Analysis on the Influence of Atmospheric Pollution Caused by Increasing Automobile in Shanghai

Jianxing Ren^{*1}, Weijun Gao², Haifeng Li³, Jian Wang⁴, Penglin Zhao⁵ and Toshio Ojima⁶

¹Professor, Department of Power Engineering, Shanghai Institute of Electric Power, P. R. China

²Associate Professor, Faculty of Environment Engineering, The University of Kitakyushu, Japan

³Research Associate, Department of Architecture, Waseda University, Japan

⁴Senior Engineer, The Architectural Design & Research Institute of Tongji University, P. R. China

⁵Chief Engineer, Shenzhen Municipal Planning & Land Bureau, P. R. China

⁶Professor, Department of Architecture, Waseda University, Japan

Abstract

This article mainly studies the influence between the increase of automobiles and air pollution in Shanghai, and analyzes the relationship between the increase of automobiles and the national economy development and tries to find out a solution to mitigate the influence of the increase of automobiles on air pollution. The increase of automobiles is linear to the increase of the GDP, and it does not have direct relation with the increase of population. The pollution caused by automobiles is getting more and more serious in the urban area in Shanghai, and automobiles have become the main factor causing the urban air pollution. There are some important measures to reduce the pollution of the environment such as to meliorate traffic, limit the increase of automobiles, develop a public traffic and increase green area.

Keywords: Shanghai; automobiles; atmospheric pollution

1. Introduction

As we all know, the main pollutant in a city the carbon monoxide CO, the sulfured and oxide SO_x, the nitride and oxide NO_x, the total suspend particle TSP and NMHC (Non-Methane Hydrocarbon), etc. These pollutant results from the combustion of fossil fuels, thus affects the environment, for example, the exhaust of automobiles, the combustion of coals in the factory workshops and so on. For a modern city, the pollution of the waste gases discharged by automobiles is even more serious.

In the recent several years, the amount of automobiles increases rapidly with the increasing needs of traffic. The waste gases discharged by a large number of automobiles have been one of the most important factors that cause the air pollution around the main roads in downtown Shanghai. The pollution sources can be divided into two kinds, immobile pollution sources and mobile pollution sources. As automobiles move along the city road networks in all directions, it is considered

as a typical mobile pollution source. With the rapidly increasing use of automobiles and the dissemination of the private automobiles and so on a great deal of nitride and oxide NO_x, NMHC, etc, will certainly be produced. If no effective measures are adopted, the air pollution will be even more serious in Shanghai.

This article mainly studies the influence between the increase of automobiles and air pollution in Shanghai, and analyzes the relationship between the increase of automobiles and the national economy development and tries to find out a solution to the influence of the increase of automobiles on air pollution.

2. Situation of Automobiles Development in Shanghai

Shanghai is a city with extremely concentrated population. Its total area is 6340.5 km², in which the urban area is 2057 km² and the suburb is 4282 km². Besides extremely concentrated population, the economic development in Shanghai is in the lead in China and it is the economic center of China. In the five years from 1991 to 1995, the GDP of national economy has increased 13 per cent averagely in Shanghai. The GDP reached 368.8 billion RMB and accordingly the population reached 13.07 million in 1998, including 9.65 million urban population. The average population density is over 2000 per km², and the urban average population density is more than 4600 per km² ¹⁾.

In the process of the economy development and

*Contact Author: Jianxing Ren, Professor, Shanghai Institute of Electric Power, No.2103 Pingliang Road, Shanghai 200090 P.R.China

Tel: +86-21-6543-0410 Fax: +86-21-6543-0410

e-mail: ren66@citiz.net

(Received May 7, 2002 ; accepted March 5, 2003)

Fig.1. Changes of the Amount of Automobiles in Shanghai

Fig.3. The Road Length per Person and per Automobile

Fig.2. The Relationship between the Amount of Automobiles and the GDP, the Population, and the Road Length

urbanization, the amount of automobiles increases every year in Shanghai as shown in figure 1. The relationship between the amount of automobiles, GDP and the population is shown in figure 2.

As shown in the figures, the amount of automobiles has entered a rapid increase period since late 1980s. It reaches about 0.21 million in 1990, about 0.32 million in 1993 and about 0.45 million in 1996 and about 0.61 million in 2000. The GDP increases about 5.3 times, correspondingly the amount of automobiles rise by about 2.9 times ⁽²⁾ from 1990 to 2000. This shows that the amount of automobiles has close relationship with the rapid increase of the GDP. However, the population increases merely about 200 thousand by 1.2 percent. A thousand people own about 41 mobiles in 2000. Therefore, according to the dynamic relationship between the amount of automobiles and the GDP, we may predict the amount of automobiles going with the increase of the GDP after several years. For example, suppose the GDP increases at 8% percent, the amount of automobiles will reach about 1 million in 2005, and about 1.6 million.

On the other hand, the speed of road construction is very fast in Shanghai. The road length is about 1,700 km in 1990 and it reached about 6,800 km in 2000. Nevertheless, with the rapid increase of the amount of

automobiles, the road length each automobile occupied has been continuously decreasing for two periods, 1990-1992 and 1994-1996. That is to say the speed of road construction is lower than that of the increase of the amount of automobiles in those period. As is shown in figure 3, the road length each automobile occupied has been coming down from 1990 and it reaches the bottom 6 m per automobile in 1992. In the same year, because the speed of road construction accelerates, the road length each automobile occupied increases 9 m per automobile in 1993. After 1993, as the speed of road construction is lower than that of the increase of automobiles, the road length each automobile occupied decreases again. Due to the constraint of the speed of road construction, it certainly will result in traffic jam with the increase of the amount of automobiles. Especially in the center of the city where automobiles move slowly and traffic jam comes forth frequently. After 1996, due to construction rush of highway, a network of road has nearly been completed. The road length has been increased dramatically. The road length each automobile occupied reached at about 11 m per automobile in 2000. The road length per capita has continued to increase with the year.

3. Influence of the Increase of Automobiles on the Environment Pollution

3.1 Gasoline consumption in Shanghai

As the economy develops rapidly and automobiles increase dramatically in Shanghai, air pollution caused by automobiles has been more and more serious, which results from the huge consumption of gasoline. The relationship between the amount of automobiles and the consumption of gasoline a year from 1980 to 1996 is indicated in figure 4. As shown in figure 4, with the amount of automobiles increasing in Shanghai, the consumption of gasoline grew by linearity. It was investigated that the consumption of gasoline came up to 1,000 thousand tons in 1997. Suppose the constitution of automobiles fuel and the consumption index approximately do not change, according to the linear relationship between the amount of automobiles and the

consumption of gasoline in figure 4, we may predict that the consumption of gasoline will exceed 2.2 million tons when the amount of automobiles break through 1 million.

3.2 Amount of the Pollutant Discharged by Automobiles

The mobile pollution sources in air pollution sources mainly come from automobiles. Generally, the pollutant directly discharged by automobiles is mainly CO, NMHC and NO_x etc. Among those, NO_x is badly harmful for human body. Figure 5 showed the yearly change of the pollutant directly discharged by automobiles. In 1990, the discharge of CO₂ from automobiles is about 117 ten thousands. But in 1996, the discharge of CO₂ from automobiles is about 268 ten thousands, about 1.3 times increase. From 1990 to 1998, the discharge increase about 3 times for CO, 4.5 times for NO_x, 3.5 times for NMHC.

Table 1 indicates the ratio of the pollutant discharged by automobiles to that discharged in the whole city in a year in Shanghai.

After 1989, the ratio of the pollutant CO, Nox and HC discharged by automobiles to that discharged in the whole city has increased evidently. In 1995, comparing to the pollutant discharged in the whole city, the ratio of NMHC is about 93 per cent, that of NO_x is about 44 per cent, and that of CO is about 76 per cent. This shows that the environmental pollution caused by automobiles as a mobile pollution source is greatly serious.

On the other hand, the ratio of the pollutant discharged by automobiles as a mobile pollution source to that discharged by factories as a immobile pollution source shows as table 2.

As the fact of the pollutant discharged in the city, since the 1990s, the pollutant discharged by automobiles has been increasing continuously with the amount of automobiles and gasoline consumption coming up. According to the statistic of the pollutant discharged by the mobile pollution source and the immobile pollution source in the city in 1998, the amount of pollution has been increased hugely. Comparing to the pollutant discharged in the whole city, the percentage has been increased to about 56% for NO_x, 85% for CO, and 96% for NMHC. This shows that the main factor affecting the air environment in Shanghai is automobiles. Consequently, in the recent years, in order to improve the air environment in Shanghai, the government regulates the function and the structure of the city continuously, and transplants the factories reasonably with plans, thus reduces the pollutant discharged by the immobile pollution sources.

According to the kind of automobiles, the amount of the pollutant discharged by automobiles changes also. The amount of the pollutant discharged by different kinds of automobiles changes as showed in table 3.

As is shown in table 3, the ratio of the

Fig.4. The Relationship of the Amount of Automobiles and the Yearly Consumption of Gasoline

Fig.5. The Amount of the Pollutant Discharged by Automobiles

Table 1. The Ratio of the Pollutant Discharged by Automobiles to that Discharged in the Whole City

Year	CO	NOx	NMHC
1989	46%	4.60%	-
1994	37%	15%	85%
1995	76%	44%	93%
1996	85%	56%	96%

Table 2. The Amount of the Pollutant Discharged by the Mobile Pollution Source and the Pollutant Discharged by the Immobile Pollution Source in 1995 and 1998 in the City of Shanghai.

Pollutant	Mobile pollution source		Immobile pollution source	
	Amount (ten thousands ton per year)	Ratio %	Amount (ten thousands ton per year)	Ratio %
1995				
NOx	3.04	44	3.86	56
CO	10.4	76	3.2	24
NMHC	2.41	93	0.18	7
1998				
NOx	8.15	56	6.4	44
CO	38	85	6.7	15
NMHC	10	96	0.28	4

pollutant discharged by Large-scale automobiles, Light-scale automobiles and Motorcycles is different. Large-scale automobiles like truck, bus in 1995 discharge much more pollutant and share a ratio about 74% for NO_x, 37% for CO, and 53% for NMHC. With the increase of private cars (small scale automobiles), discharge form automobiles in 1998 showed a large ratio in the whole pollution discharge of automobiles. The ratio of discharge from large-scale automobiles decreased from 74% to 23.5% for NO_x, from 53% to 37.2% for NMHC. The pollutant discharged by the other kinds of automobiles is very little. Large-scale automobiles and Light-scale automobiles are the main source resulting in air pollution.

Moreover, the other factor affecting the air environment is traffic jam, which is especially obvious in the center of the city. Due to the traffic jam, the deceleration, the acceleration and the frequency and time of invalid work all increase, which results in the incomplete combustion of fuels and the increase of the pollutant. It is demonstrated according to related researches³⁾ that the slower automobiles move, the more pollutant discharged by them. As shown in figure 6, the speed of automobiles is close related to the pollutant discharged. In a certain range of the speed, the higher the speed is, the less the pollutant is discharged. When it's a traffic jam, the average speed of automobiles is very low, and the sudden pause and the instantaneous acceleration both are too frequent. Thus, it's very difficult for complete combustion of fuels, then the discharged pollutant increases evidently. Especially when the average speed of automobiles is lower than 12 km/h, the discharged pollutant increases rapidly. In middle 1990s, the average speed of automobiles is very low in the center of the city in Shanghai. This situation is shown in figure 7. We took the traveling time as 100%. The figure shows what percentage it is that automobiles run at some speed range. As the figure is shown, the ratio of time at a speed range with lower 10km/h is about 57% in whole traveling time. According to survey, the ratio of time of the invalid working is about 32%. In the whole running process, the ratio of time to accelerate is about 27%, that to decelerate is 24%, and that in a low speed is about 13.8%. Hence, it can be predicted that air pollution is quite serious in the cross and the main roads in Shanghai. The investigation showed that in the cross, the average concentration of NMHC reaches 0.66 mg/m³, which is 3.1 times than the standard of the environment quality in Shanghai. The average concentration of CO reaches 6.54mg/m³, which is 1.1 times than the standard. And the average concentration of NO_x reaches 0.37 mg/m³, which is 1.5 times than the

Table 3. The Amount of the Pollutant Discharged by the Main Kinds of Automobiles in 1995 and 1998

Kinds	CO		NO _x		NMHC	
	Amount	Ratio (%)	Amount	Ratio (%)	Amount	Ratio (%)
(ten thousands ton per year)						
1995						
Large-scale automobiles	8	37	4.47	74	3.3	53
Small Scale automobiles	9.68	45	1.57	26	1.72	28
Motorcycles	2.16	10	-	-	0.94	15
Other	1.73	8	-	-	0.28	4
Total	21.57	100	6.04	100	6.24	100
1998						
Large-scale automobiles	22.8	41.4	1.46	23.5	3.38	37.2
Small Scale automobiles	24.27	38.9	4.66	75.2	4.1	45.2
Motorcycles	9.28	15.8	0.06	0.97	1.29	14.2
Other	2.25	3.9	0.02	0.33	0.31	3.4
Total	58.6	100	6.2	100	9.08	100

Fig. 6. The Relationship between the Average Speed of Automobiles and the Pollutant Discharged by Them

standard. Therefore, the influence to the air environment of automobiles is greatly serious⁴⁾.

3.3 Situation of the Environment Quality in Shanghai

The change of the concentration of the air pollutants between urban and suburban in Shanghai is shown in table 4⁵⁾⁶⁾ due to the influence of the pollutant discharged by the mobile pollution sources, such as automobiles, and by the immobile pollution sources, such as factories.

The situation of air pollutions in Shanghai is getting better. The concentration of TSP and SO_x is decreasing considerably and continuously. But it's quite different between the concentration of the pollutant in the urban and that in the suburban, and the latter is lower evidently than the former. The main factor and measure to cause this changing trend lie in:

1) In order to improve the air environment, the government regulates the function of the city and the

industrial structure in time. Concerning the immobile pollution sources such as chemical factories, the government adopts some measures to close, transform, and change them. Simultaneously, the government encourages the enterprises raise the proportion of the decontaminated waste gases. In 1998, the proportion of the decontaminated waste gases reaches 89.1%. Hence, the decrease of the pollutant discharged by the immobile pollution sources in the urban area causes the decrease of the concentration of the pollutant in the air environment, and improves the environment quality.

2) Encourage using town gas in the residential area other than using coal fuels. The rate of propagation of town gas now reaches at 100%. As a result, the discharged pollutant evidently decreased.

3) Because plants are able to absorb the pollutant, the government increases the public greening area to improve the situation of air pollution. As shown in figure 8, it's reported that the degree the greening area covers in Shanghai has reaches 18.8% in 1998 from 13.9% in 1991, and the average public greening area reaches 2.75 m²/person.

4) With the high-speed development of industry, economy and the improvement of the life style, the amount of automobiles will increase considerably. How to reduce air pollution caused by automobiles has been one of the most important tasks to research about the protection of the environment in Shanghai. There are several countermeasure to reduce the pollutant discharged by automobiles as follow:

(1) Substitute the automobiles by using natural gas for taxis and the ones using derv.

(2)Meliorate the traffic to increase the speed of automobiles.

(3)Encourage the development of public traffic, including subway, and limit the amount of automobiles.

(4) Compulsorily discard the automobiles, which discharge pollutant largely, and forbid them driving in the urban area.

(5) Analyze the situation of the traffic in Shanghai,

Fig. 7. The Relationship between Traveling Time and Traveling Speed

Fig. 8. The Increase of Green Area in Shanghai

and have a good plan for transportation development.

4. Conclusion

The environment pollution in the city will affect the civic health directly. According to the analysis and research on the increase of the amount of automobiles and its influence on the air environment, we found the dynamic relationship between the amount of automobiles

Table 4. The Concentration of Different Pollutant in Air and the Proportion of the Decontaminated Waste Gas (mg/m³)

Year	NOx		TSP		SOx		proportion of the decontaminated waste gas (per cent)	
	Urban	Suburban	Urban	Suburban	Urban	Suburban	The waste gas of fuels combustion	The waste gas from industry
2000	0.063	0.035	0.1	-	0.043	0.017	-	-
1999	0.099	0.033	0.168	0.152	0.044	0.005	-	-
1998	0.1	0.029	0.215	0.147	0.053	0.006	53.7	35.4
1997	0.105	0.028	0.233	0.167	0.068	0.008	51.2	38
1996	0.089	0.024	0.241	0.203	0.059	0.01	-	-
1995	0.073	-	0.246	0.175	0.053	0.012	52	37.4
1994	-	-	0.281	0.17	0.073	0.01	48.7	37.1
1991	-	-	0.33	0.17	0.11	0.01	45.6	42.3

and the GDP. The increase of automobiles is linear to the increase of the GDP, and it does not have direct relation with the increase of population. The pollution caused by automobiles is getting more and more serious in the urban area in Shanghai, and automobiles have become the main factor causing the urban air pollution. There are some important measures to reduce the pollution of the environment such as to meliorate traffic, limit the increase of automobiles, develop public traffic and increase the green area in a city.

Acknowledgments

This research is supported by Mitsubishi Foundation (Reprehensive Weijun Gao with research project “Monitoring and Modeling of the Effects of Asia Metropolitan Cities on the Global Environment”).

References

- 1) Shanghai statistics bureau (1997) The Shanghai statistics yearbook 97, China statistics press
- 2) Shuyu Lu (1999) ‘The Pollution of Automobiles in Shanghai and the Countermeasure,’ *Science of the Environment in Shanghai*, Vol. 18, No.12
- 3) Hayakawa (1997) Air Pollution and City Environment Situation and the Countermeasure, Japan Broadcast Press
- 4) Zhiwei Le (1997) ‘Distribution of NO_x in Shanghai and Its influence Factors,’ *Science of the Environment in Shanghai*, Vol. 16, No.6
- 5) Shanghai environment protection bureau (1999) Shanghai Environment Bulletin
- 6) Shanghai environment protection composition committee (1998) Environment Protection in Shanghai, Shanghai Social Science Institute Press
- 7) Changjian Chen (1997) ‘Study on the Pollution Control of Vehicle Exhaust in Shanghai,’ *Shanghai Automobile*, Vol. 6
- 8) Qingyan Fu et al. (2001) ‘The status quo and share responsibility rate of NO_x pollution in Shanghai,’ *Shanghai Environmental Sciences*, Vol.20, No.5