotives	25	4	122	11	-
VOC Containing Product					
HKSAR Domestic Product	2,220	-	-	-	-
HKSAR Paint	2,769	-	-	-	-
Others					
HKSAR Animal Waste Ammonia	-	-	-	-	11,200
HKSAR Dry Cleaning	626	-	-	-	-
HKSAR Fuel Terminals	595	-	-	-	-
HKSAR Human Sweat & Exhalation	-	-	-	-	1,933
HKSAR Nitrogen Fertiliser Usage	-	-	-	-	85
HKSAR Other Services	90	586	-	-	-
HKSAR Quarries	-	393	-	-	-
HKSAR Transportable Construction Dust	-	127	-	-	-
HKSAR Transportable Paved Road Dust	-	1,841	-	-	-
HKSAR Transportable Unpaved Road Dust	-	124	-	-	-
HKSAR Waste Incineration	17	35	25	31	-
HKSAR Biogenic	5,833				
Total HKSAR	24,991	8,515	89,141	41,927	13,246

Notes:
1. All emissions are rounded to the nearest whole tonne.
2. A value of "0" indicates emissions of greater than zero but less than 0.5 tonnes/year.
3. A value of "-" indicates emissions not quantified or no emissions.
4. Emission totals are not accurate to more than two significant figures.

Key:
Pass. Van denotes Passenger Van,
PLB denotes Public Light Bus
LGV denotes Light Goods Vehicle
HGV denotes Heavy Goods Vehicle
Non Fr. Bus denotes Non Franchised Bus
SD Fr. Bus denotes Single Deck Franchised Bus
DD Fr. Bus denotes Double Deck Franchised Bus

PRDEZ Control Scenario	Control Scenario Emissions (tonnes/yr)				
	VOC	RSP	NO_x	SO_2	NH_3
Energy					
PRDEZ Power Generation	1,795	1,900	90,654	36,171	-
PRDEZ Commercial Fuel Use	12	10,495	18,901	20,049	-
PRDEZ Domestic Coal Consumption	60	0	27	91	-
PRDEZ Domestic LPG Consumption	176	3	2,378	180	-
PRDEZ Domestic Other Fuel Consumption	13	0	317	2,303	-
Industry					
PRDEZ Alcoholic Beverage Production	133	-	-	-	-
PRDEZ Chemicals/Rubber/Plastic	1,818	2,213	12,468	53,313	-
PRDEZ Construction	46	584	900	4,414	-
PRDEZ Electronic Manufacture	6	164	801	2,753	-
PRDEZ Food & Beverage	243	2,332	10,531	32,081	-
PRDEZ Gas, Water & Sanitary Works	16	130	123	2,694	-
PRDEZ Manufacture - Heavy	107	1,403	5,429	13,736	-
PRDEZ Manufacture - Light/Medium	245	4,770	21,693	76,794	-
PRDEZ Mining/Mineral Extraction	-	427	107	276	-
PRDEZ Non-Metallic Mineral Products	140	7,863	10,353	42,005	-
PRDEZ Oil Refinery	1,213	-	-	-	-
PRDEZ Petrol Distribution & Handling	742	-	-	-	-
PRDEZ Printing	3,703	79	46	207	-
PRDEZ Pulp and Paper Industries	1,723	-	-	-	-
PRDEZ Transportation	21	196	977	3,644	-
Transportation					
PRDEZ Motor Cycle	54,057	12,453	15,409	3,577	213
PRDEZ Small Petrol Vehicle	35,525	7,910	27,073	10,497	252
PRDEZ Large Petrol Vehicle	35,110	644	45,735	6,161	43
PRDEZ Diesel Good Vehicle	17,111	5,797	58,456	4,107	22
PRDEZ Ports	146	439	17,698	4,422	-
PRDEZ Waters	130	351	14,163	3,548	-
PRDEZ Guangzhou Airport	354	-	3,313	138	-
PRDEZ Shenzhen Airport	200	-	887	66	-
PRDEZ Zhuhai Airport	18	-	105	9	-
PRDEZ Railway	5	4	142	17	-
VOC Containing Product					
PRDEZ Domestic Product	4,840	-	-	-	-
PRDEZ Paint	13,133	-	-	-	-
Others					
PRDEZ Agricultural Waste Burning	10,784	12,049	4,822	-	4,806
PRDEZ Agriculture	-	16	4	19	-
PRDEZ Ammonia Production	-	-	-	-	839
PRDEZ Animal Waste Ammonia	-	-	-	-	67,501
PRDEZ Dry Cleaning	201	-	-	-	-
PRDEZ Grain Drying	8,993	-	-	-	-
PRDEZ Human Sweat & Exhalation	-	-	-	-	5,407
PRDEZ Human Waste Rural Households	-	-	-	-	37,257
PRDEZ Human Waste Urban without Sanitary Facilities	-	-	-	-	1,483
PRDEZ Industrial Waste Incineration	-	-	-	-	-
PRDEZ Medical Waste Incineration	60	212	241	263	-
PRDEZ Nitrogen Fertiliser Production	-	-	-	-	12,232
PRDEZ Nitrogen Fertiliser Usage	-	-	-	-	90,298
PRDEZ Pesticide Application	2,382	-	-	-	-
PRDEZ Transportable Construction Dust	-	10,980	-	-	-
PRDEZ Transportable Paved Road Dust	-	11,907	-	-	-
PRDEZ Transportable Unpaved Road Dust	-	10,954	-	-	-
PRDEZ Biogenic	257,370	-	-	-	-
Total PRDEZ	452,632	106,275	363,752	323,535	220,353

Notes:
1. All emissions are rounded to the nearest whole tonne.
2. A value of "0" indicates emissions of greater than zero but less than 0.5 tonnes/year.
3. A value of "-" indicates emissions not quantified or no emissions.
4. Emission totals are not accurate to more than two significant figures.