China Motor Vehicle Emission Control

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Toward a sustainable energy future

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Chapter 1 Background and Introduction

1.1 Current Situations of Urban Environment Air Pollution in China

China is a country that mainly uses coal. Coal occupies 70-75% of the combustion consumption energy in energy structure. Therefore, currently the urban air pollution in China is mainly coal smoke pollution. However, in recent years, along with the continuous high-speed economic increase in China and the speed of urbanization accelerates step by step, the transportation demand of urban residents rapidly increases in recent years, and the vehicle stock amount has been widely developed. In big cities like Beijing, Guangzhou and Shanghai, coal pollution has been basically controlled, but the vehicle exhaust pollution featured with photochemical smoke pollution gradually gets heavier and heavier. NOx and ozone that represent the characteristics of vehicle air pollution are seriously above standard. Air quality is deteriorative seriously and mixed pollution of coal smoke and vehicle tail gas appears.

Air pollution in China northern cities is heavier than cities in South China in 1998. Mixed pollution of coal and vehicle tail gas in some big and mid-sized cities and fine particle problem in some cities is very serious.

TSP is the major pollutant in the city air of China. The annual average of TSP concentration in 60.0% cities exceeds national Level II standard; the annual average of SO_2 concentration in 28.4% of the cities in statistics exceeds national Level II standard. Most of the cities with heavier NOx pollution have over one million population.

According to the air quality supervision result analysis for 322 provincial-controlled cities in 1998, the major pollutant in China is TSP with the annual daily average is 0.11-1.199mg/m^3, and the average of the country is 0.289mg/m^3. SO_2 annual daily average is 0.002-0.385mg/m^3, and the average of the country is 0.056mg/m^3. The range of NOx annual daily average is 0.006-0.152mg/m^3, and the average of the country is 0.037mg/m^3.

Only 89 cities reach national Environmental Air Quality Standard Level II with regard to the above-mentioned 3 conventional items for monitor, accounting for 27.6% of the cities being investigated. 233 cities have at least 1 item superior than national Environmental Air Quality Standard II Level, accounting for 72.4% of the cities being investigated. Air quality of 140 cities is superior to Environmental Air Quality Standard III Level, accounting for 43.5% of the cities being investigated.

In 338 cities chosen for statistics of 1999, air quality of 33.1% of the cities meets the demand of national air quality Level II; 66.9% exceeds national air quality Level II. 137 cities exceed Level III, accounting for 40.5% of the cities being investigated. The general condition of urban air quality is better than 1998.

Table1-1 National General Urban Air Quality Status Table

	Total City Number	Percentage of cities reaching Level II	Percentage of cities exceeding Level II	Percentage of cities exceeding Level III
Yr. 1998	322	27.6%	72.4%	43.5%
Yr. 1999	338	33.1%	66.9%	40.5%

China has started to adopt Air Pollution Index (API) to evaluate air quality condition since June 1997. API is firstly introduced by American researchers in 1976 and is a comprehensive method to characterize regional air quality condition. It simplifies the concentration of several air pollutants for conventional monitor to single conceptional digit mode and characterizes air pollution level and air quality status in several levels. The result is concise and intuitionistic and is used to show the urban air quality status and change tendency.

API is to determine pollution index assortment and relevant pollutants concentration limits according to environmental air quality standard and the influence of each pollutant to human health and ecological condition. API assortment currently used in China is: pollutant concentration that corresponding to API 50 is National Air Quality Daily Average Level I; pollutant concentration that corresponding to API 100 is National Air Quality Daily Average Level II; pollutant concentration that corresponding to API 200 is National Air Quality Daily Average Level III; API 500 corresponds to the concentration of each pollutant when it causes serious harm to human body. Table 1-2 shows the relationship among National Standard, pollutant concentration and corresponding API and air quality levels by taking NOx as an example. Figure 1-1 is the API changes of some of China's major cities.

Table 1-2 Index Relationship Table

National Standard	Pollutant Daily Ave. Concentration (mg/m^3)	Air Pollution Index (API)	Air Quality Level	Air Quality Status
Level I	0.10	50	**I**	Excellent
Level II	0.10	100	**II**	Good
Level III	0.15	200	**III**	Low-level Pollution
	0.565	300	**IV**	Mid-level Pollution
	0.750	400	**V**	Serious Pollution
	0.940	500	**V**	Serious Pollution

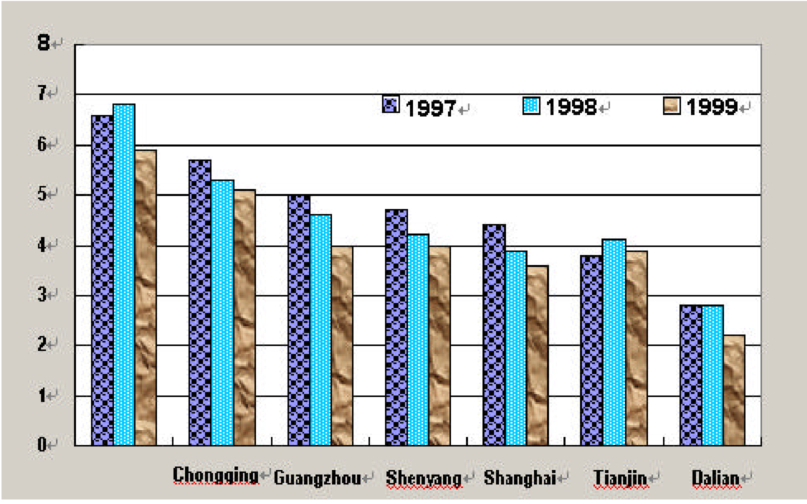


Figure 1-1 Air Pollution Comprehensive Index of some of Chinese Major Cities

In one word, coal smoke pollution will still influence the air quality of most of China's cities to the extent of the whole country. This is determined by the particularity of China's energy constitution. However, the proportion of vehicle tail gas pollution in air pollution is continuously increasing, especially in some big cities where economy is developing with a fast speed.

1.2 Increasing Proportion of Vehicle Pollution in Air Pollution

1.2.1 Urban NOx Pollution Condition in China

NOx in cities mainly comes from vehicle tail gas exhaust. Taking the general condition of the whole country under consideration, it pollution degree is relatively smaller than SO_2 and TSP, but in big cities the condition is different. According to the statistics result for 4 years from 1995 to 1998, NOx concentration annual average in 88 cities of China is between 0.012-0.129mg/m^3 and the national average is 0.047mg/m^3. In 1996, NOx concentration annual average in 88 cities of China is between 0.007-0.152mg/m^3 and the national average is 0.046mg/m^3. In 1997, NOx concentration annual average in 94 cities of China is between 0.004-0.140mg/m^3 and the national average is 0.045mg/m^3. In 1998, NOx concentration annual average in 96 cities of China is between 0.008-0.151mg/m^3 in 1996 and the national average is 0.045mg/m^3. The concentration ranges and average values of southern and northern cities differ, and generally the concentration annual average in northern cities is higher than that of the southern cities, see Table 1-3 and 1-4 for details.

China modified NOx standard limits of Air Environment Quality Standard in 1996. When calculating the NOx concentration annual average disqualified exhaust rate from 1995 to 1998, in 1995 the calculation is made by referring to the pollutant concentration limits regulated in 1982, i.e. 0.05mg/m^3 (Level I), 0.10mg/m^3 (Level II) and 0.15mg/m^3 (Level III). From 1996, the calculation is made by referring to new standard limits, and the 3 levels of annual average limits are: 0.05mg/m^3 (Level I), 0.05mg/m^3(Level II) and 0.10mg/m^3 (Level III).

Table 1-3 NOx Concentration Annual Average Statistics of Cities in China Unit: mg/m^3

Year	City Numbers	National NOx Concentration		NOx Concentration in Northern Cities		NOx Concentration in Southern Cities	
		Range	Arithmetical Mean	Range	Arithmetical Mean	Range	`
1995	88	0.012-0.129	0.047	0.017-0.123	0.053	0.012-0.129	0.041
1996	88	0.007-0.152	0.046	0.029-0.117	0.055	0.022-0.152	0.046
1997	94	0.004-0.140	0.045	0.013-0.133	0.049	0.004-0.140	0.041
1998	96	0.008-0.151	0.045	0.011-0.151	0.049	0.008-0.124	0.041

Table 1-4 NOx Annual Average Percentiles Condition of Cities in China (mg/m3)

Year	Cities Number	Max.	Min.	Percentiles						
				5	10	25	50	75	90	95
1995	88	0.129	0.012	0.015	0.017	0.029	0.043	0.061	0.074	0.092
1996	88	0.152	0.007	0.014	0.021	0.032	0.043	0.054	0.074	0.078
1997	94	0.140	0.004	0.013	0.019	0.028	0.043	0.056	0.072	0.079
1998	96	0.151	0.008	0.013	0.017	0.030	0.041	0.054	0.069	0.082

Among the 88 cities being calculated in 1995, NOx annual average in 32 cities goes beyond the limit, and ratio is 36.4%, among which 3 cities exceed Level II, and the ratio is 3.4%.

Among the 88 cities being calculated in 1996, NOx annual average in 27 cities goes beyond the limit, and ratio is 30.7%, among which 25 cities exceed Level II and 2 cities exceed Level III. The ratios are 28.4% and 2.3% respectively.

Among the 94 cities being calculated in 1997, NOx annual average in 32 cities goes beyond the limit, and ratio is 34.1%, among which 29 cities exceed Level II and 3 cities exceed Level III. The ratios are 30.9% and 3.2% respectively.

Among the 96 cities being calculated in 1998, NOx annual average in 32 cities goes beyond the limit, and ratio is 33.3%, among which 29 cities exceed Level II and 3 cities exceed Level III. The ratios are 30.2% and 3.1% respectively. See Table 1-5.

Table 1 -5 NOx Annual Average Concentration Disqualification Statistics in Cities of China

Year	City Numbers	Cities Exceeding Standard		Cities Exceeding Level II		Cities Exceeding Level III		Cities Exceeding Level III
		Number	Ratio	Number	Ratio	Number	Ratio	
1995	88	32	36.4%	3	3.4%	0	0%	Beijing, Guangzhou, Lanzhou
1996	88	27	30.7%	25	28.4%	2	2.3%	Beijing, Guangzhou
1997	94	32	34.1%	29	30.9%	3	3.2%	Beijing, Guangzhou, Shanghai
1998	96	32	33.3%	29	30.2%	3	3.1%	Beijing, Guangzhou, Shanghai

Note: 1. 3 cities exceed Level II in 1995, using Air Environment Quality Standard GB3095-82.

2. Revised Environment Air Quality Standard GM3095-1996 was carried out since 1996.

Table 1-6 Air Quality Status in 1998 (%)

City	Air Quality Status														
	Nox					SO_2					TSP				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Beijing	/	4.90	19.5	24.4	/	/	/	/	/	/	/	17.5	22.5	7.5	5.0
Tianjin	/	/	/	/	/	/	/	14.6	/	/	/	27.1	48.0	10.4	/
Shanghai	/	61.2	30.6	2.1	/	/	3.9	/	/	/	/	/	2.1	/	/
Guangzhou	/	18.4	57.2	16.3	/	/	/	/	/	/	/	4.2	3.9	/	/
Dalian	/	/	/	/	/	/	25.0	/	/	/	/	75.0	/	/	/
Chongqing	/	2.1	/	/	/	/	43.8	35.4	18.8	/	/	/	/	/	/

Table 1-7 Air Quality Status in 1999 (%)

City	Air Quality Status														
	NO_x					SO_2					TSP				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Beijing	/	5.9	29.4	11.8	/	/	/	/	/	/	/	13.7	27.7	5.9	5.9
Tianjin	/	/	/	/	/	/	/	5.9	/	/	/	45.1	31.4	13.7	3.9
Shanghai	/	62.7	33.3	2.0	/	/	2.0	/	/	/	/	/	/	/	/
Guangzhou	/	47.1	43.1	5.9	/	/	/	/	/	/	/	3.9	/	/	/
Dalian	/	/	/	/	/	2.0	7.8	/	/	/	13.7	76.5	/	/	/
Chongqing	/	/	/	/	/	/	45.1	43.1	9.8	/	/	2.0	/	/	/

There are altogether 59 cities in China successively have been publishing Urban Air Quality Weekly Report till the end of 1998. Dalian, Nanjing, Shanghai, Qingdao, Xiamen and Beijing also published Urban Air Quality Daily Report. Statistics is made according to the Air Quality Weekly Report of 1998 and 1999 for the major pollutant in 6 major cities, and the results are shown as in Table 1-6 and 1-7.

Statistics of the 4 years shows that NOx pollution in cities of China is relatively concentrated, especially in Beijing, Shanghai and Guangzhou, where vehicle stock increases rapidly. The coal smoke pollution in these 3 cities is basically controlled and the air quality is greatly influenced by vehicle pollutant exhaust. At the same time, the common features of the 3 cities are: large vehicle stock, low level of single vehicle exhaust, highly concentrated population concentration and heavy traffic jam. This shows that the vehicle pollution in China began to greatly influence the air quality in big cities. Let's take these 3 cities as the representative cities of vehicle exhaust pollution in China.

1.2.2 Beijing

In recent years, the SO_2 and TSP concentration in the air of urban and suburb Beijing keeps stable. Generally speaking, although coal consumption amount increases year by year and SO_2 during heating period seriously exceeds national air quality standard, the general pollution level of SO_2 has been basically controlled and improved to some extent. TSP in the air of urban and suburb Beijing exceeds national air quality standard both in heating and non-heating periods, and the pollution in heating period is more serious than non-heating period.

Beijing began to release Air Quality Weekly Report from 1998. In the whole year of 1998, the proportion of weeks that API reaches Level II is 15.4%, Level III is 40.3%, Level IV is 40.3% and Level V is 2%. The major pollutant is NO_x and the next is TSP.

From 1999, due to the larger control effort for air pollution, major pollution indexes decreased in different levels, and the days that API are Level III or below occupies 75% of the whole year.

I. Vehicle Stock Change Tendency

The annual rate of increase of vehicle stock in Beijing is as high as 13%. At the end of 1997, the vehicle number in Beijing was 1.27M, in 1998 1.37M and in 1999 reaches 1.46M. Figure 1-2 shows the vehicle stock change tendency in Beijing from 1990 to 1999.

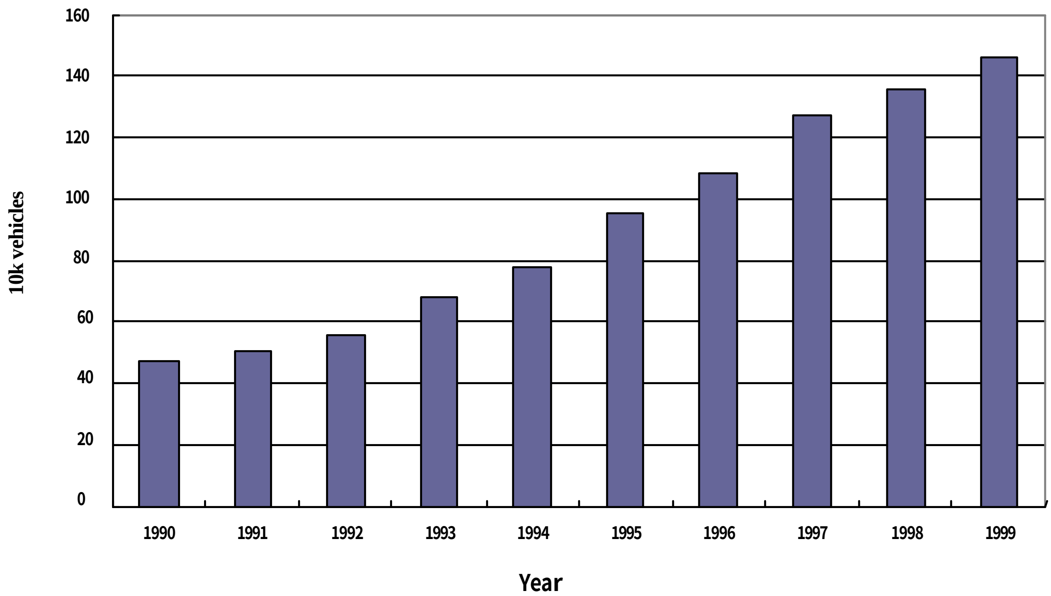


Figure 1－2 Vehicle Stock Change Tendency in Beijing

II. Pb, NO_x, CO and O_3 Pollution Status

Before aborting doped fuel, the lead that exhausted by vehicle in Beijing was estimated to be nearly 100 t per year, and the lead concentration in urban atmospheric environment is 0.3~0.5 $\mu g/m^3$, which is even higher in the air where the traffic is very busy. In the first quarter of 1997, Beijing Environment Protection Monitor Center implemented sampling and analysis near Beijing Xizhimen overpass, and the lead concentration in the air is 0.845~1.15 $\mu g/m^3$.

In recent years, the NOx concentration in the urban and suburb area of Beijing has shown an obvious rising tendency. The NOx average densities in the whole year of 1997, heating period and non-heating period are 133, 191 and 99$\mu g/m^3$ respectively and are 73%, 66% and 80% higher than those of 1987. In 1998, the daily average concentration of NOx raised 14.3% on the base of 1997 and reached 152$\mu g/m^3$, and lowered to 140$\mu g/m^3$ in 1999. The influence of coal heating exhaust pollutant to environmental concentration basically keeps balanced for many years, and it can be concluded that the NOx concentration change got from each air quality monitoring station is mainly due to vehicle exhaust.

The proportions of vehicle CO and NOx exhaust in Beijing occupy 82.5% and 41% (exhaust sharing rate) respectively of each pollution source exhaust total amount of Beijing.

In 1997, the NOx concentration in the air of traffic roads within Beijing 3rd Ring Road was 43% higher than that of urban Beijing and suburb area and reached 190 $\mu g/m^3$, which is 76% higher than the road air of 10 years ago. In 1997, the CO concentration in the air of traffic roads within Beijing 3rd Ring Road was 103% higher than that of urban Beijing and suburb and reached 6.1mg/m^3, which not only exceeds national air quality Level II, but also exceeds the air environment concentration of heating period. NOx in the air of the area within 2nd Rind Road (city center) increased to 205 $\mu g/m^3$ in 1997 from 99 $\mu g/m^3$ in 1986 and increased 107%. CO and NOx of major urban traffic backbone roads and crossroads exceeds national air quality standard throughout the year.

In 1998, since the vehicle number continuously increased by a big margin and reached 1.35M, the pollution of NOx and CO in traffic environment is very serious, and the NOx and CO in major traffic backbone roads and intersections exceed national standard throughout the year.

Table 1-8 is the comparison of vehicle exhaust pollution in Beijing traffic areas and non-traffic areas in 1997 and 1998.

Table 1-8 NOx and CO Concentration Comparison of Beijing Urban and Suburb in 1997 and 1998

		2nd Ring Road (City center)	3rd Ring Road	4th Ring Road	Outside 4th Ring Road (Suburb)
NOx (ug/m^3)	1997	205	190	177	112
	1998	220	219	197	124
CO(mg/m^3)	1997	6.8	6.1	3.3	
	1998	8.4	7.3	3.6	

During the Eighth Five-Year Plan (1991-1995), the days and hours that O_3 concentration in Beijing suburb area averagely exceeds standard were respectively 53.8 days and 294 hours, in 1997, 71 days and 434 hours. The maximum hourly concentration reached 346μg/m^3; in the whole year of 1998, ozone in 101 days and 504 hours exceeded standard, and ozone disqualified exhaust hours from June to September occupied 81.5% of the whole year, the maximum hourly concentration reached 384 μg/m^3. In the whole year of 1999, ozone exceeded standard for 119 days and 777 hours. This reflected that vehicle exhaust pollution was getting heavier to some extent. See Table 1-9 for comparison.

Table 1-9 Beijing Urban O3 Pollution Change Status

	Days exceeding Standard	Hours exceeding Standard	Max. Hourly Concentration of the whole year (μg/m^3)
Yr. 1997	71	434	346
Yr. 1998	101	504	384
Yr. 1999	119	777	

Table 1-10 1997-1999 Beijing Air Environment Quality Change Status

Year/Item	SO_2	NOx	CO	TSP
1997	0.125	0.133	3.0	0.318
1998	0.120	0.152	3.3	0.378
1999	0.080	0.140	2.9	0.364

Note: The data in the table is the annual daily average concentration, and the unit is mg/m^3.

III. Conclusion

(1) The SO_2 exhaust in Beijing has been basically controlled.

(2) Vehicle numbers in Beijing rapidly increases year by year, and the NOx and CO concentration in busy traffic areas is much higher than non-busy traffic areas.

(3) O_3 pollution that related with vehicle exhaust gets more serious and serious.

(4) During 1997 to 1999, SO_2, NOx, CP and TSP densities displayed a tendency of rising followed by lowering, and it is thought to be the result of strengthening control power.

In 1997, Beijing focused on air pollution control. From June 1, 298 petrol stations in urban and suburb areas were prohibited to sell doped fuel, and was the first city in China to promote the use of lead-free petrol. Till the end of 1997, all petrol stations in Beijing changed to use lead-free petrol and created conditions to install external purifier and further control tail gas pollution. At the same time, vehicle initial inspection, annual inspection, road inspection and random inspection ware strengthened. The tasks of road inspection for 44,100 vehicles and random inspection for 56,300 vehicles were completed.

In order to control vehicle tail gas pollution, a new standard was released in 1998 which is equivalent to that of Europe in early 1990s. Vehicle tail gas monitoring was strengthened. 551,00 vehicles received road inspection and 49,900 vehicles received random inspection in the whole year. Vehicle retirement policy was strictly carried out, and 38,000 vehicles that exceed service life were abandoned till the end of the year, among which 14,000 vehicles are microbus taxies that caused heavy pollution. Approximately 4,000 vehicles were "cremated" at Capital Steelworks.

The municipal government adopted 18 emergency measures at the end of 1998 to control coal smoke pollution, vehicle exhaust pollution and flying dust and sand pollution and implemented 68 measures to control air pollution in 3 stages and achieved preliminary effects. The tendency of air pollution getting more serious has been controlled basically till Feb. 15, 1999. From Jan.1, 1999, Beijing began to carry out Light Vehicle Venting Pollutant Exhaust Standard which was equivalent to the European level of early 1990s. 60,000 new vehicles were labeled with Green Environment Protection Symbol; over 80,000 vehicles that got their car numbers before 1995 were forced to install vacuum time-delay valve; 120,000 vehicles that got their car numbers after 1995 were renovated and basically reached new exhaust standard; 21,166 taxies, public buses, post buses and environmental protection buses were renovated to dual-fuel vehicles; 300 vehicles that using natural gas as fuel only were running along the Chang'an Street; over 30,000 vehicles that exceeded service life retired. Totally 360,000 vehicles that driven to Beijing were inspected and 109,000 were dissuaded from coming into Beijing.

The above measures controls the worsening of pollution under the condition that vehicle numbers in Beijing grows rapidly.

(5) It can be concluded from above that under the condition that vehicle numbers increase rapidly, strengthen vehicle exhaust control is an effective way to control the worsening of pollution.

1.2.3 Guangzhou

Industrial used coal consumption in Guangzhou in 1997 is 1.9 times of that of 1990, while the exhaust of SO_2 is only 96% of that of 1990. The densities of SO_2 and TSP are lessened by 1.4% and 16.5% respectively compared with that of 1990. Generally speaking, the industrial pollution in Guangzhou has been controlled, and partial environment quality index that closely related with industrial pollution has been improved.

According to the air quality communiqué and annual air quality weekly report released in 1998, the week number of the whole year that air pollution index reached Level II is 22.4%, Level III is 61.2%, and Level IV 16.4%. Major pollutant NOx occupied 8% of the monitored weeks of the whole year, and TSP occupied 2%. The API range of the total 53 weeks of the year is 55 (Good, Level II)~ 234 (Mid-pollution, Level IV) and Serious Pollution (Level V) didn't happen. API of 14 weeks was Good; 32 weeks was Low-level Pollution; 7 weeks was Mid-level Pollution; the major pollutant of 51 weeks is NOx. In old city area, 32 weeks were featured with Low-level Pollution, and in industrial area, 34 weeks were featured with Low-level Pollution. In new development zone, 32 weeks were featured with Good. For traffic backbone roads, 27 weeks were featured with Mid-level Pollution.

In the whole year of 1999, the API of 52 weeks environment air quality weekly report was ranged from 55 (Good, Level II) to 218 (Mid-level Pollution, Level IV). Serious Pollution didn't happen. API of 27 weeks was Good and occupied 51.9%; 21 weeks was Low-level Pollution and occupied 40.4%; 4 weeks was Mid-Level Pollution and occupied 7.7%. The major pollutant of 51 weeks was NOx. Environment air quality featured with Good increased by 13 weeks; Low-level Pollution weeks decreased by 11 weeks, and Mid-level Pollution weeks decreased by 3 weeks. The environment air quality further improved.

SO_2 in Guangzhou urban area in 1998 was 0.061$\mu g/m^3$, and decreased by 12.9% compared with that of 1997 (0.070$\mu g/m^3$). General TSP concentration is 0.202$\mu g/m^3$ and decreased by 6.91% compared with that of 1997 (0.217$\mu g/m^3$) and basically reached national standard Level II. CO average concentration is 2.42$\mu g/m^3$ and decreased by 4.72% compared with that of 1997 (2.54$\mu g/m^3$). NOx annual average concentration is 0.124$\mu g/m^3$ and decreased by 10.8% compared with that of 1997 (0.139$\mu g/m^3$), but still exceeded national standard Level II.

In 1999, major indexes of SO_2, NOx, CO, TSP and flying fine sand decreased compared with 1998. SO_2 and TSP are better than national environment air quality Level II. Fall dust is close to the temporary standard of Guangzhou area, but NOx is still worse than national environment air quality Level II.

In 1999, SO_2 annual average concentration was 0.054$\mu g/m^3$ and decreased by 11.5% compared with that of 1998 (0.061$\mu g/m^3$). TSP annual average concentration was

0.182μg/m^3 and decreased by 9.9% compared with 1998 (0.202μg/m^3) and was better than national Level II. CO annual average concentration was 2.29μg/m^3 and decreased by 5.3% compared with 1998 (2.42μg/m^3). Annual fall dust amount was 8.16t/km^2.month and decreased compared with 1998 (8.22 t/km^2.month) and was close to the temporary standard of Guangzhou area. NOx annual average concentration was 0.114μg/m^3 and decreased by 8.1% compared with 1998 (0.124μg/m^3), but was still higher than national Level II.

From the pollution sharing ratio of the 4 major pollutants, NOx is the prominent air pollutant. NOx and CO annual average concentration in busy taffic area decreased compared with 1998, but was still higher than other function areas. Vehicle tail gas exhaust is the major pollution source of NOx and CO pollution in urban area.

I. Vehicle Stock and Road Condition

In recent years, vehicle stock in Guangzhou has been increased by over 20% per year and reached 980,000 in 1997 from 331,000 in 1997. Guangzhou vehicle increase is featured with the rapid increase of motorcycle. The number is so large and the increase is so rapid, which is seldom seen in other cities of China. In 1967, there were altogether 583 motorcycles in Guangzhou; in 1979 the number was 6,994 and the annual increase is 493 in average. The 10 years from 1980 to 1989 was a period when motorcycle increased rapidly and the number reached 130,000 in 1989 compared with 1980, when there were 8,937 motorcycles in Guangzhou. The annual increase was 12,309 in average and the annual rate of increase was 37%. After 1990, the rate of increase began to lower down which was 18.02% from 1990 to 1995. In 1995, the motorcycle stock was 361,000 and it reached surprisingly to 400,000 in 1997.

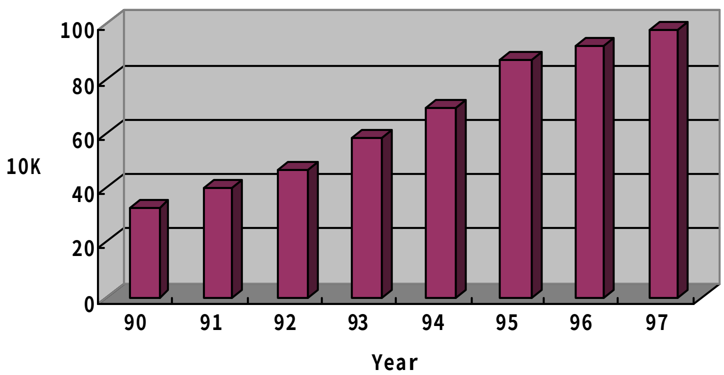


Figure 1-3 Guangzhou Vehicle Stock Development Tendency

The road speed in Guangzhou is slow with heavy traffic jam. In 1997, the daily average car speed along roads in south/north direction within 12 hours in urban area was 20.51km/hr, and that of the roads in east/west direction was 17.98km/hr. The car speed in outer side of the urban area was only 22km/hr, and the road traffic effectiveness was very low. At the same time, the landform and meteorological condition of Guangzhou is not good for pollutant diffusion and convey, which objectively worsens the pollution to air environment caused by city traffic.

Table 1-11 is the air quality change status of Guangzhou from 1997 to 1999.

Table 1-11 Guangzhou Air Envir onment Quality Change Status from 1997 to 1999

Year/Item	SO_2	NOx	CO	TSP
1997	0.07	0.139	2.54	0.217
1998	0.061	0.124	2.42	0.202
1999	0.054	0.114	2.29	0.182

Note: The data in the table is the annual daily average concentration of each pollutant. The unit is mg/m^3

1.2.4 Shanghai

The environmental air pollution in Shanghai has gradually changed from coal smoke pollution occupied a large proportion to the current compound pollution of coal smoke and vehicle exhaust pollution. The major pollutants are NOx, TSP and SO_2.

SO_2 concentration in urban Shanghai decreased to $0.068mg/m^3$ in 1997 from $0.083mg/m^3$ in 1990 and was close to national environment air quality Level II ($0.060mg/m^3$); TSP decreased to $0.229mg/m^3$ in 1997 from $0.354mg/m^3$ in 1990 and was also close to national environment air quality Level II ($0.200mg/m^3$).

I. Vehicle Stock and Car Type Proportion

Vehicle stock in Shanghai increased rapidly. From 1986 to the end of 1992, the number of vehicles increased from 158,628 to 265,940 and increased by 67.6% within 6 years. The average annual rate of increase was 9.0%. From 1992 to the end of 1997, vehicle increased to 538,378 and increased by 102.4% within 5 years. The average annual rate of increase was 20.5%. The increase tendency accelerated obviously. Till 1998, the number almost reached 580,000.

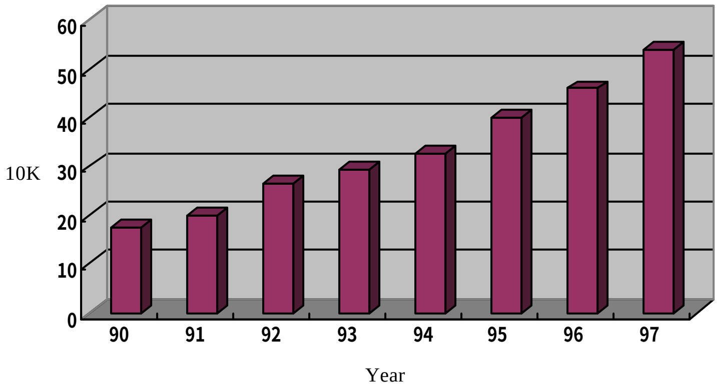


Figure 1-4 Shanghai Vehicle Stock Development Tendency

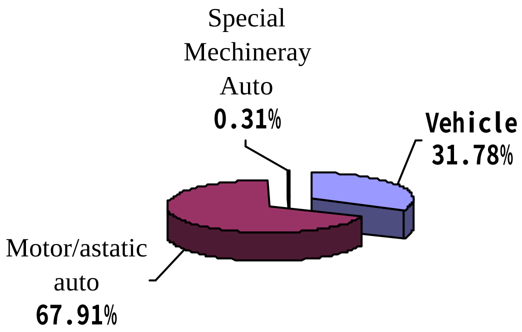


Figure1-5 Shanghai Vehicle Type Constitution in 1997

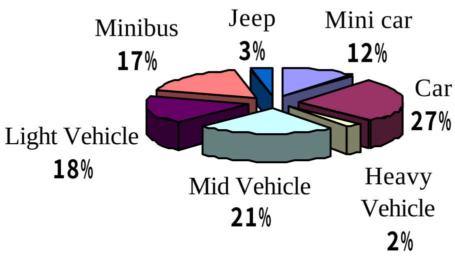


Figure 1-6 Car Models of Vehicle Group

II. Vehicle Pollution Condition

Before 1992, the annual average concentration of NOx of the whole city was lower than 0.06mg/m^3, which was close to national environment air quality Level II. After 1995, the annual average concentration of NOx in environmental air increased to 0.105mg/m^3 in 1997 from 0.059mg/m^3 in 1990 and began to exceed national environment air quality Level III.

According to the pollutant exhaust c oefficient measured from Shanghai vehicle actual riding work condition in 1996, fuel vehicle in Shanghai exhausted approx. 380,000t CO, 81,500t NOx, 100,000t NMHC and 123.5t lead each year into the air. Since there were relatively not so many industrial enterprises in the city center where the roads were concentrated with larger traffic flow, vehicle exhaust pollution load is relatively higher. In 1996, CO pollution exhaust sharing rate of vehicle in city center occupied 86% of the total pollution exhaust a mount; NO occupied 56% and NMHC occupied 96%. Vehicle exhaust pollution became the major factor of the air pollution in Shanghai.

From June 1997, Shanghai began to release Air Pollution Index (API) each week to the public, and daily report was released from June 1998. The air pollution index material of Shanghai shows that urban NOx pollution index reached Level I only for 1.5% of the days of the whole year; the pollution index reached Level II occupied 65% of the days; the pollution index reached Level IV occupied 6% of the days; pollution index reached Level V occupied 0.5%. In 1997, the max. API value in air quality weekly report was 212, and in 1998 it reached to 220; the daily report API max. value was 315 (Dec. 17, 1998).

In 1998, NOx concentration of the whole city decreased 0.001μg/m^3 compared with 1997, among which urban area decreased 0.005μg/m^3, while that of the suburb increased 0.001μg/m^3 . TSP concentration of the whole city decreased 0.024μg/m^3 compared with that of 1997, among which urban area decreased 0.018μg/m^3 and suburb area decreased 0.020μg/m^3. The SO_2 concentration of the whole city decreased 0.007μg/m^3 compared with that of 1997, among which urban area decreased 0.015μg/m^3 and suburb decreased 0.002μg/m^3.

In 1999, NOx concentration of the whole city decreased 0.001μg/m^3 compared with 1998, among which urban area decreased 0.001μg/m^3, while that of the suburb increased 0.004μg/m^3 . TSP concentration of the whole city decreased 0.014μg/m^3 compared with that of 1998, among which urban area decreased 0.047μg/m^3 and suburb area decreased 0.005μg/m^3. SO_2 concentration of the whole city decreased 0.005μg/m^3 compared with that of 1998, among which urban area decreased 0.008μg/m^3 and suburb decreased

$0.001\mu g/m^3$.

Table 1-12 is the air environment quality change status of urban Shanghai from 1997 to 1999.

Table 1-12 Air Environment Quality Change Status in Urban Shanghai from 1997 to 1999.

Year/Item	SO_2	NOx	TSP
1997	0.068	0.105	0.233
1998	0.053	0.1	0.215
1999	0.045	0.099	0.168

Note: The data in the table is the annual daily average concentration of each pollutant. The unit is mg/m^3

1.2.5 Comparison of the 3 Cities

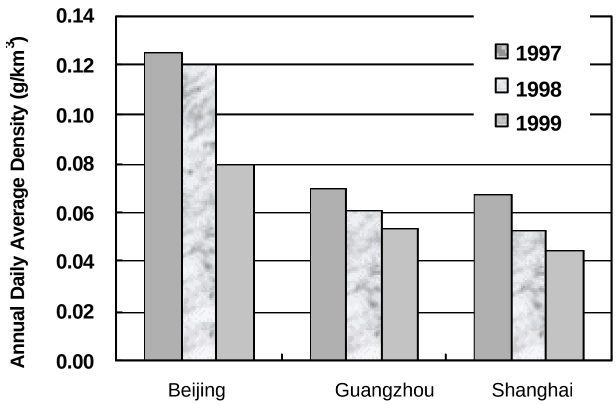


Figure1-7 SO_2 Density Change in 3 Cities

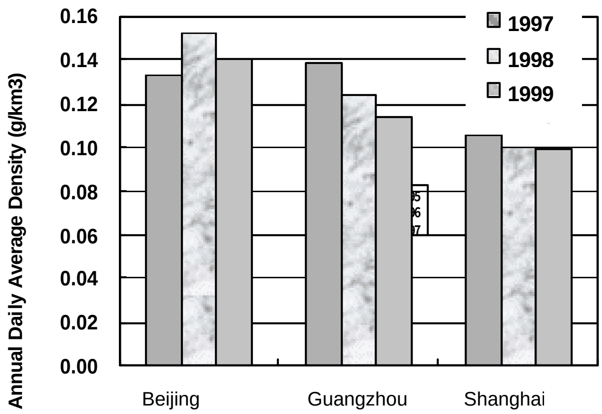


Figure 1-8 NOx Density Change of the 3 Cities

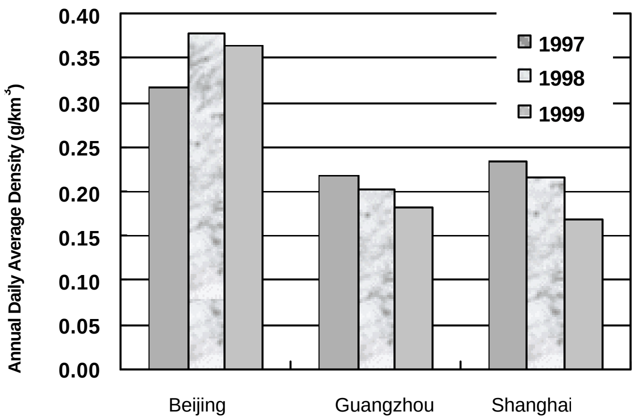


Figure1-9 TSP Density Change of the 3 Cities

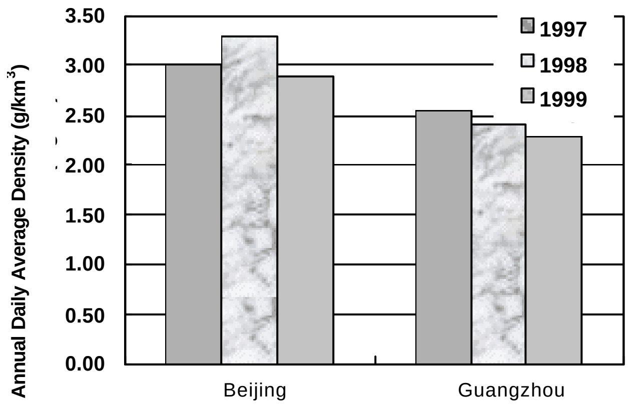


Figure 1-10 CO Density Change of Beijing and Guangzhou

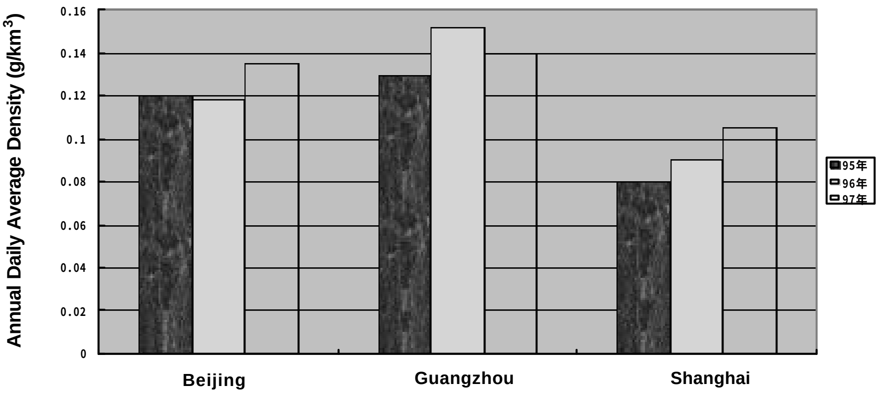


Figure 1-11 NO_X Annual Daily Ave. Density of the 3 Cities

1.3 Conclusion

(1) As the gradual improvement of urban fuel structure in China, many cities gradually cut down coal burning amount and began to use clean coal, and SO_2 exhaust reduced. Generally speaking, the overall air quality in China gradually improved, but the air pollution of most of the cities still belongs to coal smoke pollution.

(2) In some big cities like Beijing, Guangzhou and Shanghai where economy develops rapidly, coal-burning pollution has been basically controlled and SO_2 concentration gradually decreased. The photochemical smog pollution featured with vehicle exhaust pollution becomes more and more serious, and NOx and ozone disqualified exhaust which represents vehicle air pollution is very serious. Air quality gets worsened severely and mixed pollution of coal smoke and vehicle tail gas appears.

(3) Vehicle stock in Beijing, Guangzhou and Shanghai increases year by year, but the pollutant concentration exhausted by vehicle doesn't increase along with the stock increase. During 1997-1999, CO, NOx and TSP concentration in Beijing displays a trend of getting higher first then lowers down. While in Guangzhou and Shanghai, the above pollutants decrease year by year. The reason is that each city controls vehicle tail gas exhaust worsening by measures like carrying out strict exhaust standard, enforcing law execution, promoting installation of vehicle tail gas purifier and enforcing clean fuel vehicle renovation.

(4) Before lead-free petrol was put into use, lead exhausted to the air due to vehicle exhaust in Beijing was very high, especially in busy-traffic area.

(5) With the rapid increase of vehicle numbers in China, TSP and O_3 concentration long-term monitor should be strengthened in the air monitoring of some cities so as to provide evidences for constituting reasonable traffic management measurement.

Chapter 2 Health and Environment Impact Caused by Vehicle Emission Pollutant

Vehicle can be divided into petrol vehicle (including astatic vehicle and motorcycle) and diesel vehicle according to fuel type. The main exhaust of petrol vehicle is petrol, while that of the diesel vehicle is particulate matter. The petrol is constituted mainly of CO, HC and NOx; in places where doped petrol is used, the lead exhausted by vehicle is also an important lead pollution source of the city. The rapid growth of vehicle numbers and its exhausted matters caused serious environment pollution and health impacts for many big cities.

The impact of each pollutant is analyzed as below.

2.1 Lead

In many big cities, the biggest lead pollution exhaust source is the vehicle that using doped petrol. Over 90% of the lead in the urban air comes from vehicle exhaust. The lead concentration in the air of city center is usually several times higher than that of the suburb. Lead suspends in the air and enters human body through breathing. The investigation of lead pollution made by related departments of China shows that lead dust smaller than 3μm can be directly breathed in by human body. Lead particles with larger diameters deposit into water and soil and enter food chain. They are further absorbed by animals and plants and indirectly ingested by human body. Lead pollution is featured with multiple polluted objects and longtime pollution and causes serious harm to health.

2.1.1 Research on Human Body Health Impact

2.1.1.1 Overseas Research Results

A research report published by Herbert Needleman and his colleagues in 1979 firstly raised people's attention to the impact of longtime and low-concentration lead environment to human health [1]. The report showed that children who have a large amount of lead deposition in teeth relatively have a low IQ and are easier to have problems such as behavior difficulty and non-concentrated attention. Lead prevents children from development in intelligence and body growth, and causes barriers in reading and understanding. Children absorb lead mainly through digestive system (the sources are dust and soil polluted by lead), and children bodies have a stronger absorption and conservation rates. Researches show that when the lead concentration in the air is 1µg /m^3, children's blood lead content is 4.2µg/dl, while that of adults is 1.2µl/dl. Therefore, lead has a much stronger impact on children than adult, and the harm caused by lead to children is non-reversible. When disease develops, though medical care can control the illness condition from getting worse, there is definitely no way to completely cure the disease.

Further researches shows that compared with normal people, pregnant women, babies and fetuses are colonies that most easily to be attacked by lead. As an agent of lead absorption for fetus, the blood lead in the body of a pregnant woman is transferred to baby through placenta. As a result, lead pollution of pregnant woman will cause baby agenesis, abortion, gestational period shortening and lightweight of newborn babies, which results in an increased medical nursing and charge for babies. In Cairo, Egypt, over 800 babies die from lead contact of their mothers each year.

The following materials provided by American Public Health Association show different diseases caused by different blood lead levels: 5-15µg/dl level does harm to baby growth. Most of the reports convince that when blood lead concentration is within the range of 5-35µg/dl, children IQ level will decrease 2-4 when increasing 10-15µg/dl each. See the table below for details.

Table 2-1 Relationship between Children Blood Lead Level and Diseases [3]

Blood Lead Level (mg/dl)	Diseases and Symptoms
10	IQ declining, hearing function declining and slow body growth and development
20	Red blood corpuscle rises
30	Central nerve reaction speed declines
40	Vitamin D metabolism function declines
50	Hemoglobin synthesis decreases
50-100	Stomachache, Frankfort anemia, kidney diseases and cerebral diseases
100-150	Death

Although the impact of lead on adults differs in seriousness due to sex difference, the major harm it causes is similar. The World Bank published the research result of Ostro, an expert, proving that there is a relationship between lead pollution concentration in the air and the impact on adult cardiovascular system. Each 1µg/m^3 lead increased in the air will cause hypertension of 44,800-97,000 persons among 1M; nonfatal heart diseases of 180-500 persons, and early death of 200-650 persons (see Scientific Committee Research Programs, P.12). Besides, according to the report of American Environment Protection Bureau, the United States cut down lead content in petrol from 1.0g /gallon to 0.1g/gallon in mid 1980s, and hypertension patients reduced 400,000; myocardial infarct patients reduced 5,350, aphasia patients reduced 1,115 and death reduced 5,160. In Bangkok, 200,000-400,000 hypertension patients and 400 deaths each year are related with lead pollution.

2.1.1.2 Domestic Research Results

China's research on low-concentration lead harm is mainly focused on the impact on children growth and development and has little research on the harm of low-concentration lead to adults [3].

In 1987, Zhang Xiaoming's research showed that the blood pressure of lead polluted children aged over 10 years was obviously higher than the children of the check group. This difference was very significant.

In 1989, the research of children experts at Shanghai Medical University showed that the physique development of children who had absorbed low-concentration lead was not good. If other factors were the same, blood lead level increased 10μg/dl and the average height would reduce 1.3cm. In 1989, after investigation on 180 pupils in Shanghai, Wang Ling and other experts found that there was an obvious dosage-reaction relationship between blood lead concentration and IQ. The result of a series of analysis was: blood lead concentration increased 10μg/dl and correspondingly language IQ would reduce 8 points, operation IQ points would reduce and thus total IQ value reduced. In 1989, Zhang Yan and other people made an investigation to Shenyang female workers and found that natural abortion rate of female workers who had contacted lead was 12.9% and total abnormal remainder rate was 15.3%, which were obviously higher than those of the normal female workers, i.e. 7.4% and 7.5%. Obvious and non-obvious differences still existed after controlling miscellaneous factors.

Through the research on the surrounding areas of county lead metallurgical plants in Jiangsu Province in 1992, Lu Yaoliang and other experts found that the standard life-reducing rate of high-risk population below 20 and above 60 in age in lead polluted areas was higher than the check area, which was especially serious in 0-5 years old children. The first death reason in the polluted area was angiocardiopathy with the constitution ratio of 33.0%.

In 1993, the research result made by Su Guochen and other experts on the air lead pollution influence on the disease attack of hypertension showed that hypertension detectable rate had an obvious positive correlation with the lead concentration in the air.

In 1995, Su Guomeng's research proved that the IQ exam grades of high-lead group children were lower than those of the low-lead group. Lead had an negative influence to the neural behavior function of school-aged children.

In 1996, researchers of Guangdong Medical College found through research on children of urban Guangzhou that the impact of low-concentration lead contact on children intelligence was first reflected in the decline of abstract inference capability. Lead had certain impact on children intelligence and neural behavior.

In 1997, researchers of Zhongshan Medical University found through research on children living in Guangzhou suburb free of lead pollution source that children intelligence and school grades displayed a decline tendency along with the increase of blood lead concentration.

In 1997, researchers of Beijing Medical University took umbilical cord blood lead content as the intrauterine lead exposure index of newborn babies and found that intrauterine lead exposure had negative influence on neural behavior development, especially for vision and hearing function of newborn babies. They also suggested that the children lead intoxication standard of China should be at least lowered to 10μg/dl.

It can be seen from the above research results that of the harm range of low-concentration lead exposure to children in China is similar with overseas research results. However, the harm degree might differ due to different blood lead densities. Generally speaking, currently there are not many research reports in China with regard to children lead intoxication. China has little researches on children aged 0-6, while children of this age period are high-risk colony of lead intoxication. At the same time, the measurement methods and analysis levels of blood lead in China are under development, and comprehensive comparison and analysis are lacked.

2.1.2 Blood Lead Threshold Research

The most common way of measuring human lead contact degree is to measure the lead content in blood, which is called blood lead and is expressed by μg/dl (microgram per deciliter, 1dl=100ml). If the blood lead in human body is higher than standard value then it is treated as lead intoxication [4]. Scientists began to pay more and more attention to and confirm the negative influence of non-disorderly low blood lead level to children through past 20 years of research and investigation. Before 1960s, people thought that blood lead level below 60μg/dl did not need any treatment, and obvious symptom only appeared when blood lead level was higher than the standard. So American pediatrics textbooks of the United States at that time pointed out that the permitted upper limit of blood lead concentration was 60μg/dl. This value was revised as 25μg/dl in 1985[3]. A report of

American State Science Academy showed that children's blood lead content reached 10µg/dl would accompany early-stage mental and physical development and growth imbalance and later barriers of intelligent behavior and activities. On the basis of plenty of basic and clinic science researches, American National Illness Control Center re-established new children lead intoxication diagnosis standard in 1991, which is blood lead concentration ≥ 10µg/dl. No matter related clinical symptoms and other blood biochemistry changes existed or not, human body blood lead concentration higher than this standard value will be treated as lead intoxication.

Australia adopted the same standard in 1993. This standard new concept was accepted and recognized by officials and scholars from over 30 countries and areas whom were attending the First Universal Children Lead Intoxication Prevention Congress held on May, 1994 in Washington D.C. E.E.C. is also considering to set the standard at 10-15µg/d. The research of Chinese scholars also takes it for granted that it is reasonable to set the diagnosis standard of Chinese children lead intoxication at 10µg/dl.

2.1.3 Chinese Residents Blood Lead Concentration Level Current Status

Internationally recognized human body blood lead content standard is 10µg/dl. The background value of human body blood lead is 0.16µg/dl. Blood lead content of Guangzhou traffic police is 11.6µg/dl. That of pupils who walk and live near the main communication lines is 14.2-16.7µg/dl. That of female shop assistants is 9.4µg/dl. While for male and female college students and pupils who live far from the main communication lines, the values are 9.1, 9.5 and 9.1µg/dl respectively.

In 193, researchers of Children Lead Intoxication Research Center of Shanghai No. 2 Medical University implemented researches to the umbilical blood lead level of 348 Shanghai normal newborn babies, and the result showed that the blood lead level of 40.8% of the newborn babies under investigation exceeded 10µg/dl when they were born. At the same time, they found that living near the roads was one of the dangerous factors for fetus lead exposure.

In 1994, Yu Qing made an investigation for 96 children at 4 kindergartens in Jinan, Shandong Province whose family members did not have lead contact history and found that 36.83% of the blood lead level in 0-6 year(s) old babies and children in Jinan exceeded 10µg/dl. In children group aged from 0-2 years old, the average blood lead level was 10.23µg/dl. Blood lead level did not have gender difference.

In 1995, Li Jiazhen and other people monitored the blood lead level of 141 children aged from 2 to 6 in Xi'an and found that the blood lead level of 53% of 2-4 years old children group was 10μg/dl., and 18.4% of the children have their blood lead level exceeded 15μg/dl. In 4-6 years old children group, 38.7% of them have their blood level exceeded the standard level, and the total disqualification rate was 45.4%. In order to make it convenient for comparison, Li Jiazhen compared the sampling investigation results of the United States in mid 1980s (1985-1986) in the research. At that time, 46% of American children blood lead level exceeded 10μg/dl, and 17% exceeded 15μg/dl. The two groups of data were very close to each other.

In 1996, Li Pei and other scientists made blood lead level evaluation for 259 children aged from 9 to 11 who lived in urban Guangzhou where there was free of industrial lead pollution. The result showed that the disqualification rate of children blood lead level was 55% in urban Guangzhou.

In China's Children Lead Intoxication Current Status Report released by Shanghai International Children Lead Intoxication Seminar held in 1996, Chinese children lead intoxication prevention experts pointed out that in industrial areas, children's blood lead level was between 20-40μg/dl, and lead intoxication prevalence rate was mostly over 85%. In Shanghai and Shenyang, almost all the children living in industrial areas were lead intoxicated. Even in common urban areas where there was not obvious industrial pollution, children's blood lead level was around 10μg/dl. The proportion of children in China who had got lead intoxication was 50%.

In 1997, researchers of Lanzhou Medical College found through investigation for Lanzhou traffic intersection air lead concentration that the air lead concentration of major intersections of urban Lanzhou exceeded national Residential Quarters Air Harmful Matters Highest Permitted Concentration Standard (0.0007mg/m^3) by 1.6-3.8 times.

In 1997, researchers of Beijing Medical University found through investigation for 238 children aged from 11-12 living in Beijing city center, suburb and countryside that the proportions of children whose blood lead level exceeded 10μg/dl for city center group, suburb group and countryside group were 78%, 62% and 30% respectively. Generally speaking, children living in Beijing were more seriously harmed by lead pollution.

In order to make it easy for comparison and analysis, Table 2-2 lists children lead intoxication proportion of most of the big cities in China and the twice surveys in the United States.

Table 2-2 Children Lead Intoxication Condition Summary [4]

Location	Investi ga- tion Yr.	Sample Source	Sample #	Age Range	Disqualification Rate %
Beijing	1997	Common Urban Area	120	11-12	78
		Suburb	50	11-12	62
Shanghai	1993	Common Urban Area	348	0	40.8
	1991	Industrial Polluted Area	273	1-7	95
Guang-zhou	1996	Common Urban Area	259	9-11	55
Jinan	1994	Common Urban Area	296	≤6	36.8
Xi'an	1995	Common Urban Area	66	2-4	53
			75	4-6	38.7
Shenyang	1991	Common Urban Area	758	7-10	67.9
		Industrial Polluted Area	198		99.5
USA	1996	Whole Country			46
	1994	Whole Country	2234	1-5	5.5

2.1.4 Foreign Analysis of Economic Loss Caused by Lead Pollution

The World Bank considers that lead pollution causes economic losses for man and society in different ways.

In the United States, children whose study capability decline and need extracurricular mentor and education because of lead pollution are 17% more than those who have not got lead polluted but need extracurricular mentor. The extracurricular mentor charge for children whose blood lead content is over 25μg/dl is estimated to be USD3,220 per year per student. Since pregnant women are polluted by lead, the costs used for reducing baby mortality and baby health nursing are estimated to be USD1,140M and USD67M respectively.

For adults, expenses related with lead pollution including: 1) medical expenses for angiocardiopathy and apoplexy; 2) working day loss; 3) other discomforts such as work limitation and pains; 4) early death risk. Materials show that every 1μg/dl blood lead content decrease in American population will result in economic benefit of USD 172, which is 10 times bigger than the funds needed to reduce lead content in petrol.

The high blood lead concentration in Chinese children will not only influence the physical condition of our future country builders; lead intoxication will also become a serious social problem including its impact on children's intelligence development, the medical expenses thus caused and the social value reduced due to lead intoxication. At present, the health and economic benefit analysis of children blood lead intoxication are still at preliminary stage and need to be further strengthened.

2.2 Impact of Gaseous Pollutants

Except for lead contained in automobile tail gas, other pollutants also include poisonous and harmful gases such as CO, CO_2, Nox and hydrocarben. These pollutants do not only have strong toxicity, but also can affect each other and form second pollutants. Hydrocarben and Nox may form more harmful photochemical smog under strong sunshine. The major pollutants of photochemical smog including O_3, aldehyde and nitrate have a strong stimulation to human respiratory tract and may cause respiratory diseases like cough, asthma and pulmonary function decline. Although CO_2 does not directly affect human health, it is a kind of greenhouse gas and has certain impact on climatic change.

2.2.1 CO and HC

CO is generated due to incomplete combustion of fuels and prevents hemoglobin from transmitting O_2 to human body and causes anoxia and paralysis of central nervous system, which result in functional disturbance of feeling, reaction, understanding and memory. The serious will die due to blood circulation termination. People who live and work in low-concentration CO polluted environment may develop diseases such as arteriosclerosis, cerebral haemorrhage and peripheral neuritis, it also have a deep impact on the development and growth of fetuses and babies.

According to the research of environmental toxicology [2], when CO concentration in the air reaches $12.5mg/m^3$, it begins to take effect physically and affects central nervous system and does harm to judgment. When CO concentration in the air reaches $37.5mg/m^3$, mutation occurs for ECG of coronary heart disease patients. When it exceeds $50mg/m^3$, heart vessels activity of most of the people over 40 years old will be affected. When CO concentration exceeds $250mg/m^3$, it will cause headache. When CO concentration exceeds $750mg/m^3$, it will cause coma and higher concentration will result in death.

HC consists of over 200 different ingredients, including paraffin gas, olefin and arene, among which ethane, propylene and acetylene are major ingredients of HC in the tail gas. These three ingredients occupy 29-42% of the total HC compound exhausted by vehicles. The reaction activity of olefin is very active with strong tendency of forming O_3 and is likely to cause second pollution. Current toxicological research found that they have a strong effect on plants. HC also contains approx. 4% of oxygenic hydrocarbon----aldehyde, and the rest 20% is satisfied hydrocarbon. Except for engine tail gas exhaust, the leak-out of crankcase and fuel system and evaporation loss also increase HC and CO exhaust.

Arene contains nitrogenous arene (PNA), and parts of them are suspected to be carcinogenic substances. Benzene is a known carcinogenic substance and may cause loss of appetite, weight decrease, dizziness and mucohemorrhagic symptoms. It also has a close relationship with acute granulocytic leukemia of contactors and causes symptoms such as thrombocytopenia, leucopenia or leukocyte abnormal increase, red blood corpuscle decrease and anemia, and even leukemia. Part of benzene in tail gas comes from uncombusted benzene in petrol and the rest part is generated from the combustion of other kinds of aromatic substances. According to reports, nearly 70% of benzene indoors comes from outdoor vehicle tail gas under national ventilation condition, and 80% of the benzene in the air comes from vehicle tail gas. In Great Britain, Air Quality Standard Environment Experts Committee recommends that annual average short-term benzene contact concentration is 0.017 mg/m^3 (5ppb) and long-term contact concentration is 0.003 mg/m^3 (1ppb). Benzene and aromatic substances contents in petrol must be limited in order to reduce the benzene concentration in the air.

2.2.2 CO_2

The global climatic change is mainly due to the gas exhaust with greenhouse effect. CO_2 is a kind of greenhouse gas. Vehicles exhaust 20-25% CO_2 worldwide and most of it is generated from rich and highly industrialized countries. These countries must take actions to stabilize and reduce the exhaust of these pollutions in order to balance climatic change. On the other hand, developing countries are facing the urgent need of more motorized transportation. All these reasons mean that CO_2 exhausted by vehicles cannot be easily controlled within a considerably long period of time.

In industrialized countries, the annual average increase of CO_2 exhaust of transportation departments is approx. 190Mt, and less than 50% (<870Mt) of which is contributed by non-OECD countries, which means 85% of CO_2 exhaust increase rate in non-OECD countries is less than 50%.

2.2.3 NOx

NOx is compounded by nitrogen and oxygen under high pressure and high temperature by air in combustion chamber.

NO_2 contained in NOx has great effect on human health. It is a respiratory tract stimulation gas with low solubility in water and is difficult to be absorbed by upper respiratory tract, but goes deep into the lower respiratory tract and lung. When lung is seriously impaired, pheumochysis may be developed which will even threaten human life. When human being stays in the air where NO_2 concentration is 5ppm for 10 minutes, he feels difficulty in breathing. If human being stays in low-concentration polluted environment for a long time, he is likely to develop respiratory tract infection, lung function decline and get diseases such as chronic bronchitis, coronary heart disease, heart disease, tuberculosis, pneumonia and neurasthenia. For children, even short time of contact will cause cough and laryngeal pain. NOx and HC form photochemical smog with strong oxidizability under photochemical reaction. Serious condition will cause human suffocation.

NOx also causes the rich nutritionalization and nitration of sensitive river mouths with rich nitration and ecosystem and results in the rapid growth and increase of algae and other plants. Monitoring in the United States, Europe and other developed areas in the world show the continuous increase of nitrogenous substances in surface water, and the nitrogenous level has a close relationship with the nitrogenous substances generated by human being and poured into waters. The importation of the nitrogen is caused by fertilizer application and atmosphere sedimentation. Human activities also increase nitrogen flowing into water and cause serious ecological and economic influence, including the plenty growth of loathsomely algae, reduction and atrophy of underwater creatures due to the influence of sunshine and the prosperity of poisonous plankton. Algae and plankton also reduce the generation amount of O_2 and further influence the quantity of fishes and shells. These conditions are more serious at beaches with bad water circulation. In these areas, overgrown algae fall into underwater and rot and consume most O_2 and further cause reduction or extinction of fishes and shells living underwater and destroy the normal balance of ocean ecosystem. Extreme conditions will cause extinction of fishes. In fact, in the past 20 years, due to people’s increased exhaust of nitrogen to oceans, red tide phenomena becomes more and more obvious and is causing more and more losses for human being.

NOx also influences acid precipitation which may destroy trees and increase the acidity in lakes and does great harm to water ecosystem. Besides, exhaust of NOx also increases particulate matter concentration in the air by ways of changing to hydrogen in the air and forming nitrate radical (NO_3^-) in the particulate form. When SO_2 and NOx react with water, O_2 and oxide in the air, various kinds of acid compounds may be formed and fall into ground by ways of wet sedimentation and dry sedimentation of acid particles. It will cause great harm to trees. Under extreme conditions, it will also cause over-acidity of water and makes the water not suitable for water creature to live and grow. Besides, acid sedimentation also causes corrosion on building surfaces and covering, including part of un-recoverable constructions and sculptures which are countries’ cultural legacies. Acid sedimentation mainly influences waters on ground surface. These waters have a weak capability of complex acid. Acid sedimentation also causes decline in forests. Some valuable national parks have been severely harmed.

2.2.4 Influence of O_3

O_3 near the ground is the major ingredient of photochemical smog and is formed by VOC and NOx under the effects of sunshine and heat energy. O_3 is mainly generated in lower atmosphere in hot summers. VOC that forms O_3 has several sources including vehicle exhaust, commercial products of chemical products and other industrial sources. VOC also has some national sources such as plants exhaust. NOx mainly comes from vehicle exhaust, power plants and some combustion sources.

The mechanism of the formation, transmission and deposit are very complicated. O_3 of ground level is generated and destroyed during a series of chemical processes (including effects of VOC, NOx, heat energy and sunshine). Consequently, different O_3 densities occur in different areas, different seasons and climatic conditions with different VOC and NOx exhaust. Most of the chemical reactions that attending the formation of O_3 are sensitive of temperature and lighting. When high-environmental temperature and strong lighting conditions last for several days and slow circulation of ground air, O_3 and its prosomal substances will accumulate and result in much higher O_3 concentration than under merely high temperature weathers. The more complicated condition is that O_3 may be transported to places hundreds of kilometers away from pollution source in upwind and cause down-wind areas where NOx and VOC densities are not high also form high concentration O_3.

Plenty of researches show that O_3 affects respiratory tracts greatly including symptoms such as chest pain, cough and non-expedition of breath. When breathing in, hat breathed in will cause acute respiratory tract diseases and asthma and cause the lung function of some healthy adults decline 15-20%, lung inflammation and affect human Vitamin C. Children often playing outdoors are more easily to be affected by O_3 exposure, especially when they are playing and exercising outdoors in summers, at which time the sunshine intensity is high with the highest O_3 concentration. Besides, since children's respiratory system is under development, they are more easily to be negatively affected than adults. Outdoors workers and patients of respiratory system are the major targets of O_3 influence.

Exposing in high concentration O_3 for a short period of time (1-3 hr.) causes respiratory system diseases that require emergency treatment. For example, researches in northeastern U.S. and Canada that O_3 has relationship with 20% of respiratory system emergency. Repeated exposure also causes lung infection, pneumonia and is easier to induce old diseases like asthma. In conclusion, exposure in O_3 impair lung functions in different degrees.

Long-time low concentration O_3 exposure has great effect on health. Research on the allergenic effect of O_3 to health shows temporary lung function imbalance, and these symptoms occur when man exposes in 0.12ppm O_3 concentration for a long time, especially when the sampling concentration is >0.09ppm. Research on 6-8 hr. exposure shows that the concentration of long-time and repeated O_3 environment should <0.08ppm.

O_3 also influences environment in many ways except for its influence on health, including reducing the production of grains, fruits, vegetables and economic forests. It damages city green grasses and trees and reduces survival rate of trees, and trees are more likely to be attacked by pests and tree timber will be damaged.

2.3 Health Influence of Particles

Particles can be exhausted directly into the air and can also be generated through gas exhaust reaction. The shape of particles varies greatly with time, climate and source, and thus the influences they cause also differ greatly. Ingredients of some of the particles (mainly come from H_2SO_4 and HNO_3) affect acid sedimentation. Higher particulate concentration affects health, visibility limit and substantial materials.

Although it is not very clear about the mechanism of the harm caused by particles, it has been recognized already that heart diseases and respiratory system diseases are the major influence approaches of the particles. The influences of particles mainly include early death, tachypnea, heart diseases, lung function impair, change of lung level of organization and change of the defense mechanism of respiratory system. The above symptoms are related with the concentration of environmental particles and these diseases are often used to evaluate human colony exposure in many research of epidemiology. Particles take polymeric carbon granule as core and display a loose status. Many carcinogens are absorbed on them. The diameters of over 80% of the particles are smaller than 1μm and can suspend in the air for a long time. Once being breathed in by human being, they enter the deep lung area and stay for a long time with the possibility of carcinogen. Exposing in higher PM concentration will cause the great increase rate of early death and heart system diseases of the old. Researches show that both high and low densities particles have great influence on the old, especially when they themselves already have heart or respiratory diseases. Children reflect in higher respiratory system diseases and lung functional decline. Symptoms of some of the asthma patients will get heavier.

Chemical and physical properties of coarse particles and fine particles differ greatly. Fine particles include acid gasoloid, vitriol, nitrate, transition metal and particles exhausted by diesel. And coarse particles mainly include mineral particles and suspending particles. Coarse particles often result in respiratory diseases such as asthma; while fine particles result in early death or diseases of heart system. Statistics of many researches show that fine particles have a more serious influence on human health than coarse particles with high correlation.

China Environment Monitor General Station researched the correlation of respiratory system diseases and PM_{10} in 4 heavily polluted cities in China, and the results show that there was a positive relationship between PM_{10} and children's incidence rate of respiratory system diseases such as expectoration, bronchitis and asthma. They researched children's lung functions in Lanzhou, Guangzhou, Wuhan and Chongqing and found that in Lanzhou where the pollution was heavier, children's lung functions were lower correspondingly.

Vehicle exhausted particles and the organic extracts of gas condensates have strong mutagenicity and are mainly featured with indirect mutagenic activity.

Particles mainly include organic compound that will cause gene mutation as well as some trace metals. These metals may have gene toxicity effect.

American National Environment Protection Bureau found through the basis of summarizing many researching materials and found that lung cancer proportion of workers working near diesel engines has a large correlation with diesel exposure. Evidences show that some organic compound related with diesel particles can be absorbed by lung liquid and enter blood and even other parts of the body in this way. Researches also show that exposing in high-concentration diesel particles (including carbon core in element form and the organic it absorbs) will cause lung cancer. Carbon that exists in diesel particles in element form and organic particles has a great correlation with respiratory system diseases of animals.

In 1993, American National Environment Protection Bureau constituted referential standards so as to minimize the non-cancer health influence due to exposing in diesel exhaust.

At the end of 1980, International Agency for Research on Cancer confirmed that diesel exhaust was a potential carcinogen of human body.

In 1990, under the research basis of International Agency for Research on Cancer, California, U.S. confirmed that diesel exhaust was a matter that might cause cancer and after a extensive re-investigation in 1998, they confirmed that diesel exhaust matters were ingredients of poisonous air.

American National Job Security and Health Association also list diesel exhaust pollutant as “potential job carcinogen”. World Health Organization also suggests that “emergency measures should be adopted to reduce diesel exhaust, especially to control the exhaust of diesel particles, which can be realized by ways of changing exhaust technologies, re-designing equipment and fuel composition”.

Taking the influence of diesel exhausted pollutants on lung cancer under consideration, the Department of Health and Human Services is also considering whether to add it in its list of Report on Carcinogen of Yr. 2000.

In 2000, American National Environment Health and Science Association listed diesel exhaust pollutants in the list of Substances that have Carcinogen on Human Body at the 9tgh National Carcinogen Toxicology Public Lecture.

2.4 Environmental Influences of Metallic Addition in Gasoline

Common additions in petrol include Mn, Cu and Fe except for lead. The harms of lead have been described in detail above.

Manganous metallic addition represented by MMT is an effective octane level improver. Adding 18mg manganous MMT in 1 liter increases over 3 research octane (RON). Researches in Canada show that since the Mn level in people who exposed in the environment increases less than 1%, MMT is adopted in Argentina, Australia, Bulgaria, Canada, Russia and part of New Zealand. American Environment Protection Bureau approved MMT adoption in lead-free petrol in July 11, 1995.

In recent years, overseas scholars researched the health impact of MTBE, a petrol addition, including its genetic toxicity, neurotoxicity and animal carcinogen, development and reproduction toxicity. The results show that MTBE does not have obvious genetic toxicity, but has certain animal carcinogen and reproduction toxicity under the condition of high dosage. Human group contact has subjective symptoms, but the mechanism of the above toxicity is not very clear. The research of Shanghai Medical University of China also got the above results. Through the investigation on the workers of some oil refinery plants, the subjective symptoms occurrence (including eye stimulation, burning feeling in respiratory tract, headache, sleep disorder and nausea) of the MTBE contact group is obviously higher than the check group, which shows that the health condition of the workers who have contacted with MTBE has been influenced obviously.

The research on health influence of new petrol additions should be strengthened.

2.5 Summary

(1) Pollutants in vehicles exhaust have a great influence on both environment and human body. Generally speaking, vehicle exhausted substances have genetic damage on human group cells, reduce human body immunity and cause diseases in respiratory system and cardiovascular system, especially have a more serious influence on children. For professional contact human colony, they cause decrease in cell and immunity level and the decline in resistance; antineoplastic immunogenic function is also obviously declined. Table 2-3 briefly summarizes the influence of vehicle tail gas to environment and human body.

Table 2-3 Harms of Vehicle Tail gas to Environment and Human Body

Pollutant	Major Harm
Pb	Prevent children's intelligence and body from development and cause troubles in reading and understanding. Harms done to children are irreversible. Influence adult cardiovascular system with a high correlation with myocardial infarct.
CO	Prevent hemoglobin from transmitting oxygen to human body system and cause oxygen deficit. Paralyze central nervous system. Stay in low-concentration pollution condition for a long time may result in diseases such as arteriosclerosis, cerebral hemorrhage and peripheral neuritis, and has a great influence on the development and growth of fetuses and babies.
CO_2	Greenhouse gas with the influence on climatic change
NO_X	Serious carcinogen and result in lung function decline. Cause rich nourishment and have a serious influence on water ecosystem. Cause acid sedimentation and increase the acidity of lakes. Cause serious damage to plants and buildings. React with hydrocarbon substances and form photochemical smog under the effect of sunshine. Serious condition causes human group apnea immediately.
Particles	Ingredients of some of the particles influence acid sedimentation High concentration of particles influences health, visibility and substantial materials. Diseases of heart and respiratory systems are the major influential approaches of particles
HC	Strong carcinogen, especially high disease rate of lung cancer and liver cancer

(2) In China, currently the health influence of vehicle tail gas is mainly focused on the influence of lead in the petrol. At the same time, a few researches on the influences of particles and petrol addition have been implemented. The researches show that before lead-free petrol was put into use, the proportion of Chinese children intoxicated by lead was 50%. In some industrial areas and cities with a rapid vehicle increase rate, children's blood lead Overproof condition is very serious. Besides, blood lead concentration of residents and workers near communication areas is higher than people group living far from communication areas. This shows that in China, the health influence of lead caused by vehicle exhaust is very serious.

(3) The research of the health influence in China of pollutants exhausted by vehicles is not completed. Researches on the change of human body blood lead concentration after completely using lead-free petrol, influences of other pollutants exhausted by vehicles, the health influence of new petrol additions and the application of alternative fuel are to be improved.

(4) Researches on the health influence of vehicle exhausted pollutants on professional people group (traffic police, vehicle driver, conductor, etc.) are to be strengthened.

(1) Materials provided by Walsh
(2) Researches on the Dynamic Principle and Solutions for Guangzhou Vehicles Tail gas Pollution
(3) Researches and Analysis Report of China's Implementation of Petrol Lead-Free Problems
(4) Researches and Analysis Report of China's Implementation of Petrol Lead-Free Problems

Chapter 3 New Vehicles Exhaust Control Strategy

The most fundamental way to put down vehicles exhaust pollutants is to depending on the development and application of vehicle exhaust control technologies. The driving force of pushing the development of these advanced exhaust control technologies is mainly implementing strict exhaust standards. As the strictness of exhaust standards, various kinds of exhaust control technologies emerged accordingly. This chapter mainly introduces the recent exhaust standards of new vehicles recently carried out in the United States and countries and areas in Europe as well as the exhaust standards recently released in China for some of the new vehicles. This chapter also makes comparisons for exhaust standards of new vehicles implemented in China, U.S. and countries and areas in Europe with regard to light vehicles, heavy vehicles and motorcycle, in order to provide experiences for the future middle and long term vehicles exhaust control in China and also providing beneficial ideas for the development of control technologies of new vehicles in China.

3.1 Light Vehicle Exhaust Standards

3.1.1 New LEV2 Standards of California, U.S.

Table 3-1 is the current standards carried out in California, U.S. for light petrol vehicles (1mi=1.609km).

Table 3-1 Exhaust Standards of Light Petrol Vehicle (g/mi，50,000mi)

	NMOG	CO	NOx
1993MY	0.25	3.4	0.4
TLEV	0.125	3.4	0.4
LEV	0.075	3.4	0.2
ULEV	0.04	1.7	0.2

In Nov.5 1999, CARB decided to carry out stricter standards for cars, special used vans (SUVs), motor wagons and pole trailers. See Table 3-2 (1 lb. =0.4536kg).

Revision of the new exhaust standards compared with the previous one mainly include:

(1) Specifies that all light trucks and mid-sized trucks that weighing below 8,500 lb. should follow the LEV and ULEV standards which are the same with light cars.

(2) From 2004 to 2007, currently applied exhaust standards LEV, ULEV and SULEV

will be stricter, including: in LEV and ULEV standards, NOx exhaust standard of cars and light trucks will be tightened from 0.2g/mile to 0.05g/mile. Stricter particles exhaust standards of diesel vehicles will be implemented. Reliability of the exhaust control system of cars and light trucks will be increased from 100,000 miles to 120,000 miles.

(3) From 2004 to 2010, NMOG average exhaust of each type of vehicles will continuously decrease. Special exhaust decrease plan will be constituted for HLDT. Besides, for mid-sized trucks, the proportion required to meet LEV and ULEV standards will be changed from 60 versus 40 in 2004 to 40 versus 60 in 2010.

(4) Further tighten evaporation exhaust limits of 3-day and hot-dip test and 2-day and hot dip test.

(5) Service life should be no shorter than 15 years or 150,000 miles. New standards require that 40% of the vehicles manufactured till 2004 should meet this exhaust limit demand. This proportion should reach 50% in 2005, and 100% in 2006.

The 4 basic strategies to meet LEV2 exhaust standards are: improve fuel control system, optimize fuel transmission system, improve functions of catalytic converter equipment and reduce engine exhaust.

Table 3-2 Light Vehicles Exhaust Standards in Yr. 2004, California (g/mi)

Vehicle type	Service life	Exhaust standard	NMOG	CO	NOx	Aldehyde	Diesel particles
LDTs (<8,500 lb.)	50000mi	LEV	0.075	3.4	0.05	15	n/a
		LEV (1)	0.075	3.4	0.07	15	n/a
		ULEV	0.04	1.7	0.05	8	n/a
	120000mi	LEV	0.09	4.2	0.07	18	0.01
		LEV (1)	0.09	4.2	0.1	18	0.01
		ULEV	0.055	2.1	0.07	11	0.01
		SULEV	0.01	1	0.02	4	0.01
	150000mi	LEV	0.09	4.2	0.07	18	0.01
		LEV (1)	0.09	4.2	0.1	18	0.01
		ULEV	0.055	2.1	0.07	11	0.01
		SULEV	0.01	1	0.02	4	0.01

(1) Among LDT2 sold by manufacturers, NOx exhaust concentration of 4% of the vehicles can be higher.

3.1.2 New Vehicles Emission Standards in American Federal Government

Table 3-3 shows the trucks classifications in the U.S. Table 3-4 is currently applied LEV and LET exhaust standards of American Federal Government. Table 3-5 is the National Low Exhaust Standards of Vehicles (NLEV). NLEV is a voluntary standard and can only be carried out under the consent of northeastern states and vehicles manufacturers. Later all the vehicles manufacturers and related states voluntarily follow NLEV standards. From 1999 to 2001, northeastern states will carry out stricter LDVs and

LLDTs exhaust standards.

Table 3-3 American Trucks Classification

	Gross Weight (GVWR)	Empty Truck Weight (CW)	Load (LVW)	Front face area (ft^2)
Light-Light trucks (LLDT)	0-6000			
Light trucks (LDT)				
Light trucks I (LDT1)	0-8500	>6000	0-3750	
Light trucks II (LDT2)			>3750	<45
Heavy-light trucks (HLDT)				
Light trucks III (LDT3)	6001-8500		0-5750	
Light trucks IV (LDT4)			<5750	
Heavy trucks (HDV)	8500>	6000>		45>

Table 3-4 Currently LEV and LET Exhaust Standards of American Federal Government (g/mi)

	5 years or 50,000 mi service life					10 years or 100,000 mi service life			
	NMHC	CO	Cold CO	NOx	PM	NMHC	CO	NOx	PM
Gasoline Vehicles									
LDV and LDT1	0.25	3.4	10	0.4	-	0.31	4.2	0.6	-
LDT2	0.32	4.4	12.5	0.7	-	0.40	5.5	0.97	-
Diesel Vehicles									
LDVs and LDT1	0.25	3.4	-	1.0	0.08	0.31	4.2	1.25	0.10
LDT2	0.32	4.4	-	-	0.08	0.40	5.0	0.97	0.10
HLDT Vehicles*	NMHC	CO		NOx		NMHC	CO	NOx	PM
LDT3	0.32	4.4		0.7*		0.46	6.4	0.98	0.10
LDT4	0.39	5.0		1.1*		0.56	7.3	1.53	0.12

* Not applicable for diesel light trucks

Table 3-5 NLEV Exhaust Standards of LDVs and LLDTs (50,000mi)

Vehicle type	Year	Average NMOG	NO_X	CO
LDV & LDT1	1999*	0.148	0.2	3.4
	2000*	0.095	0.2	3.4
	2001 and after**	0.075	0.2	3.4
LDT2	1999*	0.190	0.4	4.4
	2000*	0.124	0.4	4.4
	2001 and after**	0.100	0.4	4.4

* 9 northeastern states and District of Columbia, except New York and Massachusetts

** All states except California, New York, Massachusetts, Vermont and Maine. These states carry out the standards of California.

In Dec. 12 1999, American Environment Protection Bureau discussed Tier2 standards and further tightened new vehicle exhaust standards. New federal exhaust standards (Tier2 standards) are for vans, light trucks and large passenger vans. This is also the first time to carry out a unified standard for the vehicles above. Light trucks include LLDTs and HLDTs. Middle passenger vans (MDPVs) are new newly introduced vehicle types into this regulation, including SUVs weighting 8,500-10,000 lb. In Tier2 plan, these vehicles are in the same group with HLDTs, and they follow the same exhaust standards.

Tier2 Standards decrease the NOx exhaust standards of new vehicles to 0.07g/mi. For new vans and LLDTs, these standards are estimated to be accomplished in stages starting from 2004, and completely meet the standards in 2007. For HLDTs and MDTs, Tier2 Standards will be accomplished in stages starting from 2008 and completely meet the standards in 2009.

Manufacturers may make the vehicles meet different tail gas exhaust standards, i.e. "Tank".

The tank structure of Tier2 includes 8 parts of exhaust standards (Tank 1-8). Each part of standards is corresponding to vehicles of certain type. Table 3-6 and Table 3-7 show the vehicle exhaust standards in Tier2 corresponding to each tank. Tank 9 and 10 are two additional ones and are only applicable for transition period and will be expired for use before the final Tier2 standards are put into use. Tank 11 only applies to MDPVs, see Table 3-8.

Table 3-6 Whole Service Life Tail gas Exhaust Standards of Light Vehicle (g/mi)

Tank #	NOx	NMOG	CO	HCHO	PM	Remarks
10	0.6	0.156/0.230	4.2/6.4	0.018/0.027	0.08	a,b,c,d
9	0.3	0.090/0.180	4.2	0.018	0.06	a,b,e
Above are temporary tanks and valid till 2006 for LDVs and LLDTs; valid till 2008 for HLDTs.						
8	0.20	0.125/0.156	4.2	0.018	0.02	b,f
7	0.15	0.090	4.2	0.018	0.02	
6	0.10	0.090	4.2	0.018	0.01	
5	0.07	0.090	4.2	0.018	0.01	
4	0.04	0.070	2.1	0.011	0.01	
3	0.03	0.055	2.1	0.011	0.01	
2	0.02	0.010	2.1	0.004	0.01	
1	0.00	0.000	0.0	0.000	0.00	

Notes：

a. Tanks will be expired till the end of 2006 (HLDTs tanks will be expired at the end of 2008)

b. There are 2 sets of temporary NMOG, CP and HCHO standards. The higher ones are only applicable for HLDTs.

c. Temporary tanks of the higher values of MDPVs will be discussed later.

d. LDT4s and MDPVs may select temporary standards of NMOG 0.280 g/mi but are only limited to LDT4s and MDPVs.

e. LDT2s may select temporary standards of NMOG 0.130g/ mi but is only limited to LDT2s.

f. The higher temporary standards of NMOG 0.156g/mi will be expired at the end of 2008.

Table 3-7 Tail gas Exhaust Standards of Light Vehicles of Mid-level Service Life (50,000mi) (g/mi)

Tank #	NOx	NMOG	CO	HCHO	PM	Remarks
10	0.4	0.125/0.160	3.4/4.4	0.015/0.018	--	a,b,c,d,f,h
9	0.2	0.075/0.140	3.4	0.015	--	a,b,e,h
Above are temporary tanks and valid till 2006 for LDVs and LLDTs; valid till 2008 for HLDTs.						
8	0.14	0.100/0.125	3.4	0.015	--	b,g,h
7	0.11	0.075	3.4	0.015	--	h
6	0.08	0.075	3.4	0.015	--	h
5	0.05	0.075	3.4	0.015	--	h

Notes:

a. Tanks will be expired till the end of 2006 (HLDTs tanks will be expired at the end of 2008)
b. Higher values of NMOG, CO and HCHO standards are only applicable for HLDTs and will be expired in 2008.
c. Can be used as temporary tank to constrain MDPVs exhaust.
d. LDT4s and MDPVs may select temporary standards values of NMOG0.195g/mi but are only limited to LDT4s and MDPVs.
e. LDT2s may select temporary exhaust standards of 0.100g/mi but are only limited to LDT2s.
f. Tank 10 diesel engine may select mid-level service life standards.
g. The higher temporary standards of NMOG 0.156g/mi will be expired at the end of 2008.
h. For experimental group of service life of 150,000 miles, mid-level service life standards may be applied.

Table 3-8 Temporary Tail gas Exhaust Standard Tank of MDPVs (g/mi)

Whole Service Life	NO_x	NMOG	CO	HCHO	PM
120,000 miles	0.9	0.280	7.3	0.032	0.12

Note: valid till 2008.

All Tier2 light vehicles and light trucks adopt stricter evaporation exhaust standards, see Table 3-9. From the table it can be seen that for most of the vehicles, hot-dip daily exhaust standards are reduced more than a half. These standards will take effect before the execution of Tier2. All non-diesel MDPVs will begin to follow OBDII from 2004. Tier2 also stipulates that MDPV2 must pass CO cold test and short working mode certification test.

Table 3-9 Evaporation Exhaust Final Standards (g/time of inspection)

Vehicle types	3 days (daytime) + hot dip	Supplementary 2 days (daytime) + hot dip
LDVs and LLDTs	0.95	1.2
HLDTs	1.2	1.5

3.1.3 New Vehicles Exhaust Standards of EU

In June 30, 1998, European Parliament and committee passed Vehicle Fuel Program with the purpose of further decreasing vehicle pollution. In this program, the exhaust standards of light vans and light trucks I will take effect in 2000 and 2005 respectively. The exhaust standards of light trucks II and III will take effect in 2001 and 2006 respectively. Table 3-10 shows new standards for light vans. Table 3-11 and 3-12 respectively show the new standards for light petrol trucks and light diesel trucks.

Table 3-10 New Vehicle Exhaust Standards for Light Vans (g/km)

	CO	HC	NOx	HC + NOx	PM
2000	P: 2.30 (2.2) D: 0.64 (1.0)	P: 0.20 D: —	P: 0.15 D: 0.50	P: — (0.5) D: 0.56 (0.7)	P: — D: 0.05 (0.08)
2005	P: 1.00 D: 0.50	P: 0.10 D: —	P: 0.08 D: 0.25	P: — D: 0.30	P: — D: 0.025

Notes: Values in brackets are current standards.
P= petrol; D=diesel

Table 3-11 New Standards for Light Petrol Trucks (g/km)

Light Vehicle Type	CO		HC		NOx	
	2000	2005	2000	2005	2000	2005
Type I (RW <1305)	2.3	1	0.2	0.1	0.15	0.08
Type II (1305 < RW <1760)	4.17	1.81	0.25	0.13	0.18	0.1
Type III (1760 <RW)	5.22	2.27	0.29	0.16	0.21	0.11

RW: Referential Weight (kg)

Table 3-12 New Standards for Light Diesel Trucks (g/km)

Light Vehicle Type	CO		HC + NOx		NOx		PM	
	2000	2005	2000	2005	2000	2005	2000	2005
Type I (RW <1305)	0.64	0.5	0.56	0.3	0.5	0.25	0.05	0.025
Type II 1305 < RW <1760	0.8	0.63	0.72	0.39	0.65	0.33	0.07	0.04
Type III (1760 <RW)	0.95	0.74	0.86	0.46	0.78	0.39	0.1	0.06

RW: Referential Weight (kg)

From 2000, petrol vehicles are required to install OBD system and diesel vehicles will have OBD system installed from 2003. The installation on light trucks Type II and III will be delayed to 2005. From 2002, petrol vans and light trucks must receive cold test.

3.1.4 New Vehicles Exhaust Standards in China

In July 9 1999, China National Environment Protection General Bureau released Pollutants Exhaust Standards for Light Vehicles (GWPB1-1999) which took effect from Jan.1 2000. It stipulates the exhaust standard values of pollutants type certification of light vehicles exhaust and production unification inspection tests and durability requirements for exhaust control devices.

Light vehicles defined in the Standards refer to vehicles of Type M1, M2 and N1 with the max. gross weight <3.5t. (See Pollutants Exhaust Standards for Light Vehicles GWPB1-1999 for definitions of M1, M2 and N1 and vehicles type I and II).

Table 3-13 is the tests required for different types of vehicles at Type Certification. Table 3-14 and 3-15 are pollutants type certification test exhaust standard values for vehicles type I and type II.

Table 3-13 Test Requirements for Type Certification

Type Certification Tests	Vehicles with Ignition Engine		Vehicles with Compression-ignition Engine	
	Vehicle type I	Vehicle type II	Vehicle type I	Vehicle type II
Air Exhaust Pollutants Test	Doing	Doing	Doing	Doing
Crankcase Exhaust Substances Test	Doing	Doing	Doing	Doing
Evaporation Exhaust Substances Test	Doing	Doing	Doing	Doing
Durability Test of Exhaust Control Device	Doing	Doing	Doing	Doing

Table 3-14 Type Test Standard Values of Vehicle Type I (g/km)

Experimental Stages	Pollutants		Exhaust Standards
First Stage：(Jan.1 2000 – June 30 2004)	CO		2.72
	$HC+NO_x$ (1)		0.97（direct-injection diesel engine1.36）
	PM(1)(2)		0.14（direct-injection diesel engine0.20）
First Stage：(start from July 1 2004)	CO	Ignition engine	2.20
		Compression-ignition engine	1.00
	$HC+NO_x$ (3)	Ignition engine	0.50
		Compression-ignition engine	0.70（direct-injection diesel engine 0.90）
	PM(3)	Compression-ignition Engine	0.08（direct-injection diesel engine 0.10）

Notes: (1)The exhaust limit valid time of vehicles using direct-injection diesel engine for driving force listed in the table is 2 years.

(2) Only applicable for vehicles using compression-ignition engine for driving force.

(3) The exhaust limit valid time of vehicles using direct-injection diesel engine for driving force listed in the table is 4 years.

Table 3-15 Type Certification Test Standards of Vehicle Type II (g/km)

	Referential Weight (RM), kg		RM≤1250	1250<RM≤1700	RM>1700
First Stage (2001.01.01－2005.06.30)	CO		2.72	5.17	6.90
	$HC+NO_x$ (1)		0.97（1.36）	1.40（1.96）	1.70（2.38）
	PM(1)(2)		0.14（0.20）	0.19（0.27）	0.25（0.35）
Second Stage (2005.07.01－)	CO	Ignition Engine	2.20	4.00	5.00
		Compression-ignition Engine	1.00	1.25	1.50
	$HC+NO_x$ (3)	Ignition Engine	0.50	0.60	0.70
		Compression-ignition Engine	0.70（0.90）	1.00（1.30）	1.20（1.60）
	PM(3)	Compression-ignition Engine	0.08（0.10）	0.12（0.14）	0.17（0.20）

Notes:

(1) The exhaust limit valid time of vehicles using direct-injection diesel engine for driving force listed in the table is 1 year.

(2) Only applicable for vehicles using compression-ignition engine for driving force.

(3) The exhaust limit valid time of vehicles using direct-injection diesel engine for driving force listed in the table is 3 years. Values in brackets are standards for direct-injection diesel engine.

Any gas in crankcase ventilation system of the engine is not permitted to be leaked into the atmosphere. Evaporation exhaust substances should not exceed 2g/per test.

3.2 Exhaust Standards for Heavy Vehicles

3.2.1Heavy Vehicle Exhaust Standards of American Federal Government

Table 3-16 summarizes the heavy vehicle exhaust standards currently applied by American Federal Government.

EPA has published the strategic plan of greatly decreasing highway heavy vehicles (GVWR>=8,500lb.), including diesel engines and petrol engines used in large-scale commercial trucks, large-scale towed-vehicles, large vans and large special vehicles. The first stage of this plan will take effect in 2004, and the second stage will take effect in 2007.

Table 3-16 Highway Heavy Vehicles Exhaust Standards (g/bhp-hr)

	Year	HC	CO	HC + NO_x	NO_x	Diesel engine
Diesel Vehicles	1991-93	1.3	15.5		5.0	0.25
	1994-97	1.3	15.5		5.0	0.10
	1998	1.3	15.5		4.0	0.10
	2004	1.3	15.5	2.4**		
Urban public bus	1991-92	1.3	15.5		5.0	0.25
	1993	1.3	15.5		5.0	0.10
	1994-95	1.3	15.5		5.0	0.07
	1996-97	1.3	15.5		5.0	0.05*
	1998	1.3	15.5		4.0	0.05*
Otto Circulation		HC	CO		NOx	Organic Vapor***
	1991-97(A)	1.1	14.4		5.0	3.0
	1991-97(B)	1.9	37.1		5.0	4.0
	1998 (A)	1.1	14.4		4.0	3.0
	1998 (B)	1.9	37.1		4.0	4.0

Notes:

(A) Applicable for engines on GVWR less than 14,000 lb.

(B) Applicable for engines on GVWR heavier than 14,000 lb.

* 0.07 g/bhp-hr. when using.

** When the upper limit of NMHC is 0.5, the permitted standard is 2.5.

***Organic vapor unit (g/per test)

I. First Stage

In Aug.1 2000, American EPA passed a regulation on the heavy vehicle exhaust standard of Yr. 2004. The regulation stipulates heavy diesel engines must pass a new set of tests. First of all, EPA newly adds steady-state test for heavy diesel engines. The test must satisfy with the federal test procedure. This test will be implemented in 2007. Secondly, EPA adds Not-to-Exceed (NTE) test for vehicles currently under use which will be implemented in 2007. Thirdly, EPA requires heavy diesel vehicles to pass Load Response Test (LRT) which will be implemented in 2004. EPA also requires that vehicles with heavy diesel engine must install OBD system. This regulation will take effect from 2005 to 2007.

The regulation stipulates stricter exhaust standards for Otto circulate engine and vehicles, as shown in Table 3-17.

Table 3-17 Exhaust Standards for Otto Circulate Vehicles (g/mi)

GVWR	NMOG	NOx	CO
8,500 - 10,000 lb. *	0.28	0.9	7.3
10,001 - 14,000 lb.	0.33	1.0	8.1

Including MDPV defined in Tier2.

II. Second Stage

Table 3-18 and 3-19 are the exhaust standards for heavy engine and heavy vehicles respectively issued by EPA.

Table 3-18 Exhaust Standards for Heavy Engine (g/bhp-hr)

	NMHC	HCHO	NOx	PM
Petrol Engine	0.14	0.016	0.20	0.01
Diesel Engine	0.14	0.016	0.20	0.01

Notes: Various pollutants exhaust standards of petrol engine will take effect from 2007. Diesel engine exhaust standards will be effective from 2007 to 2010 except that PM exhaust standards will take effect from 2007.

Table 3-19 Exhaust Standards for Heavy Vehicle (g/bhp-hr)

GVWR	NMHC	HCHO	NOx	PM
8,500 - 10,000 lb.	0.195	0.016	0.2	0.02
10,001 - 14,000 lb.	0.230	0.021	0.4	0.02

Note: the implementation plan is the same with engine standards.

EPA suggests revising the evaporation exhaust standards for mid-size engine and vehicles. The newly suggested standards are shown in Table 3-20. These standards tighten 50% than currently applied standards.

Table 3-20 Evaporation Exhaust Final Standards (g/per test)

GVWR Vehicle Type	3 days (daytime) + hot dip	Supplementary 2 days (daytime) + hot dip
8,500–14,000 lb.	1.4	1.75
>14,000 lb.	1.9	2.3

3.2.2 EU Heavy Vehicles

European parliament passed regulations on the limitation of the exhaust of trucks and public buses. The regulation stipulates obligatory standards aimed to the diesel engines used on trucks and public buses for CO, hydrocarbon, NOx and particle smog they exhaust. These standards also applicable for vehicles using natural gas and LPG for fuel.

The regulation includes stricter standards and improvement of test methods, and forcibly installs measurement system on heavy trucks. It also demands to install particles catcher in 2005 and DeNOx or SCR catalyst in 2008.

The main content of the regulation is:

2000 (Euro 3) ---- The committee initially suggested cutting down 30% of the current standard in an overall state with only one exception, i.e. the cylinder delivery of small high-speed diesel engine is expanded from 0.70L to 0.75L.

2005 (Euro 4) ---- Reach the required CO, HC and NOx exhaust standards by way of improving engines. But in order to reach the exhaust standards of particles, particles catcher is required. Gas engine only needs to pass ETC circulation test, and other types of engines do not only need to pass ETC circulation test, but also have to pass steady-state and change circulation tests. This means standards of CO, HC and NOx will be further tightened 50%, and PM will be tightened 80%.

Table 3-21 shows the limit values aimed to the ESC and ELT tests of traditional diesel engines. Table 3-22 shows the limit values of diesel and petrol engines during ETC tests, especially for the diesel engines which have installed advanced processing equipment such as PM catcher and DENOX catalyst.

Table 3-21 Limit values for Diesel Engines during ESC and ELT Tests (g/kWh)

Implementation Date	CO	HC	NOx	PM	Smoke concentration*
2000/01	2.1	0.66	5	0.10 0.13(a)	0.8
2005/06	1.5	0.46	3.5	0.02	0.5
2008/09	1.5	0.46	2	0.02	0.5

(a) = For engines that cylinder stroke capacity <0.75 dm^3 and rotation speed under rated power <3000 min^{-1}.

*Smoke concentration unit is (m^{-1})

Table 3-22 Limit Values for Diesel and Petrol Engines during ETC Test (g/kWh)

Implementation Date	CO	NMHC	Methane (b)	NOx	PM (c)
2000/01	5.45	0.78	1.6	5	0.16 0.21
2005/06	4	0.55	1.1	3.5	0.03
2008/09	4	0.55	1.1	2	0.03

(a) = For engines that cylinder stroke capacity <0.75 dm^3 and rotation speed under rated power <3000 min^{-1}.

(b) = Only applicable for natural gas engines

(c) = Only applicable for diesel engines

3.3 Standard Exhaust of Motorcycles

In European and American countries and areas, the sharing rate of motorcycles in the total exhaust amount is small, so that the exhaust standards of motorcycles are much loose than those of other vehicle types. But in Asian countries and areas, the exhaust of motorcycles and tricycles occupies a large proportion in gross HC and particle exhaust, and as a result, some Asian countries and areas pay high attention to the exhaust control of motorcycles, such as in Japan, Taiwan and Thailand where implement the most strict motorcycle exhaust standards in the world.

In recent years, the motorcycle production volume in China is doubled and redoubled, and the stock rate is also increased rapidly as well, but the current exhaust standards are relatively loose. The experiences of some of the Asian countries and areas (such Thailand and Taiwan) with regard to motorcycle control are worthy to be learned.

3.3.1 Motorcycle Exhaust Standard of California, U.S.

Californian Air Resources Bureau tightened the exhaust standards for Type III motorcycle in use (≥280cc) in 2004 at the public meeting held in Dec. 10 1998. In Tier1 standards, the exhaust limited values of HC+NOx of Yr. 2004 is 1.4g/km, and 0.8g/km in 2008. Small manufacturers must meet Tier1 standards till 2008. At the same time, manufacturers may reach HC+NOx exhaust standards of Tier2 ahead of schedule in order to obtain exhaust point certificates.

3.3.2 Motorcycle Exhaust Standards of Taiwan, China

Current tendency shows that the annual quota of motorcycles till Yr. 2010 will reach 9M, and it is estimated that the quota of electric motorcycles will occupy 1/3 of the total motorcycle quota, i.e. 3M. Taiwan Environment Protection Bureau has calculated that under this condition, CO exhaust will reduce 42,000t each year; the exhaust of HC and NOx will reduce 23,400t; the exhaust of CO_2 will reduce 62,800t. Besides, 22,000,000megawatt electric energy will be saved, and the electricity consumption rate during non-peak period will be increased. Table 3-23 is the action plan of Taiwan for electric motor cars development.

As for regulation controls, Taiwan Environment Protection Bureau will continue to tighten exhaust standards and eliminate vehicles of high pollution. This will greatly increase the sales potential of electric motorcycles. Once the electric motorcycles are fully developed, Taiwan Environment Protection Bureau will cooperate with municipal communication departments and prevent vehicles of combustion engine from registration. This plan has got support from Taipei Communication Bureau.

Table 3-23 Electric Motorcycle Development Plan of Taiwan Environment Protection Bureau

Time Schedule	Vehicle Sales Quota	Action
1999	10,000	Taiwan Environment Protection Bureau starts to implement the first step of the plan in designated place. Kwang Yang Motorcycle Co. (Kymco) plans to start production in batch from Mar. 1999.
2000	40,000	Electric motorcycle sales quota reaches 2% of the total motorcycle sales quota. Taiwan Environment Protection Bureau implements stricter exhaust standards and reduce the sales amount of double stroke motorcycles of high pollution.
2001	80,000	Electric motorcycle operation condition is put to the right track and the sales quota begins to increase.
2002	150,000	Electric motorcycle replaces 50% of the double stroke motorcycles; and 4-stroke motorcycles will replace another 50% of the double stroke motorcycles.
2003	200,000	Technologies of electric motorcycle become mature and production of Ni-H battery starts. Exhaust standards become stricter and the price of 4-stroke motorcycle is higher than that of electric motorcycle.
2006	400,000	Sales amount of electric motorcycle continue to grow. Annual sales quota of electric motorcycle reaches 40% of all vehicle sales amount.

After discussed with motorcycle manufacturers for many times, Taiwan Environment Protection Bureau constituted preliminary draft of motorcycle exhaust control standards. In order to further tighten the exhaust level, these standards separately regulates the motorcycle model numbers of double stroke and 4-stroke and they are required to pass engine exhaust cold test. These new standards tighten 80% of the exhaust restriction of CO, HC and NOx.

In Aug. 5 1999, Taiwan Environment Protection Bureau announced that these standards would take effect from Dec. 31 2003. Below are the main features of the 4th stage standards.

(1) Different exhaust standards are stipulated for double stroke and 4-stroke motorcycles. In the 1st, 2nd and 3rd stages, the same exhaust standards are applied for double stroke and 4-stroke motorcycles. However, according to investigation results, the average exhaust amount of double stroke motorcycles is 3 times of that of 4-stroke motorcycles during engine cold test. Besides, when the condition is very bad, the exhaust amount will be worse. Therefore, the exhaust standard of double stroke motorcycles will be 1 time stricter than that of 4-stroke motorcycles during the 4th stage.

(2) Change hot test to cold test for engine. The standard test procedure of the 1st, 2nd and 3rd stages adopt hot engine method. According to the investigation of Taiwan Environment Protection Bureau, the exhaust amount of cold engine test is 2.5 times of that

of the hot test.

(3) Tighten exhaust standards. In the years hereafter, the exhaust standards of inspecting CO and HC of motorcycles in use will remain unchanged, and the average is 3.5% and 2000ppm respectively. It will be very difficult for motorcycles in use that have not been carefully maintained to pass the inspection in the future.

At present, double stroke motorcycles occupy 50% of the total motorcycle number. Under current condition, double stroke motorcycles will be hard to meet the standard when the 4th stage standards begin to implement and are likely to be eliminated.

As for motorcycles exhaust, the CO exhaust reduction rate of double stroke and 4-stroke is roughly estimated to be 20% in average, and the exhaust reduction rate of HC and NOx is 80% and 60%. For idle speed motorcycles, the exhaust reduction rate of CO and HC is 25% and 67% respectively. Therefore, the exhaust gas concentration during peak time and at urban big intersections will be reduced.

Table 3-24 Current and Suggested Standards of Motorcycles (including scooter and autobike)

Engine Test Condition	Pollutants	Current implementation (3rd stage) Double & 4-stroke (hot test)	Dec.31 2003 Double stroke (Cold test)	Dec.31 2003 4-stroke (Cold test)
Ride Circulation Test	CO (g/km)	3.5	7.0	7.0
	$HC + NO_x$ (g/km)	2	1	2
Idle Speed Test	CO (%)	4.0	3.0	3.0
	HC (ppm)	6,000	2,000	2,000
In-use Test	CO (%)	4.5	3.5*	3.5*
	HC (ppm)	9,000	2,000*	2,000*

Note: * Standards for engine hot test. The average value of CO, HC+NOx cold test is 2.5 times of the hot test average.

3.3.2 Motorcycle Exhaust Standards of Beijing China

On Aug 23 2000, China National Environment Protection General Bureau released Pollutants Exhaust Standards for Motorcycle (DB 11/120-2000) which equaled to Euro 97/24/EC and took effect on Jan.1 2000. It's shown as Table 3-25. While other areas in China implement more looser standards as GB14621-93.

Table 3-25 Pollutants Emissions Standard for Motorcycle in Beijing

Test Conditions	Pollutants	2001.01.01 (2-Stroke)	2001.01.01 (4-Stroke)	2004.01.01
Idling test	CO (%)	1.5	1.5	
	HC (ppm)	3000	300	
Working test	CO (g/km)	4.5	4.5	3.5

$HC + NO_x$ (g/km)	3.0	3.0	2.0

3.4 Summary

There is a big gap between the whole exhaust regulations and standard systems of China in the past compared with those of the developed countries and areas. The exhaust standards in China are constituted based on the exhaust regulations of Europe, U.S. and Japan but with a low control level. Light Vehicles Exhaust Standards GB14761.1-93 is only analogous to European ECE15-03 of the late 1970s; the control level of heavy petrol engines is analogous to American level of mid 1970s. In 1999, China started a new round of revision for exhaust standards, and Light Vehicles Pollutants Exhaust Standards (GWPB1-1999) and Diesel Vehicle Work Condition Method Exhaust Standards (including granule exhaust control) were released in 1999. New exhaust standards will basically adopt European system (except for the heavy petrol vehicles which do not exist in European markets), and the limit values of the 1st stage are identical with those of the 1st stage in Europe (Europe implemented from 1992 or so) and China will implement between 2000 and 2001. The limit values of the 2nd stage are also identical with those of the 2nd stage in Europe and will be implemented between 2005 and 2006.

The standards for petrol vehicles and light diesel vehicles are analogous to European 91/441/EEC and 94/12/EC saloon cars exhaust standards, 93/59/EEC and 96/69/EC other light vehicles exhaust standards and the heavy petrol vehicles exhaust regulations implemented in 1991 and 1994 in the U.S. Vehicle-use diesel engine follows the standards which are analogous to the exhaust standards of European 91/54/EEC. Motorcycles follow the standards that are analogous to European 91/54/EEC exhaust regulation and the exhaust control standard of Taiwan in 1991.

The vehicle exhaust test rules in China directly adopt foreign methods. Currently light petrol vehicles adopt ECE R15-04 test rules. The new round of national standards will correspondingly adopt the test methods of European No.1 regulations, i.e. adding an urban-suburb high-speed rotation test circulation.

Although there is a big gap between the economic foundation of China with developed countries and areas, the gaps of vehicle exhaust control level can be shortened; the advantage of China is that new technologies with regard to vehicle exhaust control already existed and becomes more and more mature. China may constitute the strictest standard on the applicable bases and adopt the most advanced technologies. Therefore, the control standards and technologies of developed countries and areas have a great significance for China and can be used for reference.

Chapter 4 The Important Role of Clean Fuels in Implementation of Cleaning Technology

4.1 Fuel Quality and Exhaust

Decreasing vehicle exhaust pollution must be implemented from both sides of improving vehicle functions and petrol fuel quality. During the progress of promoting clean vehicle act, vehicle-use fuel must receive special attention as a basic condition; because fuel composition directly influences the vehicle exhaust. Change the content of certain ingredients in petrol (diesel) will improve vehicle exhaust. And once fuel quality is improved, vehicle exhaust decrease will be immediately realized without hysteresis. For instance, in many big cities, the biggest lead pollution source is the vehicles that using doped petrol, and over 90% of the lead in urban air come from vehicle exhaust. Since the lead content in the petrol has an obvious correlation with the lead concentration in the air, reducing the lead content in the petrol will obviously decrease the lead concentration in the air. With the continuous strictness of vehicle pollutants exhaust limit values, when vehicle exhaust pollution control technologies develop to some degree, as a basic condition, the quality of petrol will become a key factor that restrict the whole clean vehicle act plan to be implemented, so that many countries are dedicating to research the relationship between fuel quality and exhaust.

4.1.1 Influences of Petrol Quality on Exhaust

The researches implemented by American Vehicle/Fuel Air Quality Improvement Research Program and other organizations show that the 8 features of petrol (i.e. RVP, oxygen content, sulfur content, arene content, benzene content, olefin content, E200 and E300) are the major governing factors of vehicle exhaust pollutants.

I. Influences of Olefin

The olefin contained in petrol is the high-octane level ingredient in the petrol but it is a thermal instable substance. It is easy to take oxidizing and condensation reactions under working temperature around air spout and inlet valve and forms colloid and resin-like incrustation. The incrustation absorbs particulate substances in the surround environment, such as the micro-dust and burning particles return to the system through engine crankcase air exhaust and engine waste gas entering admission passage through re-circulation system. Finally, these ropy substances change into solid carbon and deposit at air gate, spout, inlet valve and combustion chamber, and affect the normal working condition of the engine and result in efficiency decline in engine and exhaust increase. According to foreign related research materials, the petrol engine that adopts electric ejection design is very sensitive to deposit matters. When petrol engine rides to 2,500km, each spouts and inlet valves will begin to generate varnish field and deposit matters in different degrees and results in bad phenomena such as fuel flow speed decline, atomization imbalance, exhaust pollution increase and fuel energy consumption increase. The influences are described as below one by one:

- Carburetor deposit generates inside the carburetor, especially near the fuel quantity hole and idle speed quantity hole and results in instable idle speed, flameout, worse fuel economical efficiency and exhaust increase of HC and CO.
- Spout deposit is generated on the surfaces of needle valve and valve hole. The fuel flux is restricted and causes fuel ejection deformation, which results in dynamic reduction, worse activation and acceleration, instable idle speed, thrashing and worse fuel economical efficiency, especially when one or two spouts in the same set of spouts are blocked and the difference of spouts flux is great, the fuel economical efficiency will have great loss and HC, CO and NOx exhaust will increase.
- Inlet valve deposit is generated on inlet valve lever, valve surface and foot valve and results in dynamic decline, slow speed-up and exhaust increase of HC, CO and NOx.
- Combustion chamber deposit has higher heat capacity and results in local overheating and preignition burst. At the same time, since the deposit occupies combustion chamber space and increases compression rate, octane demand increases and the exhaust of HC, CO and NOx increases.

At present, there is no ma ture research for the quantum influence of olefin for deposit both at home and abroad. American LUBRIZOL Company used to make researches on the influence of different ingredients to spout carbon deposit, and found that there is a good correlation between total contents of olefin and allenes and the average blocking rate of fuel spouts. Researchers of China used to implement exhaust inspection for 58 Shanghai Santana carburetor cars and 62 electric ejection cars according to Beijing local standards DB11/044-1999 before maintenance, and the percent of pass was 15.5% and 85.5% respectively. Works such as cleaning and adjusting carburetors and oil ejectors, changing air filters and changing a few ignition system components were implemented strictly according to maintenance techniques procedures for unqualified cars and then exhaust of 93.1% of the cars reached the standards. All of the electric ejection cars meet the standards. It was found during strip inspection that it was the high content of olefin in the petrol that caused disqualification.

Olefin substances also have high atmosphere reaction activity. Olefin vapor enters atmosphere and forms O_3; its combustion resultant can form poisonous allenes. When olefin content in petrol is decreased from 20% to 5%, the load vehicle O_3 peak value can be reduced from 13% to 25% and result in the potential urban O_3 formation decreasing 20-30%. For electric ejection cars, it may cause HC increase by 6% and NOx decrease by 6%.

II. Influences of Arene

Arene refers to hydrocarbon substances whose molecular formula have at least one benzene ring and is an ideal high-octane value ingredient in petrol. Arene substances have higher C/H ratio. Higher C/O results in more CO_2 generated by unit heat quantity. CO_2 is a known greenhouse gas and causes the global temperature becoming higher. Besides, aromatic hydrocarbon increases carbon deposit in steam cylinder after combustion and thus increase the exhaust of tail gas. Researches show that the arene content in petrol decreases from 45% to 20%, and the HC in tail gas will decrease by 6%, CO will decrease by 13% and poisonous substances will decrease by 28%. When the arene content in petrol decreases from 50% to 20%, CO_2 in vehicle tail gas will decrease by 5%. The arene substances in petrol will also increase the reaction activity of volatile organic substances (VOC) in tail gas. Therefore, decreasing the arene content in petrol will decrease the exhaust of NOx and CO_2 as well as decreasing the tail gas reaction activity and benzene exhaust.

III. Influences of Oxygenic Compounds

Oxygenic compound (organic ethanol and ether compounds) represented by MTBE may increase the octane value and oxygen content in petrol. At the same time, MTBE reduces petrol vapor pressure and decreases light hydrocarbon volatilization. MTBE is a high-octane value (RON117) oxygenic compound with good antiknock features, and is a good harmonic ingredient for lead-free petrol. Adding it into petrol does not only restrict arene (especially benzene) and olefin contents, but also decrease the exhaust of volatile hydrocarbon and other pollutants in vehicle tail gas. It has a good intersolubility with petrol without lamination and has high harmonic octane value. It provides oxygen and makes the combustion more completed and decrease CO exhaust (increasing oxygen by 1% each time will decrease CO exhaust by 5-6.5%) and particles exhaust. Low boiling point with low vapor pressure is good for start-up and does not cause air resistance. Since MTBE has the above advantages, its application range becomes wider and wider since 1970s when it was put into use. American Congress passed Clean Air Act in 1990 in order to decrease vehicle tail gas exhaust of CO and required that MTBE should be added into petrol in all places where CO exhaust concentration exceeded standards. Thanks to the implementation of this act, CO exhaust amount in U.S. decreased 900,000t each year.

In Japan, during the initial stage of realizing lead-free petrol action, high-octane value was guaranteed by petrol reforming and cat-cracking. From 1986, petrol alkylate was added in order to increase octane value. MTBE began to be added to increase octane value from the beginning of 1990s. The purpose of using MTBE was to restrict the content of benzene and arene, but if the proportion of MTBE added into petrol was not controlled and the theoretical equivalence air fuel ratio exceeded the adjustable range of self-adaptability of the close-loop control engine electric control unit, it will cause the close-loop control to be interfered due to oxygen enrichment and the conversion efficiency decline of TWC. Recent researches also find that MTBE pollutes underground water source, so that some places such as California, U.S. are preparing to prohibit the use of MTBE. The research results of a Japanese research organization also show that when MTBE content in petrol exceeds 7%, NOx exhausted by vehicles will increase. Therefore, the MTBE addition in high quality lead-free petrol does not exceed 7% in Japan.

IV. The Influences of Volatility

Volatility of petrol is represented by RVP which is an important parameter of fuel standard. Reducing petrol vapor pressure can obviously reduce the exhaust of hydrocarbon substances, mainly reducing C4 fraction contents in the petrol. At the same time, fuel vaporability greatly influences the exhaust of the evaporating pollutants at petrol stations. If the volatility of petrol is too low, then the mixed gas generation is not completed and results in difficult start-up and insufficient warming-up function and affects combustion and exhaust. In winter seasons, if fuel vapor pressure is <58Kpa, it will result in the decline in cold start-up function and driving function. If the volability is too high, then evaporation exhaust will increase and the carbon tank in electric controlled petrol ejection engine overload. And many bubbles are generated in the oil circuit which will affect the stability of oil ejector flux and thus directly influence λ close-loop control and further influence exhaust. Petrol vapor pressure and distillation process are items for evaluating petrol volatility specifications. In summer seasons, petrol evaporation exhaust is very serious, so that there should be strict restriction especially during summer seasons.

V. The Influences of Sulfur

The influences of sulfur for the exhaust of vehicles have been widely tested. The researches show that decreasing sulfur content in the fuel will result in the exhaust decline in HC, CO and NOx of vehicles installed with TWC, and at the same time it will cause the exhaust decline in poisonous and harmful substances (such as benzene, 1, 3 bivinyl, formaldehyde and aldehyde) and thus decrease the forming possibility of O_3. According to the researches implemented by GE Vehicle Company in 1981, when using old catalytic converter and the sulfur content in fuel decreases from 900ppm to 100ppm, HC in the tail gas exhausted will decrease by 16.2%, CO decrease by 13.0% and NOx decrease by 13.9%. Using newer catalyst will result in decrease to further extent.

The most obvious adverse effect of sulfur in petrol, however, is decreasing the activity of catalyst and even causing inactivation. Besides, it has side effect to exhaust oxygen sensor. At the same time, sulfur contained in petrol generates harmful substances such as sulfate particles, SO_2 and H_2S under different combustion conditions and are exhausted to the atmosphere. Since the change of NOx exhausted by vehicles is the most sensitive to the sulfur content change in petrol than arene and hydrocarbon, so sulfur content should be reduced with priority.

VI. Influences of Metallic Substances (Lead, Manganese, Phosphorus, Iron and Copper)

Lead (Zn), manganese (Mn) and phosphorus (P) come from petrol and lubricant addition and deposit in tail gas catalytic converter, decrease catalyst activity and increase engine carbon deposit and exhaust of particles. Lead intoxication thereinto is irreversible; catalyst works in lead environment for several tens of hours will totally lose activity.

Iron (Fe) and copper (Cu) contained in petrol cause abnormal working mode of engines and result in exhaust increase and affect environment. Fe has antiknock function in petrol, but since combustion results are not easily exported, it is likely to cause deposit and has an obvious defacement for the engine. It will also gradually block the catalytic converter, decrease conversion efficiency and affect exhaust. Cu ion is a strong catalyst in petrol. It destroys the stability of petrol, impels the generation of colloid and results in carbon deposit in engines.

Table 4-1 shows the research results of American Vehicle/Fuel Air Quality

Improvement Research Program and other organizations and comprehensively summarizes the effects of petrol constitution to vehicle exhaust.

Table 4-1 Effects of Petrol Constitution to Vehicle Exhaust (AQIRP)

	Old style vehicles (1983~1985)				New style vehicles (1989)					
	Arene	Hydro-carbon	MTBE	T90	Arene	Hydro-carbon	MTBE	T90	Sulfur Content	Vapor Pressure
	v%	v%	M%	F	v%	v%	m%	F	ppm	psi[1]
	45→20	20→5	0→15	360→280	45→20	20→5	0→15	360→280	450→50	9→8
HC	14	5.7	-9.0	-5.8	-6	6.1	-5.1	-21.6	-18	-4
CO	*	*	-14.1	13.6	-13	*	-11.2	*	-19	-9
Nox	-11	-6.7	*	*	*	-6.0	*	5	-8	*
Poisonous Substance	-23	*	*	*	-28	*	*	-16	-10	*

[1] 1psi = 6.9kPa

[2] * means no significant effects.

In Table 4-1, though decrease of hydrocarbon increases HC exhaust, it reduces 1&3 bivinyl with strong second reaction activity by 30%; vapor pressure reduces 1psi (6.9kPa), and fuel evaporation loss decreases by 34%.

4.1.2 Diesel Quality and Exhaust

Diesel quality is generally determined by cetane number, fraction, intensity and low temperature property. The major parameters that affect diesel engine exhaust are cetane number, sulfur content, fuel intensity and gross arene content.

I. Cetane Number

Cetane number is the most important factor that affects HC and CO exhaust, and also affects NOx and particles exhausts. Higher cetane number results in lower exhaust. When cetane number is raised from 41 to 45, HC/CO and particles decrease by 38%, 19% and 8% respectively. When using cetane number enhancer to raise cetane number from 45 to 55, NOx, particles, CO and HC decrease by 4%, 6%, 15% and 40% respectively. Cetane number affects NOx exhaust; the main reasons is that when cetane number is high, the self-ignition property is good, inflammation lag phase is shortened, the combustion is milder and decreases the generation of NOx. Under the condition that no changes are made on the engine, when cetane number increases 10, NOx exhaust of transient test decreases 0.55g/kwh.

II. Sulfur Content

The sulfur content in diesel has direct effect on particles exhaust and is related with the formation of sulfate in particles. Most of the sulfur in diesel is oxygenized into SO_2 gas during combustion process, and then part of it is reoxidated and finally compounds with H_2O generated during combustion and forms sulfuric acid and particulate sulfates such as calcium sulfate, and increases particle exhaust of engines. At the same time, too much sulfur content in diesel also affect the application of oxidize catalyst and changes SO_2 in exhausted gas into S_2O_3, and then forms sulfuric acid mist or solid sulfate particles and additionally increases the exhaust of particles. Researches show that if sulfur content decreases from 0.12% to 0.05%, then particle exhaust will decrease 8%-15%. Besides, low sulfuration of diesel is also to prevent catalyst from inactivation due to sulfur intoxication. Experiments also show that fuel with high sulfur content causes prolonged catalyst conversion pre-heat time, increased catalyst conversion pre-heat target temperature and decreased catalyst conversion efficiency.

III. Arene Content

Arene content has great effect on NOx exhaust (some materials indicate that arene content is the major factor that affects NOx exhaust). High arene content results in difficulties of mixed gas inflammation and long inflammation lag phase, and thus there is more fuel deposited at initial combustion stage and combustion temperature increases (high temperature is one of the conditions to form NOx), and NOx exhaust amount increases accordingly. Generally it is considered that arene content should be decreased, especially the content of polycyclic arene (PAH), such that soluble organic substances amount in particles can be decreased so as to decrease the exhaust amount of particles, and can also decrease the harmful toxicity of particles. When arene content is decreased from 30% to 10%, particles will approx. decrease 16%.

IV. Fuel Intensity

Fuel intensity directly affects HC, CO, NOx and particles exhaust in tail gas, among which the particles exhaust amount increases along with the increase of fuel intensity. This influence is more obvious for non-direct-injection diesel engine.

Table 4-2 summarizes the effects of diesel ingredients to exhaust.

Table 4-2 Effects of Diesel Property to Exhaust

Diesel Property		White smoke	Black smoke	HC	CO	NO_X	Particles	Noise
Intensity ↑		↑	↑	-	-	-	↑	-
Distill property	Initiation point↑	↑	↓	-	-	↓	-	-
	T_{10} ↑	↑	↑	↓	-	↑	-	-
	T_{50} ↑	↑	↑	↓	-	↓	↑	-
	T_{90} ↑	-	↑	-	-	↑	↑	-
	终燃点↑	-	↑	-	-	↑		-
Viscosity ↑			↑		↑		↑	↑
Cetane number ↑		↓	-	↓	↓	↓	↓	↓

4.2 Vehicle-use Fuel Quality Current Status in Cities of China

The rapid development of China's vehicle industry brought the problems such as vehicle tail gas pollution increase and fast consumption of petrochemical resources. In 1995, vehicles all over China consumed 28.4Mt petrol and 36.84Mt diesel. In 1998, vehicles all over China consumed 32Mt petrol and 45.5 diesel. In 1999, China consumed 40Mt petrol and 60Mt diesel.

4.1.1 Current Status of Petrol Output, Consumption and Quality in China

4.2.1.1 Output

The petrol output in China occupies 21% of crude oil processing amount and is one of the major products of petrol refining industry. See Table 4-3 for detailed output. At present, vehicle petrol occupies 89-90% of the total petrol consumption in China, and motorcycle petrol occupies 8-9%, and the rest is the consumption of agricultural and other industrial machines and tools.

Table 4-3 Vehicle-use Petrol Output in China (10kt)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Output	2153	2345	2633.4	3019.5	2694.7	2840.8	3053.2	3253	3196.8	4000

4.2.1.2 Quality Status

I. High-grade vehicle petrol proportion continues to increase, and low-grade vehicle petrol rapidly decreases.

Vehicle petrol cetane number in China has been considerably improved since 1990s. At present, vehicle petrols sold in China market are #70, #90, #93, #95 and #97. From 1990 to 1997, #70 petrol proportion of total vehicle petrol decreased from 62.6% to 28.24%; #90 petrol proportion of total vehicle petrol increased from 35.1% to 62.01%. The increase speed of high quality petrol is not very fast, but the general tendency is rising (see Table 4-4). From Jan.1 2000, all petrol production enterprises in China began to manufacture lead-free petrols of # 90 and above. We also improved the stability of petrol and implemented deodorization for petrol. Hydrotreating or demercaptan technologies for all #90 and above petrols have been implemented.

Table 4-4 China Vehicle Petrol Grade Proportion (%)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	2000
#70	62.6	55.5	54.1	57.09	52.39	50.64	40.72	28.24	14.5	0
#90	35.1	41.7	43.0	39.94	40.97	42.10	51.33	62.01	73.9	
#93	2.2	2.3	2.2	2.68	5.22	5.76	6.57	6.76	9.3	
#95 & above	0.1	0.5	0.7	0.29	1.42	1.47	1.38	1.88	2.3	

II. Vehicle Petrol Lead-free Speed Accelerates

The lead contained in petrol is added for the purpose of improving the antiknock property of petrol. Exhaust of lead is a pollution source of the atmosphere; the more important is that it poisons catalytic converter and oxygen sensor and causes inactivation. In order to solve the lead pollution of the environment and ensure the effective and long-time normal working mode of catalytic converter and oxygen sensor, lead-free petrol must be applied.

Vehicle lead-free petrol proportion used in China has been increasing year by year since 1996. In 1990, lead-free petrol occupied 51.82% of the gross petrol amount, and in 1994 increased to 56.30%. The average annual increase rate was 8.5% and was higher than the increase rate of vehicle petrol. Besides, the increase speed of #90 and #93 lead-free petrol is faster. In 1997, vehicle lead-free petrol occupied 65% of the total petrol amount, in 1998 reached 80%. The average lead content in petrol decreases year by year. According to the requirements in Notice of State Council Office on Terminating Production, Sales and Application of Vehicle Doped Petrol within a Limited Time Period (State Council Office Notice [1998]#129), the whole country stopped to produce doped petrol from Jan.1 2000; stopped to sell and use doped petrol from July 1 2000 and thus realized lead-free of petrol. This greatly improves the petrol quality in China, and also makes it possible for in-depth purification of vehicle tail gas. Table 4-5 shows the average lead content of vehicle petrol in China and the proportion of lead-free petrol in total vehicle petrol usage.

Table 4-5 Average Lead Content of Vehicle Petrolin China and Proportion of Lead-free Petrol

Year	1990	1992	1994	1996	1997	1998	2000
Lead Content (g/L)	-	0.037	0.031	0.028	0.019	-	<0.013
Proportion of Lead-free Petrol (%)	51.82	-	56.3	-	65	80	100

III. Structural Change of Petrol Congruity Ingredients

The reasonable optimization of vehicle petrol congruity ingredients is the key of upgrading and regeneration of vehicle petrol quality. See Table 4-6 for the composition of vehicle petrol congruity ingredients in China. In 1997, the proportion of straight-run petrol in total vehicle petrol amount decreased by 9.4 percentage points compared with that of 1994. Production device capability of catalytic cracking, catalytic reforming, hydrocracking, alkylation and MTBE for the production of high cetane number petrol ingredients have been improved to a great extent.

Table 4-6 Vehicle Petrol Congruity Ingredients Composition in China (%)

Year	1992	1993	1994	1995	1996	1997
Straight-run petrol	18.1	19.7	16	13	13	6.58
Catalytic petrol	72.3	71.9	68.6	76.3	76.3	82.44
Reformed petrol	3.8	3	7.8	6.2	5.4	6.19
Petrol alkylate	1.2	1	1.1	0.3	0.27	0.26
Hydrotreating naphtha	2.2	1.2	1.2	0.9	1.01	1.16
Coking naphtha	0.8	1.6	0.9	0.65	0.27	0.24
Others	1.6	1.6	1.4	2.65	3.79	3.13

4.2.1.3 Differences of Petrol Quality between China and other Countries

Differences exist between the benzene content, sulfur content, hydrocarbon content and petrol vapor pressure of petrol in China and that of international level. Table 4-7 shows the current status of petrol quality in China and comparison with petrol quality of other countries.

Table 4-7 Comparison of Petrol Quality Current Status

	China	U.S.	Euro2000	Japan
Benzene, v%	3-4	≯1.0	≯1.0	≯5.0 (Yr. 1999)
Sulfur Content, m%	≯0.05	≯0.01	≯0.01v%	≯0.01
Vapor Pressure RVP,kPa	Winter：62-85 Summer：27-60	≯55	≯60	44-78
Hydrocarbon, v%	30-40	≯10	~10	/
Oxygen Content, m%	/	≥2.0	≯2.3	MTBE≯7v% (Yr. 1996)
Arene, v%	20-25 (Lead-free petrol)	≯27.0 (New formula simplified model)	≯37	/

Petrol ingredients structure in China also needs to be optimized and reformed: in other countries, catalytic reformed petrol, petrol alkylate and MTBE are the major congruity ingredients of petrol. Hydrobarbon content is as low as 20% and arene content is high. The petrol structure in China is mainly catalytic petrol and occupies 80% of the vehicle petrol in China in average. The hydrocarbon content is as high as 30-40% in average.

4.2.1.4 Differences of Fuel Standards between China and the World

On June 1999, vehicle manufacture associations of U.S., Europe and Japan unitedly released global fuel tableer and reached agreement on the quality of lead-free petrol. Petrol type I is applicable for vehicles without exhaust control requirement or with low exhaust requirement; petrol type II is applicable for vehicles of strict exhaust control (such as vehicle exhaust standards 0 and 1 in the U.S. and standard 2 in Europe), and petrol type III is applicable for vehicles with stricter exhaust control requirements (such as low exhaust standards or zero exhaust standard of California, U.S. and standard 3 & 4 in Europe). The fuel standards in China regulate the limits of 9 harmful substances.

Table 4-8 shows the comparison between the major control index in Vehicle Petrol Harmful Substances Control Standards of China and the fuel specification of the world. Table 4-9 is the new formula petrol specifications of California Air Resources Committee (CARB). Every oil refinery plant in the U.S. began to produce lead-free petrol from 1996 according to new formula specifications.

From Table 4-8 it can be seen that there is a great difference between the fuel standards of China and world fuel specifications, especially contents of lead, benzene, hydrocarbon and sulfur which still do harm to the atmosphere quality and have potential destructive effect to engine control system. For instance, the lead content (<0.013g/L) regulated in the standards of China is for the purpose of controlling atmosphere lead pollution, but cannot satisfy the normal working requirement of ternary catalytic converter and results in the short life cycle of the ternary catalytic converter used in China. By comparing Table 4-7 and 4-8 it can be seen that the petrol quality of China at present cannot fully meet the standards and there are still many aspects with regard to fuel quality need to be improved.

Table 4-8 Comparison of Vehicle Petrol Harmful Substance Index in China and World Fuel Specification

Item	Control Index			
	Lead-free petrol Type I	Lead-free petrol Type 2	Lead-free petrol Type 3	Lead-free petrol in China
Benzene (%V/V) ≤	5.0	2.5	1.0	2.5
Hydrocarbon (% V/V) ≤	-	20	10	35
Hydrocarbon (% V/V) ≤	50.0	40	35	40
Mn (G/L) ≤	-	Not perceivable	Not perceivable	0.018
Zn (G/L) ≤	0.013	Not perceivable	Not perceivable	0.013
P (G/L) ≤	-	Not perceivable	Not perceivable	0.013
S (% M/M) ≤	0.10	0.02	0.003	0.08
Fe①	-			Uncheckable
Cu②	-			Uncheckable

① Checkout limit is 0.005g/L. ② Checkout limit is 0.001g/L.

Table 4-9 CARB New Formula Petrol Specification

Item	Unit	Upper limit	Normal limit	Ave. Limit
Sulfur Content	PPM	80	40	30
Benzene Content	V %	1.2	1.0	0.8
Arene Content	V %	30	25	22
Hydrocarbon Content	V %	10	6.0	4.0
RVP	PSI	7.0	7.0	7.0
Oxygen Content	M%	1.8-2.7	1.8-2.2	
50% Recovered Temperature	F	220	210	200
90% Recovered Temperature	F	330	300	290

4.2.2 Diesel Output and Quality Current Status in China

4.2.2.1 Output

Light diesel in China is divided into 6 numbers according to solidifying points under the Light Diesel Standards (GB252-94): #10, #0, #-10, #-20, #-5 and #-50. The diesel output of 1998 in China was 45.5Mt and occupied 30% of crude oil processing amount. In recent years, #0 diesel occupied the largest proportion due to the geographic and climatic characteristics; for instance, #0 light diesel output in 1997 occupied 71.3% of the total amount. Light diesel output in China during recent years is shown in Table 4-10.

Table 4-10 Light Diesel Output in China (10kt)

Year	1993	1994	1995	1996	1997	1998
Diesel Output	3385.97	3314.27	3684.30	4108.66	4593.99	4543.9

4.2.2.2 Quality Current Status and Differences with Other Countries

Sulfur content in homemade crude oil is low and thus the sulfur content in homemade diesel is low accordingly. The straight-run distillate sulfur content in China usually is below 0.05%. Sulfur content of a little diesel produced from crude oil with high sulfur content is 0.2%-0.3%. However, the sulfur content of the secondary processing diesel is higher, usually around 0.2-0.5%. The sulfur content of diesel produced from imported crude oil is usually around 0.5%. The diesel with high sulfur content is mainly due to the large proportion of secondary processing diesel fraction without hydrogen refinery and result in overall sulfur content increase. In order to improve the substance quality of light diesel products, oil and chemical industries renovated, expanded and newly setup diesel hydrogen refinery devices. The petrol, paraffin and diesel hydrogen refinery capability of China expanded from 210,000 sets/5.55Mt in 1990 to 480,000 sets/18.24Mt in 1997. The proportion of first class light diesel produced by the former Oil and Chemistry General Company in 1997 was 62.8%. [1]

In other countries, there are strict requirements for cetane number and sulfure and arene contents. The actual level of cetane number in1 Hong Kong, Korea, Indonesia, Taiwan and Singapore is 50-58. The amendment to the cleaning air law of the U.S. stipulates that diesel arene content should be ≤ 10% (≤20% for small and mid-sized refinery plants). Sulfur content in other countries mostly has been decreased below 0.05%. For instance, urban-used diesel in Sweden is divided into 3 levels (1, 2 and 3), and the sulfur content is 10ppm, 50ppm and 500ppm respectively. The arene content is 5%, 10% and 25%.

The sulfur content of diesel in the U.S., Germany and Japan is below 100mg/L, while the sulfur content of diesel in China is around 5,000mg/L. Chinese diesel standards (GB252-87) stipulates the sulfur content of high quality product, first class product and quality product is 0.2%, 0.5% and 1.0%. Cetane number ≥45 (cetane number of each number of light diesel produced from intermediate base, naphthene base or mixed with catalytic fraction is allowed to be ≥40). The sulfur content of type II and type III diesel is 300ppm and 30ppm respectively according to world fuel specification.

Table 4-11 shows the diesel quality current status comparison of some countries [1]. Table 4-12 compares the diesel standards of China with world diesel petrol standards.

Table 4-11 Diesel Quality Current Status Comparison

	China	U.S.	Europe	Japan
Sulfur Content	0.1-0.2% (Light Diesel)	0.05% (From Oct. 1993)	≤0.05m% (From Oct. 1996)	47-58
Cetane Number	40-50	≥42		
Arene Content, v%	/	35% (capacity, 1993)		

Table 4-12 Comparison between Diesel Standards in China and World Diesel Fuel Standards

Item	Control Index			
	Diesel Type I	Diesel Type II	Diesel Type III	Standards of China GB252-87
Sulfur Content	≤0.10%	≤300ppm	≤30ppm	≤1.0% (quality product) ≤0.2%(High quality product)
Cetane Number	≥48	≥53	≥55	≥45
Arene Content, % m/m	-	≤25	≤15	-

Solving the problem of diesel quality is the precondition of promoting clean diesel vehicles. The current diesel quality in China, however, is that the percent of pass of light diesel occupies 42% of the total amount; among which catalytic cracking ingredients occupy 40-50. The cetane number of quality product is low (40-50) with bad stability, high colloid and high arene content. The sulfur content of light diesel is 0.1-0.2%. Comparing with the data in Table 4-11 and 4-12 it can be found that the diesel quality and standards in China are far from the international levels. The high sulfur content of diesel makes it impossible for the import and application of many effective exhaust control technologies, such as electric control ejection plus TWC and particles catching technology, and results in the limitation of promoting high quality clean diesel engines that meet the demands of Euro 1 and Euro 2.

4.3 Petrol Cleanser

Promoting the application of petrol cleanser is an important measure to decrease vehicle tail gas pollution. Petrol cleanser can effectively improve working mode of vehicles.

4.3.1 Action Principle

The instable olefin compound in petrol especially double olefin compound is easily to form deposit after oxidation, and blocks the engine parts such as carburetor, oil burner and inlet valve, and results in the uneven atomization and admixture of fuel and air, incomplete combustion, increased exhaust pollutants content and fuel consumption increase.

Petrol cleanser is a surface-active matter. Its major ingredient is long chain amine surface-active agent. Engine deposit carbon is mainly low acid substance. Petrol cleanser absorbs the oxidate on the surface of the deposit carbon and seizes the metallic surface with substances easily to form deposit carbon, and disperses and encloses the potential deposit oxidated and formed in petrol and prevents them from depositing on the above key places so as to keep these places clean. For the deposit that already formed on the key places of fuel and inlet system of the engine, the cleanser molecule in the petrol peels it off from the metallic surface and makes it dispersed in the petrol so as to recover these places to or nearly to the state of new vehicle [1], in order to decrease tail gas exhaust and oil consumption and prolong engine service life.

4.3.2 Development Progress of Petrol Cleanser

Cleanser has experienced 3 generations till now. Petrol cleanser was firstly introduced in mid 1950s and was conventional amine cleanser dispersant agent. It was a surface-active agent and contained azotic simple compound such as amino and amide. It effectively controlled the formation of deposits of the carburetor and oil circuit in the carbureted engine. It mainly solved the problem of deposits on the carburetor and was called the 1st generation cleanser.

At the beginning of 1980s, vehicle manufacturers began to use more advanced engines to meet the continuous demands of improving fuel economical efficiency and engine capability and decreasing tail gas exhausted substances. This engine adopted electric fuel ejection system and had obvious advantages: good economical efficiency and driving capability and low exhaust. But the precisely designed ejector was easily to be affected by dirts. When deposit was formed on the needle valve and valve-opening surface of the air spout, it restricted fuel flux and resulted in the deformation of fuel ejection form, decline in atomization, dynamic features, driving forces and accelerating features, instability of idle speed, thrashing and decline in fuel economical efficiency and exhaust increase in HC, CO and NOx. Therefore, the cleanser that mainly sovling air spout problem was the 2nd generation cleanser.

Traditional amine cleanser is effective to control the deposit on carburetor and air spout. But for the deposit carbon control of the air spout, a higher concentration cleanser is needed which results in the deposit increase of inlet valve. Inlet valve deposit is formed on the valve lever and valve face of the inlet valve and results in cold start-up difficulty, acceleration slowness and increased exhaust of HC, CO and NOx. Convergence disperser has good hot-stability under high temperature and can control the deposit of inlet valve. It does not have cleaning effect for air spout and carburetor, but also for the inlet valve. This is called the 3rd generation cleanser.

Since the environmental requirements for exhaust is getting more and more strict and more captious for the combustion working mode, the 4th generation cleanser that can solve deposit carbon in the combustion chamber is under development.

4.3.3 Application Condition Abroad

In the United States, due to the energy crisis of the 1970s and the society began to think highly of environment protection, strict requirements were continuously raised for vehicle tail gas exhaust which pushed the development of vehicle industry and oil refinery industry. In the amendment to Air Cleaning Law released in 1990 in the U.S., it is clearly stated that new formula petrol must have petrol cleanser added from 1995. This act speeded up the promotion and application of petrol cleanser in the U.S. market. See Table 4-13 for the application condition of petrol cleanser around the world. From Table 4-13 it can be seen that cleanser is widely used in industrial developed countries, the annual consumption of which is estimated to reach 289,000t in the world.

Table 4-13Statistics of Petrol Cleanser Application in the World

	Petrol Total (Mt)	Cleanser-added petrol (%)	Cleanser Consumption (10kt)	Estimated cleanser consumption in 1998 (10kt)
North America	360	90	22.0	25.0
Western Europe (excluding Germany)	93	50-60	3.5	4.5
Germany	32	90	2.4	2.4
Japan	50	20	0.4	1.5
Other countries	125	10	0.6	2.0
Total	660	--	28.9	35.4

4.3.4 Development and Application of Petrol Cleanser in China

At present, the hydrocarbon content in vehicle petrol of China is as high as 30-40% and is 2-3 times of the hydrocarbon content in petrol of the U.S. This shows that the petrol self-cleaning property in China is far from the western developed countries. Taking the actual condition of high hydrocarbon content of homemade petrol under consideration, it is stated in Vehicle Petrol Harmful Substances Control Standards that cleanser with the effectiveness of cleaning deposit carbon must be added in vehicle petrol.

The former State Machinery Ministry used to require China Petro-chemical Corporation to research and add cleansing disperser in the petrol with the purposes of adding dust-free cleansing disperser in vehicle fuel and improving the vehicle tail gas exhaust. The former China Petro-chemical Corporation (now China Oil and Chemistry Group Company) entrusted China Oil and Chemistry Sciences Research Institute to be the first in China to implement the research of petrol cleanser as early as 1993. In 1997, Oil and Chemistry Sciences Research Institute developed compound petrol cleansing disperser with multiple functions such as cleansing, rot-proof, anti-emulsification and inoxidizability. This cleanser is completely made up of organic ingredients such as C, H, O and N. The main ingredients is cleansing disperser, antirusting agent, demulsifying agent , antioxygen, porting oil and solvent naphtha. These additions are commonly used fuel additions or ingredients at home and abroad and exclude harmful substances such as metals and benzene. After sufficient combustion, it will not cause extra burden for the exhaust of HC, CO and NOx. After research, evaluation and criteria driving test (including comparison with petrol cleanser of the same type made in other countries) and application tests in batch for different vehicles, this cleanser passed national verification in 1997. The verification considers that this product is similar with the product of the same type manufactured abroad in the 1990s with regard to product performance and is in accordance with the petrol properties of China (high hydrocarbon content). Its adaptability for homemade petrol is better than foreign products of the same kind and reaches international advanced level with obvious social and economic benefits and is a product of urgent need for the vehicle industry. Through the tail gas exhaust tracking inspection for several types of vehicles implemented by Beijing and Chengdong Environment Protection Bureaus, the results showed that the average purification rate of CO and HC is above 25%. The production scale of self-developed petrol cleanser in China at present can fully satisfy the domestic needs.

Currently, cleanser has been added in petrol used in most of the big and mid-sized cities in China and good results have been achieved with regard to vehicle service performance and exhaust performance. From Oct.1 1999, all petrol stations run by China Oil and Chemistry Group began to provide clean petrol with cleanser added, but compared with the U.S. where petrol cleanser has been added in 90% of the vehicle petrol, there is still a big gap.

4.4 Alternative Fuels

According to the definition of Energy Policy and Regulations (EPACT) of the U.S. in 1992, alternative fuels including: methanol, ethanol (not edible) and other alcohols.

Mixtures of methanol, ethanol and other alcohols with petrol (the capacity content $\geq$85%), natural gas, liquefied petroleum gas (LPG) and hydrogen gas, liquid fuel extracted from coal, non-alcohol biological fuel and electricity. Among these fuels, compressed natural gas and LPG are the most commonly used alternative fuels currently used. Generally speaking, alternative fuels either decrease exhaust or save energy. Taking natural gas for example, combusting natural gas causes much less pollution than combusting petrol: HC decreases by 62%, CO decreases by 97%, NOx decreases by 90% and noise reduces by 40% without the pollution of lead, benzene and arene.

4.4.1 Natural Gas

The major ingredient of natural gas is CH_4. The production technology of natural gas is mature with convenient storage and transportation, and usually the price is 50% lower than petrol. Natural gas is high ignition point light fuel is more effumable than petrol. Its ignition point is 1.7-5 times higher than petrol; under the same condition, natural gas is more difficult to self-ignite and explode than petrol. Natural gas has high cetane number with wider combustion limits. It can combust thin mixed gas in order to improve the economical efficiency of the combustion engine. The waste gas exhaust is less than petrol and diesel. CO_2 of the same capacity and H_2O vapor of twice of the capacity are generated during combustion process. Natural gas also contains substances such as ethane, propane and H_2S with very small amount. It does not contain harmful substances such as lead, benzene and arene.

Natural gas vehicles can be divided into two types: compressed natural gas vehicles and liquefied natural gas vehicles. The pressure of compressed natural gas is usually 20-30Mpa. The heat-isolating container pressure of liquefied natural gas is 0.05-0.5Mpa. Compressed natural gas vehicles are the main vehicle types of natural gas vehicles. Vehicles manufacturers such as Honda of Japan, FIAT of Italy and GE of the U.S. have produced mature vehicle types with good marketing results. According to the research report of AQIRP, U.S., the exhaust performance of CNG vehicles is superior to the petrol vehicles. HC decreases by 90%, CO decreases by 40-80% and NOx decreases by 10-80%. But the fuel economic efficiency decreases by 15-20%.

4.4.2 LPG

LPG is a by-product during the production of oil and oil gas and can also be synthesized by natural gas. The major ingredients consist of propane (C_3H_8), propylene (C_3H_6), butane (C_4H_{10}) and butylenes (C_4H_8). The ignition temperature is 441-550℃ and is higher than that of vehicle petrol (427℃). Its cetane number is as high as 103-105 with good antiknock property. Properly adjust ignition advance angle will obtain good dynamic and economical efficiency.

LPG engine technology is mature with light sole weight of the steel cylinder. Gas filling stations layout is flexible and the station spacing can be 300km, while CNG gas filling stations must be arranged along the natural gas pipeline that the station spacing should be no farther than 200km. Beside s, LPG vehicle renovation cost is as low as RMB5, 000-6,000 per car; the cost for a CNG vehicle is RMB10, 000-12,000. As an alternative fuel for vehicles, LPG does not require lead addition such that CO and HC exhaust decreases. LPG vehicles have developed very fast since 1980s. At present, LPG vehicle is the major vehicle type of the taxies in Japan.

The result of working condition exhaust test shows that compared with petrol, the exhaust of LPG engine obviously improves under idle speed working condition as shown in Table 4-14.

Table 4-14 Exhaust Amount Comparison between Petrol and LPG under Idle Working Condition

	Excessive air coefficient	Waste Gas Exhaust Amount			
		HC, ppm	CO, %	CO_2, %	NO_X, ppm
#90 Lead-free Petrol	1.45	140	0.14	10.1	35
LPG	1.48	104	0.09	9.2	21
Decrease Rate (%)		25.7	35.7	8.9	40

4.3.3 Carbinol and Carbinol-Petrol Fuel Combination

Carbinol can be synthesized by coal, natural gas, wood and rubbish, and another way is to electrolyze water by the electric energy generated by solar energy, hydroenergy or atomic energy to get hydrogen; then synthesize hydrogen with CO_2 to get carbinol. Therefore, the resource of carbinol is very rich and currently natural gas and coal are mostly used as raw materials in the world. China has a rich coal storage capacity, and there is a good prospect to use coal for the synthesis of carbinol.

Many years of experiments show that except for the energy-saving property of carbinol, the more remarkable feature is that it decreases air pollution. First of all, cabinol has high cetane number and can be mixed with petrol without adding tetra ethyl lead.

Secondly, the theoretical air fuel ratio of carbinol small and is good for complete combustion; the exhaust of CO, HC and NOx is decreased. But after mixed with petrol for combustion, the exhaust of carbinol and formaldehyde increases. Besides, carbinol is in liquid form under room temperature and with easy operation and storage and transportation. The commonly used admixture methods are: M5-M20 (M5 carbinol fuel combination refers to petrol with 5% carbinol bulk concentration), M50-M85, M85-M100. Since the heat value of carbinol is a half of the oil series fuel with low cetane number and cannot implement compression ignition, when carbinol is used for diesel engine, it requires other assistant ignition methods. From the research report of AQIRP, U.S., it can be learned that comparing the exhaust behavior of M85 vehicle with petrol vehicle, HC decreases by 31%; CO decreases by 13%; NOx decreases by 6%, but fuel economical efficiency decreases by 40%.

At present, carbinol fuel vehicle has entered utility stage with regard to technologies and cost. In Japan and the U.S., carbinol dual-fuel vehicle and flexible fuel vehicle have been put into use. China has begun the feasibility study of corrosion resistance research and flexible fuel technology which is planned to be promoted in specific areas (e.g. areas with rich coal but poor oil storage).

4.4.4 Ethanol and Ethanol-Petrol Fuel Combination

Ethanol can be synthesized by various kinds of grains, fiber organism and plants and is a kind of regenerative energy. Using ethanol or ethanol-petrol fuel combination can decrease the exhaust of pollutants. In Brasil, ethanol vehicle occupies 30% of the total vehice number. The reason is that Brasil is located in tropical zone and is suitable for plants growing that are used to synthesize ethanol. As learned from AQIRP research report, U.S., compared with the exhaust behavior of E85 vehicle and petrol vehicle, HC decreases by 5%, CO increases by 7%, NOx decreases by 40-50% but fuel economical efficiency decreases 25%.

4.4.5 Ether Alternative Fuel

Most of research of today is to substitute diesel with methyl ether, which is a suitable alternative fuel for diesel engines. Experiments show that methyl ether eliminates the smog in the tail gas and decreases the exhaust of major pollutants. The toxicity of methyl ether is milder than carbinol. According to the reports on actual application, when using methyl ether for fuel, it meets the super-low exhaust standards of California in 1998 without catalytic conversion. However, there are not too many reports on this kind of fuel so that this fuel is not the hotspot for research.

4.4.6 Hydrogen Fuel

Hydrogen is an ideal clean fuel. The hydroge n content in the nature is much less than oxygen, but it has a wide distribution. Many kinds of compounds with hydrogen exist in the nature. Therefore, it is a new energy that can hopefully replace oil series fuel. Engines using hydrogen for fuel only has one harmful exhaust: NOx, and thre is no exhaust pollution of CO and HC. Besides, combining 1% hydrogen and 99% petrol for combustion will get good purification effects and this is a feasible measure to control idle speed exhaust especially. However, the industrial production and abstraction of hydrogen and storage problem are to be solved, and hydrogen engine is still in the experimental stage without formal product release.

4.5 Solutions

The continuous tighteness of vehicle exhaust standards makes the improvement of oil quality an important method to control the vehicle tail gas pollution in China. The environment protection regulations in China raise higher requirements for vehicle industry and oil refinery industry. Beijing began to carry out Light Vehicle Tail gas Pollutants Exhaust Standards (DB11/105-1998) from Jan.1 1999, and Light Vehicle Tail gas Pollutants Exhaust Standards (GWPB1-1999) released by National Environment Protection General Bureau was promoted from Jan.1 2000. Strict exhaust standards call for high-quality fuel. National Environment Protection General Bureau released Vehicle Petrol Harmful Substances Control Standards in June 1 1999 after eliminating lead in the petrol. Besides, the obligatory requirement of adding cleanser in the petrol was raised aiming at the actual condition that olefin content in the homemade petrol is too high. At present, National Environment Protection General Bureau is actively working on the national environment protection standard on Petrol Cleanser.

Under the guidance of the above control standards, the petrol development in China will focus on the following aspects:

1) Increase cetane number of petrol in order to improve petrol antiknock property and engine efficiency.

2) Use low-sulfur and lead-free petrol.
3) Control petrol ingredients, such as controlling the content of arene (esp. benzene) and olefin. The general petrol ingredients congruity proportion is changed greatly. The proportion of catalytic reforming petrol will reach 24%. The proportion of petrol alkylate will be increased significantly and ingredient of low cetane number (straight-run petrol ingredient) will be decreased to 5%.
4) Gradually increase the application proportion of petrol cleanser.

The diesel quality in China is in dire need of decreasing sulfur content.

4.6 Summary

(1) Fuel composition has direct effect on vehicle exhaust. Changing the content of certain ingredients in petrol (diesel) will improve the exhaust of vehicle. Besides, once the fuel quality is improved, the exhaust reduction of vehicle will soon take effect without hysteresis. As the continuous tighteness of vehicle pollutant exhaust limits standards, when vehicle exhaust pollution control technologies develop to certain degree, the quality of fuel which is a basic condition will become a key factor for restricting the implementation of the whole cleaning vehicle action plans.

(2) The 8 features of petrol (i.e. RVP, oxygen content, sulfur content, arene content, benzene content, olefin content, E200 and E300) are the key factors determining the vehicle exhaust pollutants. The major parameters that affect diesel exhaust are cetane number, sulfur content, fuel intensity and gross arene content. Table 4-15 briefly summarizes the effects of fuel quality to vehicle exhaust.

Table 4-15 Effects of Fuel Quality to Vehicle Exhaust

Petrol Ingredients Change	Effects on Exhaust
Olefin Decrease	Decreases potential O_3 formation in cities. For electric ejection vehicles: increases HC exhaust and decreases NOx exhaust.
Arene Substances Decrease	Decreases NOx, CO_2 and benzene exhaust. Decreases tail gas reaction activity.
Add MTBE	Restricts arene (esp. benzene) and olefin content. DecreasesCO and particles exhaust.
Vapor Pressure Decrease	May cause hydrocarbon exhaust decrease
Sulfur Content Decrease	Decreases the exhaust of HC, CO, particles and NOx of vehicles with TWC and reduces O_3 formation possibility.
Diesel Composition	**Effects on Exhaust**
Cetane Number	The most important factor that affects HC and CO exhaust, and also affect the exhaust of NOx and particles. Higher cetane number results in lower exhaust.
Sulfur Content Decrease	Particle exhaust decreases.
Arene Substances Decrease	NOx and particles exhaust decreases.
Fuel Intensity Increase	Particles exhaust increases.

(3) The current status of petrol quality in China is: the average proportion of catalytic petrol is 80% of the vehicle petrol. From Jan.1 2000, all domestic petrol manufacturers began to produce #90 and above lead-free petrol. From July 1, 2000, doped petrol was no longer sold and used.

The current status of diesel quality in China is: the pass rate of light diesel occupies 42% of the total amount, among which catalytic cracking occupies 40-50. Cetane number of the quality product is low (40-50) with bad stability and high arene content. The sulfur content in light diesel is 0.1-0.2%. Such a high sulfur content retricts the promotion of high-performance clean diesel engine that meets Euro1 and Euro2 demands in China.

There is still a big gap between the fuel standards in China and world fuel specifications, especially the content of lead, benzene, olefin and sulfur which is potentially destructive for the atmosphere quality and engine control system.

Low fuel standard and bad fuel quality have become an important issue in China for vehicle tail gas pollution control.

"Special pipes (tanks) for special use" does not implemented during the storage and transportation process of diesel (petrol) of different grades, and the result is that actually used diesel (petrol) cannot meet standards. Therefore, complement devices and facilities should be developed along with the refinery technology development and fuel quality improvement in order to ensure the quality of fuel actually used.

(4) Petrol cleanser is very effective to reduce vehicle exhaust. Currently China is already capable of self-researching and producing petrol cleanser. From Oct.1 1999, all petrol stations operated by China Oil and Chemistry Group began to provide clean petrol with cleanser added. But compared with the U.S. where 90% of the vehicle petrol has cleanser added, there is still a big gap.

(5) Alternative fuel can reduce exhaust or save energy. At present, China is actively developing alternative fuel vehicle. The public system in some of the big cities already began to use LPG vehicles. The problem now is that complement facilities should be further completed.

Chapter 5 Emission Control Strategy for in-Use Vehicles

Since 1990s, since cities in China began to face more and more serious vehicle exhaust pollution, the strict control of vehicle exhaust becomes a must. As the first step to tighten the vehicle exhaust control, state and local governments began to constitute and release vehicle exhaust standards and implement strict control for new vehicles. For example, Light Vehicle Pollutants Exhaust Standards released by National Environment Protection General Bureau was carried out from Jan. 1 2000. However, only depending on the stricter standards for new vehicles cannot fully control the pollution exhaust of vehicles. The deterioration of vehicle exhaust will make the effort of controlling new vehicle exhaust spent in vain if no controlling methods were carried out for vehicles in use. However, compared with new vehicle exhaust control, it is impossible to implement a unified technical scenario in the whole country for the control of vehicles in use.

5.1 Inspection and Maintenance (I/M) System

At present, the vehicles in use in China mainly include two types: carburetor vehicles and electronic fuel injection vehicles. Carburetor vehicles occupy most of the vehicle stock, but the exhaust level of carburetor vehicle is far from electronic fuel injection vehicles. The deterioration of carburetor vehicle exhaust is due to two reasons: defacement and block of certain vehicle parts and improper adjustment of certain related parts. The above conditions show that on one hand, the exhaust condition of vehicles in use is getting worse and worse along with the increase of road haul; on the other hand, even vehicles with less road haul will have serious disqualified exhaust. Although the exhaust behavior of electric election vehicles is much better than carburetor vehicles, the above conditions will occur either. Therefore, a measure should be taken to promptly find phenomena such as defacement, block and improper adjustment in order to prevent vehicles from increase in an uncontrolled manner so as to ensure the vehicles riding with a good exhaust condition. I/M system is a measure of this kind. It timely detects vehicles with bad exhaust condition through regular inspection and related parts will be cleaned, replaced or properly adjusted to restore the normal working mode.

Regular inspection and maintenance keeps the vehicle exhaust control system at a reasonable level and plays an important role in controlling vehicle pollution. First, implementing I/M system helps to recognize and adjust vehicles with high exhaust due to malfunction or other mechanical problems, and the pollutant caused by this small number of high-exhaus t vehicles occupies a relatively high proportion in the total exhaust. Related research abroad shows that 20% of the high-exhaust vehicles occupies over 60% of the total exhaust amount. Secondly, I/M can be used to identify failure type and prevent from removing exhaust control device. If the vehicle catalytic converter or oxygen sensor fails, the exhaust of CO and HC may increase over 20 times, and the exhaust of NOx will increase 3-5 times. However, this usually doesn't cause driver's attention since it does not influence the riding performance. The function of I/M system is that it can identify problem vehicles and require them to be repaired or maintained so as to ensure the exhaust of vehicle always maintaining the normal level and release its tendency of getting worse and effectively control the exhaust pollution of vehicles.

5.1.1 I/M System Current Status at Home and Abroad

I. Overseas I/M System for Vehicles in Use

Currently, the U.S., Japan, Europe and many developing countries have set up regular I/M system for light vehicles, and some of the countries have expanded this system for heavy trucks and motorcycles.

American I/M system was firstly implemented from late 1970s and early 1980s. The amendment to Cleaning Air Regulation released in 1977 in the U.S. required places where CO and O_3 did not meet standards to reach the standards before 1982. Taking the serious traffic pollution of some places under consideration, the standards deadline was postponed to 1987. Places where standards deadline was postponed to 1987 were required to implement I/M system. In 1990, the U.S. raised the concept of enhanced I/M system in the amendment to Cleaning Air Regulation and made inspection for evaporation emission and NOx, and also suggested to adopt testing method IM240 which was close to actual working mode exhaust so as to adapt to the vehicle technology development.

Developed till today, western developed countries have formed completed system with regard to the I/M system for vehicles in use. Still taking the U.S. for example, its I/M system is not only used to ensure the vehicle in use to get proper maintenance, but is also an important method to push the management of new vehicle quality. American I/M system provides information for new vehicle quality supervision tasks, i.e. during the implementation of I/M system, if the standard satisfaction rate of a certain vehicle model is mostly low, this information will be passed to related department and related department will strengthen the quality supervision of this vehicle model. Besides, I/M system also helps to ensure the smooth implementation of new vehicle quality guarantee system. For example, the U.S. implements exhaust control system guarantee period system for new vehicles manufactured after 1981. This system requires all manufacturers to promise that: ① products are designed manufactured and assembled according to related regulations; ②

materials are free from any defect and always meet related regulations in 5 years. If the vehicle owner uses the vehicle according to the application specification provided by manufacturer and exhaust disqualification phenomena occur within 5 years, manufacturer is obliged to repair the vehicle, among which the failure of pollution control device is determined according to the inspection result of I/M system.

See Table 5-1 for the test method and limit value level of some of the countries that implementing I/O system at present.

Table 5-1 Current I/M Systems Summary of the Petrol Vehicles in some Countries

Country	Test method	Vehicle Year and Model	Limit Value
U.S. (Basic Model) (Enhanced Model)	Idle Arizona: Load method + Idle speed Transient Working Condition Method (IM240) Steady State Working mode Method	Since 1981 Since 1981 Before 1984 1984-1995 1968-1986	CO 1.2% HC 220ppm CO 1.2% HC 220ppm CO_2 4% (Min.) CO 25-30g/mile HC 1.2-2.0g/mile NO_x 3.0-3.5 g/mile CO 15g/mile HC 0.8g/mile NO_x 2.0g/mile CO 1.2% HC 220ppm CO_2 6% (Min.)
Japan	Idle Speed Method	All vehicles 4-stroke: Dual-stroke: Rotary engine:	CO 4.5% HC 1200ppm HC 7800ppm HC 3300ppm
E.U. (92/55/EEC)	Idle Speed	Uncontrolled vehicles Since 1986.10 1970.1-1986.10 Before 1970.1	 CO 3.5% CO 4.5% Exempt
	Idle Speed High Idle Speed	Controlled vehicles	CO TA or CO 0.5% CO 0.3% λ 1±0.03
Australia	Idle Speed Method	All	CO 4.5%
Canada	Idle speed + Load method	All	TBD
South Korea	Idle Speed Method	1979-1984.7 1984.7-1987.7 Since 1987.7 Old-style cars New-style petrol vehicles New-style LPG vehicles	CO 4.5% CO 4.5% HC 1200ppm CO 4.5% HC 1200ppm CO 1.2% HC 220ppm CO 1.2% HC 400ppm

Note: TA: Type Authentication Limit Value.

II. China I/M System Implementation Current Status of Vehicles in Use

Since mid 1980s, China began to implement supervision and management for vehicle exhaust. This supervision and management include 3 segments: ① implement supervision and management for vehicle manufacturers; ② implement supervision and management for maintenance vendors; ③ implement annual inspection and road inspection for vehicles in use. The latter two segments are exactly the important parts of I/M system.

The Standing Committee of the People's Congress released The Law of Atmosphere Pollution Prevention and Cure of People's Republic of China in 1987. In 1995, amendment was made for this law. The State Council released Implementation Details of the Law of Atmosphere Pollution Prevention and Cure of People's Republic of China in 1991. These laws and regulations raise standards for the vehicle exhaust, requiring that "vehicles and watercrafts exhausting pollutants to the atmosphere shall not exceed the regulated exhaust standards. Controlling methods shall be applied for vehicles and watercrafts that exceed the exhaust standards." At the same time, these laws and regulations clarify the responsibilities of each related department with regard to vehicle exhaust pollution control, i.e. "environment protection departments of each local people's government shall implement unified supervision and management for vehicles and watercrafts tail gas pollution control. Management departments of each level of public security, transportation, railway and fishery shall implement supervision and management for vehicles and watercrafts tail gas pollution control according to its responsibilities and duties."

Some of the cities in China further constituted local management procedures for vehicle tail gas pollution control based on the related laws and regulations above. These procedures make more clear regulations for the responsibility range of related departments:

(1) Environment protection department is the supervision authority for the implementation of unified management of vehicle exhausted pollutants control.

Environment protection departments shall implement spot-check inspection for vehicles, vehicle engines and exhaust purification devices that being produced, maintained and in use (except for those riding on the road).

Vehicle inspection units shall carry out vehicle pollutant exhaust inspection business under the verification and approval of environment protection departments and receive the supervision and inspection of environment protection departments.

(2) The supervision and management for pollutants exhaust of vehicles in use is the duty of public transportation management departments.

Public transportation management departments shall list vehicle exhaust pollutants inspection into vehicle annual inspection items.

Road inspection is implemented jointly by environment protection departments and public transportation departments. During road inspection, vehicles that exceed pollutants exhaust standards shall be punished according to related provisions in Transportation Management Regulations of People's Republic of China.

(3) The control and management for exhaust pollutants of vehicles being repaired by vehicle maintenance scenariots is the responsibility of transportation departments.

In China, however, the supervision and management for vehicle exhaust is still in preliminary stage and the management ways and analysis methods are still need to be completed. At present, the I/M system for vehicles in use has the following deficiencies:

1) The coordination and cooperation between management departments need to be strengthened.
2) Lack of effective supervision methods for the non-standard behaviors of inspection personnel, drivers and maintenance personnel.
3) Supervision for vehicle maintenance quality needs to be strengthened.
4) The lack of effective implementation result analysis methods makes it difficult for related departments to implement improvement measures aimed at current status.

At present, the I/M system test method is mainly idle speed method. Some places such as Beijing adopt dual idle speed method. Compared with other I/M test methods, idle speed method is the simplest to carry out, but is of the worst correlation with actual working mode.

5.1.2 Evaluation Index and Result Analysis of Current I/M System Implemented in Cities of China

I. Inspection Data Comparison Analysis

Inspection data includes two parts: annual inspection data and road inspection data. Annual inspection data refers to the inspection data comes from annual regular inspections; road inspection data refers to the inspection data gets from road random spot-check. If there is too much difference between these two parts, it means I/M system is not implemented well. On the contrary, if there is not too much difference in between, it means I/M system is well implemented. Through the analysis of inspection data characteristics the implementation result of I/M system can be evaluated.

The analysis result of the annual inspection and road inspection data in typical cities show:

(1) In 1998, the vehicle standard satisfaction rate in Beijing for idle speed CO and HC annual inspection was 75% and 94% respectively. While the vehicle standard satisfaction during road inspection was 60% and 78% respectively. In Shanghai, the vehicle idle standard road inspection standard satisfaction rate from 1990 to 1998 was also between 50-70%.

(2) Under the same exhaust density, the accumulated vehicle number of annual inspection number is higher than road inspection data, which means that annual inspection data represents a lower exhaust level.

(3) The difference of high idle speed HC and CO annual inspection and road inspection result is not as distinctive as idle speed inspection. Taking HC for example, the vehicle standard satisfaction rate in 1998 in Beijing during annual inspection was 98%, and road inspection vehicle standard satisfaction rate was 92%.

From above analysis it can be seen that annual inspection data is obviously better than road inspection data. Since the analysis instruments used for annual and road inspections are the same, basically there are no system error problems caused by instruments. This reflects the unhealthy tendency in I/M system implementation in cities of drivers' embezzlement, i.e. before routine annual inspection, the driver adjusts the vehicle to better exhaust level so as to smoothly pass the annual inspection. After inspection, the driver privately re-adjusts the vehicle to previous condition. Due to the existence of embezzlement, annual inspection data cannot fully reflect the true level of vehicle exhaust. However, since road inspection is implemented at random, the driver cannot make preparation beforehand and adjust vehicle exhaust condition. Therefore, road inspection result is more likely to reflect the true exhaust level of vehicles.

II. Current Standards Analysis

The current standards are reasonable or not will directly influence the implementation results of I/M system. Analysis for current standards mainly include the following 3 aspects:

(1) Comparing dual idle speed and idle speed test methods, if most of the vehicles of disqualified tail gas exhaust detected by the two speed are mostly the same, then it means there is no need to adopt test methods of 2 rotation speeds.

(2) If there is a big difference between the vehicle proportion identified by CO and HC, it means the strictness of the two pollutants limit value standards does not match and adjustment should be made for the limit values.

(3) For the same kind of pollutant under different rotation speed, if there is a big difference between the proportions of tail gas disqualified vehicles identified under different rotation speed, then it means adjustment should be made for the limit values.

Taking Beijing for example, it can be concluded from the analysis of currently effective dual idle speed standards that:

Assume the identification rate for tail gas disqualified vehicles by dual idle speed test method is 100%, then according to the accumulated distributing curve of each vehicle model, the identification rate and undetectable rate of only adopting one rotation speed for vehicle inspection is shown in Table 5-2. Results show that when only adopting one rotation speed for vehicle inspection, the identification rate is obviously lower than that of dual idle speed. Compared with dual idle speed method, using idle speed cannot identify a considerable amount of tail gas disqualified vehicles which cannot be properly controlled. Therefore, it is reasonable and necessary to adopt dual idle speed method in currently effective standards in Beijing for vehicle tail gas inspection.

Table 5-2 Tail Gas Disqualified Vehicle Identification Rate under Different Rotation Speed Inspection Methods

Vehicle Model	Identification rate of dual idle speed	Identification rate of high idle speed	Undetectable rate of high idle speed	Identification rate of idle speed	Undetectable rate of idle speed
All vehicles	100%	76%	24%	83%	17%
Saloon cars	100%	88%	12%	75%	25%
Light vehicle I	100%	60%	40%	92%	8%
Light vehicle II	100%	75%	25%	86%	14%
Jeep	100%	77%	23%	85%	15%
Heavy vehicle	100%	76%	24%	71%	29%

It is usually stipulated in the currently effective standards in cities of China to control the CO and HC exhausted by vehicles. The inspection data of Beijing shows that the currently effective standards in Beijing set an obviously stricter limit value for CO than HC. This means that the control degree and strength for CO and HC in currently effective standards is not balanced. The limit value standards of CO are relatively over strict and that of HC is relatively not so tight.

Inspection data in Beijing shows that no matter analyzing from the average results of all vehicles or from the different angles of various kinds of vehicles, it can be found that the identification rate of idle speed CO limit value and high idle speed CO limit value is almost the same. This indicates these two inspection indexes play a similar role in identifying tail gas disqualified vehicles. Therefore, it means the sampling span of idle speed CO limit value and high idle speed CO limit value in currently effective standards of Beijing is reasonable. However, the identification rate of idle speed HC limit value of tail gas disqualified vehicle is much higher than that of high idle speed. This means high idle speed HC inspection does not fully bring into play to identify tail gas disqualified vehicles, i.e. the high idle speed HC exhaust limit value in currently effective standards is too loose.

III. Up-line Qualification Rate Analysis

At present, up-line qualification rate is the most commonly used index to evaluate I/M system by related departments in China. Once up-line qualification rate refers to the proportion of vehicles that passed inspection in the first time of total inspected vehicles. Twice up-line qualification rate refers to vehicles that passed inspection in the second time. Once up-line qualification rate reflects the vehicle exhaust control level, and twice up-line qualification rate reflects vehicle maintenance level. Therefore, comparing the once up-line qualification rate with twice up-line qualification rate can make evaluation for I/M system implementation condition.

Taking Beijing for example, the annual inspection data of up-line qualification condition in 1998 for all vehicle models is shown in Figure 5-1.

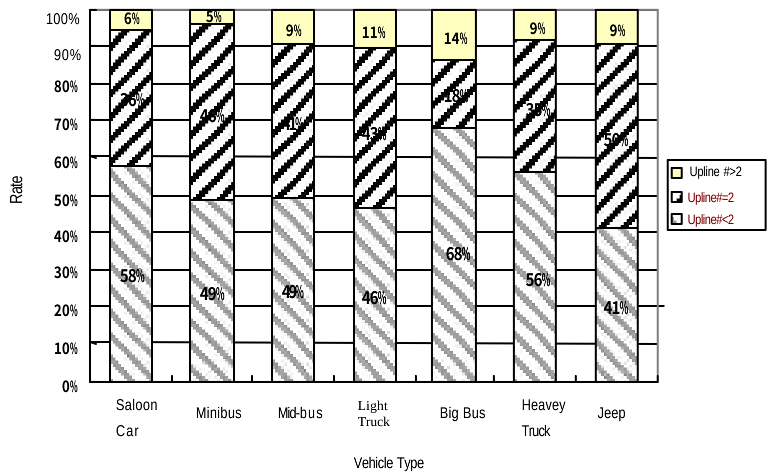


Figure 5-1 Qualification Status of Different Vehicle Models in Beijing (1998)

From Table 5-1 it can be seen that the once up-line qualification rate of every vehicle model is low. Once up-line qualification rate of more than half of the vehicles is below 50%. This exposes the serious problems of disqualified tail gas exhaust in Beijing, and also means the I/M system implementation result in Beijing is not very satisfactory. From the total amount of once and twice up-line qualification, it can be seen that almost all vehicle models reach 90% qualification rate. This means most of the unqualified vehicles during annual inspection reach the demand of exhaust limit values after adjustment and maintenance for one time.

From the analysis of annual inspection data it seems that Beijing vehicle maintenance result is good. But in fact, the result of random road inspection shows the vehicle tail gas disqualified exhaus t proportion still remains high. That is to say, the repair result during annual inspection is not maintained. To some extent this condition shows the existence of malpractice in currently effective mixed I/M system (not completely separate inspection from maintenance) in Beijing.

IV. Exhaust Level Deterioration Analysis

The exhaust of vehicle increases along with the increase of road haul; this phenomenon is call deterioration. The function of I/M system is to alleviate the deterioration of vehicles in use through obligatory inspection and maintenance and keep the exhaust at a reasonable level. If the new vehicle exhaust is low, the exhaust of vehicle gets worse obviously along with the increase of mileage, it means the I/M system does not play its role. Vise versa, if the exhaust does not get worse obviously along with the increase of mileage, it means I/M system really take effects. On the other hand, if the new vehicle exhaust is high, even deterioration is not obvious, it does not mean I/M system is well implemented.

The result of studying Beijing annual inspection vehicle deterioration curve shows that the tendency of vehicle deterioration with the increase of mileage is not so distinctive. However, through the analysis of new vehicle tail gas exhaust once up-line qualification rate it can be find that the exhaust rate of new vehicle is often high, and the once up-line qualification rate of new vehicle reflects the exhaust control level of new vehicle. Therefore, the reason for non-distinctive deterioration of vehicle exhaust in Beijing is not because vehicles are always maintained at a good exhaust level, but the vehicle exhaust condition is always not good. This also shows that the low deterioration level of vehicle doesn't mean the I/M system implementation in Beijing is effective.

5.1.3 Simple Working Mode Method Implementation Demo for Inspection of Vehicle in Use in Beijing

Dual idle speed inspection is used for current vehicle in use in Beijing, i.e. inspecting HC and CO exhaust density under idle speed and high idle speed (engine rotation speed

2000±50r/min.). This method is widely applied in I/M system. But the result is far from the inspection data under true working mode. Besides, under idle speed condition, NOx exhaust density is very small. Therefore, in order to further satisfy the inspection demand of NOx and reflect the exhaust of actual working mode, it is necessary to introduce overload inspection method, among which steady state inspection working mode is the simplest kind in overload method.

In 2000, Beijing set up simple working mode method implementation demo station for vehicle in use at Tsinghua University. The inspection method is Acceleration Simulation Mode (ASM). Simple working mode method is: reflects the actual riding mode of vehicle on the road on the chassis dynamometer machine through simulating vehicle weight and the resistances (friction resistance and wind resistance) the vehicle bears during road riding. Tail gas inspection includes pollutants such as HC, CO and NO. Inspection result is shown by average tail gas exhaust density.

I. Test Result Analysis of Different Vehicle Models

The test equipment adopted is the ASM system provided by American Wildhorse Company mainly including 5 parts: chassis dynamometer machine, sensor, sampling analyzer, control tank and control host. Tested vehicles are light vehicles with the max. gross weight ≤2.5t. Vehicle sampling method is random sampling. The total sample amount is 174 vehicles; vehicle models involved include carburetor vehicles, electronic fuel injection vehicles and renovated vehicles (renovate carburetor to electric control air replenishing plus TWC). The test method is ASM5015, i.e. feeds the vehicle according to its weight and makes the tested vehicle reach 24km/h speed and keeps for 1 min., and measures the HC, CO and NO average density after the vehicle tail gas exhaust is stable. The relationship of tested pollutants density and vehicle mileage is shown in Table 5-2 to 5-4. Due to the limitation of tested sample numbers, the test results are dispersed and the relationship between the two aspects is not very obvious. Support of more test data is needed.

The average exhaust level statistics result of above pollutants exhausted by tested vehicles is shown in Table 5-3. The results show that the 3 pollutants density of electronic fuel injection vehicles is the lowest, then the renovated vehicles, and the tested density of carburetor vehicles is the highest. However, due to the limitation of testing sample numbers, different mileage of different vehicles will affect the above result. Therefore, further tests are needed to testify the results above.

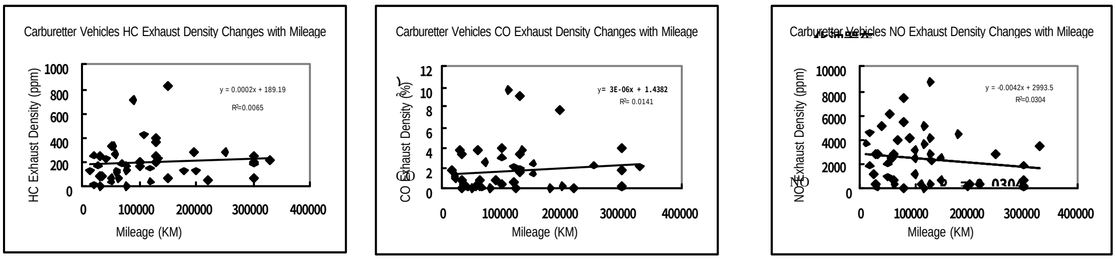


Figure 5-2 Relationship between Carburetter Vehicle Pollutants Exhaust Density and Mileage

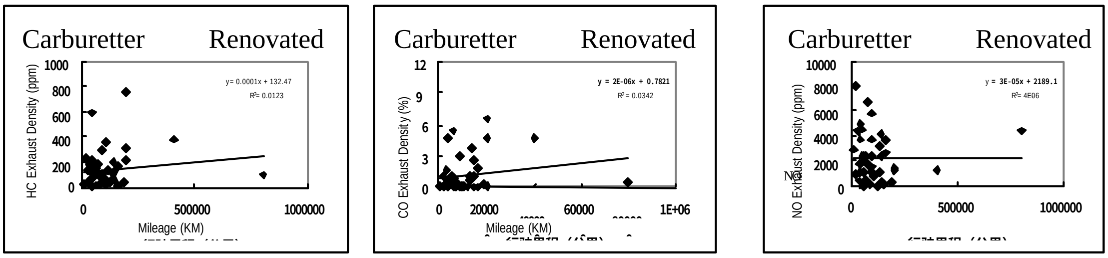


Figure 5-3 Relationship between Electronic Fuel Injection Vehicle Pollutants Exhaust Density and Mileage

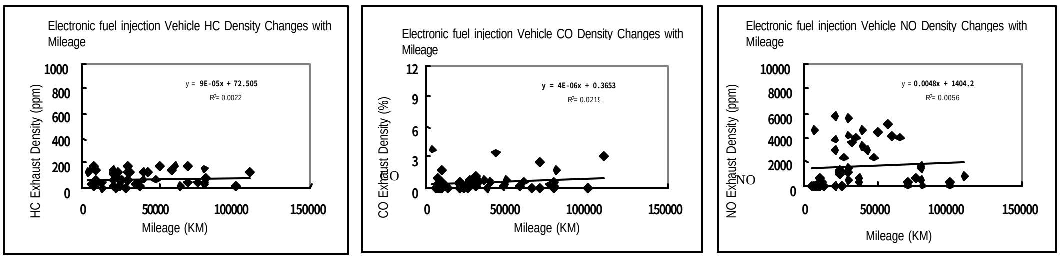


Figure 5-4 Relationship between Renovated Vehicle Pollutants Exhaust Density and Mileage

Table 5-3 Pollutants Average Density Comparison of Different Vehicle Models under ASM Test

	HC exhaust density (ppm)	CO exhaust density (%)	NO exhaust density (ppm)
Carburetor vehicles	208	1.8	2502
Renovated vehicles	134	1.0	2078
Electronic fuel injection vehicles	76	0.5	1578

II. ASM Simple Working Mode Method Test Standard Research

The purpose of adopting stricter ASM steady state test working mode is to screen high-exhaust vehicles more effectively and more accurately, and the main purpose of setting up ASM test demo station is to set up ASM simple working mode method test standards that suitable for China. According to the experiences of inspection and maintenance systems for vehicles in use both at home and abroad, the high-exhaust vehicles that occupy 20% of vehicle stock often contribute over 50% of the pollutants exhaust. Therefore, the main purpose of setting limit values of ASM inspection standards is to identify this part of high-exhaust vehicles. Table 5-5 shows the NO exhaust density of 174 carburetor vehicles, electronic fuel injection vehicles and renovated vehicles under ASM5015 test.

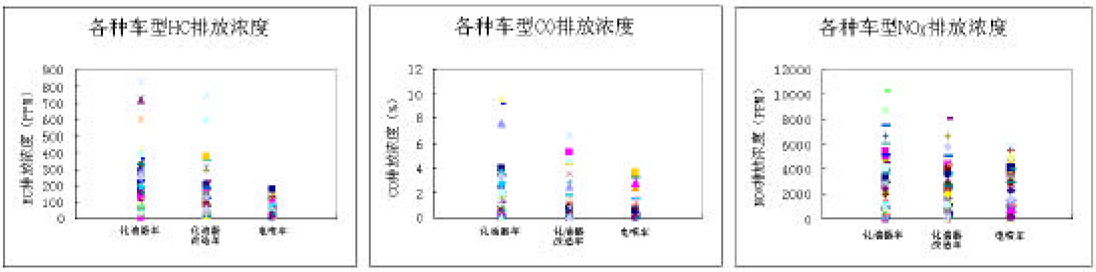


Figure 5-5 Pollutants Exhaust Density of Each Vehicle Model during ASM5015 Test

According to the figures above, a reasonable exhaust limit value can be set to screen high-exhaust vehicles. Assume 10% of the samples tested are high-exhaust unqualified vehicles, then the standard limit values of each vehicle model are shown in Table 5-4. Of course, the setting of this limit value is only a demo research. The determination of standard limit values requires support of a large amount of sampling data.

Table 5-4 Standard Limit Value Setting for ASM5015 Test of Different Vehicle Models (Demo Research)

	HC (ppm)	CO (%)	NO_X (ppm)
Carburetor vehicles	360	3.9	5700
Carburetor renovated vehicles	300	3.5	4300
Electronic fuel injection vehicles	150	1.5	4200

III. Comparison Test Result Analysis of ASM and Idle Speed/Dual Idle Speed Method

At present, many researches abroad show that the identification rate of ASM for high-exhaust vehicles is much higher than idle speed/dual idle speed method, especially for high NOx exhaust vehicles identification. Tsinghua University made preliminary comparison for the detectable rates of ASM and idle speed/dual idle speed method. The vehicle samples for idle speed and ASM5015 test comparison is 96, and the vehicle samples for dual idle speed and ASM5015 test comparison is 12. The tested vehicles include carburetor vehicles and electronic fuel injection vehicles. The tested vehicles are light vehicles with the max. gross weight ≤2.5t. The test standard for idle speed/dual idle speed adopts DB11/044-1999, and the ASM test standard adopts DB11/DXX-2000 (trial version). The two standards above set different exhaust standard satisfaction limit values for carburetor vehicles and electronic fuel injection vehicles. This test adopts carburetor vehicle standard satisfaction limit values for vehicles manufactured before 1999, and electronic fuel injection vehicle standard satisfaction limit values for vehicles manufactured after1999. Besides, the research assumes that the test result of ASM5015 is correct. The comparison results are shown in Table 5-4 and 5-5. The results show that the undetectable rate of both idle speed and dual idle speed inspections are high. Therefore, ASM inspection has more advantage with regard to more effectively identifying high-exhaust vehicles. Due to the limitation of tested sample numbers, the condition of each pollutant is not analyzed which will be got through further research.

Table 5-4 Detectable Rate Analysis Results of Idle Speed and ASM5015

Inspected vehicle model	Exhaust tail gas disqualified vehicle#			Idle speed method Undetectable rate	Idle speed method misdetectable rate
	Idle speed method	ASM5015	Idle speed method + ASM5015		
Carburetor vehicles	15	33	5	29%	10%
Electronic fuel injection vehicles	42	53	30	24%	11%

Table 5-5 Detectable Rate Analysis Results of Dual Idle Speed and ASM5015

Inspected vehicle model	Exhaust tail gas disqualified vehicle #			Idle speed method Undetectable rate	Idle speed method misdetectable rate
	Dual idle speed method	ASM5015	Dual idle speed method+ ASM5015		
Carburetor vehicles	2	8	1	58%	8%
Electronic fuel injection vehicles	8	9	5	33%	25%

5.1.4 Future I/M System Scenario in Cities of China

I/M system is one of the most effective measures to control the exhaust pollution of vehicles in use. However, many problems exist for the supervision and management of vehicles in use in China: the imperfect regulations and laws, incomplete administration system, loose management; most of the inspection tools cannot meet demands, inspection quality is not guaranteed, data unreliable and bad maintenance service quality. The existence of these malpractices already seriously affected the efficiency and effectiveness of I/M system. Although the annual inspection, road inspection and sampling inspection for vehicles in use have been implemented since 1989 and were developed in 330 cities in China, the annual inspection and road inspection carried out in only 40% of the cities are jointly implemented by public security and environment protection departments. For the rest of 60% cities, environment protection departments do not participate the inspections, and the supervision system has not been carried out effectively.

In order to straighten out the relationship among departments, effective system of vehicle exhaust pollution control must be set up and the work share and mutual assistance must be strengthened on the current basis; the function of environment protection departments should also be strengthened during supervision inspection. In the Law of Atmosphere Pollution Control newly revised and passed on May 2000, the management system of controlling vehicle pollution was amended, and the supervision and management responsibilities of environment protection departments are further clarified:

"Provision 33 Vehicles in use that do not comply with the currently effective pollutants exhaust standards for vehicles in use are not allowed to riding on the roads. People's governments of provinces, municipalities and cities directly under the Central Government implement new pollutants exhaust standards and carry out renovations for vehicles in use must report to the State Council for approval. Vehicle maintenance units shall implement maintenance and repair in accordance with the requirements of atmosphere pollution control and related national technical standards so as the make the vehicles in use reach regulated pollutants exhaust standards."

" Provision 35 Environment protection administrative departments under people's governments of provinces, municipalities and cities directly under the Central Government may entrust units that taking in charge of vehicle annual inspection which have passed qualification certification of public security organs to implement annual inspection for vehicle exhaust pollution according to standards. Departments with supervision authorities such as transportation and fishery administrative departments may entrust organizations in charge of vehicles and watercrafts annual inspection under the qualification certification from related administrative departments to implement annual inspection for vehicles and watercrafts exhaust pollution according to standards. Environment protection administrative departments of people's governments of county level and above may implement supervision and sampling inspection for the pollutants exhaust condition of vehicles in use at vehicles parking places."

Operation of future vehicle I/M system shall be deeply and carefully scenarioned in order to comply with the vehicle management in accordance with the above new situation and strengthen the supervision for vehicles in use.

I. I/M System Structure and Related Operation Mechanism

The pollution control management system of vehicles in use should be based on the management system of the whole vehicle pollution control. The former one is a very important component of the latter. From the management of vehicle in use point of view, I/M system is affected by multiple factors such as local vehicle stock, economy development level and specific pollution condition and has distinctive regional features. Therefore, different stages of economic development should be taken under full consideration during the scenarioning for I/M system so as to implement control for vehicles in use in stages.

1) Scenarioning and Establishment of the First Stage

The first stage is to proceed from actual conditions, take the multi-department management in pollution control system of vehicles in use, determine to take the local people's government as core, decide to take related functional departments as assistance, and take vehicle pollution exhaust supervision and inspection as implementation methods in order to form an organic whole. The administrative management departments of pollution control for vehicles in use are the management center of I/M ("Management Center") It consists of: environment protection departments, public security transportation management departments, vehicle maintenance trade supervision departments and technical supervision departments. The main function of the Management Center is to implement guidance and coordination for each vehicle pollution control management departments, and set up each level of I/M Management Centers according to actual conditions when necessary. The functions of each subordinate management departments are divided as below:

① **Environment Protection Department:** In charge of the implementation of specific and unified supervision and management for vehicle exhaust pollutants. The supervision method of this stage is: based on the perfection of current database, use multiple inspection methods and measures, select the disqualified tail gas exhaust vehicles for sampling inspection objects and implement supervision for non-standard behaviors through comparison of exhaust conditions during different inspections.

② **Public Security Transportation Management Department:** In charge of the implementation of specific management and quality control for vehicle exhaust inspection stations.

③ **Vehicle Maintenance Trade Supervision Department:** In charge of the implementation of specific management and quality control for vehicle exhaust maintenance stations.

④ **Technical Supervision Department:** In charge of the implementation of measure authentication for technical execution organs (inspection stations and maintenance stations) of vehicle exhaust pollution supervision inspection.

In order to comply with the above management organs establishment, the setup of each level of inspection place adopts the principle of concentrated annual inspection stations, dispersed maintenance stations and supervision of remote inspection (road inspection). For the maintenance system already existed, trade management is still adopted. But the problems that prevent the maintenance trade from healthy development should be solved.

2) Scenarioning and Establishment of the Second Stage

The second stage mainly takes the long-term scenario of vehicle pollution control under consideration. Its operation and management should comply with the market promotion actions of the whole technical execution organs. The management system is still taking the local people's governments as the core and set up I/M management center. The main body of the management center is the environment protection departments and assisted by local technical supervision departments. Its main function is to implement supervision and management for technical execution organs and ensure I/M system to play its role effectively and implement management for the pollution control of vehicles in use. Since the technical execution organs face the IM management centers directly, the coordination among different management departments is not necessary, so this is easier to manage than the first stage. As for the supervision, the importation and application of new technology (such as remote sense test) are strongly encouraged and database management should be strengthened.

Each corresponding technical execution organs will also go into market, i.e. inspection stations (spots) will be formed into integrated companies. The companies are authorized by management departments through bidding, and the specific functions are mostly similar with the first stage. The difference is that the integrated companies self-manage its inspection performance and are responsible for the business of the companies themselves. Besides, they are under direct supervision and management of the upper level management departments (environment protection bureau or I/M Center).

The I/M Center sets up floating inspection stations and supervises I/M integrated companies and vehicles on the road by remote sense test devices or sampling inspections so as to evaluate the service quality of I/M integrated companies and trace vehicle models of high exhaust and provide feedback to manufacturers in order to find solutions. Set up database to make comparison between fixed inspection annual data and make evaluation for I/M implementation results.

Maintenance organs and inspection organs is a unified department system and its maintenance quality will be supervised and managed by I/M Center. I/M integrated company can be the multilevel company in order to encourage competition and avoid monopoly and is responsible to I/M technical center.

II. I/M System Inspection Technical Standards

1) Determination of Characteristic Parameters

① **Limit Value** is a very important characteristic parameter for I/M system. The determination of limit value should take vehicle exhaust level statistics distribution under consideration as well as the acceptable max. disqualification rate during implementation.

② **Organization Method** I/M system can by divided into 3 types according to the different organization of inspection and maintenance: concentrated type, dispersed type and mixed type. The vehicle exhaust inspection in China is implemented together with safety inspection, so that the dispersed I/M system is impossible to be carried out in China at present or in the future. In the early stage, each city implements concentrated method for exhaust inspection, but the vehicle stock in some of the cities increases rapidly and the result is that vehicle owners have to wait and queue for a long time at the inspection stations. In order to shorten the waiting time and bring convenience to the vehicle owners, some cities such as Beijing implements mixed system. The mixed system overcomes the shortcomings of concentrated system and provides convenience to vehicle owners, but it has problems such as management difficulties and is unable to get higher implementation result as that of the concentrated type.

③ **Inspection Frequency** The overseas experiences show that inspection frequency has little effect on the pollutants decrease benefits. In the U.S., most I/M systems use to require vehicles to accept inspection each year. Later, EPA recommends the inspection frequency to be 2 years; because the latter saves much cost compared with the former one, and there is not too much difference between these two scenarios. Taking the specific condition of China under consideration, the inspection time interval should not be set too long. It is recommended that flexible inspection frequency may be applied for regular inspection for vehicle models with different exhaust levels.

④ **Inspection Method** According to overseas experiences and the current economic level in China, different inspection methods may be applied for carburetor vehicles and electronic fuel injection vehicles. The selection of above testing methods is mainly based on the cost benefit analysis of different testing methods. Considering the current technical level, it is still recommended to use free acceleration method to inspect diesel vehicles at present.

⑤ **Inspected Pollutants** Vehicle pollutants mainly include CO, HC, NOx and carbon smoke, etc. At present, the inspection method types also determine the range of inspected pollutants.

2) Inspection Standards

① **Test Methods** A series of inspection methods used for vehicle I/M system have the same feature: technically feasible and fast inspection speed. Along with the development of technology, the test result of these methods is more and more closer to the test result of working mode method. At present, the most commonly used inspection methods for vehicles in use in the world are: non-load test method (idle speed/high idle speed test method, dual idle speed+λ test method, free acceleration test method, etc.), steady state test method (ASM, etc.), transient test method (IM240, etc.), remote sense inspection, vehicle-load diagnosis system, etc. Which method(s) should be applied depends on the environment quality and actual economic level of the city.

② **Inspection Standards** Pollutants inspection procedure is usually divided into petrol engine tail gas exhaust inspection and diesel engine smoke intensity inspection. Data collected includes vehicle inspection data and quality control data of inspection tools. Besides, I/M system should insure to provide various reports such as inspection data, quality guarantee, quality control and obligatory execution to local environment protection bureau.

I. I/M System Maintenance Mechanism Technical Standards

For carburetor engine, the most common factor that affects CO exhaust is the over density of gas mixture. For HC, there are many reasons that affect its exhaust, but most of the exhaust is caused by fuel evaporation and incomplete combustion.

Electronic fuel injection engine uses the air pressure in the intake manifold or air mass flow as basic signals, calculates the fuel amount needed by petrol engine by microcomputer and controls oil atomizer to realize oil injection. The error adjustment of its electric fuel injection system is a very careful task and needs professional personnel and equipment.

The troubleshooting and analysis of exhaust control system can be processed from TWC, EGR, PCV and evaporation pollution control system.

Many differences exist for the adjustment and parts and methods of maintenance for vehicles with different disqualified tail gas exhaust features, so that the adjustment and maintenance should be differed according to the exhaust features.

5.2 Quicken up Elimination

According to the new standards of vehicle elimination released in 1997, the provisions related with pollutants exhaust stipulate that vehicles whose pollutants exhaust still exceed the country's exhaust standards after maintenance, adjustment or having adopted new exhaust pollution control technologies should be eliminated. For vehicles in use whose various indexes still meet the standards of the country, the owners are encouraged to renew their vehicles voluntarily. Or, an effective and reasonable method is to adjust tax system to force old vehicles to be eliminated or transferred out of key cities. Environment protection and vehicle management departments of each level shall constitute preferential and encouraging policies on economy and vehicle management according to the principles above, and eliminate old vehicles in a feasible way. Vehicle supervision and management organs should be set up to execute strict elimination system for old vehicles that exceed standards.

From the exhaust performance point of view, the effect of renewing vehicle engine to reach new exhaust standard is equivalent with eliminating vehicles. Some of the developing countries decrease urban vehicle pollution exhaust in this way. Encouraging transferring some of the old vehicle models out of key city areas ahead of schedule and replace them with low-exhaust new vehicle types that adopting closed loop TWC purification technology can effectively improve the atmospheric environment quality in the city. Each city can flexibly constitute detailed encouragement methods according to actual conditions such as exempting some of the additional tax of renewed vehicles and providing more favorite loan (such s renewing taxi).

Refer to the related policies constitution and implementation of vehicles for the elimination and rejection system of old motorcycles.

Environment protection departments of each level should constitute feasible exhaust standards for the elimination of old vehicles according to the principles above and reach the goal of pushing the high-exhaust vehicle to be eliminated more quickly through the gradual tightening of standards. In order to effectively eliminate vehicles with serious exhaust pollution, old vehicle rejection system must be strictly executed. The operation management mechanism of the above systems include:

1) The research of exhaust life curve can be authorized to qualified manufacturers and scientific research departments.
2) Environment protection departments are responsible for the constitution of exhaust elimination standards. The base for constituting this exhaust elimination standards should comprehensively include the following aspects:

① According to the elimination number of year;
② Renovation measures of old vehicles;
③ Requirement of environment quality;
④ Vehicle industry and national economy development;
⑤ New vehicle output and stock level of vehicle in use.

3) Vehicle elimination supervision and management organs include departments of public security, transportation, industry and commerce, environment protection and material management.
4) Administrative protection measures for vehicle elimination include: regular inspection and random inspection combined with license plate change; for heavy exhaust pollution vehicles that meet elimination standards, license plates will be revoked and the vehicles will be forced to eliminate.
5) Vehicle elimination economic protection measures include: gradually add inspection times for vehicles that exceed certain years; collect additional increase pollution fee; encourage vehicle owners to replace the old vehicles, etc.

5.3 Promotion of Alternative Fuel Vehicles

At present, much attention has been paid to the method of adopting clean alternative fuel to replace traditional petrol and diesel. Many countries and every major vehicle manufacturer are devoting to developing alternative fuel vehicles. The purpose of adopting alternative fuel is to save energy, improve energy structure and decrease the exhaust of gassy and particulate pollutants. But the forecast for the effects of alternative fuel exhaust should be cautious. Under most conditions, alternative fuel can effectively improve terminal exhaust; but sometimes it may increase exhaust. Besides, the exhaust of alternative fuel during production and storage process, i.e. life cycle exhaust should not be neglected.

5.3.1 Alternative Fuel Vehicle Classification

Vehicles that using alternative fuel can be generally called alternative fuel vehicles. At present, alternative fuel vehicles are divided into the following 3 categories:

I. Flexible-Fuel Vehicle

Flexible-fuel vehicle refers to the vehicle that using petrol and alcohols mixture. Usually there are flexible-fuel vehicles of carbinol and ethanol. For example, carbinol flexible-fuel vehicle can use both carbinol and lead-free petrol or mixture of these two fuels with arbitrary mixing proportion. This kind of vehicle is especially welcomed in the world since it can use arbitrary mixture of a certain alcohol and petrol.

II. Dual-Fuel Vehicle

Dual-fuel vehicle refers the alternative vehicle that can either use petrol or a certain kind of alternative fuel. Generally there are natural gas and LPG alternative fuels. The vehicle models also include vehicle renovated from petrol vehicle and special manufacture. Dual-fuel vehicle is also a popular alternative fuel vehicle in the world. Compressed natural gas/petrol dual-fuel vehicle made by Ford Co. has been promoted to the market successfully. Other companies such as FIAT and Toyota also have released their vehicle models. In 1993, Xinjiang Oil Bureau Transportation Company of China firstly imported a batch of LPG storage devices from the Republic of Kazakstan and installed on vehicles for use. This device has dual-fuel selection switch and is LPG/petrol dual-petrol vehicle. In recent years, China also renovated some Jiefang CA14 and Dongfeng EQ140 trucks. The application result shows that dual-fuel vehicles decreases exhaust and obtain good economic effect and environmental and social benefits.

III. Dedicated Vehicle

Dedicated vehicle refers to vehicle that is dedicated to use a certain fuel, such as LPG vehicle, compressed natural gas vehicle, liquefied natural gas vehicle, dedicated carbinol vehicle, dedicated ethanol vehicle and dedicated carbinol/ethanol-petrol mix vehicle. Ford F-700 liquified natural gas truck, Victoria compressed natural gas vehicle and F series compressed natural gas vehicle of Ford Company and Townace, Carola tool van of Toyota Company and the compressed natural gas vehicle of FIAT are compressed natural gas dedicated vehicles that have been promoted to the market with mature technologies. In China, the application experiment of M100 carbinol fuel on homemade vehicles has passed technical certification.

5.3.2 Appropriately promote alternative fuel vehicles according to conditions of each place

Using compressed natural gas or LPG vehicles and through systematic and reasonable matching and adjustment, the HC and CO exhaust amount is lower than petrol vehicles of the same technical level (tail gas purification system not installed), and the fuel cost is usually a little bit lower too (depends on local fuel gas price). Therefore, each place may appropriately promote alternative fuel vehicles renovation according to actual conditions.

The following aspects should be taken under consideration for constituting specific alternative fuel vehicle promotion scenario:

(1) According to overseas experiments, to set up a coordination group including environment protection bureau, government industrial management department, transportation management department, municipal administration department, public security department, oil and chemistry company, vehicle company and municipal government of each level is the necessary guarantee of promoting alternative fuel vehicles. Environment protection bureau should be the department that takes the lead for the coordination group. Coordination group is responsible to constitute policies, regulations and supervision and management policies with regard to alternative fuel vehicles and is in charge of coordinating the work among related departments and promotion tasks.

(2) Alternative fuel gas filling station is the most important complement construction project for alternative fuel vehicle implementation program. The urban land lease charge is often high, and newly setting up gas filling stations will imperceptibly increase the cost for alternative fuel vehicle implementation. The petrol station is often set up at vital communication lines where is the best place for setting up gas filling station. It is widely accepted in the world to expand the original petrol station to gas filling station so as to set up dual-fuel petrol/gas station for vehicles. This construction measure can greatly reduce cost and improve the convenience for alternative fuel gas filling. To successfully coordinate between oil company and natural gas company is the key factor for implementation.

(3) Related standards must be followed strictly to renovate common petrol vehicle to dual-fuel vehicle in order to guarantee the dynamic feature, safety and reliability of the renovation technology as well as due exhaust decrease effects. For each vehicle model, system matching test must be implemented first and matching and renovation will then be carried out by original vehicle manufacturer or authorized renovation units. Besides, it

should be noted that when renovating alternative fuel vehicle, catalytic and purification devices must be matched and installed, otherwise NOx exhaust would not be decreased or even increased. Therefore, environment protection bureau and vehicle industrial management department should constitute related technology and trade technical certification methods so as to effectively guarantee the performance of alternative fuel vehicles.

(4) The running range of alternative fuel vehicles is restricted by fuel supply system (complement facilities such as gas filling stations), so that alternative fuel vehicles should give priority to some of the vehicles with fixed routines, such as public buses and post buses. The source and price local vehicle fuel gas supply should be also taken under consideration as well as the potential effects of the loss of alternative fuel vehicles dynamics to running operation.

(5) Renovated vehicles should use alternative fuel as far as possible instead of petrol Local government should guarantee the supply of high quality vehicle fuel gas, and the fuel gas quality should meet the standards of the country.

(6) In order to further improve the competency of alternative fuel vehicles, local governments may adopt proper economic stimulation measures according to specific conditions. For example, lend the gas cylinders of LPG and compressed natural gas, derate the road maintenance fee and tax, provide loan for gas filling station construction, provide loan to the renovation of civil petrol vehicle for using alternative fuel, etc.

At present, the major alternative fuels used in China are LPG and compressed natural gas (CNG). China began to develop natural gas vehicle from 1950s. In late 1980s, China began to trial operation of CNG vehicles. From this stage, energy and environment protection requirements were taken under consideration.

In 1996, China began to set up and complete standard regulation system and perfect management system, and develop natural gas vehicles according to different regions, especially Sichuan where natural gas storage is rich under scenarioning and with focus. In 1998, Beijing firstly renovated 10 LPG vehicles; then the fuel gas vehicles in every province and city began to develop rapidly. In 1998, fuel gas vehicles in 12 demo cities in China reached 10,813 in number, among which there are 6232 LPG vehicles and 4581 CNG vehicles. Fuel gas vehicles and complement facilities developed more rapidly in Sichuan, Harbin, Xi’an, Beijing, Shanghai, Shenzhen, Guangzhou and Haikou.

5.4 Renovation for Vehicles in Use

5.4.1 Carefully consider the renovation for vehicles in use

The implementation of technical renovation for some of the heavy-exhaust vehicles in use can decrease the pollution exhaust of vehicles in use after getting successful experiences of focused whole vehicle matching and implementation models. However, mature and complete technologies have not been formed for the renovation of vehicles in use in the range of the whole country. Technologies that being developed and experimented are: additionally install tail gas catalytic and purification devices, high-energy electric ignition device, carburetor electric control air replenishing plus close-loop TWC device, and renovate dual-fuel or single-fuel vehicles that using LPG and CNG as fuel. Local environment protection departments must comprehensively take multiple factors such as the local vehicle model stock condition under consideration together with the city environment quality (determine the necessity of renovation) and the economical efficiency of renovation technologies, in order to select technical routine and implement experiments and adjust measures to local conditions. Specific regulations should be made in accordance with the following points in order to insure the renovation program for vehicles in use to really get pollution decrease result.

1) Introduce adaptability and restriction conditions of usable technologies and avoid the blindly implementation of renovation without satisfactory conditions, such as using tail gas catalytic purification device must ensure lead-free of fuel quality.
2) Must carefully select vehicle model and service life conditions that suitable for renovation. Vehicles that already being used for too many years do not have values for renovation. All vehicles in use must receive normal maintenance before technical renovation in order to recover the engine to normal technical condition.
3) Before promotion and application, renovation technologies being used must pass the renovation matching research for each vehicle model and actual vehicle installation demo in a certain scale. Sufficient tracing and test must be implemented for the actual reduction results (working mode test) and durability (30k-50k km) of the control devices.
4) Local environment protection departments should set up renovation technology quality guarantee system according to the specific index of usable technologies in order to timely supervise and inspect during the implementation of renovation program so as to ensure the implementation results.
5) Dynamic tracing management system should be set up for vehicle tail gas purification products.
6) Consumers' interests and rights should be taken under consideration for the renovation

of vehicles in use. Certain encouraging policies and preferential measures from management and economy point of view should be adopted in order to better motivate vehicle owners' enthusiasm.

See Table 5-6 for technical scenarios for renovation experiments of vehicles in use at present.

Table 5-6 Technical Scenarios for Renovation Experiments of Vehicles in Use

Technical Scenario	Applicable Vehicle Models	Preconditions	Problems	Estimated Results
(High energy ignition)+oxidized catalytic purifier	Carburetor vehicles after 1980s, serve for 3-7 years.	Dilute gas mixture, add secondary air in front of catalytic converter	Fill secondary air may increase noise. High density HC and CO makes the catalytic converter overheat and affects service life	ECE15-04
(Carburetor) strong gas mixture+high energy ignition+close-loop air replenishing+TWC	Carburetor vehicles after 1980s, serve for 3-7 years.	Make matching research for vehicle models of large stock	Petrol consumption increases; condition of vehicles in use differs greatly; large carburetor dispersion; instable performance; durability needs tests.	Close to ECE83-01
Change close-loop electronic fuel injection engine+TWC	Average vehicle served for 6-10 years; taxi served for 2-4 years.	Special matching for vehicle models. Policies give 8 more years before elimination	Vehicle manufacturer should have technologies of the vehicle model and the cost is high	Reach ECE83-01
Add TWC on electronic fuel injection vehicles	Electronic fuel injection vehicle served for 1-9 years.	Changed to close-loop control. Every vehicle model should be matched	Complicated technologies. Need responsibilities of vehicle manufacturers and electronic fuel injection manufacturers. High cost.	Reach ECE83-01
Renovate dual-fuel or gas vehicles (See Chapter 4)	A few of vehicle models with fixed riding routines	Careful matching experiments should be taken.	Reduction effect depends on matching. First generation technology without catalytic converter may increase NOx.	Exceed ECE15-04

5.4.2 Results Evaluation for Vehicles in Use in Typical Cities

In order to hold back the vehicle tail gas pollution which is getting more and more serious in Beijing, after promoting stricter new vehicle exhaust standards firstly, Beijing spent strong efforts on the renovation of vehicles in use, and successively released several measures for renovation of vehicles in use with stronger force and has accumulated some experiments. The tentative evaluation of the renovation results of the vehicles in use can be used as references for renovation of vehicle in use in other cities.

I. Tentative Evaluation for the Effect of Petrol Vehicle TWC (oxidized type)

There is much difficulty in additionally installing tail gas purification device for vehicles in use. Before leaving factories, vehicles received system matching according to their conditions. Additionally installing tail gas purification device actually changes the composition of vehicle system. Therefore, matching and optimization must be implemented again for vehicles. Besides, catalytic purification device only normally works under certain air fuel ratio and temperature, and the control of carburetor for fuel distribution can hardly reach precision requirement. So the actually usable method is to adopt close-loop electric controlled air replenishing for carburetor to ensure the air fuel ratio precision. Anyway, additionally installing purification devices for vehicles in use must be very carefully implemented with good quality guarantee system. Otherwise, the purpose of purifying tail gas cannot be realized and lead to the other opposite: the installation of catalytic converter will result in the abnormal working condition of vehicles and damage vehicles and catalytic converter and further increase exhaust.

Through the service life tracing experiments of 12 products produced by 6 domestic manufacturers that are installed on 10 vehicles respectively, the results show that:

1) The purification result is not very satisfactory from the installation initial purification efficiency of the purification devices made by each manufacturer. Some products have negative values.
2) After installing purifier, most of the drivers said that the noise increased with serious carrier crash.
3) Tracking and testing vehicle with longest mileage has driven for more than 50,000km and the result show that this vehicle can reach standards. This means that the quality of purification devices can control exhaust under normal driving condition.
4) The condition of vehicles with carburetor is not very stable and causes the exhaust instability of exceptional vehicles with purification devices installed. The exhaust is suddenly high or low ad the purification result cannot reach the best state. This means the vehicle maintenance and repair is very important and is an important measure to make the vehicle stably reaches the standards.
5) The engine condition of carburetor vehicles that installing catalytic purification device must be good; otherwise backing pressure will increase due to installing catalytic purification device and cause exhaust increase.
6) The collective results of the experiments show that the manufacture of purification devices in China is still in the beginning stage. The products quality is not stable, and the service life of purification devices is very short. Temporarily they are not suitable for promotion and application in a large scale and management of purification device market should be further strengthened, such that stable products can be installed on vehicles that necessary.

II. Electric Control Air Replenishing + TWC

In 1999, Beijing implemented technical renovation of close-loop electronic fuel injection or electric control air replenishing plus TWC for light vehicles registered after 1995. The statistics of implemented status is as follows: nearly 120,000 vehicles had been renovated till the end of 1999. It is estimated the total number for renovation is 150,000.

Policies for renovation of vehicles in use are in steady implementation stage. The scenarios raised by manufacturers are close-loop electronic fuel injection or electric control plus TWC, and the technology and products adopted are mostly imported from other countries and areas directly. The renovation results are basically guaranteed from the renovation scenario and products that reported and submitted.

According to the dual idle speed exhaust test results obtained on June 1999 from firstly renovated over 6000 vehicles, idle speed CO and HC exhaust density of most of the vehicles is very low, but idle speed exhaust density of about 5% of the vehicles is higher. Although they still satisfy the exhaust standards of renovation for vehicle in use, as newly renovated vehicles, the initial activity of catalyst should be very high. This reflects that the idle speed disqualified exhaust may occur in these vehicles after a short period of time, or working mode inspection result exceed standards, and will influence the pollution decrease effect of a few of the vehicles. Therefore, the inspection and maintenance for renovated vehicles becomes very important.

According to the data of 31718 vehicles obtained on Dec. 1999, further analyzing the dual idle speed exhaust test result of renovated vehicles results in the following tentative conclusions:

① The results of idle speed test before and after renovation show that the renovation result is obvious.

Comparing the vehicle in use idle speed exhaust before and after renovation, the decrease rate of exhaust density for vehicle in use at low idle speed is CO: 97.8%; HC: 89.1%; at high idle speed: CO: 97.1%; HC: 89.5%.

② Decrease results of single vehicle exhaust before and after renovation is obvious

The working mode test results of some of the vehicles before and after renovation show: the single vehicle exhaust factor decrease rate of vehicle in use is CO: 78-90%; HC+NOx: 71-88%. The decrease rate is obvious.

③ Tracking inspection result analysis for renovated vehicles in use after 10,000km mileage

Most of the renovation for vehicles in use were implemented in the second half of 1999, and the driving mileage of renovated vehicles in use is very limited. Therefore, analysis can only be made for 310 renovated vehicles in use after 10,000 km of mileage. The result shows that for those popular vehicle models with short service time and relatively good technical conditions, such as Citroen, Santana and Audi, the deterioration value after renovation with 10,000km mileage is lower. But the deterioration value of some of the non-popular vehicle models is higher; some have exceeded standards during idle speed test after 10,000km mileage. Therefore, regular inspection and maintenance must be implemented for these vehicles strictly according to regulated maintenance and repair standards.

④ 50,000km durability test result for renovated carburetor vehicles in use

The renovation time is short and now analysis can only be made for renovated vehicles in use produced by some manufacturers for 50,000km durability exhaust test results. The test results show that each vehicle model works normally with reliable performance. The exhaust factor during working mode test of each tested vehicle after 50,000km is lower than Beijing New Vehicle Consistency Inspection Test Standards Limit Values (CO: 3.16g/km, HC+NO_X: 1.13g/km).

It should be pointed out that the standards at present do not require model certification and running certification for renovated vehicles, and durability test data are mostly implemented by manufacturers themselves, so that the vehicle model number is relatively small. Besides, the renovation has only been carried out for a short period of time and further tracking inspection shall be implemented for the result of renovated vehicles. In order to retain the existed results of renovated vehicles, it is very important to strengthen I/M system and management.

⑤ Fuel Economical Efficiency

Since renovated vehicles require engine working point to be close to theoretical air fuel ratio, fuel consumption of renovated vehicles is usually increased and thus the fuel economical efficiency decreases. According to multiple working mode test result, the fuel consumption of Red Flag and Citroen increases by 7.8% and 5.1% respectively, and that of Santana decreases a little bit (-4%). After renovation, the dynamic feature change of the above vehicle models is normal, so that the renovation does not greatly affect the application performance under normal application conditions.

Besides, the test result of dual idle speed air fuel ratio equivalency implemented simultaneously for some of the renovated vehicles show that the high idle speed air fuel ratio equivalency of 8% of the vehicles exceeds the limit range of 1$\pm$0.03, but the idle speed CO and HC exhaust density of these vehicles still meet the standards. However, the exhaust condition of NOx need to be tested by working mode methods. Therefore, ASM should be further adopted for exhaust test (simulate working mode on simplified rotor drum test stand), especially for NOx test, which shall be used as the final base to determine the result of this renovation scenario. This is necessary to ensure the substantial exhaust decrease result.

Test results show another problem, i.e. the exhaust consistency after renovation is difficult to be guaranteed, because different vehicles have different mileage and the maintenance degree is different too. Therefore, the vehicle condition of different vehicles differs greatly, and this raises higher requirements for the special maintenance unit for renovation. They can only well carry out the renovation for vehicles in use with high technical levels. Maintenance should be implemented first for vehicles in bad conditions then carrying out renovation. Renovation should be made only for the purpose of renovation. At the same time, it is very important to raise renovation quality guarantee restrain for these units from management point of view. Related government departments should strengthen the guidance, management and supervision for special maintenance units.

As a tentative estimation and taking the deterioration factors under consideration, the decrease effect of this renovation technology is sampled as: CO, HC-80%; NOx-70%; the service life is 2 years or 50,000km. Calculated with this data, renovation 150,000 vehicles can decrease pollutants each year:

CO: 120,000t/year; HC: 18,000t/year; NOx: 6400t/year

It can be seen that after the accomplishment of the renovation for these vehicles, pollutants exhaust can be decreased to some extent. Compared with the total exhaust pollutants amount of the vehicles of the whole city, the decrease rate is 5-8%. Since the renovation vehicles are mostly saloon cars, their NOx exhaust factor is small so that the decrease proportion of NOx is less than CO and HC. According to the vehicle pollution sharing rate in Beijing and saloon cars occupy a larger proportion of the vehicles running in the urban area, it can be analyzed roughly that the air quality improvement rate of NOx is around 7%, and the air quality improvement rate of CO is around 8-9%. On the two sides of the communication lines and during non-heating seasons, the improvement rate for air quality is higher.

III. Vacuum Timing Valve

Another renovation measure in Beijing with large coverage range is to install vacuum timing valve on vehicles in use before 1995. As a tentative estimation, assuming the decrease rate of this measure for NOx is 10%, and totally 400,000 vehicles are to be renovated; the result can be analyzed as below:

NOx decrease amount: 4,000t/year; the NOx air quality improvement rate is 5%.

The above calculation and analysis are based on the precondition that each technical measure works normally with completed quality guarantee system. Vehicles with vacuum timing valve should be inspected and maintained regularly in order to timely find out errors of engine and its exhaust control device so as to keep proper exhaust decrease effect.

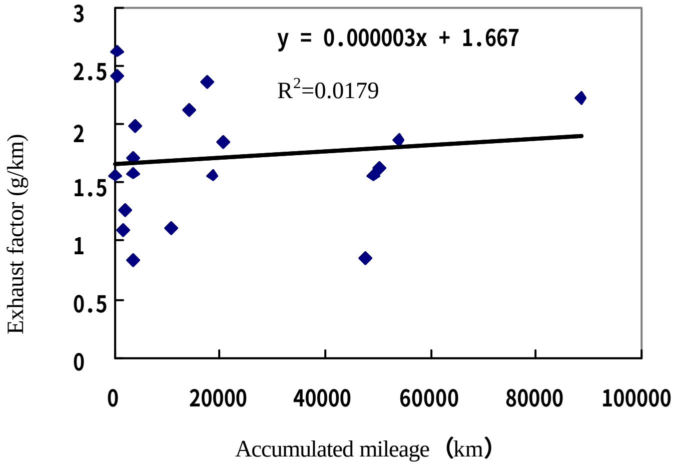
Chapter 6 Exhaust Decrease Analysis of Vehicle Exhaust Pollution Control Solutions

Vehicle exhaust control closely relates with local economic and technical conditions and management levels, therefore, the selection of vehicle pollution comprehensive control solutions differs in different places. This report takes Beijing for example and makes careful analysis and screen for every possible control solution through analysis of current status of Beijing and forecast of future economic and technical conditions and management level development, and determines the basic scenario for Beijing vehicle exhaust control and mid scenario and senior scenario of exhaust control on this base. This report is aimed to provide references and ideas to other cities through the research of vehicle pollution control solution in Beijing – a demo city.

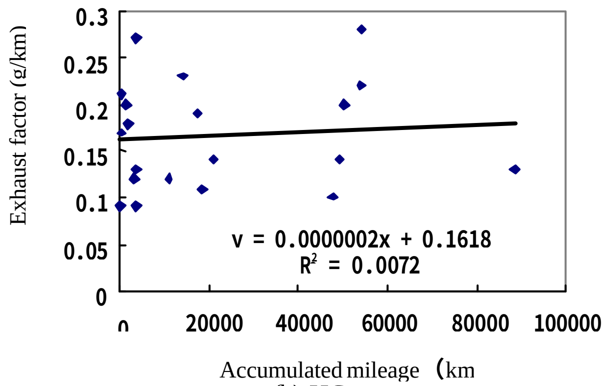
6.1 Vehicle Exhaust Factor Test

In Jan.1 1999, Beijing firstly released and implemented new light vehicle pollutant exhaust standards (DB11/105-1998), which represented that the structure of city vehicles in China began to change greatly, and low-exhaust vehicles that adopting electronic fuel injection technology (EFI) and TWC gradually increase. In order to obtain the basic exhaust level and the deterioration condition during application of these vehicles, China Environment Sciences Research Institute implemented exhaust factor laboratory test for these vehicles. At present, 50 valid tests have been implemented: 5 for mini vehicles, 40 for saloon cars; 5 for jeeps and buses. The service time of these vehicles are mostly short so that the mileage is mainly focused in the range of 0-60,000 km, among which most of them are ranged from 5,000-20,000km.

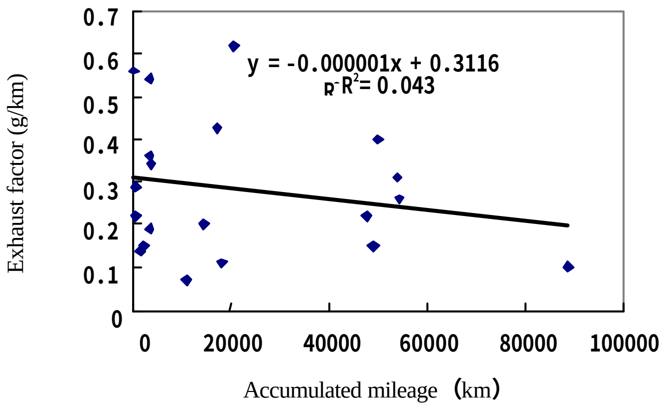
Regressing vehicle exhaust factor to its mileage can get the basic exhaust level of electric ejection vehicles and its deterioration coefficient. Figure 6-1 shows the regression analysis results of 20 light vehicles (14 M1 vehicles and 6 N1 vehicles). Since there are only a few sample numbers of statistics, the regression results pertinence obtained from above test is not very good and cannot be used as quantitative analysis data. However, compare the regression result with that of earlier test shown in Table 6-2 and 6-3 (both for carburetor vehicles), it can be seen that 0-mileage exhaust level (ZML, intercept in the Figure) of electric ejection vehicles is far below that of carburetor vehicles. CO ZML of electric ejection vehicles decreased over 90% than that of carburetor vehicles, and NOx ZML also decreased over 70%.



(a) CO

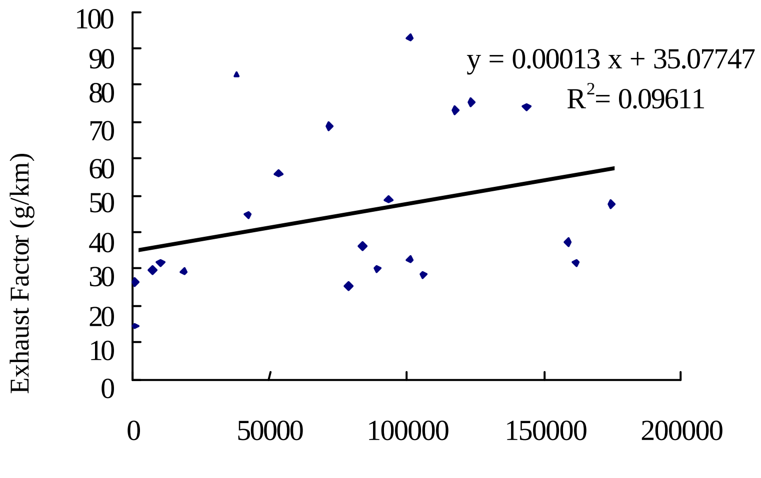


(b) HC

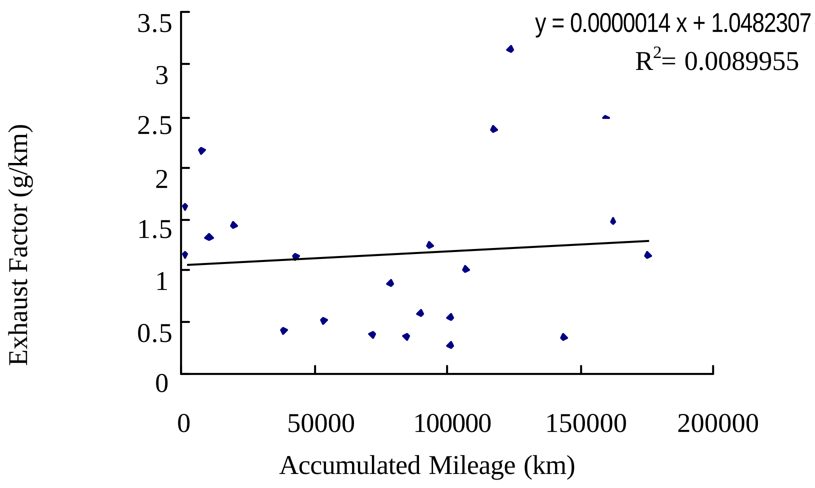


(c) NOx

Figure 6-1 Regression Analysis of Light Petrol Vehicles (M1+N1 vehicles) Exhaust Factor and Mileage

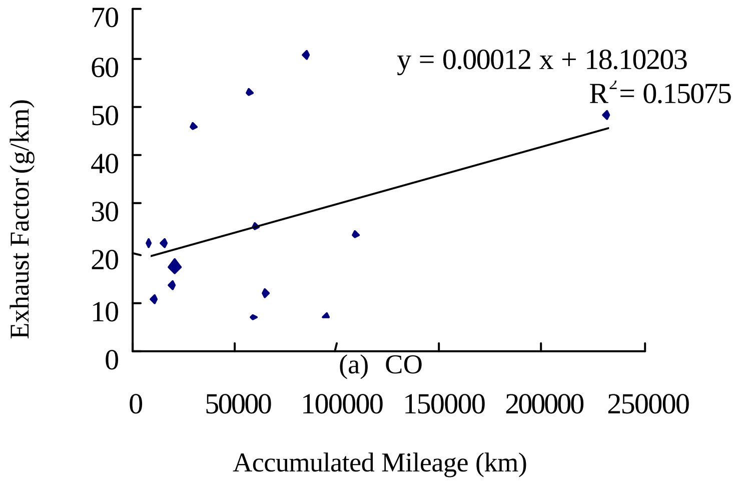


(a) CO

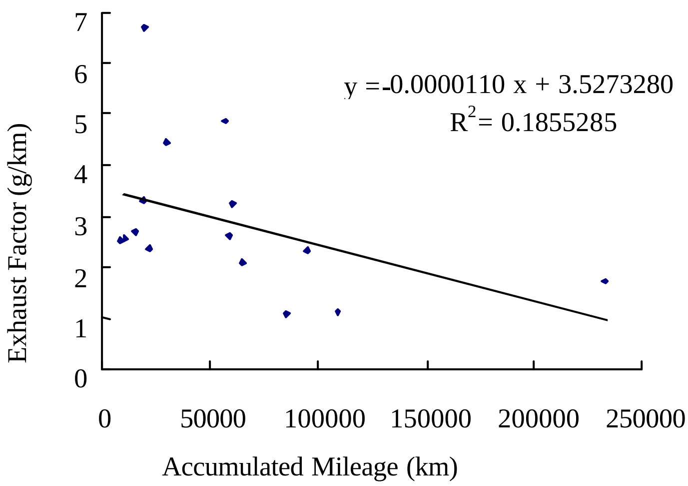


(b) NO_X

Figure 6-2 Regression Analysis of Carburetor Saloon Cars Exhaust Factor and Mileage



(a) CO



(b) NO_X

Figure 6-3 Regression Analysis of Carburetor Light Petrol Vehicles (LDGT) Exhaust Factor and Mileage

6.2 Scenarioning Annual Vehicle Stock Forecast

According to the analysis of Beijing economic and per capita income and vehicle stock increase condition for years and the effects of the implementation of new vehicle exhaust standards on vehicle stock, it is estimated that the stock of yr. 2002 and 2010 will reach 1.91M and 3.05M respectively (see Table 6-1) and is 2.22 and 3.55 times of the stock of 1995. From the table it can be seen that the number and proportion of saloon cars will increase more greatly; this is closely related with the strategy of speeding up the development of home-use cars.

Table 6-1 Beijing Vehicle Stock Forecast (10k)

Year	Saloon Car	Light Vehicle	Mid Vehicle	Heavy Petrol Vehicle	Heavy Diesel Vehicle	Motorcycle	Total
2002	70.9	36.9	31.9	10.6	5.6	35.4	191.4
2010	153.9	56.4	40.1	11.0	5.1	38.4	304.9
2020	346.12	101.80	37.50	10.72	5.03	32.15	535.77

From the table above it can be seen that if vehicle exhaust control is not tightened, till 2010, only taking the exhaust increase caused by vehicle stock increase will result in the heavier atmosphere pollution level in Beijing, and this will directly cause serious harm to human health. Therefore, effective vehicle exhaust control in Beijing must be implemented step by step and in stages so as to reduce the effect of vehicle exhaust to atmospheric environment in Beijing, and this is also the guarantee to realize Beijing's goal of meeting annual atmosphere quality standards.

6.3 Beijing Vehicle Exhaust Control Comprehensive Scenario Design

This report collects already implemented and to be implemented scenarios in Beijing based on the analysis of current status in Beijing and the forecast of future economic and technical conditions and management level development, carefully analyzes and screens various kinds of control measures and determines the basic scenario of Beijing vehicle exhaust control, and the exhaust control mid-scenario and high-pan on this base.

6.3.1 Beijing Vehicle Exhaust Control Base Scenario

1. New Vehicle Exhaust Control Scenario (See Table 6-2)

Table 6-2 Beijing New Vehicle Exhaust Control Basic Scenario

Control Standards	Europe 1*	Europe 2*
Light Vehicle Type I	1999.1.1	2004.1.1
Light Vehicle Type II	2000.1.1	2004.1.1
Heavy Vehicle	2000.1.1	2004.1.1

(*: Europe 1 and Europe 2 have been released and implemented according to the time above in Beijing. The standard is DB11/105-1998).

2. Exhaust Control Scenario for Vehicles in Use

1) ASM inspection will be implemented from 2001

2) Electric control air replenishing plus TWC will be installed on 200,000 vehicles got license after 1996.

3) Additionally install PVC valve (ignition delay valve) for vehicles put into use before 1996.

4) Some of the high-frequency used vehicles (taxi, public bus, etc) be renovated to LPG and CNG vehicles.

3. Oil Quality Control Scenario

1) Realization of major control index in vehicle petrol harmful substances control standards

6.3.2 Beijing Vehicle Exhaust Control Mid-Scenario

1. New Vehicle Exhaust Control Scenario (see Table 6-3)

Table 6-3 Beijing New Vehicle Exhaust Control Mid-Scenario

Control Standards	Europe 1	Europe 3*
Light Vehicle I		2007.1
Light Vehicle II		2007.1
Heavy Vehicle		2007.1
Motorcycle	2001.1	

(*: Europe 3 is equipped with OBDII and requires 10% super-low exhaust vehicle and 0 exhaust vehicle)

2. Strengthen I/M System for Vehicles in Use

1) Inspection method

Implement ASM inspection from 2001

2003: develop inspection working mode that comply with the condition in China

Adopt remote control inspection and plays its supervision function in I/M system.

2) Organization Structure

Adopt concentrated I/M system; concentrated annual inspection and divide maintenance from inspection; remote inspection supervision.

3. Other Control Methods:

1) In 2004, 25% of the public buses are CNGV; in 2007, 50% of the public buses are

CNGV; in 2010, 75% of the public buses are CNGV; in 2012, 100% of the public buses are CNGV.

2) In 2007, all local taxies are CNGV, LPGV or vehicle models that reach stricter new vehicle standards.

3) Develop 43km of city light railway track.

4) Develop 3rd stage subway (south-north line)

5) Restrict the riding area of high-exhaust vehicles. Only light vehicles that meet new vehicle standards of the year and vehicles with green label are allowed to ride inside the 2nd Ring Road.

6) Improve transportation and increase vehicle speed. The average vehicle speed will be increased from 23km/h to 30km/h.

7) Strengthen the implementation of urban parking charge system.

8) Ensure the reliability of vehicle exhaust control system 80,000km.

9) Actively develop mixed power petrol vehicles and fuel battery vehicles and encourage the application of zero-exhaust vehicles.

4. Oil Quality Control Scenario

1) Control index of harmful substances in vehicle petrol and diesel reach the oil quality requirement of new vehicle standards respectively.

6.3.3 Beijing Vehicle Exhaust Control Senior scenario

1. New vehicle exhaust control scenario (see Table 6-4)

Table 6-4 Beijing New Vehicles Exhaust Control Senior Scenario

Control Standards	Europe 1	Europe 2	Europe 3	Europe 4/5
Light Vehicle I			2005.1	2010.1
Light Vehicle II			2005.1	2010.1
Heavy Vehicle			2005.1	2010.1
Motorcycle	2001.1	2005.1		

2. Exhaust control of I/M system for vehicles in use

1) Inspection methods

Implement ASM inspection from 2001

2003: develop inspection working mode that comply with the condition in China

Adopt remote control inspection and plays its supervision function in I/M system.
Release defected vehicle callback system.

2) Organization structure:

Set up bidding system. Inspection companies in charge of vehicle I/M inspection and implementing maintenance station certification

Vehicle obligatory maintenance system

Remote measurement supervision

3. Other control methods:

1) In 2003, 25% of the public buses are CNGV; in 2005, 50% of the public buses are CNGV; in 2007, 75% of the public buses are CNGV; in 2010, 100% of the public buses are CNGV.
2) In 2007, all local taxies are CNGV, LPGV or vehicle models that reach stricter new vehicle standards.
3) Develop 120km of city light railway track.
4) Develop 3rd and 4th stages subway
5) Only vehicles with green label are allowed to ride within the 3nd Ring Road.
6) Only vehicles with green environment protection label are allowed within the 4th Ring Road during air pollution forecast alert.
7) Ensure the reliability of vehicle exhaust control system 160,000km.
8) Improve transportation and increase vehicle speed. The average vehicle speed will be increased from 23km/h to 35km/h.
9) Actively develop mixed power petrol vehicles and fuel battery vehicles and encourage the application of zero-exhaust vehicles.
10) Defected vehicle callback system

4. Oil Control Scenario

1) Control index of harmful substances in vehicle petrol and diesel reach the oil quality requirement of new vehicle standards respectively.

6.4 Beijing Vehicle Pollutants Exhaust Reduction Potential Analysis

The scenarioned urban goal of annual vehicle pollutants exhaust calculation results are shown in Figure 6-4 and Table 6-5 according to the vehicle comprehensive control scenario above. The figure and table also list the increase condition of Beijing vehicle pollutant exhaust amount without any control measure in order to make comparisons.

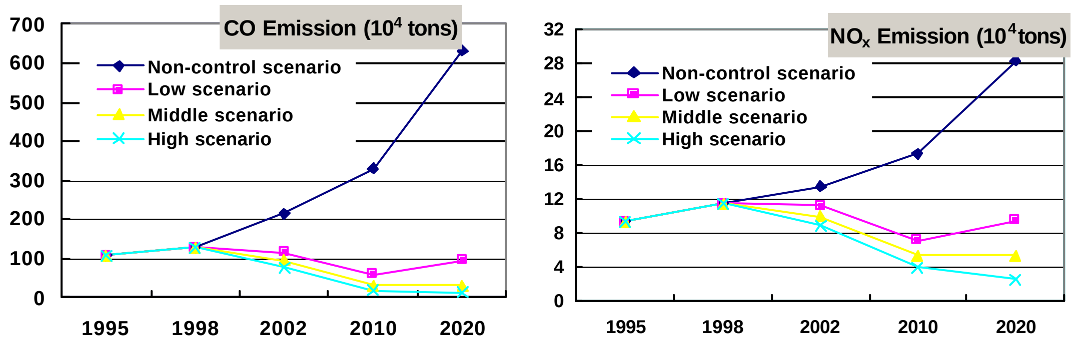


Figure 6-4 Vehicle Emission Potential Reduction under Different Control Scenarios

Table 6-5 Vehicle Emission Change Forecast under Different Control Scenarios (10kt)

	CO			NO_X			HC		
	2002	2010	2020	2002	2010	2020	2002	2010	2020
No Control	213.2	329.0	629.3	13.4	17.4	28.3	32.6	47.3	84.6
Basic Scenario	117.2	61.7	96.2	11.2	7.2	9.4	19.8	8.9	8.5
Mid Scenario	94.9	29.0	30.8	9.8	5.3	5.4	14.9	6.7	4.8
High Scenario	77.6	15.9	10.8	8.8	4.0	2.5	13.7	4.8	2.0

The following conclusions can be drawn from the data in Table 6-5 and Figure 6-4:

(1) There are differences between control scenarios to the decrease of different pollutants. The above 3 scenarios have high decrease result for CO and HC. Till 2010, the implementation of mid/senior scenarios will keep CO exhaust at a very low level. Compared with non-control scenario, the decrease rates are above 90%. Emission in 2020 will increase.

(2) The NOx decrease effect of each scenario is not as good as CO, but compared with non-control scenario, these scenarios show a considerable decrease potential. The implementation of will make the NOx exhaust in 2010 only 57% of 1995 and 43%. The NOx pollution in Beijing is much more serious and the environment capacity is limited, so that only selecting strict control scenario can change the condition of serious NOx disqualification.

(3) The implementation of control scenario has hysteresis for the decrease of vehicle exhaust. From the table it can be seen obviously that compared with non-control condition, the decrease rate of each pollutant of 2002 is not as good as yr. 2010; this is mainly because the existence of a considerable amount of carburetor vehicles. Compared with the exhaust condition of 1995, if only basic scenario is implemented, then the CO and NOx exhaust of vehicle in 2002 will increase 9% and 20% compared with 1995; the implementation of

mid-scenario will result in the decrease of CO in 2002 by 12% compared with 1995, but NOx exhaust is still 5% higher than 1995. Only the implementation of senior scenario can realize the decrease of these two pollutants in 2002 to the level lower than 1995; CO decreases by 28% and NOx decreases by 6%. Therefore, the measures in each control scenario should be pushed to be implemented as soon as possible if the technical and economic condition permits.

6.5 Annual Air Quality Improvement Forecast in Beijing Planed Urban Target

The urban vehicle pollution is ultimately due to two factors, i.e. the exhaust feature of vehicle pollutants and the pollutants transportation and conversion process in the air. The latter one is affected by city topography, climatic factors and the physical and chemical properties of the pollutants and is featured with complexity. As a vehicle pollution evaluation system that supports decision-making, it should clearly describe the process above, and also reacts promptly and flexibly for the change of exhaust so as to satisfy the demand of decision control. The method of using diffused mode calculation is very complicated, and Tsinghua University describes the transportation feature of pollutants by establishing pollutants transportation matrix, and determines the quantitative response relationship between pollutant exhaust and density. (see Formula 6-1 for the expression of transportation matrix). The research adopts secondary grid system to re-divide the researched area. For urban margins where pollutants density is relatively low, $6\times 6km^2$ grid is used for division. For city center where pollutants density is high with obvious density distribution change, $3\times 3km^2$ grid is used for division. The urban area is divided into 39 grids (see Figure 6-5 for the grid system). The area covered by secondary grid system is $756km^2$ and part of urban margins is neglected. Pollutants exhausted in this area and the density generated for the urban area is taken as the city background value.

The meaning of transportation matrix can be shown by the following equation:

$$AX = C \qquad (6\text{-}1)$$

Among which A: Transportation Matrix; X: Exhaust Source Strong Vector. Vector element X_i is the exhaust intensity of source No.i; C: Receptor Density Vector. Vector element C_i is No.i receptor intensity.

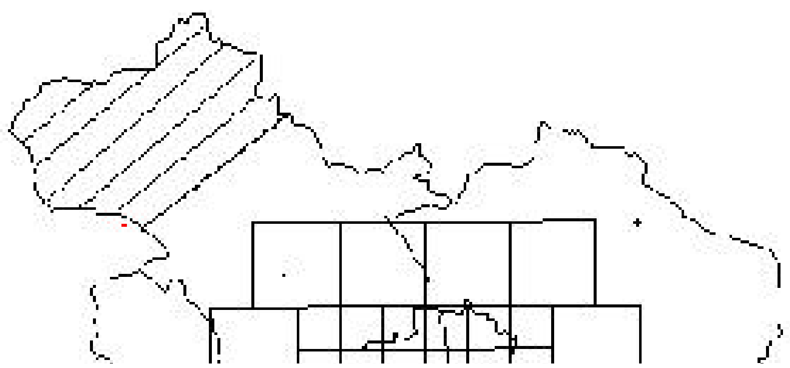


Figure 6-5 Grid System Used for Control Target Analysis

Vehicle exhaust density formed in different grids can be determined by divided grid system and the exhaust decrease of each vehicle control scenario and vehicle pollutants transportation matrix. The transportation matrix includes all long-term average feature information of vehicle pollutants diffused in urban Beijing. When vehicle exhaust condition changes, the change of pollutants long-term density distribution can be quickly reflected by transportation matrix.

Table 6-6 and 6-7 show the result of pollutants density forecast under different control scenarios. (Note: the pollutants density forecast of each synchronized fixed source control scenario is accomplished by ISCST3 model.)

Table 6-6 Each Scenarioned Yearly NOx Annual Average NOx Density Area Distribution Forecast under Different Control Scenarios (Unit: ug/m^3)

	1995 (non-control)	2002 (Mid-scenario)	2010 (Mid-Scenario)	2010 (Basic Scenario)	2010 (High Scenario)
Outside 4th ring road	87.4	106.5	74.7	89.0	65.0
Between 3rd and 4th ring road	141.0	167.8	101.3	119.0	79.8
Between 2nd and 3rd ring road	201.6	170.1	104.1	121.9	82.1
Inside 2nd ring road	236.8	174.9	107.0	125.7	83.8
Urban average	125.0	125.8	83.1	98.9	69.8

Table 6-7 Each Scenarioned Yearly NOx Annual Average CO Density Area Distribution Forecast under Different Control Scenarios (Unit: ug/m^3)

	1995 (non-control)	2002 (Mid-scenario)	2010 (Mid-Scenario)	2010 (Basic Scenario)	2010 (Senior Scenario)
Outside 4th ring road	1436.9	1283.1	569.5	949.3	442.7
Between 3rd and 4th ring road	2087.2	1860.0	733.7	1171.0	498.5
Between 2nd and 3rd ring road	2916.2	2163.8	838.1	1358.8	551.3

Inside 2nd ring road	3865.3	2167.5	838.5	1359.8	551.5
Urban average	1955.9	1528.0	643.1	1062.7	473.1

Figure 6-6 and Figure 6-7 show the changes of pollutants density after the implementation of vehicle exhaust mid-scenario.

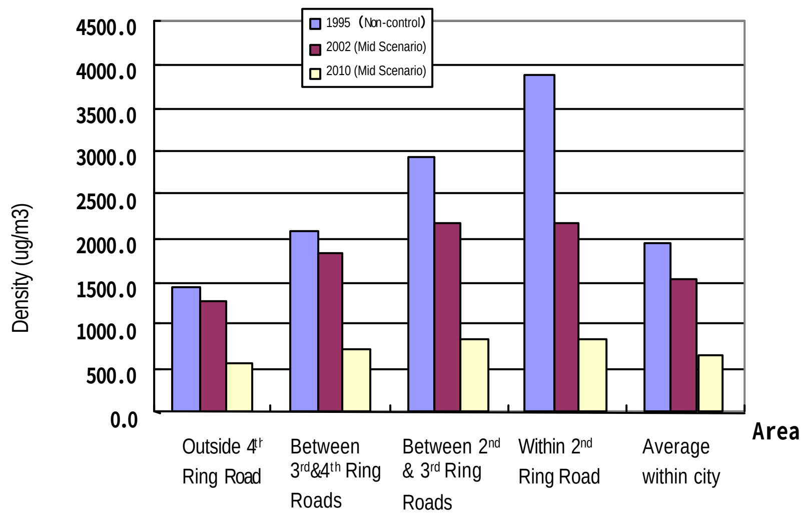


Figure 6-6 Changes of CO density in each area under the mid-scenario

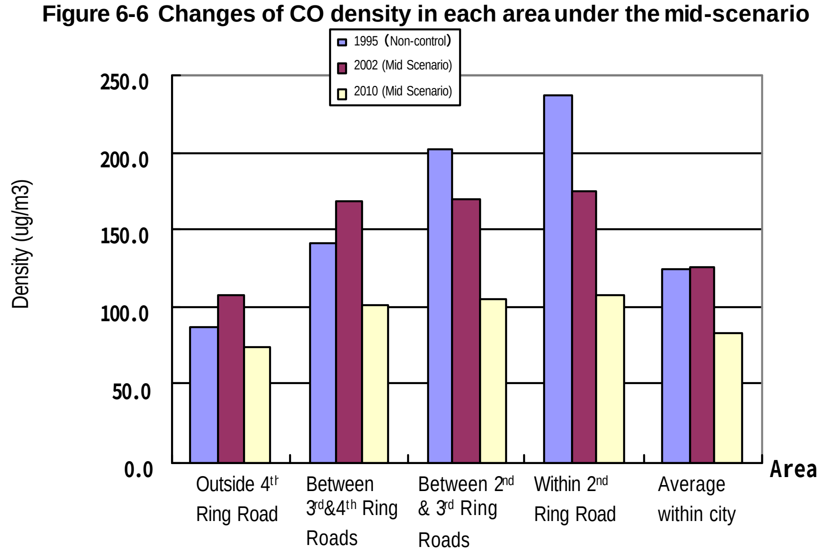


Figure 6-7 Changes of NOx density under the mid-scenario

Figure 6-8 to 6-13 show the grid distribution result of pollutants concentration forecast under comprehensive mid/senior control scenarios.

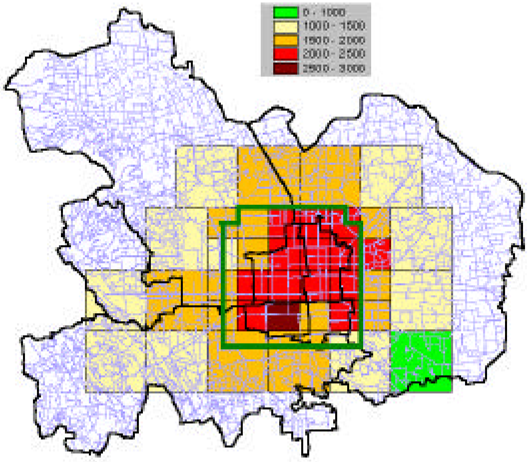


Figure 6-8 CO Annual Density Regional Distribution in 2002 under Comprehensive Control Mid Scenario (ug/m^3)

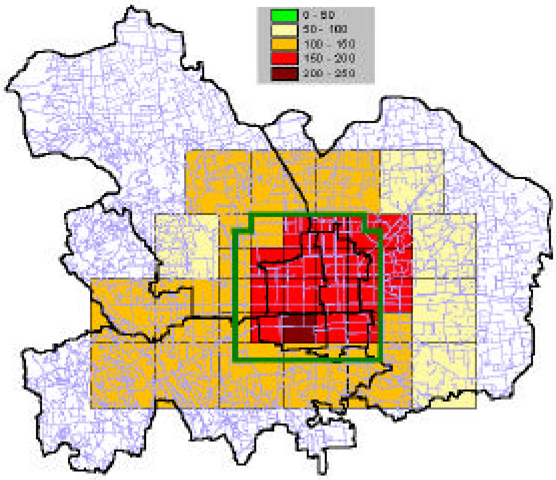


Figure 6-9 NOx Annual Density Regional Distribution in 2002 under Comprehensive Control Mid Scenario (ug/^{m3})

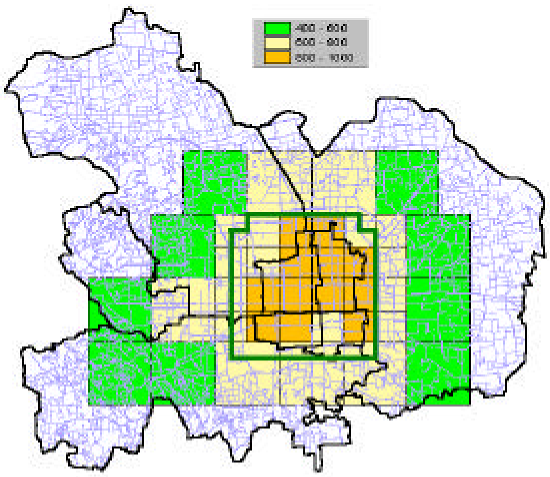


Figure 6-10 CO Annual Density Regional Distribution in 2010 under Comprehensive Control Mid Scenario (ug/m^3)

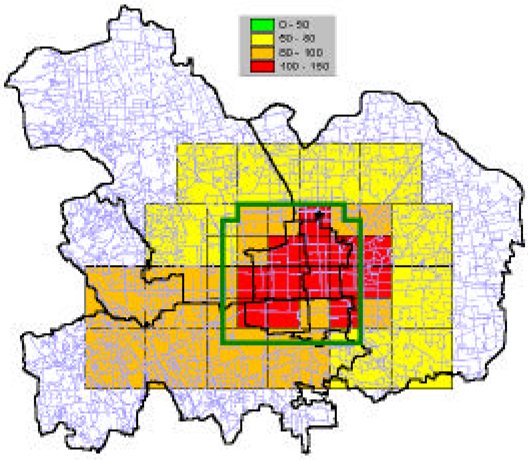


Figure 6-11 NOx Annual Density Regional Distribution in 2010 under Comprehensive Control Mid Scenario (ug/m^3)

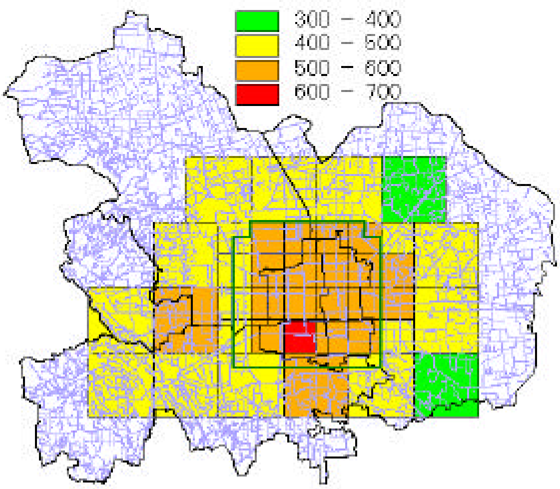


Figure 6-12 CO Annual Concentration Distribution in 2010 under Comprehensive Control High Scenario (ug/m^3)

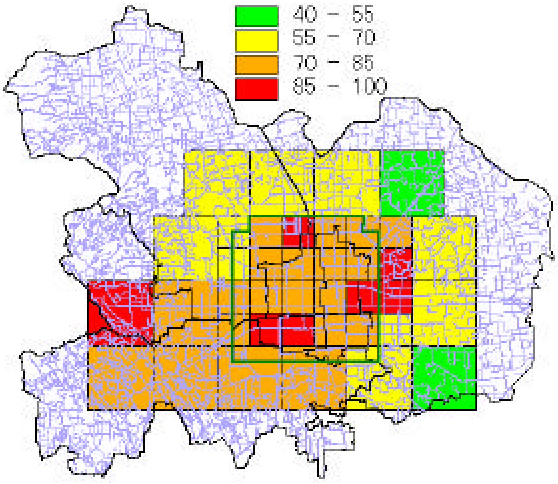


Figure 6-13 NOx Annual Concentration Distribution in 2010 under Comprehensive Control High Scenario (ug/m^3)

The following conclusions can be drawn from the analysis results above:

(1) After the implementation of basic/mid/senior pollution control comprehensive scenarios (including flow source and fixed source), the annual simulated density of CO in each region greatly decreases. The implementation of mid/senior scenarios will decrease the simulated CO density of each region below 1 mg/m^3 in 2010. Based on similar analysis, CO pollution in Beijing urban transportation environment will be also greatly decreased at that time. But it should be noticed that the during implementation of mid scenario in 2002, average density within the 3rd Ring Road will still exceed 2mgm^3, this means after the implementation of control scenario (especially the vehicle exhaust control measures), the exhaust decrease result reflection has certain hysteresis. Correspondingly, the CO density in the transportation environment in 2002 will still remain at a high range. So the CO control in transportation environment should be paid serious attention to till 2002 and after. This is identical with the above pollutants exhaust decrease potential analysis.

(2) The decrease tendency of NOx simulated density is not as remarkable as CO. The implementation of comprehensive control mid scenario can only ensure the NOx annual average density of scenarioned urban area in 2002 to retain at the level of yr. 1995. This indicates that the decrease result of vehicle exhaust control solution such as Europe 1 and natural gas alternative is not as obvious as CO. Besides, since the load of each communication lines with the 3rd Ring Road nearly reaches saturation point at present and communication lines outside the 3rd Ring Road begin to bear more and more traffic flows. This reflects that till 2002, when NOx density begins to decrease within the 3rd Ring Road, the NOx density outside the 3rd Ring Road begins to increase compared with 1995. From Table 6-6 it can also be found that after implementing mid/senior control scenarios, the scenarioned urban area average simulated density in 2010 can reach 83.1 and 69.8 ug/m^3 respectively and meet the environment air quality standards stipulated by the country.

(3) According to the urban inspection results in Beijing, the density ratio of NO_2 and NOx is kept at 0.5. So a half of the simulated NOx density is set as the simulated value of NO_2 based on this ratio. Therefore, after implementing mid-scenario, 45% of the grids of Beijing scenarioned urban area in 2010 is lower than 40ug/m^3, and density of 39% of the grids is between 40-50ug/m^3, and density of 14% of the grids is between 50-60 ug/m^3. This indicates that the NO_2 density in Beijing scenarioned urban area at that time can reach national NO_2 second level standards. It should be pointed out that the during the implementation of mid-level, there are still 19% of the grids exceeds 80 ug/m^3 in 2002 (concentrated within the 3rd Ring Road).

Chapter 7 Control Technology of Vehicle Pollution and Cost-Benefit Analysis

7.1 The purpose of Cost-Benefit Analysis

The purpose of Cost-Benefit Analysis (CBA) on the vehicle pollution controlling strategies is to offer reference for the policy makers and control vehicle pollution effectively and distribute the resource rationally.

7.2 Calculating Methods of Cost Benefit Analysis

Up to now, many international research institutes are conducting CBA of control measures on vehicle emission pollution, but when they calculate cost benefit, they use different calculating norms and methods instead of a uniform norm. In this part, we'll adopt the compute mode that has been used by other researchers. That's to consider the economic cost, environmental benefit and health benefit of unit reduced pollutants in the life-cycle of the control strategies or techniques. Only cost of the control strategies and techniques is analyzed in detail. Because of the complicated computation of health benefit analysis, we just analyzed it briefly.

This chapter will fix the calculating life cycle as long as ten years from 2001 to 2010, define different discharge control scenarios including No.1, No.2, No.3, No.4 European Standards in different periods, analyze the change of emission pollution, and realize the costs of different scenarios.

Using the calculating methods of the B-9-3 Project for reference, we take in consideration in this cost analysis the direct cost and the expenditures concerned in the use of different technological measures taken by different motor models in order to meet discharge standards, which include the hardware cost necessary to be added, the changing repairing cost, and the improvement and aggravation of economic oil. In order to compare the different technological measures and different times of practice, we calculate different costs based on the defined standard of the dollar cost in 2000 and convert all the costs of the following years into the dollar costs in 2000 by the use of the discount rate of 5%.

Because of the differences of data sources and the lack of comprehensive data gathered nationwide, the calculating results in this chapter are sure to be partial. Also its cost calculation is somewhat different from the cost in the treatment of discharge pollution of motor vehicles in reality. However, in the total calculation of cost benefit, the comparative prices of all kinds of treatment measures adopted by this chapter are of great importance to cost benefit analysis.

During the process of calculating cost, first, we must take into account the effect of some discharge treatment measure in improving the environmental atmosphere without influencing the other control technologies. Second, we must take into consideration the effect of the control technology in treating discharge pollution.

In calculation, based on the different emission standards, we adopt the yearly discharge elements calculated by the MOBILE5 Model and the yearly mileage got by research and calculate the total of discharge pollution. Then we compare this total with the total of discharge pollution resulted from the standard scenario and find the reduction of discharge pollution if some control scenarios are put in effect.

The following cost benefit calculation will convert the cost of reducing one thousand kilograms of discharge pollution into the dollar cost in 2000 in life cycle of the technology which is as long as 20 years.

The detail computing method is presented in appendix A.

7.3 Computation of Cost Benefit Analysis

7.3.1 The Design of the Control Scenario

Based on the three control scenarios on new motor vehicles in Beijing defined in Chapter Six, we put the discharge standards of motorcycles in the middle and upper scenarios into the standard scenario, because Beijing is carrying out the discharge control of motorcycles. The following Table7-1, Table7-2, Table7-3 show the three control scenarios in detail. Table-4 shows the standard limitations of the control scenarios.

Table 7-1 Standard scenario for the control of discharge from new vehicles in Beijing

Control Standards	Euro 1	Euro 2	Taiwan 2	Taiwan 3
LDGV LDGT1	1999.1.1	2004.1.1		
LDGT2	2ooo.1.1	2004.1.1		
HDGV HDDV	2000.1.1	2004.1.1		
MC			2001.1.1	2001.1.1

Table 7-2 Middle scenario for the control of discharge from new vehicles in Beijing

Control Standards	Euro1	Euro 3
LDGV LDGT1	1999.1.1	2007.1.
LDGDT2	2000.1.1	2007.1

HDGV HDDV	2000.1.1	2007.1

Table 7-3 Upper scenario for the control of discharge from new vehicles in Beijing

Control Standards	Euro 1	Euro 2	Euro 3	Euro 4
LDGV LDGT1	1999.1.1		2005.1	2010.1
LDGT2	2000.1.1		2005.1	2010.1
HDGV HDDV	2000.1.1		2005.1	2010.1

The discharge elements of each motor model are got by MOBILE5 Model. These motor models include LDGV, LDGT1, LDGT2, HDGV, HDDV, and MC. The different cost benefits of the above-mentioned vehicles will be analyzed and calculated respectively.

Table 7-4 Standard limits applied for the various controlling scenarios

Model	Standard		Limits			
			CO	HC	NOx	PM
Cars g/km	Euro1（91/441/EEC）		3.16	1.13		0.18
	Euro 2（94/12/EC）		2.2/1.0*	0.5/0.7/0.9		-/0.08/0.1
	Euro 3（EC2000）		2.3/0.64*	0.2/-*	0.15/0.5*	0.05
	Euro 4（EC2005）		1.0/0.5*	0.1/-*	0.08/0.25*	0.025
Large cars and light trucks	Euro 1 (93/59/EEC)	I	2.72	0.97		0.14
		II	5.17	1.4		0.19
		III	6.9	1.7		0.25
	Euro 2（96/69/EC）	I	2.2/1.0*	0.5/0.7/0.9		-/0.08/0.1
		II	4.0/1.25*	0.6/1.0/1.3		-/0.12/0.14
		III	5.0/1.5*	0.7/1.2/1.6		-/0.17/0.2
	Euro 3 Repair testing Condition	I	2.3/0.64*	0.2/0.56**	0.15/0.5*	0.05
		II	4.17/0.8*	0.25/0.72**	0.18/0.65*	0.08
		III	5.22/0.95*	0.29/0.86**	0.21/0.78*	0.11
	Euro 4 Repair testing Condition	I	1.0/0.5*	0.1/0.3**	0.08/0.25*	0.025
		II	1.81/0.63*	0.13/0.39**	0.1/0.33*	0.04
		III	2.27/0.74*	0.15/0.46**	0.11/0.39*	0.06
Heavy Diesel motor/bhp-hr	USEPA	Weight≤14000lbs	14.4	1.1	6.0	
		Weight>14000lbs	37.1	1.9	6.0	
Heavy Diesel Motor g/kwh	Euro1（91/542/EEC）		4.9	1.2	9.0	0.4
	Euro2		4.0	1.1	7.0	0.15
	Euro3（ESC/ETC）		2.09/5.53	0.66/0.83	5.04/5.13	0.10/0.16
	Eurp4（ETC）		2.76	0.41	2.56	0.08
Motor car g/km	Euro1（97/24/EC）		8/13***	4/3***	0.1/0.3***	
	Taiwan2		4.5	3.0		
	Taiwan3		3.5	2.0		

Notes：1） *indicates：gasoline/diesel，**indicates：HC/HC+NOx；

2） gasoline/non-direct-ejection diesel/ direct-ejection diesel;

3） all PM values are restricted in diesel vehicles;

4） ***indicates：two wheels with two strokes/ two wheels with four strokes

7.3.2 Relevant Technological Strategies

China's technological route and policies roughly conform with those adopted by the other countries on discharge control of motor vehicles; that is, first attention is paid to the inside of motor to control CO and HC and second attention is the outside to control NO_x and PM. Table7-5 shows that different motor vehicles must have some technologies and measures in order to meet different discharge regulations.

Table 7-5 Discharge standard and relevant technological measures

Model of Vehicle	Standard	Technological Measures
Light Gasoline Cars	Euro1	Closed loop electronic control ejection +triple catalytic converter
	Euro2	Closed loop electronic control ejection +coldstart triple catalytic converter
	Euro 3	Optimized Closed loop electronic control ejection and catalytic converter +multi-level triple catalytic converter
	Euro 4	Rarefaction combustion + Deoxidization catalytic converter under rarefaction condition +oxidation catalytic converter, vehicles with mixed drive
Light Gasoline Trucks1	Euro 1	Closed loop electronic control ejection +triple catalytic converter
	Euro 2	Closed loop electronic control ejection +coldstart triple catalytic converter
	Euro 3	Optimized Closed loop electronic control ejection and catalytic converter +multi-level triple catalytic converter
	Euro 4	Rarefaction combustion + Deoxidization catalytic converter under rarefaction condition +oxidation catalytic converter, vehicles with mixed drive
Light Gasoline Trucks 2	Euro 1	Catalytic converter +exhaust gas recycling
	Euro 2	Closed loop electronic control ejection +triple catalytic converter
	Euro 3	Closed loop electronic control ejection +coldstart triple catalytic converter
	Euro 4	Optimized Closed loop electronic control ejection and catalytic converter +multi-level triple catalytic converter
Motor Car	GB14621	Engine maintenance
	Euro 1	Engine maintenance +oxidation catalytic converter
	Taiwan2	Air ejection + oxidation catalytic converter
	Taiwan3	Electronic control ejection + triple catalytic converter
Heavy Gasoline Truck	Equivalent to Euro1	Oxidation catalytic converter + exhaust gas recycling
	Equivalent to Euro 2	Close loop multi-spot ejection + triple catalytic converter
	Equivalent to Euro 3	Optimized Closed loop electronic control ejection and catalytic converter +multi-level triple catalytic converter
	Equivalent to Euro 4	Rarefaction combustion + Deoxidization catalytic converter under rarefaction condition +oxidation catalytic converter
Heavy Diesel Truck	Euro1	Renewal engine maintenance + pressured medium cold + exhaust gas recycling
	Euro2	Electric ejection + pressured medium cold + exhaust gas recycling + oxidation catalytic converter
	Euro3	Electronic control high-pressure shared track + pressured medium cold + exhaust gas recycling + oxidation catalytic converter
	Euro4	Electronic control high-pressure shared track + pressured medium cold + exhaust gas recycling + multi-gas valve technology + transformable gas entrance vortex + post-exhaust treatment (oxidation, CRT, SCR)

7.3.3 Annual Traveling Mileage of Vehicle

In this part, the data of vehicle annual traveling mileage is based on the investigate results in the B-9-3 program. Table 7-6 shows the detail data of each vehicle type.

Table7-6 Annual Traveling Mileage of Each Vehicle Type

Vehicle Type	LDGV	LDGT1	LDGT2	HDGV	HDDV	MC
Annual Traveling Mileage (km)	28400	24000	17500	19700	19700	10000

7.3.4 Fuel Economy

The unit of fuel economy is oil consumption per 100 km traveling mileage. Fuel economy is very important in CBA, we adopt the statistical result of B-9-3 program. Table 7-7 gives average fuel economy of each vehicle type.

Table 7-7 Average Fuel Economy of Each Vehicle Type (L/100Km)

Vehicle Type	LDGV	LDGT1	LDGT2	HDGV	HDDV	MC
Average oil Consumption	9	10.5	12.5	25	22	2.5

7.3.5 Cost Analysis of Different Technological Control Measures

The cost calculation also takes into consideration the research data of the B-9-3 Project and some data from the internal supply market of motor parts. Table7-8 fixes the different motor models, their discharge standards, and costs involved in the use of technological measures, including the costs of hardware, the repairing costs, and the changing percentages of economic oil.

Table 7-8 Original data table of cost investigation

LDGV

Standard	Technological measures	Hard ware cost $	Maintenance cost $	Improvement rate Of the economy of fuel
Euro1	Closed loop electronic control ejection + triple catalytic converter	955	80	3%
Euro2	Closed loop electronic control ejection +coldstart triple catalytic converter	1075	80	3%
Euro3	Optimized Closed loop electronic control ejection and catalytic converter +multi-level triple catalytic converter	1500	80	5%
Euro4	Rarefaction combustion Deoxidization catalytic converter under rarefaction condition +oxidation catalytic converter，vehicles with mixed drive	4500	90	10%

LDGT1

Standard	Technological measures	Hard ware cost $	Maintenance cost $	Improvement rate Of the economy of fuel

Euro1	Closed loop electronic control ejection + triple catalytic converter	955	80	3%
Euro2	Closed loop electronic control ejection +coldstart triple catalytic converter	1075	80	3%
Euro3	Optimized Closed loop electronic control ejection and catalytic converter +multi-level triple catalytic converter	1600	80	5%
Euro4	Rarefaction combustion Deoxidization catalytic converter under rarefaction condition +oxidation catalytic converter, vehicles with mixed drive	5000	90	10%

LDGT2

Standard	Technological measures	Hard ware cost $	Maintenance cost $	Improvement rate Of the economy of fuel
Euro1	Catalytic converter +exhaust gas recycling	150	80	-3%
Euro2	Closed loop electronic control ejection +triple catalytic converter	1050	80	1%
Euro3	Closed loop electronic control ejection +coldstart triple catalytic converter	1600	80	3%
Euro4	Optimized Closed loop electronic control ejection and catalytic converter +multi-level triple catalytic converter	2200	80	3%

MC

Standard	Technological measures	Hard ware cost $	Maintenance cost $	Improvement rate Of the economy of fuel
93GB	Engine maintenance	9	0	0
Taiwan2	Air ejection + oxidation catalytic converter	115	5	-1%
Taiwan3	Electronic control ejection + triple catalytic converter	300	5	3%

HDGV

Standard	Technological measures	Hard ware cost $	Maintenance cost $	Improvement rate Of the economy of fuel
Equivalent to Euro1	Oxidation catalytic converter +exhaust gas recycling	528	38	-3%
Equivalent to Euro 2	Close loop multi-spot ejection + triple catalytic converter	1352	90	3%
Equivalent to Euro 3	Optimized Closed loop electronic control ejection and catalytic converter +multi-level triple catalytic converter	2100	90	3%
Equivalent to Euro 4	Rarefaction combustion + Deoxidization catalytic converter under rarefaction condition +oxidation catalytic converter	2750	90	5%

HDDV

Standard	Technological measures	Hard ware cost $	Maintenance cost $	Improvement rate Of the economy of fuel

Euro1	Renewal engine maintenance + pressured medium cold + exhaust gas recycling	1125	95	1%
Euro2	Electric ejection + pressured medium cold + exhaust gas recycling + oxidation catalytic converter	1425	95	3%
Euro3	Electronic control high-pressure shared track + pressured medium cold + exhaust gas recycling + oxidation catalytic converter	2200	95	3%
Euro4	Electronic control high-pressure shared track + pressured medium cold + exhaust gas recycling + multi-gas valve technology + transformable gas entrance vortex + post-exhaust treatment (oxidation, CRT, SCR)	3885	100	1%

*1: At present Chinese standard for the discharge from automobiles has controlling requirement on the evaporation and the pollutant from crankcase.

*2: The estimate of the cost of motorcycles is based on the two-wheel model with the exhaust range of 100-150 ml.

In the preceding table the hardware cost is the final hardware cost during the cycle of treating pollution; the repairing cost is also the repairing cost during the cycle of treating pollution; the calculation of economic oil is based on the consumption of oil every one hundred kilometers and the yearly mileage, multiplied by the improvement percentage of economic oil and the oil prices, and converted to the dollar cost in 2000 by the use of the discount rate of 5%. For example, according to the standard scenario for LDGV, its hardware cost is 955 dollars, but if No.2 European Standard is used, its hardware cost is 1075 dollars; its repairing cost is 80 dollars; its improvement percentage keeps the same at 3%. When No.3 European Standard is used, its hardware cost is 1500 dollars; its repairing cost is 80 dollars; its improvement percentage is 5%. When No.4 European Standard is used, its hardware cost is 4500 dollars; its repairing cost is 90 dollars; its improvement percentage is 10%. When the middle scenario is used, economic benefit of oil from the first year to the sixth year is 0, for economic improvement of oil happens only from the seventh year. Based on the preceding research data and the discount rate of 5%, we can get the economic benefits of oil from the seventh year to the tenth year respectively: 14.532, 13.84, 13.181, 12.533 dollars. During the life cycle of ten years the total cost benefit economic benefit of oil in the middle scenario brings about is 54.106 dollars.

The hardware cost is divided equally by the life cycle of 20 years. The hardware cost of a scenario is based on the accumulated data from the standards of different years.

In this way we get the costs of the four parts: the hardware cost of the standard scenario, the hardware cost of a scenario, the repairing cost, the economic benefit of oil of a scenario, and the economic benefit of oil of the standard scenario. The total cost of a scenario is: the total cost of a scenario = the hardware cost of the standard scenario + the hardware cost of a scenario + the repairing cost- the economic benefit of oil of a scenario + the economic benefit of oil of the standard scenario. Take the middle scenario for LDGV for example, The total cost of the middle scenario is=1173+80-54.106-1039+0=159.894 dollars

Each vehicle type has its own cost and the three pollutants CO, HC, NO_x, share the same cost.

Several Points of Cost Calculation:

1. Because the discharge standard of motorcycles in Beijing is relatively rigid internationally, there is no design of a stricter scenario necessarily. When calculating, we can use the national standard of 1993 as the standard scenario and make the economic benefits analysis of the current standard.

2. HDGV has no counter European Standard, so we take the American discharge standard of HDGV for reference when calculating and design the calculating method similar to the European system.

7.4 Cost Benefit Analysis

7.4.1 Emission Situation Analysis under Different Control Scenarios

The calculation involves six motor models together and each model has three pollutants. Different scenarios have different influences on the discharge and treatment cost benefit of CO, HC, and NO_x, because they are different from each other in the data of pollutants.

7.4.1.1 LDGV

Table7-9 and Figure 7-1 show the emission of a LDGT2 under each control scenario.

Table 7-9 Contrast of the discharge of individual gasoline -driven car (ton)

	CO	HC	NOx
Basic Scenario	9.2453	0.8077	0.679
Mid Scenario	7.2366	0.7231	0.5618
High Scenario	5.6351	0.5916	0.4411

According to Table7-9 and Figure 7-1, it is not easy to reduce sharply the discharge of a single vehicle when the stricter No.1 European Standard is put into effect after it can meet the discharge standard. Taking into account the data of cost benefit, we can use the middle scenario to achieve the improved costs of CO, HC, and NO_x respectively: 418.903, 10827.040, and 11033.335 $/T. The improved costs of CO, HC, and NO_x achieved by the upper scenario are 738.331, 11093.306, and 11986.727$/T respectively. The control cost of

CO of the upper scenario is 40% above that of the middle scenario. The control costs of HC and NO_x of the upper scenario are higher than those of the middle scenario and both are above 10,000$/T. This shows that today it will cost a lot to reduce further the discharge pollution, for the control measures of discharge pollution are rather strict.

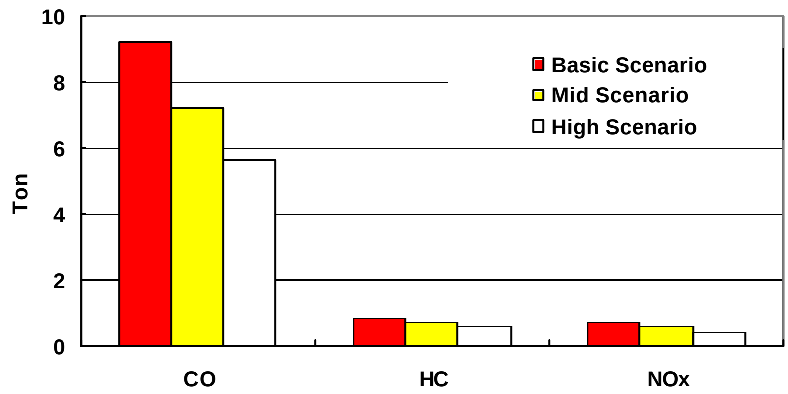


Figure 7-1 Emission Comparison of LDGV

7.4.1.2 LDGT1

Table7-10 and Figure 7-2 show the emission of a LDGT2 under each control scenario. The future results are roughly the same as those of LDGV.

Table 7-10 Contrast of the discharge of 1 individual gasoline-driven truck (ton)

	CO	HC	NOx
Basic Scenario	10.1575	1.9476	0.8119
Mid Scenario	6.3636	1.6334	0.7001
High Scenario	5.4794	1.429	0.617

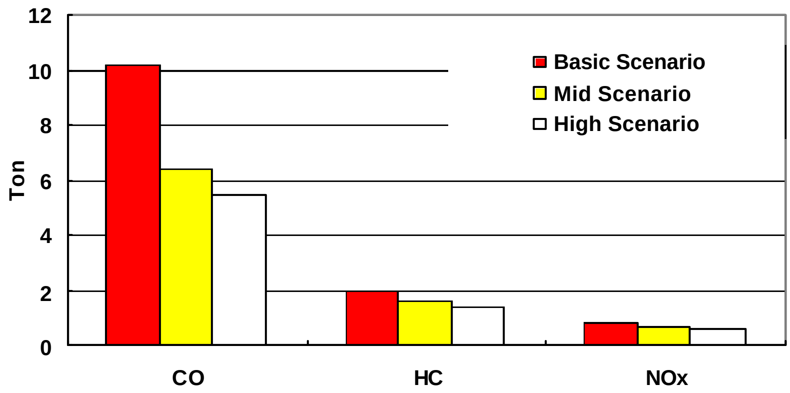


Figure 7-2 Emission Comparison of LDGT1

7.4.1.3 LDGT2

Table7-11 and Figure 7-3 show the emission of a LDGT2 under eachcontrol scenario.

Table 7-11 Contrast of the discharge of individual middle gasoline-driven vehicle (ton)

	CO	HC	NOx
Basic Scenario	11.7915	2.3611	1.1447
Mid Scenario	9.3289	2.0699	0.9636
High Scenario	7.8302	1.6756	0.8409

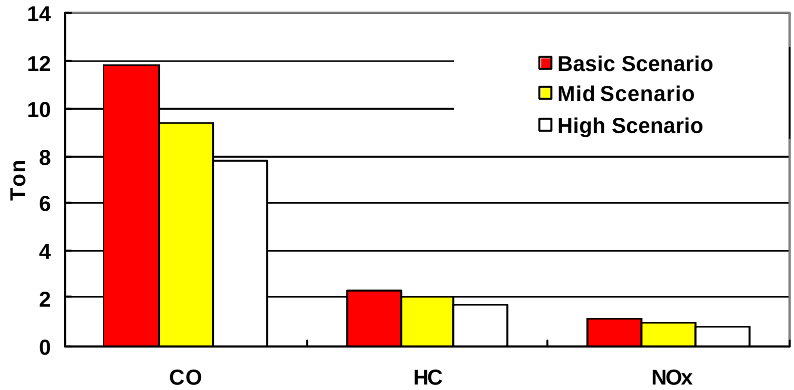


Figure 7-3 Emission Comparison of LDGT2

7.4.1.4 HDGV

Table7-12 and Figure 7-4 show the emission of a HDGV under each scenario.

Table 7-12 Contrast of the discharge of individual heavy gasoline-driven vehicle (ton)

	CO	HC	NOx
Basic Scenario	27.1027	2.8597	2.8924
Mid Scenario	22.0683	2.6394	2.3776
High Scenario	18.2067	2.221	2.0868

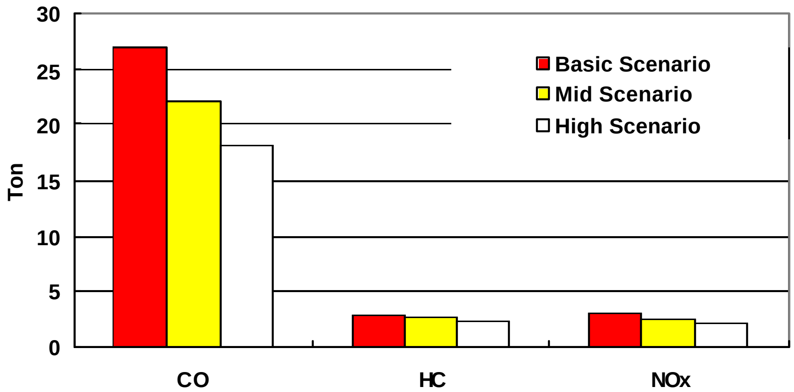


Figure 7-4 Emission Comparison of HDGV

7.4.1.5 HDDV

Table7-13 shows the discharge of a single HDDV in different scenarios.

Table 7-13 Contrast of the discharge of individual heavy diesel-driven vehicle (ton)

	CO	HC	NOx
Basic Scenario	5.5985	1.2135	6.2502
Mid Scenario	4.5107	1.0006	5.3023
High Scenario	3.9414	0.7992	4.7367

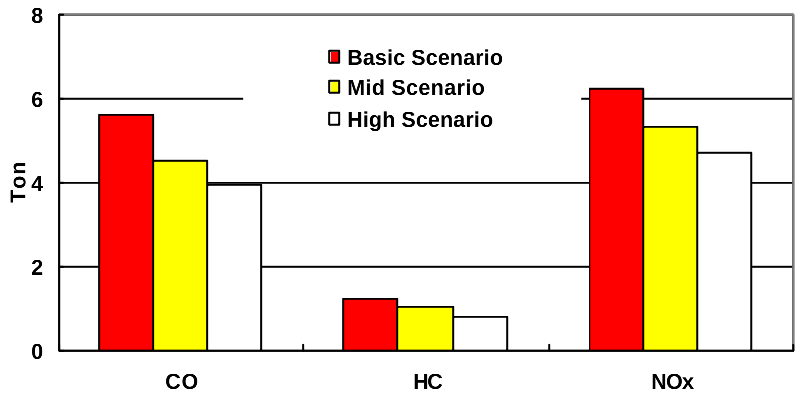


Figure 7-5 Emission Comparison of HDDV

7.4.1.6 MC

Table7-14 shows the discharge standard of motorcycles in Beijing in the standard scenario and the discharge of a single MC in the national standard of 1993. The table clearly shows that the current standard is much better than that of 1993. The discharge of three pollutants is largely reduced. The data of cost benefit shows that the work of the current standard in Beijing, that is, the standard scenario, has made the costs of the three pollutants 65.603, 145.169, and 587.270 $/T respectively. Those are much lower than the data of the other five models, so the cost benefit from the discharge control of motorcycles is the best.

Table 7-14 Contrast of the discharge of individual motorcycle (ton)

	CO	HC	NOx
Mid Scenario	11.4578	4.4403	1.2643
High Scenario	2.962	1.196	0.018

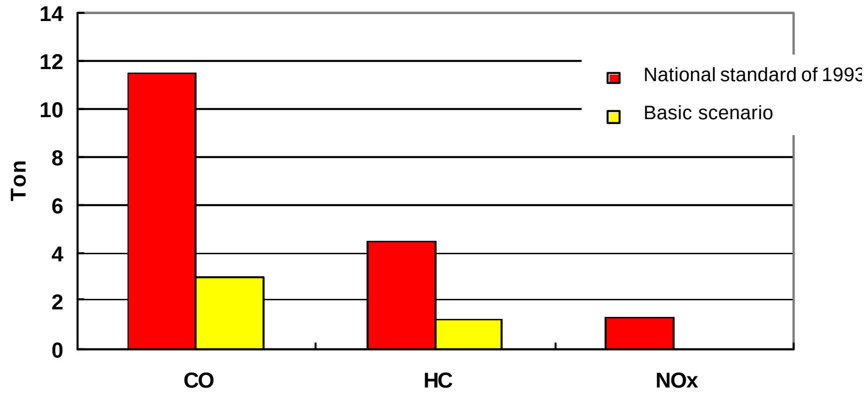


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Figure 7-6 Emission Comparison of MC

7.4.2 Comparing Cost Benefits of the Control Scenarios by Vehicle Type

Table7-13 and Table-1 show the calculating results of cost benefits of discharge pollution in the different control scenarios of motor models.

Table 7-13 Contrast of cost and benefit of under each scenario by vehicle type ($/ton)

	CO		HC		NOx	
	Mid	High	Mid	High	Mid	High
LDGV	103.777	446.917	2463.14	7465.455	1777.278	6779.488
LDGT1	73.957	410.401	893.136	3701.772	2508.832	9851.637
LDGT2	114.948	171.095	972.086	988.745	1562.852	2230.942
HDGV	152.564	100.156	3487.277	1395.047	1492.069	1106.076
HDDV	619.639	608.424	3165.259	2433.698	711.065	666.155
MC	28.456		74.517		193.987	

Table7-13 shows that if LDGV and LDGT1 which are controlled strictly by the standard scenario can follow the stricter upper scenario, its cost of the unit pollutant is higher than that of the middle scenario. This can also tell us that when the discharge standard comes a certain degree, it is more difficult to reduce further the discharge pollution and it needs more fresh money to achieve this. On contrary, HDDV and HDGV which are less controlled by the standard scenario can make their control costs of the unit discharge of the upper scenario lower than those of the middle scenario, especially those of CO and HC, so the upper scenario can bring them more cost benefits.

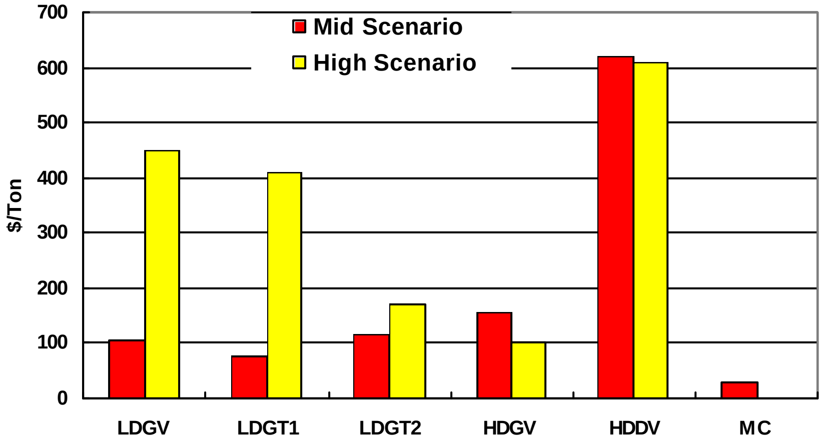

Figure7-7 Cost of CO Emission reduction under each Scenario

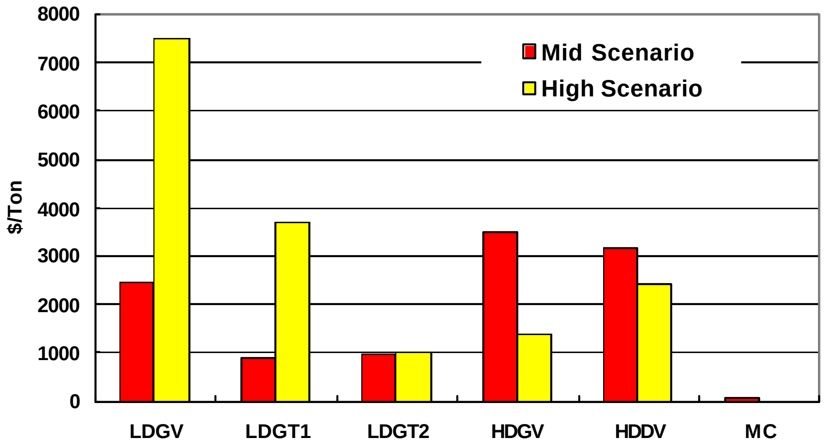

Figure7-8 Cost of HC Emission reduction under each Scenario

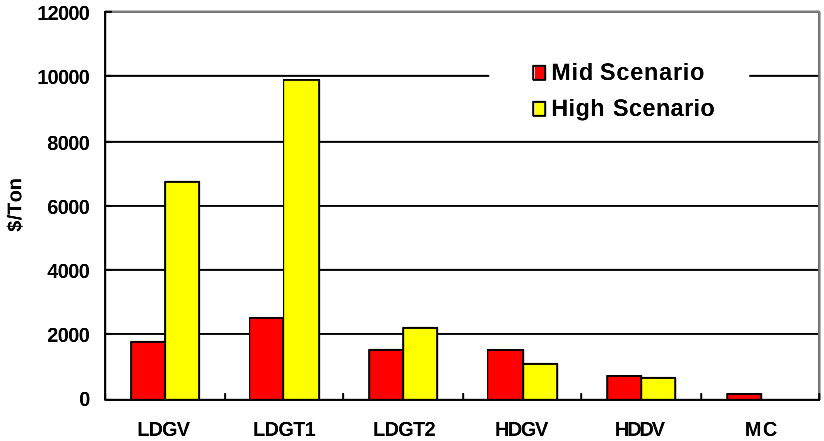

Figure7-9 Cost of NO_x Emission reduction under each Scenario

7.4.3 Analyzing the Influences of the Control Variables on the Results

Such variables can influence the results as the yearly mileage, the changing percentage of economic oil, and the discount rate.

The yearly mileage: The longer the yearly mileage is, the more discharge, which can make little difference.

The changing percentage of economic oil: The bigger the percentage is, the less time it needs to get back the hardware cost and the better cost benefit it can achieve. This also indicates that the standard of economic oil is of great importance to discharge control, so the government should make up such standards as soon as possible.

The discount rate: The bigger the discount rate is, the conversion rate of the cost is sma ller and the total cost is larger. The smaller the discount rate is, the conversion rate of the cost is bigger and the total cost is smaller.

7.4.4 Recommended cost optimal Strategy

From the preceding calculations and results, we can find the control scenarios with the best cost benefits for different motor models. Table7-14 can show this clearly.

Table 7-14 Recommended controlling scenarios for various vehicles

Models	Control Scenarios
LDGV	Mid Scenario
LDGT1	Mid Scenario
LDGT22	Mid Scenario
HDGV	High Scenario
HDDV	High Scenario
MC	Basic Scenario

7.5 Health Benefit Analysis about Vehicle Pollutant Reduction

China hasn't perfectly analyzed the health benefit of decreasing vehicle pollution yet, but the researchers have done some studies about it.

In 2000, Tsinghua University finished a program named "Loss evaluation of Air pollution in China—Case Study in Hunan Province". NO_x emitted from coal burning and vehicles is analyzed in this program. Four control scenarios are set for coal burning system. Euro I and Euro II standards are supposed to be in effect in 2001 and 2005 respectively. Researchers computed the NO_x emission amount in model year under each scenario, then analyzed the economic loss of NO_x based on the New York Study Results.The results of this study are showed as Figure 7-10.

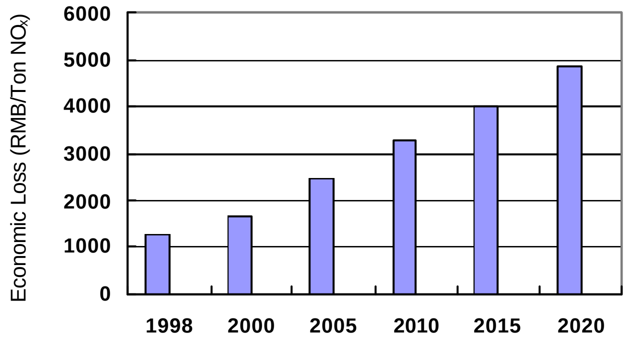

Figure 7-10 Economic Loss of NOx Emission in Hunan Province (RMB/Ton NO_x)

Beijing Medical University recently finished a program to compute the health effect and economic loss of environmental pollution in Yuzhong district in Chongqing. Researchers considered the concentration of SO_2 and TSP. Human Capital Approach(HCA) and Willingness to Pay (WTP) were used to compute the economic loss respectively. The study concluded that the economic loss due to health impair would reduce 144RMB per person (HCA) or 314RMB per person (WTP).

In Jan 2001, Clean Air Policy Center analyzed the health benefit of controlling SO_2 and $PM_{2.5}$ pollution in Shanghai. Researchers set 1995 as base year and 2020 as model year. Researchers designed two scenarios, which were Install IGCC in New Large Power and Forbid Coal used in Shanghai. This study concluded that in the model year, the health benefit is 222-1009 million dollars in the first scenario and 166-741 million dollars in the second scenario.

As the first chapter of this report said, the proportion of vehicle pollution of air pollution is increasing in large cities in China. According to B-9-3 program completed by Tsinghua University and other research institutes in 1997, the emission share of NO_x and CO emitted by vehicles were 41% and 82.5% respectively in Beijing in 1995 and 42.3% and 84.8% for Guangzhou city. In 2000, Tsinghua University analyzed the source the $PM_{2.5}$ in Beijing. The result showed that above 40% of $PM_{2.5}$ in Beijing was from vehicles.

Although the researches above are not completely for vehicle emission pollutants, with increasing share of vehicle pollutants and proportion of vehicle pollution in air pollution, we can conclude that controlling the vehicle pollution would bring in large economy benefit.

Since 1999, China SEPA, in cooperation with US EPA, has funded the program named “Reduction of air pollutant and Benefit Evaluation of Human Health in China”; since 2000, US Energy Foundation has funded the program named “Air Pollution of Main Industry and Health Effect in China”. The results of there programs need CBA described above.

Chapter 8 Barriers before China in Popularizing Cleaning Motor Vehicles and Fuels

China has stepped into a whole new period in 2000 in treating discharge pollution of motor vehicles and in developing the regulations, standards, management system, research capacity, and application of technological equipment. As The Protection Law of Atmosphere of the PRC came into effect in May 2000, people begin to pay more attention to the control practice of discharge pollution of motor vehicles and have an urgent need to protect the environment in face of the 21st century. In order to realize the sustainable development of economic construction, every Chinese involved in this career should work hard to reduce and control discharge pollution of motor vehicles effectively and strictly and achieve the general goal of controlling the atmosphere quality.

During the past years we have done a lot of work in controlling and treating discharge pollution of motor vehicle and made a lot of exciting achievements. However, when we examine the past work from a reasonable angle, we can find a lot of flaws. So we must think it over and make clear the problems and barriers.

8.1 Management System and Regulation System

8.1.1 Problems in Managing New Vehicles

Since 1999 China has learned and adopted scientific methods from foreign countries in controlling and managing motor vehicles and put in effect the managing method of discharge qualification, which is our great progress in developing management system of controlling discharge. But it is a fact that the low discharge standard results from the lack of scientific management of the Chinese motor industry, the stagnancy of technology, the separation of research institutes from manufacturing enterprises, the low transformation rate of scientific achievements, and the designing and manufacturing standards in China below the international standards. Another reason is that the slack implementation of discharge regulations and management and imperfect system of discharge control make new vehicles go into the market through some mismanaged channels and run freely to produce direct pollution without meeting the defined discharge regulations. The Protection Law of Atmosphere before revised made no clear regulations on the units' duty to control discharge pollution of motor vehicles. Without the support of laws and regulations, the environment-protecting units were not strong to administrate nationwide new vehicles and they had different management methods, so the environment-protecting units, the units of public security, communications, construction, and technological administration joined together in a messy management. This only made more difficult to control discharge pollution of motor vehicles and achieve the expected social benefits.

Since the acknowledgement system of new motor models has not been defined, there is no comprehensive, effective, and directly-connecting management system of motor products. The appraisals of new motor models still follow the old catalogue-registering system founded in the scenarioned market system; that is to follow the uniform test appraisal according to the development procedures and standards and examine mainly whether new models can meet the requirements of the designed tasks and standards. This aims to define its value of application and popularization based on the examination of scientific results and takes the designed tasks for reference, so the flaws are clear. Although some compulsory checking points have been put into practice since 1996, no comprehensive directly-connecting acknowledgement system of motor models is built. What is more, at present China has not yet built a chain of management systems for uniform check and sustainable discharge check of motor models, not to speak of motor management. Besides, the current management system of new vehicles mainly involves professional management without the administration and supervision of the environment-protecting units. And such professional management has its own limitations, because the management of new vehicles mainly examines new vehicles' common functions, safety functions, motive functions, and reliable functions and often ignore discharge functions.

There are some other problems in the catalogue register and acknowledgement management, such as unnecessary and over elaborate channels and formalities, and the prolonged time of the registering and acknowledging processes, which makes it hard for manufacturing enterprises to apply new technologies and equipment of controlling discharge. Generally speaking, in the application of technologies of controlling discharge, most motor-producing and engine-producing enterprises will be based on the profitable and long-cycle products, apply new technologies and equipment step by step according to the force of implementation of regulations, and improve nonstop their products. Such technological improvement is dynamic and developing. When a certain technology and equipment fit for reduction of discharge are developed for application and examined and appraised for a new vehicle, or they are changed to meet such requirements of regulations, market demand, and fuels, it is necessary to make them popular and beneficial in the market quickly. This is in the interests of the state and in the anticipation of the enterprises. However, the problems in the registering and acknowledging processes make the efforts for social benefits impossible to become true and this is also bad to the popularization of new technologies of controlling discharge of motor vehicles.

8.1.2 Overlapping of Current Standards

At present there coexist two regulation standards in China. GB14761-1999 and GWPB1-1999 share the same standard limitations but start to work in different times, which makes it difficult to implement the regulations. In fact, this is a problem of administration, or this is an administrator's opinion of administration by law. Both the Laws of Atmosphere, before revised and after revised, make clear definitions of the national power and duty on drafting discharge standards like this: "The units of administrating and protecting environment under the State Council can make up the national discharge standards based on the atmosphere quality standards, national economic conditions and technological conditions." This is really a clearly-defined clause. In doing this, the State Bureau of Environmental Protection is the only legal body with the participation of the other units. In this way the Law defines the duty and guarantees the exclusiveness and authority of the state standards. But in the past we did not follow the law or finish our duty responsibly and carefully. Knowing little about our power and duty, sometimes we rushed into mess action and overlapped each other and sometimes we all paid no attention to some channels. Such messy management made our efforts in vain. So we must deepen our learning and understanding of administration by law, try to perfect the system of regulations, construct the effective reasonable management system so that no mixed managing power would lead to vague duty.

8.1.3 The State's Steering Policy of Applying New Technologies

The state does not make enough policy support in adopting high-new technologies serving the technological development and value-added technologies. Especially the state does not make directly-connecting, forceful, and encouraging policies. It will need more cost to increase the quality of motor vehicles and to add equipment of controlling discharge pollution, so this value-added product must first face the problem of price after it goes into the market. Of the increased cost, a small amount is absorbed by the producing enterprise; while the most amount is finally shared by consumers, because of the increased sales price through the price adjustment strategy. But at present the current market environment has not formed fair competition mechanism and good constraint conditions, so the practice of High Price for High Quality can not work via market policies and not accepted by consumers. This constructs great barriers for new technologies to go into the market for trade. At the same time, in limiting those high-consumption and high-pollution products and technologies, the state has no compulsory policies to regulate the enterprises' business activities. This is a double-edged sword, so the government should make good research and use of it and make it an effective weapon to lead the healthy development movement of cleaning vehicles. The policy newly put forward declares that all the vehicles that meet the requirements of No.2 European Standard in advance can be reduced the consumption tax by 30% and shows that the state gives policy support to the motor industry which can work to increase the motor quality and reduce discharge pollution by applying new technologies. Such role of steering policies should be strengthened further.

8.1.4 Management System of Discharge Control of Motor Vehicles

The unsound management system of discharge control leads to imperfect control measures, low efficiency, and low quality of management, which is the direct cause of many problems and barriers. China has a very large territory with many provinces. In the transformational period of economic development, China must face the problems like the backward motor industry with more than fifty million vehicles, the aggravating discharge pollution of motor vehicles, the contradiction between the environment urgently needed to be treated and the limited economic support from the government, the public opposition owing to the lack of environmental education, and the unharmonious between the administrative units. The said problems determine that it is rather hard in China to achieve discharge control of motor vehicles, or it is a complicated and severe project. Hence it is necessary to work out a corresponding perfect system to finish such a systematic project. At present many problems of discharge control are related to the unsound system and many problems result from the management system. When we make a sum-up and analysis of the problems and barriers in popularizing cleaning vehicles and fuels in China, we can list a lot, such as, the problems of the regulation standards, the problems of the institute staff, the problems of fuel quality, the problems of acknowledging and managing new motor models, the problems of applying the technology of discharge control, the problems of losing the control of I/M management channels, the problems of converting vehicles, and the problems of infrastructure. But when we try to find the causes, we conclude that they all arise from the unsound system. When we are trying to finish the enormous systematic project of controlling and treating discharge pollution, there is no effective management system to help to put in effect many good thoughts, opinions, and measures. When some problems appear, the scenario to popularize cleaning vehicles and fuels is sure to meet barriers. However, the problem of the unsound management system is not an independent problem, because it is related to many deeper problems, such as, the supporting role of the state in legislature, the supporting force of the government in finance, the public understanding and support, the working mechanism and efficiency of the administrative units, the sound effective degree of market economy, and the stability of market order in the transformational period. These problems influence each other and are interwoven with each other, which makes it rather difficult and complicated to solve the problem of management system. It is right to say that the key to successfully realizing discharge control and popularizing cleaning vehicles and fuels in China is to make the management system a sound, enormous, and clear network to cover all the channels of discharge treatment. This job has two characteristics. One is that it needs some time and a process. The other is that in the process of building a sound and perfect management system, we should pay more attention to solving the problems and barriers arising from improving the management system rather than constructing the management system itself.

8.2 Backward Research of Technology on Discharge Control

Compared with those countries that have developed industry, China lagged behind them in researching discharge regulations, constructing the control and management systems, and developing the motor industry, especially in researching discharge control technology. So we must overcome a lot of difficulties if we want to improve our motor industry rapidly in a short time, because China just begins to touch upon the advanced technologies which lead the international direction of discharge control of internal-combustion engines. This gap resulting from different levels of development produces some constraints and barriers when China works to popularize cleaning vehicles.

The following are examples.

The development and application of the collectively-controlled electronic system of engines

The OBDII mobile defect self-analysis system which can monitor and alarm the discharge control system

The application of high-altitude combustion technology

High-efficiency changeable gas entrance, changeable phase and changeable gas valve.

The development and application of pre-positioned combustion-type fast fire catalyzing device, NOx deoxidization catalyzing device.

The development and application of the electronic control fuel ejection technology for diesel engine and the special TWC for diesel engine, as well as the granule collecting device.

The development and application of the electronic control system of LPG, CNG, LNG

The development and application of electricity-powered vehicles, mixed-powered vehicles, and high-efficiency battery

The above technologies are results of stricter discharge regulations as well as the international top motor technologies that have developed in the latest ten years. It needs a process for China to grasp these technologies and popularize them. This is a large gap between China and the developed world. At the same time, because of the low discharge control standards, the serious pollution, and the lagged treatment work, it is a hard and severe job for China to implement the requirements of treating discharge in phases and lead all motor vehicles to make three successive strides in order to meet the international discharge standards in 2001. On the one hand, there must be a lot of advanced technological equipment for quick use so as to realize discharge control of motor vehicles according to the timetable. On the other side, we must take into account our national conditions. When we try to work out the technological direction, we must think over the atmosphere quality and current technological conditions as well as the supporting capacity of financial conditions and other conditions. Now the Chinese government pays much attention to the treatment and control of atmosphere. What is more, the government values this job so much that it leaves a separate chapter for discharge control of motor vehicles in The Protection Law of Atmosphere and explains it in detail. In the past years of treating practice, the government has made a large investment in the project, but because of a lot of defects in the work and insufficient financial support for so many jobs which start simultaneously, it is a rather big barrier for us to level up the technological gap quickly within the constraint of insufficient finance.

8.3 Oil Product Quality

8.3.1 Gasoline for Automobiles

In the Clean Vehicle Action, transport fuels deserved special attention from the public. With the more and more tightened standard on vehicle exhaust discharges and with the development of discharge control technology, serving as the basic material, fuels quality became the key factor for the whole action whether it can be carried out successfully or not.

In western countries, they have proved that reducing exhaust discharges should be done through both improving vehicles performance and fuels quality. In China, because the improvement of fuels quality fell behind to the application of vehicle discharges control technology, when auto industries introduced new technology and products from developed countries, some related exhaust discharges control technologies were not practical or even cannot be introduced because of the poor quality of fuels.

In early 1990s, some auto companies had tried to dynamically introduce new technology and products from their foreign counterparts step by step according to their cooperation agreements. At that time, the auto model was (a closed loop electronic control multi-point fuel-jet triple catalytic converter). But there were only leaded gasoline, which contained higher levels of olefin, sulfur, phosphor, copper, iron, and manganese that they cannot meet the need of the machine. Therefore, our companies had to invite another foreign company to change the electronic control system into the open-loop control system, and also they had to give up the tripled catalytic converter so as to match the temporal standard on exhaust discharges. Years later, these products inevitably came up against the challenge of China's new discharge standard.

Using clean fuels is primary to reduce exhaust discharges to protect the environment. The disuse of leaded fuels indicated that China had started its way to promote the using of cleaner fuels in the future. But in order to make clean fuels come true, we should do full-scale comprehensive analyses on how to make up or add octane to unleaded gasoline, plus on what impact the change of components in gasoline will bring to vehicle exhausts. All these analyses will help to prevent from introducing other more harmful pollutants to health and the environment. It has become one of the most concerned issues in fuel industry in many other countries. In the past few years, China has just made its first step in this field. However, this issue was worth much attention.

In its standard, China has limited the amount of 9 harmful substances. But it lagged to the international level, especial the amount of lead, benzene, olefin, and sulfur can still affect air quality and have the potential to damage the engine control system to certain extent.

Table 8-1 Comparisons of Harmful Substances Standard between China and the World

Item	Unit	Target		
		II Unleaded Gas	III Unleaded Gas	Chinese Unleaded Gas
Benzene	% V/V	2.5	1.0	≤2.5
Olefin	% V/V	20	10	≤35
Arene	% V/V	40	35	≤40
Manganese	g/L	Invisible	Invisible	≤0.018
Lead	g/L	Invisible	Invisible	≤0.013
Phosphor	g/L	Invisible	Invisible	≤0.013
Sulfur	% m/m	Invisible	Invisible	≤0.08

Table 8-2 Standard for New Formula Gasoline from (CARB)

Item	Unit	Maximum	General	Average
Sulfur	ppm	80	40	30
Benzene	V %	1.2	1.0	0.8
Arene	V %	30	25	22
Olefin	V %	10	6.0	4.0
Reid Vapor Pressure (RVP)	psi	7.0	7.0	7.0

Oxygen	m%	1.8~2.7	1.8~2.2	
50% Cut Point	F	220	210	200
90% Cut Point	F	330	300	290

From 1996, all oil companies through the US produced unleaded gasoline according to the new formula standard.

Olefin can cause precipitation and also increase the discharges of some active hydrocarbons and poisonous compounds. It is thermal-labile and easy to produce colloid to form precipitation, thus can greatly affect vehicle exhaust discharges. Olefin also has high volatility, so when it goes into the open air, it will speed up the formation of ozone in troposphere and the formation of photochemical smog. In the US AUTO/OIL PROGRAM, the result showed that when olefin drops from 20% to 5%, hydrocarbon discharges will drop by 6% and nitrogen oxides discharges by 6%, and the peak value of the ozone density in the air will drop as well. In foreign countries, gasoline is a complex mixture in which catalytic reforming oil, alkylation gasoline, isomerization gasoline, MTBE and other high-octane components occupy a large scale, in most countries, their gasoline contained little olefin, for example, in the US and Japan, the olefin level was generally 13~20% (V/V). In China, because of a high level of catalytically cracked gasoline, the olefin level is relatively high. In the target for fuels, the maximum for olefin level is 35% (V/V). This kind of high-olefin-level gasoline will be a potential obstacle to the tougher vehicle exhaust discharges target in the future.

In our standard, we target that the amount of sulfur should be no more than 0.08% (m/m). The most evident damage of sulfur is to reduce catalyst activity, also to deactivate exhaust oxygen sensors. Researches had shown that to reduce the level of sulfur in fuels could drop the discharge of HC, CO, and NOX in those vehicles equipped with triple catalytic converters, and also reduce the production of some poisonous substances, such as formaldehyde, acetaldehyde and benzene and could lower the possibility of the formation of ozone. From 90s, the Auto/Petroleum Improvement Research Program (APIRP) organized extensive experiments to study what impacts the sulfur and other components could bring to vehicle exhaust discharge and air quality. The data showed that, if the level of sulfur in fuels drops from 450ppm to 50ppm, normally under general driving conditions the nitrogen oxides from exhausts could drop by 18%, NO by 19%, other harmful substances by 10%, and nitrogen oxide by 8%. In Europe, EPEFE organized the same experiment, which supported the conclusions. The experiment also indicated that, fuels with a high level of sulfur could prolong the preheating time, increase the target temperature and lower the efficiency for catalytic conversion. In addition, the application of high-attitude lean combustion technology could obviously increase thermal efficiency of gas engines and improve the discharge of CO and hydrocarbons. As a result, the discharges of heavy concentration of nitrogen oxides depended on the function of catalytic conversion equipment based on the lean combustion of NO_X. However, such equipment set a tougher requirement—less sulfur. Now in Japan, US, and Germany, the sulfur level was less than 50ppm, some even was 30ppm. In the International Fuel Standard, for gasoline Model 2, the maximum of contained sulfur was 200ppm and Model 3 was 30ppm, but now in China it was no more than 800ppm. This has already become a barrier to the Clean Vehicle Action program.

8.3.2 The Sulfur Level in Diesel Oil

Advanced diesel motors can entirely come up to the tough standard on exhaust discharges, such as Model 2 and Model 3. However, introducing newly developed diesel technologies to China was still restricted by our unqualified diesel oils. In US, Japan, and Germany, the sulfur level in diesel oils was limited to 100mg/L, while it was 5000mg/L in China. The national standard (GB252-87) set regulations for the top, first, non-defective products respectively. They were 0.2%, 0.5%, and 1.0%. In the international standard, the level of sulfur for gasoline Model 2 and Model 3 were 300ppm and 30ppm. Solutions for diesel oils were preconditions for popularizing clean diesel vehicles. But now in China, the fact was that, the qualification rate for light diesel oil was just 42%, among which catalytic cracking components occupied 40~50%. For those up-to-standard oils, they contained low cetane numbers (40~50), poor stability modes, yet high level of colloid and arene. The light diesel oil contained sulfur at such a high level of 0.1%~0.2% that it was unable to use some effective discharge control technology, such as electric control jet triple catalytic converters and particle collection technology. Therefore, it limited the popularization of high performance clean diesel engines in China.

8.3.3 Engine Oils for Vehicles

Nowadays the engine oils made in our country were far from satisfactory. The level of products lagged behind that of the application of vehicle exhaust discharges control technology. These engine oils contained too much sulfur and phosphor, especially vehicle gasoline. Using this kind of engine oils will easily damage the closed-loop electric-control-triple-catalytic converters; moreover, it will particularly affect the working life of the tripled catalytic converters. In the late 60s when European countries and the US became more and more strict in vehicle exhaust discharges control so as to protect the environment, they used Passive Crankcase Ventilation (PCV), Exhaust Gas Recycle (EGR), the triple catalytic converters and many other discharge control technologies which required the finish products of engine oils should satisfy the standard of low dust and low phosphor. Our targe t on engine oils was out of date. It merely set regulations for oils from physical and chemical properties, but it didn't mention their discharge performance, that was, the standard for pollutants discharges. What's more, the inefficient management on import oils has already caused some problems in the market: products with mixed brands and diversified qualities can really confuse customers. The market did need powerful monitoring and controlling.

8.3.4 The Oil Storage, Transport, and Sales

If the old transport equipment, which contained lead, was used in transiting unleaded gasoline, it will cause a lead super-scale though it seemed to be invisible. The exposure to lead will later make the vehicle clean system out of work. So it's very critical to solve the problems in storing and transporting gasoline in the issue of China's unleaded gasoline. To use unleaded gasoline, besides the increased investment in gasoline production, we need to add more supporting facilities in storing and selling in accordance with more and more models of products. There are 80,000 gas stations around the world, which supply varieties of gasoline. For such a large sales network, it has a lot of difficulties both financially and materially. For example, the facilities will be in great need when they will provide various brands of gasoline at the same time. To solve this problem, we need to invest a large number of money to add new devices. As thinking about these complicated questions, we had better choose those methods with low cost and easy operating and management to smooth the way of storing and transporting. At this point, we should learn from the past. In 1986, China Automobile Corporation once formally dispatched a document which asked China Petroleum to arrange the producing and supply of No.90 gasoline, and the oil company indeed produced 120 tons more than required. But because lacked of a smooth selling channel, most car owners couldn't buy No.90 in the market. So it forced The No. One Auto Company to thicken the cylinder rings of their 70,000 CA141 light trucks in order to reduce the compression ratio from 7.4 to less than 6.75 so as let the customer to use No.70 gasoline. Such changes not only destroyed the original designed performance, but also increased oil consumption. It made the economic benefits, which should have been achieved, now gone with the time, and thus caused a great waste of energy sources.

8.4 I/M System

8.4.1 Current I/M System

Currently Chinese government attaches considerable importance to the control of pollution discharge of using vehicles. Involving around the united supervision and management of environmental protection departments, the public security and traffic departments and the supervising departments of motor vehicles maintenance carry out management respectively of the annual check, reparation and maintenance of vehicles.

At the present stage the institutions engaged in the check and annual examination of motor vehicles are respectively the Safe Function Check Station of Motor Vehicles and the Comprehensive Function Check Station of Motor Vehicles, and the check of pollutant discharge is just one of the check items. The departments, which directly manage the check stations, are the public security and traffic management departments, whereas the environmental protection departments only superintend the pollutants discharge of motor vehicles.

The Inspection/Maintenance (I/M) System of Using Vehicles' Discharge Function is the major means to control the pollutants discharge of using automotive vehicles. In main cities presently, the inspection networks are comparatively sound, the route inspection and annual inspection result has been brought into the fixed assessment index of urban environmental comprehensive administration, the inspection equipment and method comply with the national requirements, and the maintenance networks have achieved certain scope and capacities. All these have provided basic conditions for pollutants discharge control of using vehicles.

8.4.2 Existing Problems in the Current I/M Management System

The I/M System means that through administrative measures, the government forces the registered motor vehicles to perform regular discharge inspection and performs maintenance for those below standard, so as to urge the users to repa ir and maintain their vehicles regularly and achieve the goal of decreasing pollutants discharge. The technical contents of the I/M System include the inspection modes, way of organization, test methods, limitation standard, covering rate, inspection and maintenance regulations, etc. Now many cities in our country have carried out some basic I/M Systems, the basic features and main problems are as follows:

The authorities of respective administrative departments are not clear and definite enough. Insufficie nt authorization has been granted to the united supervision and management of environmental protection departments and their authority and duty are not clearly defined. It's difficult for a series of motor vehicle administrative regulations and institutions formulated by the environmental protection departments to be observed. Among the individual departments, communications are insufficient, coordination and unity are poor and the management is not vigorous enough.

No qualification acknowledgement of pollutants discharge inspection is implemented for motor vehicles and no united requirements and quality insurance system are taken effect as to the data of pollutants discharge inspection. As a result it is difficult to guarantee the vigor and quality in the regulation enforcement of the inspection departments.

There is insufficient vigor and legalization in the administration and punishment of unqualified vehicles in discharging pollutants.

The technical regulations in the inspection/maintenance of using vehicles are incomplete. The discharge standard and inspection methods need perfection. For example, it needs to be perfected in the prevention of unreasonable adjusting, the decreasing of corrupt practices in enforcing the I/M system, the adoption of simple working conditions method so as to find out the actual pollutants discharge of motor vehicles more precisely, etc.

The current annual inspection system lays special importance on the safety function of motor vehicles and attaches insufficient importance to the pollutants discharge. There is no efficient quality supervision and administration system, neither is a system guaranteeing the normal reparation and maintenance of motor vehicles available.

The inspection and maintenance is poor; so is the service quality. The operation workers lack necessary technical training, and are not skillful in maintenance management. And there is a lack of data statistics.

The pollutants discharge standards of using motor vehicles are not sound. There is no control standard and inspection methods for Nitrogen oxygen; nor is there any control standard and corresponding inspection methods for particles discharged by diesel fuel driven vehicles.

The current methods adopted to control the pollutants discharge are all static ones such as the free acceleration method for diesel fuel driven vehicles and the slackening method for gasoline driven vehicles. Such a control is incomplete so that some drivers and maintenance workers, in coping with the annual inspection, make unreasonable adjusting to the slackening/ignition rate of gasoline driven vehicles and limit the position of accelerating throttle of diesel fuel driven vehicles, thus going through the test for pollutants discharge at the cost of motive power.

There is a lack of strong I/M management center to insure the implementation of administrative regulations. There are too many chiefs in the administration and communication is insufficient among them. The leading position of environmental protection departments should be ensured. Meanwhile, the function and duties of public and traffic departments should be clearly defined so as to guarantee the unity and coordination of the I/M System.

The current vehicle maintenance administration is mainly embodied in trade administration while the environmental departments generally do not participate in the administration of the maintenance and reparation of out-of-factory vehicles. Although the pollutants discharge index of motor vehicles has been regulated by traffic departments as the key item in the quality assessment of motor vehicles and engines overhauling, yet owing to the limitations of trade administration, the administration of motor vehicles' pollutants discharge is limited to formality, but not truly carried out. Therefore, it is urgent for environmental departments to solve the problem of how to make full use of the comprehensive functions inspection stations established by the Ministry of Communications so that they may coordinate with the maintenance trade in carrying out I/M scenarios for motor vehicles and in implementing the discharge inspection for motor vehicles and engines which have passed the overhauling, the second-level maintenance or the special maintenance for prevention of motor vehicles pollution.

8.5 Misunderstanding in the Reformation Effects of Using Vehicles

In the whole work of cutting down the pollutants discharge of motor vehicles, it is a very tough task to control and manage the pollutants discharge of using motor vehicles. In consideration of the peculiarities of using motor vehicles, high-directed schemes are taken in respect of the controlling and managing measures. In those typical cities where there are large quantities of automotive vehicles and where the pollution condition caused by motor vehicles are serious, large-scale reformations of part of the vehicles are enforced. Particularly, forceful reformation programs are carried out as to carburetor motor vehicles. Taking Beijing as an example, it is regulated that carburetor motor vehicles licensed after 1995 and non-close-loop electric-controlled fuel-ejection automobiles without three-effect catalysis converter should be reconstructed. The total amount of these vehicles is nearly 100 thousand. The difficulty of reconstructing them in a short period is obvious. Presently, the reconstruction work is almost completed. It is necessary to check the result of the reconstruction. So far as the overall quality of the urban atmospheric environment is concerned, the reconstruction has achieved positive results and has made a constructive contribution to the improvement of the quality of atmospheric environment. However, it should be noted that, although the reconstruction scheme that adopts the method of electricity-controlled re-inflation combined with catalysis implement is practicable, it is not the best. First, conditions of using vehicles are different, complicated and changeable and therefore unified controlling mode is not applicable. Although the mode has been meticulously scenarioned to match a pattern of vehicles, it can't have attended to all the changing factors. Second, there are many defects such as in respect of the precision of vacant ignition rate control and the adaptation to changing working conditions, etc. in the technique of carburetor electricity-controlled re-inflation since it is a transitional one in itself. Overseas it is not spread as a sound technique, but is only put into limited use. Third, owing to the urgent deadline, the reliability of the products is not seriously assessed. And because of the large amount of refitting, the maintenance stations have been confronted with considerable difficulties in the process of construction and the quality insurance has been affected to some extent. All these have rendered the technique some problems and hidden dangers. Fourth, the displaying of the electricity-controlled re-inflation technique's efficiency is based on the proper reparation and maintenance of motor vehicles. The lack of reparation and maintenance may bring malfunction or even damage to the electricity-controlled re-inflation system. Therefore, improper emphasis or dependence on the electricity-controlled re-inflation, while ignoring the reparation and maintenance, will mislead the control work of the using vehicles' pollutants discharge. Fifth, when adopting an pollutants discharge control technique, we should consider the cost of its application and assess its beneficial costs. The cost of reconstructing a single vehicle through this technique is about 2000-3000 *yuan*. The cost for 100 thousand vehicles is estimated to be over 200 million *yuan*, which only covers the expense of reconstructing part of the using vehicles in Beijing. Most of the expense is to be born by the owners of vehicles. As a result there is a strong opposition from the public to the standardization reconstruction work of using vehicles. So we believe it necessary that, as to the reconstruction of using vehicles, we should take it carefully, investigate it scientifically, analyze its beneficial costs and be sure to avoid the eagerness for quick success and instant benefit.

Part of the reconstruction work is to adopt LPG and CNG techniques to reconstruct the vehicles which have fixed routine or which transport mainly in the city proper. These vehicles mainly include public buses and taxis. Seeing from the present reconstruction, there are some misunderstandings. First there is a lack of correct understanding of the discharge functions of the LPG and CNG vehicles. Some think that LPG and CNG are clean fuel and that the vehicles using LPG and CNG are low-pollution vehicles and clean vehicles. This understanding is partial. With methane and propane as their main elements, LPG and CNG have ideal function in the discharge of CO and HC comparing with gasoline; but after burning, they may also produce some other harmful substances such as nitrogen-oxide and aldehyde. Besides, LPG and CNG were originally applied to motor vehicles as a substitute fuel when there was a shortage of fuel because of petroleum crises. The application and research of this technique was comparatively earlier and have formed into an industry, while in our country it has just been introduced and is still at an exploration stage. Particularly, we are not absolutely clear about what problems exist when transscenarioting the LPG and CNG techniques into the gasoline or diesel oil fueled vehicles, and what problems are caused by reconstruction. These questions include the change of combustion mechanism, the model of major pollutants and their poisonous effects, the mechanism and conditions of their formation, the corresponding control techniques of these effects, whether they would adapt to the proper combustion of LPG and CNG without any change to the inputting system and the combustion chamber, what technique should be adopted to make up for these defects, how to attend for safety and reliability since the whole system are installed later, etc. All these questions need to be studied. Without thorough study of these problems, we cannot produce a clear idea to direct the reconstruction work of using vehicles, which may be blind and rash. Presently, such reconstruction works are being carried out throughout the whole country. Because of the above-mentioned defects, and with the limitation of gas sources conditions and gas inputting facilities, we should first make demonstrative exploration in some cities and then sum up and spread the experiences, while avoiding a rash situation. This is a comparatively proper way.

8.6 Some misunderstandings about the diesel oil driven vehicles

Comparing with gasoline driven vehicles, the diesel oil driven vehicles have their unique advantages. First, diesel oil is more advantageous than gasoline in cost. Second, the thermal efficiency of a diesel engine is higher than a gasoline engine so that to produce the same power, the diesel engine's oil consumption is lower than that of the gasoline engine. Moreover, the diesel engine's discharge of pollutants such as CO and HC is lower than that of the gasoline engine. But it has its disadvantages. For example, the discharge of charcoal smoke and grain substances is obviously higher than that of the gasoline engine. Scientific proof should be adopted to weigh the advantages and disadvantages of diesel engines. The national conditions of China decide that public transportation should be first developed in big and middle-size cities. Bus with large capacities, high efficiency and low pollution become the prior equipment of urban public transportation. Therefore we should give a stand to the high-power, low-pollution diesel oil driven vehicles and should not enforce a ban to them and drive them out of cities. The current problem is not to ban the diesel oil driven vehicles, but to select the high-power, large-capacity, low-pollution and high-effect diesel public buses according to the overall quality requirements of atmospheric environment of individual cities and to the restriction of pollutant discharge standards.

Chapter 9 Policy Recommendation and Conclusion

At present, air quality problems in urban areas caused by the discharge of pollution from motor vehicles are the common problems remaining unresolved in the whole world. China's rapid urbanization progress and economic increase has already led to significant motor-vehicle-model air pollution in some densely populated, relatively developed cities with more motor vehicles. On the other hand, China's current average economic level is rather low. Although the automobile industry has been developed remarkably in recent years, the major key technology still depends on the partners from developed countries; therefore the overall level is still on the preliminary stage. So it is of great importance to understand how to scientifically and effectively frame the control system for the discharge of pollution from motor vehicles according to the reality in China in order to improve the air quality in urban environment and to promote the sustainable development of city transport and automobile industry.

Based on the study of the control of the pollution caused by motor vehicles in foreign countries during the past thirty years, and according to the effort, achievement and obstacles in the control of the pollution caused by motor vehicles in China in recent years, this chapter will analyze the policy in the following eight aspects: economic policy promoting the application of high-efficiency and low discharge of pollution, quality guarantee for clean oil, coordination of administrative institutions under the new " Atmosphere Law" , the implementation of the laws and regulations for the discharge from new vehicles (such as call-back), I/M system for the currently used vehicles, sustainable development policy for city transport such as encouragement of the use of environmental marks (including clean public transport), rational development policy for diesel vehicles, and the promotion of renewal and elimination of the use of currently used vehicles.

9.1 Relevant economic policy promoting the application of high-efficiency and low pollution-discharge motor vehicles

Foreign experience has proved that the adoption of economic policy in controlling the pollution discharge from motor vehicles would always achieve the most ideal effects. The major policies adopted are as follows: 1) pass tax-reduction and exemption policy to encourage automobile manufacturers to produce vehicles whose standard is higher than that of contemporary cars in the aspect of pollution discharge; 2) discharge fee (tax) shall be collected for the vehicles with high level of exhaust discharge (such as old vehicles) with the increase of the amount of discharge in order to encourage the elimination of the use of these vehicles; 3) driving fee policy shall be carried out in downtown area according to the amount of exhaust discharge.

At present, one of the major obstacles restricting the cleanliness of the automobiles in China is economic level and regional difference. This issue is most significantly reflected in the strict standard on the discharge of new vehicles. Because the strict standard leads to the increase in the cost of the vehicle, in the relatively under-developed areas in China, the increased social cost will meet obstacles from many aspects, including those from the vehicle manufacturers, because vehicles with higher prices have no market in these areas. Regional difference is also reflected in the aspects such as the quality of the oil and the level of testing and maintenance. Because of the significant regional difference, the obstacles are stronger for the universality of a unified strict standard on the discharge of exhausts. Therefore, encouragement of the use of low-discharge vehicles through economic policy proves a better solution to the problem, especially in some relatively developed cities with more vehicles and more severe air pollution.

Among the three models of economic policies implemented in foreign countries, the second model is the most effective, which is mostly adopted in Sweden and Germany. In May, 2000, China State Treasury and State Economic Scenarioning Commission promulgated the economic encouragement policy on the vehicles meeting ahead of schedule the European No. 2 standard for the discharge from vehicles with reduction and exemption in consumer taxes, and the implementation of the policy is being carried out. This act belongs to the first model of economic encouragement policy mentioned above. As to the second model of policy, although China has tried it in Hangzhou and Zhengzhou, the original collecting policy was rather simple, and was restricted by the testing method (currently only slow-speed testing is available). Therefore the charging policy corresponding to the real amount of discharge is still not truly practiced. The second model of economic policy shall be the focus for later research and implementation. The third model of policy is mainly implemented in Singapore and other places. It has been proved to be the effective method to solve the traffic jam and air pollution in downtown areas. This method can be implemented in part of some cities.

9.2 Quality guarantee policy for the fuel

Oil quality of the automobile is essential to the implementation of effective reduction of discharge, which is mainly reflected in three aspects: 1) part of the index of the oil (such as the index of Pb and S) has great influence over the discharge control system of the automobile, such as the catalyzing transfer device; 2) difference in the quality of fuel directly influences the discharge of exhausts, such as the saturated vapor pressure of gasoline; 3) quality index of the fuel will also directly influence the normal operation and oil consumption of the automobile, such as octane rating, detergent, and impurity content of the gasoline.

In the aspect of controlling the quality of oil, the most successful experience in the world is the method through adjusting taxes. For example, in the process of eliminating lead-containing oil, the universal practice is to increase the taxes for lead-containing oil, thus make its sales price higher than that of lead-free oil, therefore it is easy to promote the use of lead-free oil in the market. Similar consideration can be given to the improvement of the quality of fuel, such as the reduction of taxes for the lead-free oil with additional detergent (realized through fuel taxes), which will help the market promotion of the oil; further practice can be taken to rate the automobile fuel according to the cleanliness of the oil with different colors labeled. Different taxes shall be collected for different colors to adjust the market share of the clean fuel, which will lead to ideal result.

In addition, the implementation of the oil quality standard is vital. To be in line with the requirement on the automobile discharge, it is the basic guarantee to scientifically make oil quality standard and provide powerful implementation measures.

9.3 Coordination of administrative institutions under the new " Atmosphere Law"

Since September 2000, China has implemented the new Atmosphere Pollution Protection Law. The new Atmosphere Law has a special chapter added concerning the pollution control over motor vehicles and vessels, which emphasizes the power of the control over the discharge from motor vehicles. Since the control over the discharge from motor vehicles involves various authority departments, the coordination among these departments becomes the key item in the guarantee of effective implementation of the control over the discharge from motor vehicles control.

Considering successful experience in the world, the system with one responsible authority functioning with relevant department is the best mode. The responsible department practices the major function which is to make relevant discharge standard, policy, regulations and detailed implementation rules, and to facilitate the coordination among relevant departments so that it can be responsible for the supervision over the implementation of the relevant regulations with the cooperation from various departments. The control over the discharge from motor vehicles mainly involves environmental protection departments, traffic administrative departments, vehicle control departments and national macro economic, taxation departments. In order to coordination the function of these departments, a detailed department division implementation regulation (detailed rules) is needed to be made with cross-department legal effect to regulate the coordination among various departments. Based on this system, the responsible department shall frame more detailed and professional technological rules, and other departments shall perform their authority to cooperate with the responsible department in the implementation of these rules.

Therefore, in order to work in coordination with the implementation of the new Atmosphere Law, it is urgent to frame China's control and administrative regulations on the discharge of pollution from motor vehicles. This kind of macro regulations is essentially the detailed regulations on how to implement the Atmosphere Law, especially on how to divide and cooperate among various departments. Therefore, this kind of rules shall be promulgated by the State Council.

9.4 Implementation of the regulations on the discharge from new vehicles

Implementing compulsive discharge standard on the newly produced and registered motor vehicles is the universal practice in the world, and is proved to be the most effective method in controlling the amount of discharge from motor vehicles. Although it is a complicated technological problem to make a strict discharge standard, no complicated technological standard can achieve substantial benefit in the reduction of discharge without the powerful measures taken to implement the standard. Therefore, the essential part of the regulations for new vehicles is the implementation of the standard.

The mechanism of the implementation of the standard on the discharge from new vehicles in the world can be roughly divided into the following stages: 1) authentication of the model of discharge of the new vehicles and the examination of the manufacturing consistency, the government shall put in large amount of resources for supervision and testing; 2) tracking research of the discharge from the vehicles and warrantee scenario undertaken by the manufacturer, the manufacturer shall put in power to perform discharge testing and analysis for the vehicles sold by them to meet the durability requirement; 3) call-back system for defective vehicles, this is the effective mechanism showing the joint effort made by the government and the enterprise based on the second stage to ensure the durability index; 4) propelled by economic encouragement policy and enterprise image, the enterprise shall have the incentive to come up with new vehicles with lower discharge.

All the experiences have proved that the implementation of the system of calling back defective vehicles is the most effective implementation mechanism in the implementation of the discharge standard for new vehicles. At present, the implementation of the discharge standard for new vehicles is still on the first stage, and meets with certain difficulty and obstacle. Because of the authentication of the new model of vehicles and the production consistency testing, the government shall put in large amount of investment and coordinate unified supervision and penalty system, and this issue has not been well solved. The other reason lies in the innate contradiction in the implementation of compulsory standard, namely how to effectively reduce the social cost. Because of the significant regional difference in China, in part of the under-developed areas with fewer vehicles, the air quality is better, so it is not necessary to make the discharge standard tighter. Furthermore, the economic level in these areas is low, and it is difficult for them to withstand the price of the vehicles with advanced controlling technology, and to be adjusted to the vehicles with advanced controlling in the aspects of oil quality and maintenance technology.

However, in some cities with higher requirement on the environment, the present discharge standard for new vehicles is still not sufficient for the requirement. Since the production consistency testing cannot be fully guaranteed, it is unknown how to ensure the durability of the discharge from these vehicles. As to some cities, it is almost impossible to reinforce the testing of the production consistency, and the testing cannot prove the durability. Therefore, some cities should start to consider the implementation of the testing of the discharge research for various models of vehicles made by different manufacturers, and shift to the call-back system for defective vehicles. Only when the durability of the discharge from the vehicles is guaranteed, can the discharge of exhausts from vehicles be truly reduced, and can air quality in city environment be improved.

9.5 I/M system for currently used vehicles

International experience has proved that successful I/M system is the necessary guarantee for the implementation of the discharge standard for new vehicles, and the most economical and effective measure to reduce the discharge of pollutants from vehicles. A successful I/M system should include two elements: 1) testing technology – the latest research and practice have proved that the simple instant testing method is the best one for the testing of the discharge from automobiles; 2) management mode --- practice has proved that the method with one contractor in one area for the unified testing is the most economic and effective mode in the implementation of I/M system. The contractor must be the winner of public bidding.

At present, the first stage of reinforced I/M system has been formally implemented in Beijing, while the research of the testing technology for I/M system is being carried out in

Shanghai and Guangzhou. reinforced I/M system will be implemented in Wuxi, Jiangsu Province in March, 2001 using simple instant method to regularly test the discharge from vehicles driven by gasoline. The existing I/M system in China was basically organized in a semi-concentration mode with non-load testing. The major problems are the following: 1) non-load testing method has a low discrimination rate for the vehicles with discharge controlling system; 2) the existing discharge testing devices do not have computer data and network, therefore subjective elements impose strong influence so that the testing quality cannot be guaranteed; 3) almost all the testing fields have adjusting and repairing tasks, so the testing quality is reduced because of the obvious interest conflicts. Therefore, although most cities have I/M system at present, the actual effect is not satisfactory.

In order to improve the real effect of the implementation of I/M system, the State shall make control regulations for I/M system and specify the I/M system for different models of cities, including the operation and management mode, testing technology, covering requirement on the models of vehicles, frequency of testing, data network and the report of testing result. Meanwhile, the State shall make technological guide for different testing methods to be used for the specific testing technology in various locations. In order to improve the testing effects and reduce the testing costs, in consideration of the semi-concentration mode in most Chinese cities (testing station as well as adjusting and repairing service provider) or the mixed management mode, the newly established reinforced I/M system network shall apply the real concentrated management mode. One testing company should result from the competitive bidding and be responsible for all the operation of testing station and data network.

A well designed and managed I/M system can not only provide direct service for the discharge control of currently used vehicles, but also establish and improve local accumulated data for the local testing of the discharge from motor vehicles to provide implementation method for the economic policy of charging for discharge from motor vehicles. Therefore, the application of instant testing method will greatly improve the implementation ability of the city in controlling the discharge from motor vehicles. Simple operational I/M system applied in Beijing has not met the requirement of the real concentrated management. Compatible technology lines for instant and stable method is being researched. Together with the implementation of the first stage I/M system in Beijing, it is feasible to develop and establish more perfect management regulations and technological guide for national I/M system.

9.6 Policy of sustainable development of city transport

The international development has proved that the demand of city transport is always on the rise. The pollution discharge from city vehicles and the improvement of air quality cannot be considered away from the larger system of city transport, which is organically connected with the air quality in a inter-restriction relationship with contradiction and unification. Increase in the length of city streets alone and expand the running ability of automobile transport, but it will also bring more vehicles into operation and lead to more discharge of pollutant; on the contrary, if city transport is irrationally restricted to improve air quality, transport capacity will be damaged and social costs will be increased. Without scientific and proper systematic scenarioning for city transport and air quality and the policy of sustainable development of city transport, the increasing demand for transport will not lead to traffic jam and low efficiency, but also lead to the deterioration of city flowing air quality, even erase the effort that has been made for the improvement of air quality. Through scientific scenarioning and proper implementation, city transport and the improvement of air quality can be combined in sustainable development. In general, because the tendency of the increase of the demand for city transport will not change, the overall transport capacity of the city must be increased to meet the demand for transport. On the other hand, in order to guarantee clean and standard air quality, the air content of the city environment is certain. Therefore, the increased transport should be realized either through electric trolley transport which will not discharge pollutant or through the reduction of the discharge from individual vehicles.

Fast public transport system with high carrying ability and low discharge refers to the track transport system. In many developed countries, the fact has proved that it is the only possible way to meet the demand for transport in the area (downtown area) with high density of transport. At present severe transport deficiency and apparent transport air pollution have occurred in many Chinese cities. In order to improve the situation in these two aspects simultaneously, while increasing transport capacity, discharge of pollutant should be controlled, that is to say, it is not advisable to build more roads in downtown areas. Certainly, the public transport proper must be clean. Therefore, the first important aspect in sustainable transport policy is to build fast track public transport system and clean system for other public transport in downtown areas and other areas with high density of transport instead of building more roads to increase the transport capacity.

Although the average roads density in Chinese cities is far smaller than those in foreign cities with similar scale, the traffic jam problem is still a thorny one in any downtown area. That is to say, building roads alone cannot solve the problem of the demand for transport; instead it will increase the discharge of pollutant. Experience in Singapore and Tokyo in Japan has proved that the control policy on transport demand is very effective, i.e., economic restriction policy for road transport and restriction policy for environmental marks made according to the situation of transport and environment can effectively solve the problem of traffic jam and environmental pollution. Of course, the precondition for this policy is that the substitutable public transport system with high capacity must be built. Therefore, large cities in China should incorporate the transport control policies, such as the encouragement of the use of vehicle with environmental marks, restriction of non-environmental vehicles in their driving range and time, into the sustainable policy for transport development.

9.7 Policy for proper development of diesel vehicles

The dispute over the advantages and disadvantages of diesel vehicles is one with no definite conclusion in the world. But one thing is certain that the diesel vehicle has its own value for its existence, so the problem should be treated by dividing the advantages and disadvantages instead of by total elimination. At present, the pollution caused by diesel vehicles is concerned in some Chinese cities, especially the problem of the " black smoke" sent off the vehicles which arouses public discontent. With all these comes the policy of restriction of the development of diesel vehicles and the elimination of diesel vehicles. Because the policy is too simple, it might be exaggerated when copied by other cities. It is necessary for the State to research and promulgate a more macro and scientific policy.

In fact, the fundamental reason for this problem is the concern over the danger caused by the fine granule discharged by diesel vehicles. In order to get rid of the influence of this pollution on the public health, traffic control policy should be implemented. First, we should notice that the problem mostly occurs in the city areas with dense population, therefore the vehicles running away from these areas shall not be restricted. Second, the major issue should be the restriction of use, or more basically, the restriction of the discharge of pollution, so the registration or licensing restriction may not be effective. For example, vehicles running at night cause litter pollution and danger. In addition, it will be economic and effective to reinforce the maintenance of the vehicles and testing of the discharge, and to restrict the running of the vehicles with large amount of discharge.

Basically speaking, the discharge from diesel vehicles is a technological and scientific problem. Therefore, only through strict discharge standard can the advancement of the control technology for the discharge of diesel vehicles be promoted. In addition, the quality of the diesel oil use by the vehicles is influential on the discharge of diesel vehicles. We should notice that the technological progress in this aspect is significant, such as the commercial application of the granule collector. We have every reason to believe that with the development of technology, the problem of the discharge of granule from diesel vehicles will be solved.

9.8 Policy for encouraging updating and eliminating of in-use vehicles

In 1997, six commissions of the Chinese Central Government made clear specification for the requirement of the elimination of the use of currently used vehicles. In December 2000, they made amendment and supplement to part of the prescriptions. The policy gives prescriptions for the maximum length of use and accumulated running mileage for vehicles used for different purposes, and makes it clear that the vehicles which have not meet the standard after three repairs within the testing cycle should be canceled and forbidden for running. The amended elimination policy prolongs the normal length of usage of private cars to 15 years, without maximum length of usage of compulsory elimination.

In the process of the implementation of the elimination policy for vehicles, the first practical problem is the obstacles in economic aspect. Because of the restriction of economic level, many owners of the vehicles still hope to use the vehicles which are due to be eliminated, or transfer these vehicles to the areas with looser restrictions. Some vehicles with low frequency of usage do have a good condition, and meet all the standards although the expiry date is reached. The wholly elimination policy will surely cause some economic exhaust. If these vehicles are allowed to be used in some remote areas, they can be used for longer time. Therefore, in order to improve the implementation of the elimination policy, we should promote the renewal and elimination of the vehicles, and apply the controlling methods of increasing using charges and testing charges with the increase of usage length to achieve better result. In addition, higher additional charge for fuel can also achieve the similar result, because the consumption of oil will increase with the aging of the vehicles.

On the other hand, in some large cities with high requirement on environment, the current elimination policy is too loose. Some vehicles with poor condition and high discharge cannot be eliminated from these cities in time, so it is difficult to meet the requirement on the improvement of air quality. Of course, if we can take some traffic control measure and restrict the usage of non-environmental vehicles (such as the old vehicles with high discharge), the elimination will be better implemented. Economic policy is still the better choice, such as the increased charge for the increase of the age and discharge of the vehicles. If scientific calculation is available, expected elimination and renewal effect can be achieved. In some areas where the economic level is high and the endurance ability is strong enough, the control of the economic policy can be tougher than in other areas to shorten the average elimination limit for the vehicles. In the areas where economic level is low and there are few vehicles, the economic control policy can be loose or canceled to accept and keep the vehicles eliminated from the developed areas.

In many developed countries, different forms of economic policies are taken to encourage the elimination of vehicles. The policies can be made according to local reality to be adjusted to the regional difference in China and realize better comprehensive social effects.

9.9 Conclusion and recommendation

In the past three years, the retaining number of motor vehicles in Chinese cities is increasing at an annual rate of 10%. In most cities, the pollution is still the result of coal and smoke. In general, the air quality has been slightly improved, yet in some areas with rapid economic development, such as Beijing, Guangzhou and Shanghai, photo-chemistry smog pollution characteristic of the discharge from motor vehicles becomes more and more severe, and the ozone standard has been severely broken. These lead to the mixed air pollution with coal smoke and tail gas from motor vehicles. From 1997 to 1999, CO, NOx and TSP density in Beijing, Guangzhou and shanghai had been slightly reduced, which was the result of the implementation of strict discharge standard and the reinforcement of law enforcement together with the promotion of the installation of tail gas cleaner and the comprehensive effect of the renovation of clean fuel.

In China, the average composition of catalyzing and cracking oil is 80%. From January 1, 2000, all the gasoline manufacturers in China began to produce 90# and above 90# lead-free gasoline; from July 1, 2000, lead-containing gasoline has been canceled for use and selling. At present, the standard light diesel oil comprises 42% of the total production, with 40-50% elements of catalyzing and cracking oil. The cetane value of the standard product is low (40-50), and the safety is weak. Fragrant hydrocarbon content is higher and the sulfur content is 0.1-0.2%. The high content of sulfur affects the promotion of the use of high performance clean diesel oil with European No. 2 standard in China.

Besides the poor quality of the oil, other issues delaying the process of the cleaning of discharge from motor vehicles in China are the following: the implementation ability of the discharge standard is low; the management system is in confusion; economic policy for the promotion of the production and application of vehicles with low discharge is insufficient; the testing technology and management mode for I/M system is backward; policies for sustainable development of city transport, such as the encouragement of the use of environmental marks, is insufficient. The next step China should take is to supervise the implementation of the discharge standard over new vehicles, to establish systematic implementation ability testing the discharge, to gradually practice the system of calling back defective vehicles and to consider regional difference in the process of the implementation. In the aspect of I/M system for the currently used vehicles, relevant regulations and standard should be made as soon as possible according to different localities and the specific situation and demand in various areas. The advanced loading testing method should be universalized and the discharge gene data should be gradually accumulated. The network of discharge testing operated by professional testing company resulted from competitive public bidding should be established to improve the implementation result of the I/M system and reduce the overall social cost.

Table 9-1 indicates the controlling scenario with the most cost effects recommended for the cities with key control over pollution from motor vehicles according to the cost calculation and analyze of different controlling scenarios.

Table 9-1 Recommended controlling scenario for each vehicles type

Model of Vehicle	Controlling Scenario
LDGV	2007.1 Implementation of European No. 3 Standard
LDGT1	2007.1 Implementation of European No. 3 Standard
LDGT2	2007.1 Implementation of European No. 3 Standard
HDGV	Synchronized with the controlling scenario for HDDV
HDDV	2005.1 Implementation of European No. 3 Standard, 2010.1 Implementation of European No. 4 Standard
MC	2001.1 Implementation of Taiwan No. 2 Standard, 2004.1 Implementation of Taiwan No. 2 Standard

Other cities and areas can divide the models into several catalogs according to the specific situation, and postpone the implementation according to the above-mentioned scenario in consideration of the real demand and feasibility.

With the rapid increase in the number of motor vehicles in China, it is advisable to strengthen the long-term testing of the O_3 density and the CO, NOx density testing along the roads to provide more scientific reference for the making of proper traffic pollution control measures. In addition, we need to strengthen the study on the influence from the discharge of motor vehicles on the health of the occupational contact groups (traffic policemen, drivers, and conductors).

Appendix: Interpretation about the Cost Computation

The computation of pollutant emission is based on each control scenario and the emission factors offered by Tsinghua University. The detail method is to multiply the emission factors under each scenario with annual traveling mileage.

For example, in the Basic Scenario, cars will comply Euro I standard from 2000 to 2003, and comply Euro II from 2004 to 2020, so the emission during 2000 and 2003 is computed by multiply Euro I emission standards and annual traveling mileage, while the emission during 2004 and 2020 is computed by Euro II emission standards. The whole emission of these 20 years is gotten by adding up emission amount in each year.

Emission reduction of each scenario is acquired from comparing with the basic scenario. Because of the low emission level of the basic scenario, it's difficult to reduce emission from basic scenario. The emission reduction for the mid-scenario and high scenario is relative low, so the expenditure for realizing this emission reduction is very high.

The method of fuel economy computation is same as that of emission.

For example, in the Basic Scenario, cars will comply Euro I standard from 2000 to 2003, and comply Euro II from 2004 to 2020, so the fuel economy improvement ratio is zero between 2000 and 2003 and 5% between 2004 and 2020. So the fuel economy improvement is the multiplication of fuel economy improvement ratio, annual oil consumption and oil price per unit, then use 5% as discount rate and compute the whole fuel economy improvement by adding that of each year.

The cost data of each control technique is from present research and study. Share the cost of each control technique into 20 years of vehicle life, then the implement cost of each scenario is obtained by adding up the cost of each period.

For example, in the Basic Scenario, cars will comply Euro I standard from 2000 to 2003, and comply Euro II from 2004 to 2020, so the cost each year during 2000 and 2003 is computed by dividing the cost of reaching Euro I by 20 and multiplying the quotient by 3, for the cost each year during 2004 and 2020, divide the cost of reaching Euro II by 20 and multiply the quotient by 17. Then add up the cost of each year, get the total cost of the basic scenario.

The meaning of each item in the form:

A2: Vehicle type

B2: Pollutant type

D2: Annual traveling mileage

H2: Discharge rate

B5-B24: Model years

C5-C7: Emission factors of Euro I standard in basic scenario

C8-C24: Emission factors of Euro II standard in basic scenario

D5-D10: Emission factors of Euro I standard in mid scenario

D611-D24: Emission factors of Euro III standard in mid scenario

E5-E8: Emission factors of Euro I standard in high scenario

E9-E13: Emission factors of Euro III standard in high scenario.

E14-E24: Emission factors of Euro IV standard in high scenario.

C26、D26、E26: The sum of emission factors under basic, mid, and high scenario respectively

C27、D27、E27: The emission amount under basic, mid and high scenario respectively

D28、E28: The emission reduction under basic, mid and high scenario respectively

C32、D32、E32: The cost under basic, mid and high scenario respectively

C33、D33、E33: The maintain expenditure under basic, mid and high scenario respectively

C34、D34、E34: The fuel economy improvement under basic, mid and high scenario respectively

D36、E36: The total cost of basic, mid and high scenario respectively

D37、E37: The total benefit of basic, mid and high scenario respectively