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Road transport and urban air quality in China

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Abstract—This paper takes a comprehensive view at transportation-related air pollution problems and solution options. While the transport infrastructure in major Chinese cities is briefed, the environmental impacts of transport activities on urban air quality are discussed in detail. Not only the contribution of automotive emissions to the CO, NMHC and NO_x pollution in urban areas is reviewed, but also concerns over the carcinogenic emissions, lead deposition and noise are presented. From a life-cycle view point, the impacts of motorway construction, as well as those from scrapped cars, car batteries and old tires in China have been taken into account.

In the second part of this paper, the current technical efforts to curb vehicular emissions are evaluated. The performances of unleaded petrol, domestic catalytic converters, and fuel injection systems have been assessed. Options of cleaner alternative fuels and "green" vehicles are discussed, with both the life-cycle impacts and economic feasibility emphasized. Policy and management aspects for effective pollution control are tackled. In particular, speculations about potential economic incentives and legislative measures for vehicular pollution control are presented.

Keywords: road transport, urban air quality, vehicular emission.

1 Introduction

The Chinese government has taken the automobile industry as one of its pillar industries of China. The current percentage of automotive transportation of passengers is 45%, while that of cargo is approximately 15%. Automobile now plays a more important role in short-range transportation. The annual production of automobiles in China in 1998 is estimated to be about 1.6 million vehicles. The government plans to establish 3 – 4 big automobile manufacturing groups by the year 2010 with a total annual production of 6 million cars. There is an increasing demand of private cars, as the middle-class considers car-ownership as a symbol of social status. The development of automotive industry brings about a series of impacts on the environment, on the land-use pattern, on the already existing energy constraint, and on the economy as well. In recent years, the State Science and Technology Commission (now it is called the Ministry of Science and Technology), as well as international organizations, such as the World Bank, the United Nations Development Program, and the Japanese government, have launched research projects in China on the environmental impacts of automotive pollution in urban areas. In this paper, we make a briefing on the various aspects of automotive pollution.

2 Vehicular pollution situation in the urban areas

2.1 Vehicular population and road infrastructure

From Fig.1 and Fig.2, we can see there is a soaring increase in vehicle population in recent years (SSB, 1997; BEPB, 1998; GSB, 1997). Since 1993, China has become the world's largest manufacturer of motorcycles despite of the fact that motorcycle usage has been found to be even more harmful to air quality than cars. The automobile production ranks the 11th place in the world. Although the in-use vehicular population is still much less than that in the developed countries, the domestically made cars emit 3～5 times more air pollutants per kilometer than the European vehicles. Because the infrastructure of road systems in Chinese cities is inferior(Fig.3),

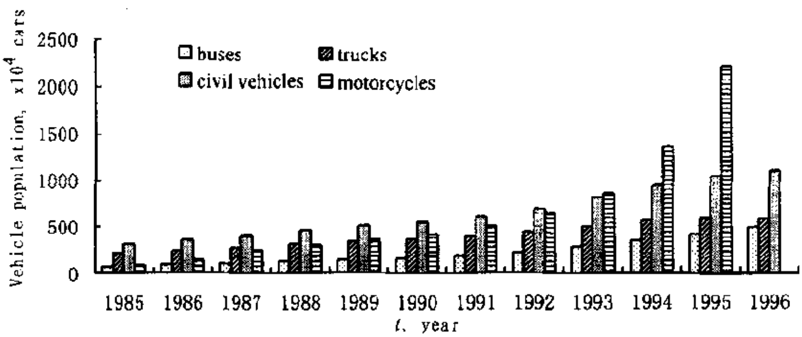

Fig.1 In-use vehicular population in China in the period of 1985—1996

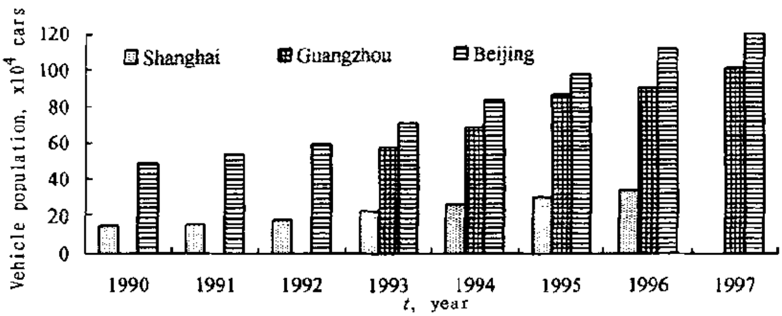

Fig.2 In-use vehicular population in municipalities in 1990—1997

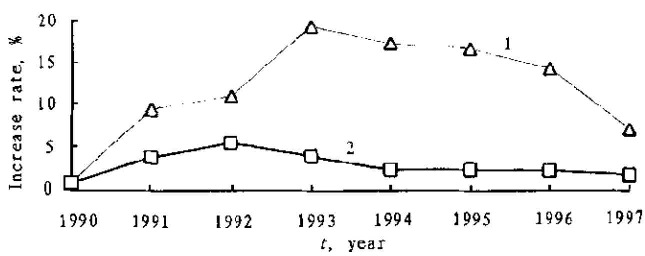

Fig.3 Increase rates of vehicles and road length in Beiing
1. increase rate, %; 2. increase rate of road length, %

the traffic flow rates in urban areas are less than that in the developed countries. For instance, the road area in Shanghai consists only of 3.6% of the total territory of Shanghai, while the road area in Tokyo is 14.1%.

2.2 Air quality in urban areas and vehicular emission modes

Recent publications on air pollutant levels in Beijing (Table 2) and on Hangzhou blood lead levels (Table 3) indicate serious impacts of automotive emissions on the environment and on human health. The frequency of incidence with urban ozone concentrations exceeding air quality standard was 40 days per year in the 1980s, and it comes into 75 days per year in the 1990s.

The contribution of automotive emissions is reviewed (He, 1996; Chen, 1997; Lu, 1998; Xu, 1998). Regarding noise pollution, 70% of the 18 cities tested had noise levels exceeding the standards 70 dB in day time, and 55 dB at night. About 30% of the in-use cars have noise levels higher than the required levels.

Table 1 A comparison of traffic characteristics between Beijing and Tokyo in 1992

	Beijing	Tokyo	China	Japan
Area, $\times 10^3 km^2$	16.1	2.77	9600	377.8
Population in 1992, million	10.32	11.94	1166	124.8
Road length, $\times 10^3$ km	12.4	22.69	1075	1150
Highway, km	–	–	1145	5600
Vehicles, $\times 10^6$ cars	0.666	6.38	20.0	79.0
Traffic signals	397	12540	~7000	135634
Traffic control centers	1	1	6	161
No. of crossroads	209	6300	350	43019
Traffic labels	28180	382780	309980	10550000
Traffic labels per km	2.5	16.9	0.3	9.5
Crossings	3230	67000	33500	801464
Flyovers	100	1000	–	

Table 2 Hourly average levels of major air pollutants during winter months of 1997 on Beijing crossroads with traffic congestion (Wei, 1998)

Air pollutant level	CO, mg/m^3	SO_2, mg/m^3	NO_2, mg/m^3	HC, mg/m^3	BaP, g/m^3	Pb, g/m^3
Hourly average level	52.8	1.35	4.40	1.00	6.3	23.0
Chinese 2nd-level air	hourly	hourly	hourly	–	daily	annual
Quality standard	10.00	0.5	0.12		0.01	1.00

Table 3 Sub-clinical lead poisoning among children in Hangzhou (Hong, 1998)

Age, year	Male				Female			
	Samples	Average blood Pb level ± SD	Incidents exceeding standard level	Exceeding standard, %	Samples	Average blood Pb level ± SD	Incidents exceeding standard level	Exceeding standard, %
1—2	50	8.12 ± 2.99	13	26.0	48	8.24 ± 3.09	12	25.0
2—3	86	7.84 ± 3.31	18	20.9	61	7.70 ± 3.68	14	23.0
3—4	150	8.40 ± 5.09	47	31.3	113	7.96 ± 4.89	35	30.6
4—5	46	7.30 ± 4.97	13	28.7	46	8.76 ± 5.07	15	32.6
5—6	17	8.14 ± 3.04	3	17.6	12	9.28 ± 3.56	6	50.0

2.3 Life-cycle monitoring

There is a problem of delayed retirement of old cars in China. Those cars retired from the metropolitan cities, rather than being demolished, are sold to small inland cities and are used again for a long period of time. This delayed retirement of obsolete cars worsens the air pollution problem in urban areas. The recycling of scrapped cars, car batteries and tires is an urgent matter in China.

3 Technical efforts to curb automotive emissions

3.1 Unleaded petrol

Leaded petrol has been banned since 1997/1998 in some major cities, such as Beijing, Shanghai, Guangzhou, Nanjing, Suzhou and Urumqi. This provides a prerequisite for installation of catalytic converters. A tax on leaded petrol has been imposed, so that the price of leaded petrol is higher than unleaded. It serves as an economic incentive for banning leaded petrol.

3.2 Electronic fuel injection system required for new cars

A total amount of capital investment of 2.6 billion RMB Yuan has been allocated by the State Council for manufacturing electronic fuel injection systems in China. This lays a sound foundation for curtailing gasoline engine emissions, and it is also the prerequisite for satisfactory performance of catalytic converters.

3.3 Catalytic converter development

The State Science and Technology Commission (now the Ministry of Science and Technology) and the Ford Foundation supported projects on the development of three-way catalytic converters. In China, three-way catalysts are being developed with less amount of noble metals (usually less than 0.6 g per liter of honeycomb) and with rare-earth metal promoters. The performance of a typical catalyst with Zr, La and Ce promoters is shown in Table 4 and Fig.4. The tests were performed by the Automotive Catalyst Division, Degussa Ltd. in Oct. 1997. The catalyst KS-2 developed by RCEES (Research Centre for Eco-Environmental Sciences) showed good three-way performance, except that the CO conversion after aging is slightly lower than the Degussa catalyst.

Table 4 Light-off temperature of fresh and aged catalysts

Catalyst	50% conversion			90% conversion			Max. conversion		
	CO	HC	NO_x	CO	HC	NO_x	CO	HC	NO_x
KS-2, fresh	317	297	313	n. m.	307	333	82	98	99
RCEES aged	314	300	320	n. m.	308	n. m.	87	99	86
MLKV102-2, fresh	200	200	206	215	215	253	100	100	100
Degussa aged	304	296	296	324	304	316	93	100	100

The price of a typical catalytic converter with rare-earth metal promoters is about 800 RMB Yuan, that is lower than the prices of imported converters.

4 Cleaner alternative fuels and "green" cars

In some big cities, such as Beijing, Shanghai, Chongqing and Harbin, fleets of 300—5000 buses have been converted to be fueled by natural gas or LPG. In Shanxi Province, a fleet of 15 long-distance buses runs on methanol fuel.

The Ministry of Science and Technology, as well as the UNDP, supported demonstration projects on fuel-cell vehicles. It is expected that fuel-cell buses will be demonstrated in 2000.

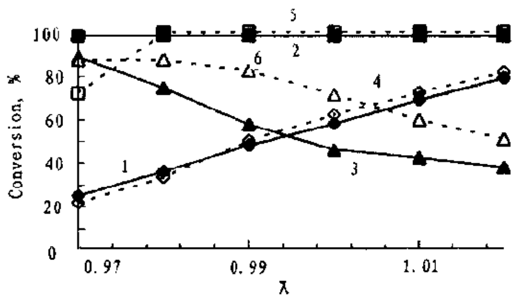

Fig.4 Three-way performance of aged catalyst (1) and catalyst (2)
Catalyst (1): KS-2 provided by RCEES; catalyst (2): MLKV102-2 provided by Degussa. Aged conditions: 960C, 16 h, 10% water vapour
1. CO(1); 2. HC(1); 3. NO_x(1); 4. CO(2); 5. HC(2); 6. NO_x(2)

5 Management aspects of vehicular pollution control

In June 1998, the State Bureau for Mechanical Industry promulgated the idling speed emission data of major automotive models manufactured in China, which can be released to the market without further testing and inspection. Obviously, there is no strict testing and inspection management system in China. Experts complained that not all new cars released by these recognized manufacturers meet the flexible idling speed requirements. Especially for NMHC, it is well known, that too high a level of hydrocarbons in the exhausts would bring about an overload to the catalytic converters. Consequently, the excess heat liberated during catalytic combustion would reduce the life-span and catalytic activities of the converters. Furthermore, there is even no NO_x requirement. Hence, there is no countermeasure to curtail nitrogen oxides emissions. Such jurisdictional contradiction that some models of new cars exceeding the current national emission standards are allowed to enter the market, is a good example of lack of inter-agency coordination.

No consistent policies have been worked out in terms of traffic pollution, traffic congestion and parking issues. For instance, the Shanghai municipal government does not encourage private cars and restricts the issuing of driving licenses to private car-owners, because the current road system in Shanghai is incapable of withstanding the impact of a fast-growing vehicle population. However, the municipal governments of some nearby cities issue driving licenses to Shanghai residents. So there is no effective coordination among the governmental organizations.

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