TECHNICAL ANNEX 4

Design and Methodology of the Base Year Emission Inventories

TABLE OF CONTENTS

List of Tables

1. HKSAR BASE YEAR INVENTORY METHDOLOGY

1.1 HKSAR Emission Inventory Methodology Summary

1.1.1 In HKSAR, three approaches were employed for the formulation of the base year emission inventory. The first approach is direct computation of emissions from activity data and emission factors representative of the base year. This method was applied to power plants, industrial, mobile, domestic, commercial and rural sources.

1.1.2 The second approach is to project PATH emissions from 1995 to 1997 using the activity factors characteristic of the emission category (i.e., activity-based projection). For example, the number of vehicles in HKSAR in 1995 and 1997 is a very good surrogate for the vehicle refuelling source emission category.

1.1.3 The third approach is used for source categories with small emission totals. In this approach, the 1997 emissions were projected from 1995 PATH value to 1997 using the growth in population in HKSAR between the two years (5.62%).

1.1.4 For all significant domestic and commercial sources, such as VOC emission, effective emission factors developed in PATH were used by applying 1997 official activity data sources. The effective emission factor is the average emission factor for a source category computed as the total category emission rate divided by the applicable composite 1995 activity data. When the effective emission factor is multiplied by the new year activity data, a projected emission estimate is obtained. For this study, this method is called an activity-based projection.

1.1.5 Past experience suggested that all emission inventories have inherent, unquantified uncertainties, which account for at least 10% of the emission totals. To increase the accuracy of the emission inventory, direct computation was used as far as possible. Table 1-1 presents a listing of the methodology employed for each source category.

Table 1-1 Base Year HKSAR Emission Inventory Methodology for Computation of Emissions

Source Sector	Methodology
Major Point Sources	
Power Generation	Direct Calculation
Incinerators	Direct Calculation
Printing	Activity-Based Projection
Cement Production	Direct Calculation
Paint Manufacturing	Population-Based Projection
Textile Manufacturing	Activity-Based Projection
Waste Incineration	Direct Calculation
Fuel Consumption (Military/Domestic/Commercial/Industrial)	Direct Calculation
Mobile Sources	
Motor Vehicles	Direct Calculation
Marine Vessels	Direct Calculation
Aircrafts	Direct Calculation
Railways	Direct Calculation
Domestic, Commercial and Rural Sources	
Animal Waste Ammonia	Direct Calculation
Human Sweat & Exhalation Ammonia	Direct Calculation
Nitrogen Fertiliser Application Ammonia	Direct Calculation
Paved and Unpaved Road Dust	Direct Calculation
Dry Cleaning	Direct Calculation
Fuel Terminals	Activity-Based Projection
Quarries	Activity-Based Projection
Petrol Handling and Distribution	Activity-Based Projection
Domestic solvent use	Activity-Based Projection
Construction Dust	Population-Based Projection
Paint Application	Activity-Based Projection

1.2 HKSAR Base Year Major Point Emission Estimation

1.2.1 There are two major sectors under point sources, namely specified processes and other industrial operations. The specified processes were designated under the Air Pollution Control (Specified Processes) Regulations which including thirty one processes such as power generation, cement, chlorine, petrochemical and gas works etc. Parameters for the industrial emission sources collected are listed in Table 1-2 below.

Table 1-2 HKSAR Source Database for Specified Processes for the Base Year Emission Inventory

	Description of the Industrial Source Data
1	Name, location and capacity of the facility
2	Facility type in accordance to the Hong Kong Industrial Code
3	Predominant fuel type and consumption
4	Maximum pollutant emission rate
5	Chimney height
6	Minimum efflux velocity
7	Stack diameter
8	Exhaust temperature
9	Information on control equipment
10	Operation hours
11	Reference key of every industrial emission source

1.2.2 For power generation, 1997 plant activity information, fuel usage and stack monitoring data were used for estimating emissions, provided by each of the power plants operated by the CLP Power Hong Kong Limited and Hong Kong Electric Co. Ltd. The total power plant emission was allocated to each chimney in proportion to the allocation of emission between chimneys in the 1995 PATH emission inventory.

1.2.3 Textile manufacturing emission for HKSAR in 1997 was estimated from 1995 and 1997 employment in the textile manufacturing industry and the effective emission factor from the PATH 1995 inventory. The above two source categories are responsible for the bulk of the point source emission in HKSAR. For all other industrial sources, emissions were projected to 1997 based upon the PATH 1995 emission rate. A summary of the data collection and emission estimation methodology for point sources is given in Table 1-3.

1.2.4 For those sources for which the data in Table 1-3 are used, the growth from 1995 to 1997 were estimated as a 2-year linear interpolation in the growth rate over the four year period, 1994 to 1998, for the most appropriate point sector.

1.2.5 No surrogates were used to project key point source categories including power generation, textile manufacturing, and printing. These source categories account for at least 90% of point source emissions for SO_2, VOC, and NO_x. The remaining source categories, responsible for a small portion of the anthropogenic emission inventory, were estimated for 1997 using direct computation or projected from 1995 to 1997 using population growth, industry-specific sector census data, or production data obtained from Census and Statistics Department of the HKSAR Government. Industrial employment growths in HKSAR between 1994 and 1999 are shown in Table 1-4.

Table 1-3 Inventory Construction for HKSAR Point Source Emissions

Sector	Sub-Sector	Activity Data Collection[#]	Emission Factor Estimation Techniques
Specified Process	31 types of industry 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	Environmental data base and information provided by EPD and plant owners with the following parameters: Name, location and capacity of the facility Facility type in accordance to the Hong Kong Standard Industrial Classification Predominant fuel type and consumption Maximum pollutant emission rate Chimney height Minimum efflux velocity Stack diameter Exhaust temperature Information on control equipment Operation hours Reference key of every industrial emission source	Pollutants involved: SO_2, NO_x, RSP, and VOC Sources are a small proportion of the industrial source inventory. Estimation technique: For VOC, projection based on PATH inventory. For combustion emissions, direct computation of fuel combustion emissions using overall Hong Kong fuel consumption statistics. Direct computation of cement works SO_2 and NO_x emissions based upon stack monitoring.
	Electricity Works: power plants operated by CLP Power Hong Kong Limited and the Hong Kong Electric Co. Ltd	The same as above and direct measurement of stack monitoring data provided by the plant operators	Direct computation of emissions based on fuel consumption data and current emission factors.
Industrial Operations	Process capacity within the exemption limit of the specified processes and other stationary fuel used operation	From EPD environmental database.	Pollutants involved: SO_2, NO_x, RSP, and VOC Estimation technique: Projection based on PATH inventory for the dominant source categories.
Printing		Hong Kong Annual Digest of Statistics Sector employment figures	Activity based estimation methodology based upon 1995 and 1998 employment data and effective emission factor from 1995 PATH inventory.

*Note: * not yet enforced*
[#] Where available and applicable

Table 1-4 Number of Persons Engaged by Major Source Sectors (thousands)

Industry sector	1994	1998	1999
All industry sectors(1)	2 381.0 (+3.7)	2180.5 (-6.5)	2,242.4 (+2.8)
Mining and quarrying	0.5 (+14.3)	0.5 (+10.5)	0.3 (-25.1)
Manufacturing	438.4 (-13.7)	257.0 (-16.9)	244.5 (-4.9)
Electricity and gas	11.8 (-1.7)	9.1 (-6.7)	8.9 (-2.6)
Construction sites (manual workers only)	60.4 (+15.7)	75.8 (-2.9)	68.7 (-9.4)
Wholesale, retail and import/export trades, restaurants and hotels(1)	1,051.2 (+9.7)	946.6 (-7.8)	997.5 (+5.4)
Transport, storage and communications(1)	166.0 (+8.3)	169.6 (-4.5)	175.6 (+3.6)
Financing, insurance, real estate and business services	361.1 (+7.5)	398.1 (-4.3)	406.9 (+2.2)
Community, social and personal services(1)	291.7 (+5.9)	323.9 (+3.2)	340.0 (+5.0)

Notes: Figures refer to September of the year.

(1) Figures refer only to those selected industries covered in the Quarterly Survey of Employment and Vacancies, and the Quarterly Employment Survey of Construction Sites.

1.2.6 The 1997 EPD inventory contains direct computation of combustion emissions for all power stations and three other industrial sources. Also included in the EPD 1997 inventory is emission for military, government, commercial, industrial, and domestic fuel combustion. All the industrial combustion emissions are based upon 1997 fuel usage for each source. The three other stationary industrial sources are the Kwai Chung and Enviropace Limited incinerators and a cement kiln. The Kwai Chung incinerator only operated part of the year in 1997.

1.2.7 A continuous emission monitor (CEM) measuring SO_2 and NO_x emission was in operation at the cement kiln. The average hourly mass flow of SO_2 and NO_x, as measured by the CEM, was used to estimate SO_2 and NO_x emissions for the kiln.

1.2.8 The EPD 1997 inventory included 1997 fuel consumption in HKSAR for non-aviation kerosene, non-motor vehicle diesel oil, gas oil, number three oil, liquid petroleum gas (LPG) and town gas. Appropriate emission factors for combustion of these fuels by military, governmental, commercial, industrial, and domestic users were also contained in the EPD inventory.

1.2.9 All emission computations for industrial fuel combustion and the cement kiln follow the computations performed by EPD for the 1997 inventory and used the EPD emission factors.

1.2.10 To prevent double counting of combustion emission from the industrial fuel use, the fuel used by specific source categories was subtracted from total fuel use prior to computation of emission. Table 1-5 presents the source categories for which fuel use subtracted from total fuel use prior to computation of fuel combustion emissions. In addition, there are two source categories for which emissions did not directly computed since emissions for the source category were indirectly included in the fuel use emission computation. These source categories are also presented in Table 1-5.

Table 1-5 Sources Considered in Preventing Double Counting of Fuel Combustion Emissions

Source Considered	Action
Cement Kiln	Fuel Use Subtracted Prior to Computation of Emission
Kwai Chung Incinerator	Fuel Use Subtracted Prior to Computation of Emission
Enviropace Limited Incinerator	Fuel Use Subtracted Prior to Computation of Emission
Marine Ferries	Fuel Use Subtracted Prior to Computation of Emission
Locomotives	Fuel Use Subtracted Prior to Computation of Emission
Airport Ground Equipment	Not Computed Since Indirectly in Fuel Use Computation
Construction Diesel Equipment	Not Computed Since Indirectly in Fuel Use Computation

1.3 HKSAR Base Year Mobile Source Emission Estimation

1.3.1 The emission from mobile sources are mainly divided into two sectors, on-road and off-road. Motor vehicular emissions are classified under the on-road category. Railway, aviation, and vessel movements are off-road mobile sources. A summary of the data collection and emission estimation methodology for mobile sources in HKSAR is given in Table 1-6.

1.3.2 Current and future motor vehicle emissions in HKSAR are available in the Strategic Environmental Assessment (SEA) report of the Third Comprehensive Transport Study (CTS3) (TD, 1999). This Study is the most recent approved government study analysing motor traffic in HKSAR and contains consistent projections of motor vehicle emission for all districts under a number of future scenarios through 2016. The base year for motor vehicle emission in the CTS3 is 1997 and from which traffic emission was estimated directly.

1.3.3 Annual vehicle-kilometres-travelled (VKT) were obtained for 18 districts in HKSAR. VKT of the 18 districts is then sub-divided into 10 vehicles categories in accordance to the CTS3 classification as shown in Table 1-7. The length of paved and unpaved roads within the territory was extracted from the Traffic Census.

1.3.4 Motor vehicle emissions were computed as the summation of emission factor times VKT over all vehicle classes and districts in HKSAR. The 1997 VOC, RSP, and NO_x emission factors used in the CTS3 study were used. For SO_2, emissions were computed as the VKT divided by mean fuel economy for each vehicle class times the mean sulphur content of the fuel (0.05% S for diesel and 0.005% S for petrol), adjusted to reflect SO_2 rather than S emissions.

1.3.5 All exhaust particulate emissions were assumed to be RSP, consistent with the combustion nature of motor vehicle emissions. VOC emissions were assumed to be 100% of hydrocarbon emissions for petrol vehicles and 88% for diesel vehicles, consistent with California Air Resources Board speciation factors for diesel exhaust (CARB, 1991).

1.3.6 For marine emission, 1997 shipping activity data for Victoria Harbour and HKSAR waters were collected from Hong Kong Marine Department, Hong Kong Port and Maritime Board, port related organisations and Hong Kong Annual Digest of Statistics. Statistics for inward and outward movement of vessels in terms of vessel types were obtained. Shipping lanes for marine traffic were obtained from Marine Department.

1.3.7 For all vessels except HKSAR ferries, emission factors were estimated using the most recent vessel emission factor methodology developed by Sierra Research for USEPA (EPA, 2000). For HKSAR ferries, fuel use statistics were used to estimate vessel emissions using current EPD emission factors for ferry emissions.

1.3.8 To obtain more port specific engine size for all vessel movements within HKSAR Waters, Marine Department has provided the port call statistics for various vessel Gross Registered Tonnage (GRT) classifications (GRT is broadly, the capacity of a ship in cubic feet of the space within the hull, and of the enclosed space above the deck available for cargo, stores, fuel, passengers and crew, with certain exceptions, divided by 100). By using these statistics, the vessel engine size could be referenced to the Corinair report (EMEP/CORINAIR, 2000).

1.3.9 Based on the port call statistics, relevant vessel engine sizes were made reference to the information presented in the Corinair report (EMEP/CORINAIR, 2000). Emission calculation for marine movement were based on the methodology presented in the USEPA document "Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data (EPA420-R-00-002 dated February 2000).

1.3.10 For the purpose of summarising emissions, emissions were computed separately for Victoria Harbour and adjoining mooring locations and also for the remainder of the HKSAR waters. In addition, emissions in international shipping lanes were also computed separately.

Table 1-6 Inventory Construction for HKSAR Mobile Source Emissions

Sector	Sub-Sector	Activity Data Collection	Emission Factor Estimation Techniques
On-Road	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; and Length of paved and unpaved road	
Off-Road	Marine	Marine Department (MD), Hong Kong Port and Maritime Board, Port Development Board, Hong Kong Annual Digest of Statistics and port related organisations: Inward and outward movement of vessels in terms of vessel types; Shipping lanes for marine traffic; and Port call statistics for various vessel GRT classifications	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): Diesel fuel usage for locomotives; and 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 and Shun Tak Heliport	Civil Aviation Department 1995 and 1997: 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; and Helicopter movement data from the Central Heliport and Shun Tak Heliport.	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

Table 1-7 1997 Base Year HKSAR VKT for 18 Districts

	HKSAR 1997 Annual Average Vehicle Kilometer Traveled by District (km/yr)										
District	**Motor Cycle**	**Private Car**	**Taxi**	**Pass. Van**	**PLB**	**LGV**	**HGV**	**Non Fr. Bus**	**SD Fr. Bus**	**DD Fr. Bus**	**Totals**
Central & Western	11,854,410	183,119,436	127,161,598	8,888,118	18,305,480	79,988,866	32,333,438	6,297,459	956,868	14,703,822	483,609,495
Wan Chai	11,976,779	185,009,714	139,195,904	9,216,470	14,447,430	50,374,412	17,665,267	6,530,104	823,684	12,657,226	447,896,990
Eastern	14,543,314	224,655,932	157,732,305	9,394,530	15,481,840	71,608,231	26,027,867	6,656,265	728,478	11,194,247	538,023,009
Southern	10,671,282	164,843,231	77,612,344	10,454,016	18,205,835	53,127,628	14,235,137	7,406,938	938,090	14,415,270	371,909,771
Yau Tsim Mong	14,038,576	216,859,055	138,536,663	11,709,307	16,234,105	97,639,648	41,857,877	8,296,343	1,306,020	20,069,110	566,546,704
Sham Shui Po	15,132,447	233,756,490	103,935,119	9,785,528	19,523,120	151,476,065	78,148,628	6,933,297	1,061,440	16,310,735	636,062,870
Kowloon City	16,707,552	258,087,716	208,941,513	11,231,834	21,598,145	113,435,433	42,240,261	7,958,041	1,076,337	16,539,658	697,816,490
Kwun Tong	22,546,351	348,281,787	167,053,656	12,956,398	20,393,645	159,644,941	55,315,421	9,179,939	1,426,136	21,914,884	818,713,159
Wong Tai Sin	8,441,837	130,404,163	77,650,100	4,870,600	11,777,455	74,379,549	28,444,145	3,450,944	627,966	9,649,704	349,696,463
Kwai Tsing	33,044,705	510,453,727	141,674,166	26,125,278	48,683,700	347,052,182	251,097,700	18,510,426	2,444,713	37,566,952	1,416,653,549
Tuen Mun	25,384,017	392,116,269	64,780,200	11,222,733	23,040,990	218,988,800	202,412,314	7,951,593	2,311,907	35,526,183	983,735,006
Island	2,797,896	43,220,136	3,949,008	3,114,791	-	79,248,783	21,996,669	2,206,909	212,935	3,272,085	160,019,212
Yuen Long	10,260,773	158,501,941	35,223,084	5,646,103	27,660,430	117,373,707	113,212,707	4,000,409	541,324	8,318,321	480,738,799
Tai Po	20,212,181	312,225,001	52,058,928	9,579,969	12,031,860	205,365,792	141,833,742	6,787,653	590,165	9,068,830	769,754,121
North	4,626,526	71,467,652	12,687,546	2,843,304	9,097,990	56,655,426	49,329,624	2,014,554	207,582	3,189,838	212,120,042
Sha Tin	40,102,932	619,484,772	162,352,146	23,361,445	17,746,300	306,357,376	176,534,120	16,552,181	2,134,833	32,805,157	1,397,431,262
Sai Kung	4,258,174	65,777,588	16,735,104	2,266,491	3,908,420	26,821,725	7,322,127	1,605,867	235,749	3,622,666	132,553,911
Tsuen Wan	6,986,672	107,925,694	14,758,848	3,932,328	12,370,945	100,384,837	95,299,109	2,786,154	256,110	3,935,550	348,636,247
Total	273,586,425	4,226,190,303	1,702,038,231	176,599,244	310,507,690	2,309,923,402	1,395,306,154	125,125,075	17,880,339	274,760,236	10,811,917,098

1.3.11 Hong Kong Kai Tak International Airport was the only operating civil airport in 1997. The 1995 and 1997 airport activity data were obtained from Civil Aviation Department including 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 (LTO). The 1997 LTO data were used, along with the emission factors for different aircraft type from USFAA Aircraft Engine Emissions Database (FAEED) Version 2.1 (Nov 95) to compute the aviation NO_x, SO_2, and VOC. Time in Mode was taken from the PATH Project (which in turn relied on default time in mode values defined by the USFAA for typical US airports). Ground equipment emissions were not computed directly, since emission from these sources was indirectly contained within the domestic/commercial/industrial fuel combustion computation for HKSAR.

1.3.12 Helicopter movement data from the Central Heliport and Shun Tak Heliport were also obtained from Civil Aviation Department. However, no information was gathered for Shek Kong Airport as its operation is considered to be very limited.

1.3.13 Emissions from diesel locomotives were computed directly using diesel fuel usage for KCRC and MTRC locomotives. The PATH line-haul locomotive emission factors specific for the two types of line-haul locomotives in use by MTRC (4-stroke turbocharged) and KCRC (2-stroke supercharged) were used. MTRC switch-yard locomotive emissions were computed using USEPA emission factors for switch-yard locomotives (USEPA, EPA 420-F-97-051 Table 3).

1.4 HKSAR Base Year Domestic, Commercial and Rural Source Emission Estimation

1.4.1 In 1998, Hong Kong Productivity Council (HKPC) conducted a territory wide research on dry cleaning industry in HKSAR. Through phone, postal and field surveys, HKPC collected extensive information of dry cleaning processes including number of dry cleaning shops, dry cleaning machines used and amount of perchloroethylene used etc. (HKPC 1998). The use of perchloroethylene was extracted for direct computation of VOC emission from dry cleaning industry in this Study.

1.4.2 HKSAR 1997 paved road dust emission was estimated in the CTS3 SEA Report. The same methodology was used to estimate emission directly for this study with one exception. Emissions of paved road dust were reduced by a precipitation adjustment factor in a manner comparable to that used by the US EPA during the preparation of the 1998 National Air Pollution Trends Report (USEPA, 1998). The emission factor equation used in the CTS3 was obtained from AP-42 and is a fleet-average emission factor as shown below: (USEPA AP 42 Section 13.2.1, 1997)

$$EF = k \times \left(\frac{sL}{2}\right)^{0.65} \times \left(\frac{W}{3}\right)^{1.5} \times \left(\frac{365 - p}{365} + 1\right) \times \frac{F}{2}$$

where EF = emission factor (g/km),
k = particle size multiplier (4.6 g/km, EPA factor for PM_{10}),
sL = roadway surface silt loading
W = average vehicle weight (assumed to be 4.3 tonnes times 1.102 to convert to US tonnes)
P = number of days per year with measurable precipitation (greater than 0.25 mm/day)
F = 0.25 (horizontal dust flux above elevation of 2m was approximately 25% of total horizontal fluxes (DRI, 1999))

The emission factor for unpaved road dust obtained from AP-42 Section 13.2.2 1998 is listed as follow.

$$EF = \frac{k \times \left(\frac{s}{12}\right)^a \times \left(\frac{W}{3}\right)^b \times \left(\frac{365 - p}{365}\right) \times F}{\left(\frac{M}{0.2}\right)^c}$$

where EF = emission factor (g/km),
s = particle size multiplier (4.6 g/km, EPA factor for PM_{10})
W = average vehicle weight (assumed to be 4.3 tonnes times 1.102 to convert to US tonnes)
M = surface material moisture content (%)
P = number of days per year with measurable precipitation (greater than 0.25 mm/day)
F = 0.25 (horizontal dust flux above elevation of 2m was approximately 25% of total horizontal fluxes (DRI, 1999))

k, a, b, c = constants

1.4.3 The "Reconciling Urban Fugitive Dust Emissions Inventory and Ambient Source Contribution Estimates: Summary of Current Knowledge and Needed Research" (DRI, 1999) report documented the immediate recommendations for National Emissions Inventory Improvement. The research report suggested that >2 m above ground level horizontal fluxes be used in urban- and regional-scale source or receptor modelling. Furthermore, preliminary estimates indicated that >2m horizontal fluxes are ~25% of total horizontal fluxes. This approximation is considered applicable to this Study and therefore a factor of 0.25 was adopted in all fugitive dust emission calculations.

1.4.4 In 1997, there were no ammonia or fertiliser production facilities in HKSAR. The primary sources of ammonia emissions were fertiliser usage, followed by human sweat and exhalation. The usage of animal wastes as fertilisers was assumed to be negligible along with the fading of agriculture production in HKSAR. Ammonia emissions from synthetic ammonia fertiliser application were assumed to be 10% of total nitrogen emitted based upon IPCC guidance (IPCC, page 4.106). Table 1-9 presents the sources of activity data and emission factors for the computation of ammonia emissions in HKSAR.

1.4.5 It is noted that the emission inventory compiled for this project is not exhaustive. Apart from the emission sources mentioned above, minor emission sources such as town gas leakage or landfills etc. were also considered. It was found that the emissions of these emission sources were not significant and therefore they are not presented in the emission inventory.

Table 1-8 Inventory Construction for HKSAR Domestic, Commercial and Rural Source Emissions

Sector	Sub-Sector	Activity Data Collection	Emission Factor Estimation Techniques
Population	Population by district board boundary	Census and Statistic Department and Hong Kong Annual Digest of Statistics 1997 population By-census for population and household statistic	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 Number of construction site/building/infrastructure project	Projection from 1995 PATH Inventory
Sewage treatment plants	Operating plants	Drainage Services Department and EPD departmental published information: Location and size, operation hours and capacity, Daily sewage handle	Projection from 1995 PATH Inventory
Quarries	Active sites	EPD Specified Process Registration: 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 and trade journals Sector employment figures; Paint manufacture and consumption rate; Solvent type and quantity of import and export	Activity based estimation methodology based upon 1995 and 1998 employment 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 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 and Transport and Highway Department Length of paved and unpaved road	Insignificant source. Not considered.
Agriculture		Hong Kong Annual Digest of Statistics Type and quantity of crop produced	Used to estimate fertiliser usage.
Fertiliser		Hong Kong Annual Digest of Statistics and AFCD 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 Type and quantity of livestock produced	Direct computation of ammonia emissions from animal waste and IPCC Table 4-19.

Table 1-9 Activity Data and Emission Factors for Ammonia Emissions

Ammonia source	Activity data	Source of Activity Data	Emission factor	Emission Factor Source
HKSAR				
Fertiliser usage	Nitrogen fertiliser used (tonnes)	Ratio from PRDEZ value using cultivated land as surrogate	0.1 kg (NH_3+NO_x/kg fertiliser applied)	IPCC Table 4-19
Human sweat and exhalation	Population	HK Population & Household Statistics, 1997. Table 4	0.25kg NH_3/ person/yr	IPCC, 1996. Section 9.4.6
Animal waste	Livestock on-hand (animals by type) times N excretion by livestock type	AFD IPCC Table 4-20	0.2 kg (NH_3+NO_x/ kg N excreted by livestock)	IPCC Table 4-19
PRDEZ				
Ammonia production	NH3 production (tonnes)	SBG Table 12-35	2.1 kg/ton production	AP-42 Table 8.1-1
Nitrogen fertiliser production	Ammonium nitrate production (tonnes)	SBG Table 12-35	46 kg/ton production	AP-42 Table 8.3-1
Nitrogen fertiliser usage	Nitrogen fertiliser used (tonnes)	SBG Table 11-18	0.1 kg (NH_3+NO_x/kg fertiliser applied)	IPCC Table 4-19
Human sweat and exhalation	Population	SBG Table 4-1	0.25 kg NH_3/ person/yr	IPCC, 1996. Section 9.4.6
Animal waste	Livestock on-hand (animals by type) times N excretion by livestock type	SBG Table 11-24, 11-26 IPCC Table 4-20	0.2 kg (NH_3+NO_x/ kg N excreted)	IPCC Table 4-19
Human waste applied as fertiliser	Households without sanitary facilities	SBG Table 4-1, 10-11, 11-4 IPCC Table 4-24	0.2 kg (NH_3+NO_x/ kg N excreted)	IPCC Table 4-19
Agricultural crop waste burning	Residue/crop production (tonnes)	SBG Table 11-1 UNDP Table 8-3	2.4 kg/ton	CORINAIR Table 8 B970 UNDP Table 8-3

References:
1. 1998 Statistical Yearbook of Guangdong, Statistical Bureau of Guangdong.
2. Compilation of Air Pollutant Emission Factors, vol. 1 & 2. (5th ed.), USEPA 1995.
3. 1996 IPCC Guidelines for National Greenhouse Gas Inventories.
4. Food and Agriculture Organisation, http://apps.fao.org/csv_down/
5. Manual for preparation of emissions inventories for use in modelling of transboundary air pollution, UNDP/UN DESA.
6. CORINAIR 1998, http://themes.eea.eu.int/showpage.php/state/air
7. Agriculture, Fisheries and Conservation Department, HKSAR Government.

2. PRDEZ BASE YEAR INVENTORY METHODOLOGY

2.1 Data Collection

2.1.1 All materials for the formulation of the base year emission inventory were obtained from the Government departments, annual statistical year books for cities, municipalities and industries published by the official sources, web sites of the industrial enterprises and conferences or seminar papers. The collected data were also reviewed for their suitability by the Guangdong Province Environmental Protection Monitoring Center (GPEMC) of the Guangdong Province Environmental Protection Bureau (GPEPB). Sources of activity data and the methodology for information gathering were described in detail in the following sections.

2.1.2 The emission inventory was prioritised to focus on the most significant source types in the Study area. With reference to previous preliminary studies completed by GPEPB, industrial source emission and motor vehicle emission are found to be the most significant in PRDEZ.

2.1.3 Based on past experience in developing regional emission inventories, that there may be data holes, data gaps, and questionable data in the emission data. All emission estimates within the study area were only based on data obtained from official sources or from other governmental or comparable sources.

2.2 PRDEZ Point Source Emissions

2.2.1 In the 1995 comprehensive and 1996 updated emission surveys completed by Guangdong Province Environmental Protection Bureau, there are approximately 11,000 point sources in the PRDEZ for 1997. These point sources include all the coal-fired and gas fired power plants, petroleum refineries, manufacturing industrial processing plants and small and village enterprises. For each emission point, a list of 28 parameters, grouped into 13 indicators, describing the premises operation mode, industrial type, gaseous pollutants emission rate, fuel type and consumption rate and installed pollution control measures have been provided by GPEMC. Details of the emission construction is shown in Table 2-1.

2.2.2 The emission inventory focused on the largest source categories for emission of NO_x and particulate matter. Process-specific and equipment-specific data required to differentiate between emission factors for PRDEZ sources are not available from official sources. On-site inspections on typical industrial premises of the dominant emission operations were carried out to obtain the process specific data.

2.2.3 The facility codes provided by GPEMC were matched with the HKSAR standard industrial classification. Some facilities have more than one chimney, but there is no information to apportion the emissions among them. Therefore, all emissions were assigned to the highest chimney at each facility. Additionally, some facilities have no data on chimney parameters. In those cases, median value of chimney heights within the same source category was inserted. Finally, there were some sources with no chimney data at all. Sources within those categories were assigned a chimney height of 5 m so that emissions were allocated to the lowest vertical layer of the air quality model.

Table 2-1 Inventory Construction for PRDEZ Point Source Emissions

Sector	Sub-Sector	Activity Data Collection	Emission Factor Estimation Techniques
PRDEZ			
Industrial Operation	Industrial operations 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	Indicators from the GPEPB comprehensive emission surveys: Name, location and capacity of the facility Facility type in accordance to the Hong Kong Standard Industrial Classification Predominant fuel type and consumption Pollutant emission rate Chimney height Volumetric flow or velocity stack diameter Exhaust temperature Total Volume of gaseous emission Emission volume of gaseous emission Information on control equipment Operation hours Reference key of every industrial emission source	Pollutants involved : SO_2, NO_x, RSP, and VOC. Estimation technique: Activity-based direct calculation with fuel consumption data for combustion sources

2.2.4 There are no process data available for the PRDEZ industrial sources. Combustion particulate matter emissions were assumed to be 50% RSP. Process fugitive particulate matter emissions were assumed to be 20% RSP. A weighted-average RSP fraction was then computed from the total combustion and process fugitive RSP emissions for a given source category. USEPA (USEPA 1996) or California Air Resources Board (CARB 1991) speciation profiles were used to supplement any missing data for industrial sources.

2.2.5 PRDEZ industrial source inventory fuel use and official government statistics of domestic fuel use were used, and these figures were cross-reference to the Guangdong Province Statistical Yearbook for consistency.

2.2.6 Generic methods were used to estimate combustion VOC emission. For fuel combustion sources, VOC emission was estimated using appropriate emission factors and activity data contained in the inventory. The draft UNDP emission inventory manual (UNDP 2000) recommends using factors developed by the IPCC and the choice of emission factors for PRDEZ industrial source combustion VOC were presented in Table 2-2. These emission factors were extracted from Table 1-11 of the IPCC Guidelines Reference Manual.

Table 2-2 VOC Emission Factors (kg/TJ net calorific value)

Sector	Coal	Oil
Energy	5	5
Manufacturing and Construction	20	5
Commercial/Institutional	200	5
Agricultural/Forestry	200	5

2.2.7 Table 1-2 of the IPCC Guidelines lists a value of 20.52 TJ/ktonne for hard coal produced or consumed in China, while Table 1-3 lists values of 43.33 and 40.19 TJ/ktonne for diesel and residual oil, respectively. Applying these values to the emission factors in the previous table, and using the average value of 41.76 TJ/ktonne for diesel and residual oils, gives the emission factors listed in the Table 2-3 in units of tonnes VOC/10^4 tonne fuel.

Table 2-3 VOC Emission Factors (tonnes/104 tonnes fuel)

Sector	Coal	Oil
Energy	1	2
Manufacturing and Construction	4	2
Commercial/Institutional	41	2
Agricultural/Forestry	41	2

2.3 PRDEZ Mobile Source Emissions

2.3.1 The collection of mobile source activity data required a joint effort among the consultants in HKSAR and the Mainland due to the large area coverage and the amount of information required for the Study. Table 2-4 shows a summary of the estimation methodology for emission from PRDEZ. All information to be obtained for the compilation of the emission inventory were collected from the following official sources:

- Guangdong Province Environmental Protection Bureau;
- Guangdong Province Environmental Protection Monitoring Center;
- Guangzhou Research Institute of Environmental Protection;
- Annual statistical yearbooks for cities and municipalities including Statistical Yearbook of Dongguan 1999, Statistical Yearbook of Guangdong for 1998 and 1999, Statistical Yearbook of Guangzhou for 1998 and 1999, Statistical Yearbook of Huizhou 1998, Statistical Yearbook of Zhaoqing 1999, Statistical Yearbook of Zhuhai 1999, Statistics and Information Yearbooks of Shenzhen 1998 and 1999, Yearbook of Huadu 1998, Yearbook of Panyu 1998, Yearbook of Zengcheng 1997 and Yearbook of Zhongshan 1991-1997
- China annual traffic and transportation statistical yearbooks including China Automotive Industry Yearbook 1998 and Yearbook of Transportation & Communication 1998;
- China Energy Statistical Yearbook 1991-1996, Agricultural Statistical Yearbook of Guangdong 1998 and Construction Statistical Yearbook of China 1998,

- China annual environmental statistical yearbooks;
- Mainland China National Standards (GB);
- Mainland Cities Government departments including traffic police, statistical bureau and EPB;
- General published literatures for car manufacture industry;
- Web sites of Mainland China companies and Hong Kong companies with main investment in the PRD; and
- Conference proceedings and technical journal papers world-wide

2.3.2 Length, daily traffic flow and type of vehicle for national super highways, highways, and major network of the PRDEZ were collected by GPEMC and various city traffic research institutes. The classification for the vehicle count at least included motorcycle, passenger cars, taxi, public buses, light-diesel goods vehicle, and heavy goods diesel vehicles.

2.3.3 Length and hourly traffic flow within the nine major cities (Guangzhou, Shenzhen, Zhuhai, Zhongshan, Foshan, Jiangmen, Zhaoqing, Huizhou, Dongguan) of the PRDEZ were provided by GPEMC and the HKSAR traffic sub-consultant. The information provided was referenced to the yearbooks and statistical yearbooks of each individual city. Discrepancies among different sources were reviewed and verified among the team members.

2.3.4 Annual VKT for each vehicle class (motor cycle, diesel goods vehicles, large petrol vehicles (20 seaters or above) and small petrol vehicles (<20 seaters)) of the nine major cities were provided by traffic police and statistical bureau of each individual city.

2.3.5 Emission factors of different pollutants for various types of motor vehicles were referenced to technical papers published in journals, conferences, seminars and any national standards available.

2.3.6 Emission factors for light-duty petrol vehicles in China have been recently measured by Yuan, Liu and Wang (1997) and Li and Yang (1997) had measured emission factors of motorcycles, mid-size vehicles and heavy-duty diesel vehicles in China. Further to the discussion with Guang Dong Province Environmental Protection Bureau, a revised set of emission factors were made for the estimation of the motor vehicles as shown in Table 2-5.

Table 2-4 Inventory Construction for PRDEZ Mobile Source Emissions

Sector	Sub-Sector	Activity Data Collection	Emission Factor Estimation Techniques
On-Road	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, and 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	
	Vehicle type and made	Direct communication: Vehicle manufacturing plants in the PRDEZ and other key motor industry cities in Mainland China	
Off-Road	Marine	Annual transportation statistical yearbooks, individual port authority web sites, Hong Kong company web sites and China shipping information network: Activity data for the major hub, river and coastal ports; Inward and outward movement of vessel type in terms of ocean-gong containers and shipping support vessels, and Shipping lanes for marine traffic	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	Transportation, provincial and city statistical yearbooks. Diesel fuel usage for locomotives; and Engine type and configuration for diesel fuelled locomotives	Activity-based projection using PATH effective emission factor and 1997 activity data.
	Aviation for Shenzhen, Zhuhai and Guangzhou Baiyun Airport	Business travel planner, airport web sites and direct communication: 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.

Table 2-5 Emission Factors for PRDEZ Motor Vehicles

	Emission Factors (g/km)			
Pollutant	**Motor cycles**	**Diesel Good Vehicles**	**Large Petrol Vehicles**	**Small Petrol Vehicles**
VOC	2.47	1.40	8.36	3.34
RSP	0.30	1.49	0.07	0.40
NO_x	0.30	4.50	7.12	1.80

2.3.7 The USEPA PART5 model was used to estimate RSP emissions from on-road vehicles. Emission factors representative of vehicles for the period 1976-1980 in the US were computed. The PART5 methodology computes particulate emissions as the sum of three components: lead emissions (EF_{Pb}), sulphate emissions (EF_{SO4}) and carbon emissions (EF_C). The total RSP emission factor is given by the sum of the three individual factors.

2.3.8 For PRDEZ motor vehicle SO_2 emissions, the emission factors were based on the assumption that 98% of the sulphur in the fuel is emitted as SO_2. This is the assumption used in the USEPA PART5 computer program for calculating emissions from motor vehicles (USEPA, 1995). Using this assumption, the emission factor is calculated from:

EF_{SO2} [g/km] = 1.96 x (S_F /100) x D_F x E_F

Where: 1.96 = factor to account for fraction emitted (0.98) and weight ratio of SO_2 to S (2.0)

S_F = fuel sulphur content (weight percent)

D_F = density of fuel (0.730 kg/litre for gasoline and 0.845 kg/litre for diesel fuel)

E_F = vehicle fuel efficiency.

2.3.9 Yuan, Liu and Wang (1997) measured an average fuel efficiency of 13.53 litre/100 km for light duty petrol vehicles in the Mainland China. No data for other vehicle classes in PRDEZ are available. Therefore, the following default fuel efficiency values for motor vehicles from CORINAIR (1999) were used:

- Heavy Duty Petrol Vehicles: 22.5 litre/100 km
- Heavy Duty Diesel Vehicles: 29.9 litre/100 km
- Motorcycles: 4.0 litre/100 km

2.3.10 Consumption of different motor vehicle fuel type and the product specifications were referenced to the energy statistical yearbooks and implemented GB standards respectively. The GB standards also provided the tail pipe emission standards for different vehicle types. Implementation schedules of the GB standards for different fuel types as well as tail pipe emission standards were referenced to public announcements made in the central and provincial Government web sites.

2.3.11 The product of three primary numbers formed the motor vehicle emission estimates: the number of vehicles, the number of kilometres travelled per year, and the emission factor for a given vehicle class. The first two numbers are used to compute the annual VKT for each vehicle class.

2.3.12 Direct communication has been made to motor vehicle manufacturers in the PRDEZ and other parts of the Mainland China to obtain the specification of different models and engine types of vehicles solid in the Study area. International motor vehicle manufacturers with products imported to the Study area were researched in terms of sales volume, product types and engine specifications.

2.3.13 In the PRDEZ, there are 3 dominant civil airports, the Shenzhen International Airport, Zhuhai Airport and Guangzhou Baiyun International Airport. Daily LTOs for each of the three civil airports were obtained from either business traffic planner and through direct communication with the airport authority. Direct computation of emissions based on aircraft types was performed for these airports. Emission factors for different aircraft types from USFAA Aircraft Engine Emission Database (FAEED) Version 2.1 (Nov 95) was used to compute the NO_x, SO_2, and VOC emissions. There are no applicable RSP or particulate matter emission factors available for aircraft in the FAEED emission database.

2.3.14 There are over 10 major hub, river and coastal ports within the PRDEZ. All of these sea ports have bagging and warehousing facilities and container handling facilities. Good transportation network in terms of highways and railway links are available for these ports. Activity data on shipping tonnage and vessel traffic of the ports were obtained from the annual transportation statistical yearbooks, port authority web sites and China shipping information network.

2.3.15 Emissions from river-traffic vessels in the PRDEZ are expected to be similar to those in HKSAR in terms of composition because most river traffic calls at HKSAR port facilities. In addition, modern container and similar ocean-going vessels all meet certain international standards and so these vessels were assumed to be similar to those calling HKSAR ports. The engine size of the vessels were made reference to Corinair report (EMEP/CORINAIR 2000) and calculation for marine emissions was based on the methodology presented in an USEPA document "Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data (EPA420-R-00-002 dated February 2000).

2.3.16 Most rail traffic in the PRDEZ is electrified and diesel railway locomotive emissions were computed based upon the amount of diesel fuel combusted. These data were estimated 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.

2.4 PRDEZ Domestic, Commercial and Rural Source Emission Estimation

2.4.1 The emissions under this category include construction activities, water treatment plants, quarries, surface coating and thinners, dry cleaning, domestic and commercial energy use, road surfacing, agriculture, fertiliser and livestock and other appropriate information useful in the estimation and verification of the source emissions.

2.4.2 Domestic, commercial and rural source emissions in the PRDEZ were computed as those in HKSAR by using the activity data times emission factor approach. Activity data, including population data, for the nine major cities were obtained from the GPEMC, city statistical yearbooks and China agriculture statistical yearbooks. The construction of the emission inventory for domestic, commercial and rural sources in PRDEZ is given in Table 2-6.

2.4.3 Within the PRDEZ, the approach was to gather the available data for the urban and suburban areas. Data gaps were filled in by extrapolating available data or by estimating the data with standard emission inventory techniques. High spatial resolution population data was available for urban areas in the PRDEZ, while lower resolution data was available for rural areas. Comprehensive land use data for the PRDEZ was available at the city and county level, as were demographic and socio-economic information. Similar data for rural cities in the PRDEZ were also available but in less detail than major cities.

2.4.4 Paved and unpaved road dusts emissions were estimated using VKT data for the PRDEZ and USEPA methodology to retain consistency with HKSAR emission estimates. It was assumed that VKT on unpaved roads accounted for 0.1% of the total VKT in PRDEZ.

2.4.5 The primary source of ammonia emission in PRDEZ rural areas is generated from agricultural activities, which have six primary sources of ammonia emissions: ammonia production, fertiliser production, fertiliser usage, animal waste used as fertiliser, and human waste used as fertiliser. Emissions were computed using the activity data times emission factor approach.

2.4.6 Production information for nitrogen fertiliser (ammonium nitrate) is available for the PRDEZ from the various city statistical yearbooks. Ammonia emission factors are available in USEPA AP-42 for uncontrolled emissions for three major ammonia production processes (neutraliser, evaporation/condensation, and solids formation) and several minor processes. Solids formation is the dominant ammonia source. Since most fertiliser plants use high density prill towers for solids formation, an average emission factor was estimated assuming use of prill towers for solids formation.

2.4.7 PRDEZ nitrogen fertiliser usage was obtained from statistical yearbooks. The emission factor for ammonia emissions from fertiliser usage was obtained from IPCC guidance. Ammonia emissions from synthetic ammonia fertiliser application were assumed to be 10% of total nitrogen emitted based upon IPCC guidance (IPCC 1996, page 4.106).

2.4.8 Ammonia emissions from livestock waste were obtained from IPCC emission factors and cities statistical yearbooks by livestock type. Ammonia emissions from animal waste applied as fertiliser were assumed to be 25% of total nitrogen emitted based upon IPCC guidance (IPCC 1996, page 4.106).

2.4.9 Ammonia emissions from the application of human waste as fertiliser in rural areas of the PRDEZ were estimated as the number of persons without sanitary facilities (SBG, 1998), per capita protein consumption (Food and Agriculture Organisation), sewage N fraction of protein, and nitrogen emission factor for waste application as fertiliser. Ammonia emissions from human waste applied as fertiliser were assumed to be 25% of total nitrogen emitted based upon IPCC guidance (IPCC, page 4.106). The approach for the estimation of ammonia emissions from PRDEZ was listed in Table 1-9.

2.4.10 All VOC evaporative loss emissions were computed as a single Province-wide emission rate. Consumption and products usage data required to estimate evaporative VOC emission from domestic solvent use and solvent application were provided from relevant professional organisations. All of the estimated VOC content was assumed to be emitted as an area source emission from activities including degreasing, architectural coatings and surface coating. Construction of the PRDEZ VOC emission inventory is listed in Table 2-7.

2.4.11 Given the fact that PRDEZ do not have any perchlorethylene consumption and usage data, VOC emissions from the dry cleaning process was projected based on the ratio of gross domestic product (GDP) of private consumption expenditure between PRDEZ and HKSAR.

2.4.12 Piped gas systems for domestic and commercial use is not very common in PRDEZ and only some large cities like Guangzhou and Shenzhen etc. have underground pipelines and handling facilities. It was anticipated that the leakage due to town gas conveyance was insignificant therefore the figure was not presented in the emission inventory.

2.5 Base Year Biogenic Source Emission Estimation

2.5.1 1997 biogenic emission within the study area was estimated using biogenic emission model within the PATH EMS-95 system. The base year land use input to the MM5 meteorological model was used as the basis for the 1997 biogenic emission modelling for the study area. The plant communities or emission factors by plant community contained within the PATH EMS-95 modelling system were used for this study.

2.5.2 Landuse information of the study area using remote sensing and GIS techniques were collected by the Joint Laboratory for Geoinformation Science of the Chinese University of Hong Kong in conjunction with the China Academy of Sciences. The landuse data were divided into 15 category including plantation woodland, woodland, low shrubland, low shrubland with grass, tall shrubland, tall shrubland with grass, grassland, urban, buildings, cultivation, abandoned cultivation, mangrove, other wetland, bare rock or soil and inland water.

2.5.3 In PATH modelling system, emission factors for predominant plant communities were assigned based on taxanomic similarity to species. The same approach was used to develop the biogenic emission for HKSAR and PRDEZ. The inventory construction for HKSAR and PRDEZ biogenic emissions is given in Table 2-8.

2.6 PRDEZ Speciation and Temporal Profiles

2.6.1 Speciation profiles and temporal allocation factors in the PATH EMS-95 modelling system were used as a reference for the emission inventory on a daily (diurnal), day-of-week, and seasonal basis if latest information is not available for areas of this Study.

2.6.2 Typical weekly operation of most industrial facilities in the PRDEZ is seven days per week. Commercial facilities tend to operate Monday through Friday and part of the day Saturday (5.5 days per week). These operating schedules imply three different "typical" days in the PRDEZ. These days are "weekday", "Saturday", and "Sunday". In addition to these day-of-week operating differences, there are potentially seasonal differences in operation. Three typical diurnal profiles were developed for application to point sources corresponding to the three above operating scenarios. In addition, winter and summer temporal profiles were developed to account for potential seasonal differences in the operation of facilities in the PRDEZ. However, diurnal variations in different emission sources or modes were found to be quite limited for PRDEZ. The base year emission inventory has been derived from best available information to reflect the most typical situation in PRDEZ for the purpose of the Study.

Table 2-6 Inventory Construction for PRDEZ Domestic, Commercial and Rural Source Emissions

Sector	Sub-Sector	Activity Data Collection	Emission Factor Estimation Techniques
Population	Population by the major cities, municipalities and districts within the study area	Provincial and city statistical yearbooks: Population and household figure	See Table 4-8 for VOC emission estimates. See Table 3-9 for ammonia emissions. Direct computation for domestic and commercial fuel combustion sources.
Construction activity	By cities, municipalities and districts within the study area	Provincial and city statistical yearbooks and China construction yearbooks: Number of construction site/building/infrastructure project	
Sewage treatment plants	Operating plants within study area	GPEMC and city environmental bureau: Location and size, operation hours and capacity, Daily sewage handle	
Quarries	Active sites within the study area	Provincial and city statistical yearbooks and China construction yearbooks: Location and size, operation hours and capacity, pollution control equipment employed	
Domestic Solvent Use (e.g. Cosmetics & toiletries) & Paint Application (e.g. paints & varnishes)		GPEMC, provincial and city statistical yearbooks: Sector employment figures; Paint manufacture and consumption rate; Solvent type and quantity of import and export	
Dry cleaning		GPEMC, provincial and city statistical yearbooks: GDP Hong Kong Hong Kong Annual Digest of Statistics 1999 edition GDP	
Energy use	Different type of fuel: Kerosene, oil, gas, naphtha, petrol & LPG	GPEMC, energy yearbook, provincial and city statistical yearbooks: Fuel type and quantity of import and export; and Location of fuel terminals;	
Road surfacing	District board boundary	GPEMC, provincial and city statistical yearbooks: Length of paved and unpaved road	
Agriculture		GPEMC, city environmental bureaux and provincial and city statistical yearbooks: Type and quantity of crop produced	
Fertiliser		GPEMC, city environmental bureau and provincial and city statistical yearbooks: Type and quantity of import and export	
Livestock.	Pigs, cattle, chicken, duck, geese and quails	GPEMC, city environmental bureau and provincial and city statistical yearbooks: Type and quantity of livestock produced	
Others	Open burning of agriculture waste	Provincial and city statistical yearbooks: Crop production and crop residue available for burning	

Table 2-7 Sources of Activity Data and Emission Factors for Computation of VOC Emissions in the PRDEZ

Source Category	Activity Data	Activity Data Source	Emission Factor	Emission Factor Source	Comment
Municipal waste incineration (PRDEZ)	MSW per capita generation rate and PRDEZ population. CH4 emissions computed using IPCC Section 6.2 methodology.	IPCC 1966 Table 6-1 and Section 6.2	15 kg/tonne	UNDP Table 10-1 p 111	Assume open burning.
Clinical waste incineration	Expected insignificant source.		7.4 kg/tonne of waste burned	CORINAIR Table 8.4 B922	Clinical waste incineration plant with only particle emission abatement equipment.
Industrial solid waste (ISW) incineration	ISW incinerated estimated as ISW production times fraction of ISW not treated in a comprehensive manner minus ISW discharged (tonnes).	SBG, 1998 Table 18-9	75 kg/tonne of waste burned	UNDP Table 10-1 p 111	Industrial waste incineration plant with single chamber.
Municipal Sewage Treatment	Domestic sewage treated (tonnes). Treatment sludge assumed to be component of ISW and incinerated (see above).	SBG, 1998 Table 18-9	Small	Small	Amount treated assumed to equal amount discharged.
Industrial Wastewater Treatment	Industrial wastewater treated (tonnes). Treatment sludge assumed to be component of ISW and incinerated (see above).	SBG, 1998 Table 18-9	Small	Small	Amount treated assumed to equal amount discharged.
Open burning of agricultural waste	Crop production (tonnes) and crop residue available for burning.	SBG, 1998 Table 11-17 IPCC 1996 Table 4-17	4-9 kg/tonne	UNDP Table 8-3, p96	Not including forest fires and stubble burning.
Coal production	Insignificant VOC source		Not Applicable	UNDP Table 5-2, p76	

Table 2-7 Sources of Activity Data and Emission Factors for Computation of VOC Emissions in the PRDEZ (Cont'd)

Source Category	Activity Data	Activity Data Source	Emission Factor	Emission Factor Source	Comment
Crude oil production	Crude oil production (tonnes)	SBG, 1998 Table 12-35 and Table 16-7	0.642 kg/tonne	UNDP Table 5-2, p76	
Natural gas production	Gas production (m3)	SBG, 1998 Table 12-35	0.027 kg/m^3	UNDP Table 5-2, p76	Including production and distribution.
Petrochemical production	Production of applicable petrochemical products (tonnes)	SBG, 1998 Table 12-35	0.4-0.6 kg/tonne	CORINAIR B451-4, B452-4	Emission factor an average value for the production of ethylene, propylene etc
Petroleum coke production	Petroleum coke production (tonnes)	SBG, 1998 Table 7-4	0.03-0.4 kg/tonne coke produced	CORINAIR Table 8.2 B146	Coke produced during coking process.
Petroleum refining	Crude oil processing (tonnes)	SBG, 1998 Table 12-36	530 g/tonne crude	UNDP Table 5-2, p76	Considering basic refinery converts crude petroleum into various products (uncontrolled fluid catalytic cracking).
Gasoline distribution	Average daily gasoline consumption (standard coal equivalent)	SBG, 1998 Table 7-5	310 kg/kt (dispatch) 310 kg/kt(transport & depots)	UNDP Table 5-2, p76	Gasoline usage was converted from standard coal equivalent to tonne.
Petrol Handling and Distribution	Average daily gasoline consumption (standard coal equivalent)	SBG, 1998 Table 7-5	2880 kg/kt	UNDP Table 5-2, p76	Gasoline usage was converted from standard coal equivalent to tonne.
Cement production	Cement production (tonnes)	SBG, 1998 Table 12-35	Not Applicable	UNDP Table 6-1, p80	Cement processing (non combustion emission).
Plastic manufacturing	Plastic production (tonnes)	SBG, 1998 Table 12-36	15-40 kg/tonne	UNDP Table 7-1, p87	
Rubber production	Rubber production (tonnes)	SBG, 1998 Table 12-35	15 kg/tonne	UNDP Table 7-1, p87	
Paint Application			327 kg/tonnes paint sold	UNDP Table 7-1, p87	
Paper/paper products production	Paper production (tonnes)	SBG, 1998 Table 12-36	3.7 kg/tonne	UNDP Table 6-1, p81	Considering per tonne of Air Dried pulp (Kraft process).
Grain drying	Grain production (tonnes)	SBG, 1998 Table 11-17	1.31 kg/tonne	CORINAIR Table 8.1 B465	

Table 2-7 Sources of Activity Data and Emission Factors for Computation of VOC Emissions in the PRDEZ (Cont'd)

Source Category	Activity Data	Activity Data Source	Emission Factor	Emission Factor Source	Comment
Alcoholic beverage production	Alcoholic beverage production (tonnes)	SBG, 1998 Table 12-35	0.08 kg/hl (wine) 0.035 kg/hl (beer) 15 kg/hl alcohol (spirits)	CORINAIR B466	Primarily ethanol emissions during processes such as fermentation, casking and maturation. Specially for wine, beer and spirits production.
Domestic LPG consumption	Total annual residential gas consumption (tonnes SCE)	SBG, 1998 Table 7.7	0.004 kg/GJ	CORINAIR Table 6 B112	Residential combustion.
Domestic coal consumption	Total annual residential coal consumption (tonnes SCE)	SBG, 1998 Table 7.7	0.225 kg/GJ	CORINAIR Table 6 B112	Considering briquettes for residential combustion.
Domestic other fuel consumption	Total annual residential other fuel consumption (tonnes SCE)	SBG, 1998 Table 7.7	0.002 kg/GJ	CORINAIR Table 6 B112	Includes oil (diesel, kerosene, and gasoline) for residential combustion.
Pesticide application	Pesticide application (tonnes)	SBG, 1998 Table 11-1	100% of VOC content		VOC content to be derived from available data.
Printing (Press and Publication)	Guangdong solvent and printing association		0.15 (Mg/yr/capita)	PATH reports	Includes press and edition/publication.
Domestic solvent usage	Guangdong solvent and printing association	1904 g/yr/ person for general domestic solvent usage; 782 g/yr/person for car care products	600-900 kg/tonne	UNDP Table 7-1, p87	Toiletries, cosmetics, household products, car care products, DIY/buildings, aerosol propellant.
Dry cleaning	Dry cleaning solvent usage not available				Projected by GPD ratio between PRDEZ and HK
Notes: GJ = 10E9 Joules Where appropriate, unit conversion was performed for activity data or emission factors to produce consistent units.					

Table 2-8 Inventory Construction for HKSAR and PRDEZ Biogenic Source Emissions

Sector	Sub-Sector	Activity Data Collection	Emission Factor Estimation
Landuse	15 vegetation categories: plantation woodland, woodland, low shrubland, low shrubland with grass, tall shrubland, tall shrubland with grass, grassland, urban, buildings, cultivation, abandoned cultivation, mangrove, other wetland, bare rock or soil and inland water.	Joint Laboratory for Geoinformation Science of the Chinese University of Hong Kong in conjunction with the China Academy of Sciences: Landuse information by remote sensing and GIS techniques by the	Emissions were computed using the Bionics Module of EMS-95 using the plant communities and emission factors established for PATH.

3. REFERENCES

- Agricultural Statistical Yearbook of Guangdong 1998
- California Air Resources Board, 1999. Personal communication with Patrick Geffen, 24th February.
- California Air Resources Board, 1991. Identification of Volatile Organic Compound Species Profiles, ARB Speciation Manual, Second Edition, Volume 1 of 2.
- California Air Resources Board, 1991. Identification of Particulate Matter Species Profiles, ARB Speciation Manual, Second Edition, Volume 2 of 2.
- Census and Statistics Department, HKSAR, 1998, Annual Review of Hong Kong External Trade 1998
- Census and Statistics Department, HKSAR, 1999, Hong Kong Annual Digest of Statistics
- Census and Statistics Department, HKSAR, 1997, Hong Kong Energy Statistics
- Census and Statistics Department, HKSAR, 1997, Hong Kong Population Projections 1997-2016
- China Automotive Industry Yearbook 1998
- China Energy Statistical Yearbook 1991-1996
- Construction Statistical Yearbook of China 1998
- Desert Research Institute (DRI), September 3, 1999, Reconciling Urban Fugitive Dust Emissions Inventory and Ambient Source Contribution Estimates: Summary of Current Knowledge and Needed Research
- EMEP/CORINAIR, 2000. Atmospheric Emission Inventory Guidebook (Second edition).
- Environmental Protection Department, 1998. Working Paper D2, Territory-wide Air Quality – Inventory Data Sets
- Gouging, Li, Manning, Yang, 1997. "Research Study on Vehicle Emission Factor for Major Highway," in proceedings of First Conference on China Vehicular Pollution, organised by Qinghua University Environmental Engineering Department, December.
- Hong Kong Port and Maritime Board, 1998, Hong Kong Port and Maritime Board Annual Report 1998
- Hong Kong Productivity Council (HKPC), 9th March 1998, Modification, Compliance Checking & Surveys of Existing Dry-cleaning Machines, Final Report
- Intergovernmental Panel on Climate Change, 1996. IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual.
- Modelling System: Inventory Detests, Hong Kong SAR Government
- Statistical Yearbook of Dongguan 1999
- Statistical Yearbook of Guangdong 1998
- Statistical Yearbook of Guangdong 1999
- Statistical Yearbook of Guangzhou 1998
- Statistical Yearbook of Guangzhou 1999
- Statistical Yearbook of Huizhou 1998
- Statistical Yearbook of Zhaoqing 1999
- Statistical Yearbook of Zhuhai 1999
- Statistics and Information Yearbook of Shenzhen 1998
- Statistics and Information Yearbook of Shenzhen 1999
- Transport Department, 1999. Third Comprehensive Transport Study, Hong Kong SAR Government, October.
- United Nation Development Program, 2000, UN DESA. Manual for preparation of emissions inventories for use in modelling of transboundary air pollution
- US Environmental Protection Agency, 1990. Air Emissions Species Manual, Volume I – Volatile Organic Compound Species Profiles, Second Edition. EPA-450.2-90-001a.
- US Environmental Protection Agency, 1995. Compilation of Air Pollutant Emission Factors, AP-42, Fifth Edition.

- US Environmental Protection Agency, 1995. Draft User's Guide to Part 5: A programme for Calculating Particle Emissions from Motor Vehicles, United States Environmental Protection Agency, Office of Mobile Sources National Motor Vehicle and Fuels Emission Laboratory, EPA-AA-AQAB-94-2, Ann Arbor, Michigan. February 1995.
- US Environmental Protection Agency, 1996. Uncontrolled Emission Factor Listing for Criteria Pollutants, Emission Inventory Improvement Program, Volume II, Chapter 14
- US Environmental Protection Agency, 1998. National Air Pollutant Emission Trends, Procedures Document, 1900-1996, Section 4.0 National Criteria Pollutant Estimates 1985-1996 Methodology, United States Environmental Protection Agency, Office of Air Quality Planning and Standards.
- Yearbook of Huadu 1998
- Yearbook of Panyu 1998
- Yearbook of Transportation & Communication 1998
- Yearbook of Zengcheng 1997
- Yearbook of Zhongshan 1991-1997
- Ying, Yuan, Xiling, Liu, Ronghai, Wang, 1997, "Light-Duty Vehicle Emissions in China - Report on Light-Duty Vehicle Emission Factor Tests," Vehicle Emissions Laboratory, Atmospheric Environmental Institute, Chinese Research Academy of Environmental Sciences (CRAES), in proceedings of First Conference on China Vehicular Pollution, organised by Qinghua University Environmental Engineering Department, December.