10 AIR POLLUTION CONTROL STRATEGIES FOR TAIPEI CITY

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INTRODUCTION

In accordance with Executive Yuan’s National Environmental Protection Project, Taipei Municipal Government has been improving urban air quality in the city. After undertaking air quality surveys and providing guidance for, and inspection of, air pollution sources, a reduction in the concentration of urban air pollutants has been achieved. These pollutants include particulate matter (PM$_{10}$), sulphur dioxide (SO$_2$), nitrogen dioxide (NO$_2$), carbon monoxide (CO) and lead (Pb).

This paper provides an overview of air pollution control strategies in Taipei city and examines the issues of air quality analysis, emission profile, control measures for greenhouse gases and mobile sources. The paper concludes by discussing the effects of implementing an air pollution reduction strategy.

TAIPEI CITY

Located in northern Taiwan, Taipei has a thriving arts and academic centre and countless modern commercial buildings. With its vibrant cultural and economic growth, it has become a modern international metropolis. Taipei is nestled in a basin with mountains on all sides and covers an area of 27,180 hectares (271.8 km$^2$) accounting for 0.76 per cent of the entire Taiwan area. Two mountain peaks rise up steeply in the north-east: Mount Tatun and Mount Chihsing, both just over 1,000 metres high. By virtue of this unusual topography, the area was made into Yangmingshan National Park. To the south-east of Taipei lies Songshan Hill and Chingshui Ravine which form a natural protective barrier of lush woods. The Hsintien Creek is located to the south-west while the Keelung River lies to the north-east. The two rivers converge to become the Tanshui River which then flows into the Taiwan Strait.

Taipei has a subtropical climate, with an average temperature of 23.6 ºC. Summer is from May until September and is characterized by scorching heat and high humidity. Average temperatures range between 25.2–28.6 ºC. Autumn is from October to November, with average temperatures ranging between 22.2–24.2 ºC.

The city had 350,000 households and a population of 1.60 million at the end of 1968, just prior to the administration reform. By the end of 2000, the number of households had reached 889,000 with a population of 2.65 million. Over the past 32 years, the population has increased by 65 per cent and the number of household have increased 1.5-fold. The number of motor vehicles reached 1,625,526 at the end of 2000 - an increase of 48 per cent (530,813) compared to the 1990 level. On average, the annual growth rate was 4.05 per cent over the decade. The number of automobiles increased from 497,127 to 666,513 in the period 1990-2000 - an average annual growth rate of 3.01 per cent. In 2000 the number of motorcycles was 938,400 vehicles more than in 1990 - an average annual growth rate of 4.87 per cent. The highest growth rate was for non-commercial compact cars which
increased 39 per cent over the decade. At the end of 2000, there were 614 motor vehicles (including 252 automobiles and 362 motorcycles) for every thousand city residents.

In recent years, urbanisation has resulted in rapid business development, mostly urban light industry. The number of factories in the city was 2,171 at the end of 2000 with a work force of 59,897 persons.

To ensure Taipei develops into a modern city with a clean and healthy environment, urban air quality management has become a priority issue on the municipal agenda. Since the city was upgraded to a municipality, laws and regulations have been amended and a specialised environmental protection agency has been established, which is responsible for the protection of air, water and the control of noise nuisance, environmental hygiene and waste disposal.

CURRENT STATUS OF AIR QUALITY IN TAIPEI

Taipei is located within the northern air quality control basin and the Environmental Protection Agency (EPA) has set up 19 stations in this basin to monitor the air quality. Since the air pollution sources of Taipei City and Taipei County affect and interact with each other, this paper will first discuss the current status of the air quality within the northern air quality basin and then the current status of the air quality monitoring activities in Taipei City.

In 1999, the number of days with a pollutant standards index (PSI) more than 100 were 189 slightly more than the 174 exceedances of the previous year (1998). Due to the effect of the sandstorm from mainland China, the number of days with PSI more than 100 from January to April 2000 were 255 although the number of exceedances would have been 177 if the effects of the sandstorm were excluded. The goal of 197 exceedances was met in 2001.

The EPA has seven automatic monitoring stations in Taipei, including five air quality monitoring stations, one traffic monitoring station and one meteorological station. If the 21 days with recorded PSI more than 100 in 2000 due to a sand storm are subtracted from the overall statistics, a comparison of exceedances (i.e. PSI more than 100) from 1995 to 2000 shows approximately 60 exceedances annually during the period, except for 70 recorded in 1997. Observing that the number of days with PSI more than 100 has remained more or less constant over the past six years, it can be concluded that the air quality improvement projects have been effectively implemented during the period.

According to monthly statistics, the days with PSI more than 100 caused by particulate matter (PM$_{10}$), one of the Criteria Air Pollutants (CAPs), are found mainly in the January–April period. Ozone (O$_3$), another CAP, may result in 365 days with PSI more than 100, but its greatest impact on air quality is found mainly in the April–September period.

Over the past few years, it has become increasingly clear that the occurrence of sandstorms in mainland China is a key factor influencing the island’s air quality. However, after excluding the sandstorm influence, the number of days with PSI more than 100 recorded by the Chung-Shan, Song-Shan and Wan-Hwa stations in 2000 showed a annual decline, while the remaining two stations showed a rise. The number of days with a recorded PSI more than 100 the Wan-Hwa station has been dropping annually by approximately 52 per cent since 1997. It is noteworthy that the number of days with PSI more than 100 recorded
by the Gu-Ting station has been increasing since 1998.

**Emission Inventory**

The emission inventory of air pollution in 1999 based on different air pollution sources in Taipei City is described below.

**Total suspended matter**
The emission of total suspended matter (TSP) totals 52,346 tonnes per year. Fugitive emissions account for 87 per cent of the total. Combustion emissions – of which the soot emitted from the food-and-drink industry takes a major share – accounts for approximately 5 per cent and road transportation emissions approximately 7 per cent.

**Particulate matter**
The emissions of particulate matter (PM$_{10}$) total 15,209 tonnes per year. The fugitive particle emissions from non-combustion sources account for approximately 60 per cent, mostly fugitive dust emission caused by vehicles (56 per cent). Construction engineering accounts for 3 per cent, non-fuel combustion 17 per cent and road transportation 22 per cent (emissions from diesels accounting for 9 per cent, cars 7 per cent and motorcycles 6 per cent).

**Sulphur oxides**
The emissions of sulphur oxides (SO$_x$) total 2,658 tonnes per year. Combustion emission accounts for approximately 62 per cent, mostly fuel combustion (44 per cent for commercial activities and 12 per cent for industries). Non-fuel combustion emissions account for some 3 per cent, and road transportation emissions 37 per cent (23 per cent from petroleum vehicles, 8 per cent from diesels and 6 per cent from motorcycles).

**Nitrogen oxides (NO$_x$)**
The NO$_x$ emissions total 22,023 tonnes per year. Road transportation accounts for 81 per cent (diesels 44 per cent; petroleum cars 34 per cent and motorcycles 3 per cent). As for non-road transportation emissions, aircraft account for some 10 per cent. Combustion emissions accounts for some 9 per cent, of which fuel combustion accounts for a major share (approximately 6 per cent).

**Non-methane hydrocarbon**
The emissions of non-methane hydrocarbons (NMHC) totals 72,769 tonnes per year. The fugitive hydrocarbon emissions of non-combustion sources accounts for approximately 55 per cent, (building construction - 22 per cent; commercial activities - 19 per cent; industrial coatings - 11 per cent, industrial solvents - 2 per cent and gas stations - 1 per cent). Road transportation accounts for 44 per cent of NMHC emissions (petroleum vehicles - 25 per cent, motorcycles - 16 per cent and diesels - 2 per cent).

**Carbon monoxide (CO)**
The emissions of CO totals 204,092 tonnes per year. Road transportation accounts for approximately 98 per cent of which emissions from petroleum vehicles are responsible for 74 per cent, motorcycles 21 per cent and diesels 3 per cent. Emissions from aircraft are responsible for approximately 1 per cent of the total.
AIR POLLUTION CONTROL STRATEGY

In order to reinforce the promotion of the National Environmental Protection Project, the Bureau of Environmental Protection (EPB), Taipei Municipal Government, focuses on the characteristics of pollution in the city and the goal of reducing air pollutant emissions, and evaluates each enforcing instrument in order to draw up the ‘Policy of Restrain Air Pollution in Taipei Municipal’. As mentioned above, apart from a handful of point sources and fugitive sources, air pollution in the city mainly comes from mobile source. In order to control the mobile sources, the Bureau of Environmental Protection has been formulating progressively stricter standards of vehicle emissions. Compared with the policy of other countries, the standards of Taipei are regarded as relatively strict. However, the experience of other countries has shown that, in addition to controlling mobile source emissions, traffic management practices are an important aspect of the overall transportation strategy. Traffic management schemes can reduce traffic congestion, reduce engine idling time and cut down the driving mileage of the whole traffic fleet. Also, fuel consumption will be reduced so that total emissions to the atmosphere can be lessened.

The EPB pollution control policy can be divided into four general areas, 16 strategies for controlling air pollution and 28 schemes of reduction:

1. Control mobile sources: Six strategies of control and 12 schemes of reduction
2. Control fugitive sources: One strategy of control and four schemes of reduction
3. Control point sources: Three strategies of control and six schemes of reduction
4. Integrative management project: Six control plans and promotion programme

Mobile Source Control Strategies

With support from the air pollution prevention and control fund, the Bureau of Transportation (BOT), Taipei City Government, has been continuously enforcing strategies to control mobile sources. In 1998, BOT implemented three projects, including the second phase of a demonstration project on natural gas buses of Taipei City, a system of displaying information on the conditions of buses for Taipei City – a project of reducing air pollution by enhancing bus service quality and furthering mass transportation development, and a demonstration project for reducing environmental pollution by replacing the traffic light controllers of Taipei City. In 1999, the BOT implemented two projects: one on the planning and arrangement of bicycle lanes and the other on the planning of a bicycle road network for Taipei City. Current proposals include the third phase of a demonstration project on natural gas buses in Taipei City, the preferential programme for transfer between Mass Rapid Transportation (MRT) System and buses, and a training programme for inspecting LPG vehicles.

Measures for reducing air pollution from mobile source include the promotion of low-polluting vehicles, inspection and control, strategies of transport system control, and other important traffic construction plans as described below:

1. The promotion of liquefied petroleum gas (LPG) vehicles: LPG vehicles are characterised by low pollution; helping to reduce emission of NOx, CO and HC as well as saving fuel expenses. In 1996, EPA promoted LPG vehicles by granting an allowance to LPG taxi drivers. Currently there are approximately 10,000 LPG taxis registered in Taipei City, with one of the three LPG stations located in An-Kang Rd. in Nei-Hu District and the other two in Bin-Jiang St. in Song-Shan District.
2. **Introduction of natural gas buses**: Since 1997, BOT has been implementing this project with the support of the air pollution prevention and control fee. Currently, there are already six in-service natural gas buses, with one natural gas filling station located in Gang-Chian Rd. in the Nei-Hu District. Thus far, NOx and HC emissions from buses have been significantly reduced.

3. **Reducing Pollution from Bus Exhaust fumes**: “Squid cars”, the term used by Taiwanese for any vehicles spewing out considerable amounts of black smoke and other pollutants (as squids do when frightened in the ocean), have long been subject to complaints in downtown’s. In order to solve this long-standing problem, the BOT, with the support of the air pollution prevention and control fund, had buses in Taipei City install smoke filters and catalytic converters.

4. **Bus Lanes and Preference Lanes**: Currently there are a total of seven bus lanes and one bus preference lane in Taipei City. Ever since implementing bus lanes, a number of positive effects have been found, such as higher bus speeds, more bus passengers, and less private transportation.

5. **Transfer and Shuttle between MRT System and Buses**: In order to encourage the use of public transport BOT, with the support of the air-pollution fee, began implementing a preference programme for MRT – bus transfer was open for service. Since then, the number of MRT commuters has been increasing, while private transportation by commuters has declined. This has eventually achieved the goal of improving air quality. Following this successful example, the agency has continued to expand the transfer-based preference programme and shuttle bus services, with a view to further promoting the utilisation of mass transportation.

6. **Chessboard-style and Mainline Bus System**: In order to enhance the overall service quality of the bus system, to offer the public straightforward accessibility to the system, and reduce detours and bus stops within the system as a whole, we devised a “chessboard-style” bus network project. Thus far, we have moved into the second stage of the project: reviewing and adjusting current bus routes. Currently, BOT are proposing a total of ten new mainline bus routes while keeping up the pace of bus lane implementation, a synergistic effect that brings about a more prompt and convenient service.

7. **Computer Signal System**: As part of the concept of transportation system management, the computer signal system facilitates efficient traffic flow by regulating intersections via signal optimisation. It is expected that the system will enhance driving speed and reduce the frequency of stopping and waiting for buses, thus decreasing vehicles’ fuel consumption and bringing about a positive effect to municipal transportation as a whole. Thus far BOT? have completed in succession the changeable information signals, intersection controllers, vehicle detectors and closed-circuit television monitoring systems, all of which are connected to our traffic control centre.

8. **Regional Traffic Control and Regional Passage Control**: In order to avoid series traffic jam problems caused by large-sized vehicles, Taipei City has prohibited large trucks and tractor-trailers from certain routes and areas at certain times. The control regulation is implemented either on the basis of the whole day (07:00–22:00), or during morning and afternoon rush hours according to the characteristics of different sections of the routes. In addition, pedestrian-only lanes are implemented on partial sections of Shimen, and motorcycle-only lanes or motorcycle prohibition areas are implemented on special sections as well. Moreover, during the period of Chinese Tomb-sweeping Day and the blossom of Yang-Ming mountain, regional passage control, shuttle services, and instrumental control of freeway ramps are implemented. All of these have proven to be highly efficient measures for improving transportation management.

9. **Small-to-Medium Bus Route Planning**: “The Small-to-Medium Bus Route Planning” and “The Research Project of Air Pollution Reduction” were implemented this year.
with the support of the air pollution prevention and control fee. These projects are carried out with a view to facilitating the shuttle services and remote suburb transport for the MRT system, so as to increase the popularity of the mass transportation system and thereby reduce the use of private vehicles.

10. **Light Rail Transit (LRT) System**: This is a project proposed in “A White Paper on Traffic Policy of Taipei City”, the LRT system is expected to alleviate the saturated transport load of bus lanes by co-ordinating with light rail cars. Powered by electricity, light rail cars are low-pollution transportation vehicles.

The EPB of Taipei Municipal Government has implemented a number of strategies to control mobile source emissions. These measures have included educating the public to undertake periodical maintenance and examination of their vehicles in order to ensure the vehicle complies with environmental protection regulations. The EPB is planning to undertake the following five major projects in 2001:

1. **Project of diesel vehicles exhaust fumes examination**: This project includes inspection of the exhaust emissions of diesel vehicles, sampling and analysis of the diesel used, building a diesel vehicle database for the city so as to facilitate related inquiry and control, organising campaigns to promote strategies controlling diesel-fuelled car exhaust emission, and to encourage and guide diesel suppliers to apply for EPA's replacement subsidy.

2. **Electric Motorcycle Promotion Programme**: At the end of October 2000, there were a total of 1,623 registered electric motorcycles, with 73 charge stations. Sixteen of the charge stations were located beside MRT stations. This programme includes planning and organization of promotion campaigns, printing promotion literature, having administrative agencies, enterprises, or communities set an example by using electric motorcycles on a trial basis, and conducting questionnaire surveys on these trial users and organizing seminars on trial experience in riding electric motorcycles as a reference for future implementation. In addition, this project will also include schemes for building charge stations, assessment of substitute solutions for charging, and planning a maintenance service system for electric motorcycles. All of these programmes are expected to enhance the convenience of using electric motorcycles and thereby promote their use with an ultimate goal of reducing pollutant emissions.

3. **Project of Publicising Periodic Examination of Motorcycle Exhaust**: Using various means this project will publicise the problems of motorcycle exhaust. For example, inspection tasks aimed at those motorcycles in public and private parks which are not regularly examined (a card publicising regular examination will be attached to these vehicles), reinforcing publicity of related regulations, and conducting examination campaigns free-of-charge.

4. **Auditing and assessment project of motorcycle exhaust periodic examining stations of Taipei city**: This will involve assessment and inspection of the motorcycle exhaust examination and service centres authorised by Taipei municipal government. Including analysis of assessment results, and educational and training courses for the relevant personnel.

5. **The control and investigation of air pollution from mobile sources**: This will involve road-side inspection of motorcycles to check whether they have had the regular examinations as required by the authority, restricting those vehicles without regular examination and conducting exhaust emission inspections, carrying out recurrent examinations of vehicles reported to have emitted excessive exhaust gas until these vehicles pass related examination, and informing the owners of vehicles of examination deadline.
Below are the descriptions of the future strategies to control mobile sources in Taipei City:

- **Promotion of Low-Pollution Vehicles**: Low-pollution vehicles include electric motorcycles, electric bicycles, LPG cars, CNG buses, and those automobiles powered by alternative fuels. We expect, by increasing the use of low-pollution vehicles, to reduce emissions of Criteria Air Pollutants (CAPs) such as NOx, NMHC and CO. Associated tasks will include providing subsidies for purchasing electric motorcycles and replacing their batteries, establishment of an extensive network of charging facilities for electric vehicles and launching campaigns to promote the use of other low-pollution vehicles (such as electric bicycles).
- **Survey on Pollution Characteristics**: A survey of pollution characteristics, so as to facilitate formulating control countermeasures. Eligible CAPs will include TSP, SOx, NOx, NMHC and CO. We will carry out surveys on pollutants emitted by various types of mobile vehicles that are in use including a survey on the pollution characteristics of aircraft.
- **Replacement of High-Pollution Vehicles**: Enactment of stricter emission standards and provision of various subsidies (such as subsidies for replacing two-stroke motorcycles), with a view to reducing the number of highly-polluting, old vehicles that are in use. Eligible CAPs will include NOx, NHMC and CO.
- **Promotion of Automobile Pollution Control Devices**: We expect to achieve reductions in pollutant emissions by subsidising the upgrading of exhaust emission devices on diesels. Associated tasks will include programmes of reducing exhaust gas emission of diesels, with TSP as an eligible CAP.
- **Reduction of Motorcycle Pollutant Emission**: Establishment of a regular examination system for motorcycles through launching inspection, regulation and publicity campaigns. Eligible CAPs will include NMHC and CO. Associated tasks will involve launching extensive road-side clamp-downs on motorcycles and organizing campaigns to promote the examination system for motorcycles.
- **Control strategy of Mobile Sources**: Formulation of a medium-to-long term plan and control strategy which will serve as a guide for regulating mobile source emissions in the future. Eligible CAPs will include PM10, VOC, SOx, NOx and CO. Associated tasks will involve integration and renewal of mobile source parameters and emission inventories for Taipei City, review of changes in mobile sources and the effect of controls in Taipei City, and the formulation of a practicable solution to controlling mobile sources for Taipei City including traffic management, mass transportation planning, guidance, phasing out high pollution vehicles and an overall reduction of vehicle kilometres travelled.

**Effects of Implementing the Reduction Strategy**

For the past few years, the EPB, Taipei Municipal Government has implemented the programme to improve air quality and has succeeded in continuously reducing polluting emissions. The major measures promoted to control air pollution include:

- Controlling Mobile sources – includes the promotion of low emission vehicles, the enhancement of testing and the elimination of high contamination vehicles, and so on.
- Controlling Point sources – reinforces the inspection of businesses such as restaurants, automobile repair shops, laundries, gas stations, and industrial facilities located in the city, as well providing assistance in improving emission controls.
- Controlling Fugitive sources – controlling pollutant emissions from construction sites and associated measures such as street-sweeping.
With the air-pollution allowance subsidised by the Bureau of Transportation, Taipei Municipal Government, the EPB continuously enhances related control measures, such as the renovation of traffic signal controllers, the preferential programme for transfer between Mass Rapid Transportation (MRT) System and buses, and the demonstration project for natural gas buses of Taipei City. Up to the end of October, 2000, the number of vehicles re-equipped with LPG had reached 8997, and there were three gas filling stations: One was established on An-kang Road, Nei-hu District and the other two in Bin-jiang Street, Songshan District. Also, the number of licenses issued for electric motorcycles was 1729 and there were 73 charge stations (with 392 sockets) of which 16 were installed beside the MRT stations. Also, there were 6 natural gas buses in service, and natural gas filling stations were established on Gang-chian Road, Nei-hu District.

The effects of enforcing the reduction strategy are explained in Table 10.1:

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Reductions Achieved</th>
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<tr>
<td>TSP</td>
<td>Reductions achieved mainly from point sources, the control programme for construction sites, and the improvement of the emission test for diesel vehicles</td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td>Reductions achieved mainly from the examination and spot checks of new automobiles, but also from the emission testing of diesel vehicles and the phase out of diesel buses</td>
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<tr>
<td>SO$_x$</td>
<td>Reductions achieved mainly from the control of the sulphur contained in diesel fuel and partly from the control of point sources</td>
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<tr>
<td>NO$_x$, NMHC, CO</td>
<td>In addition to reductions from fixed sources, NO$_x$, NMHC, and CO have also been reduced from mobile source (e.g. by enacting stricter emission standards for exhausts). A secondary cause is the effect of exclusive lanes for buses and the chessboard-style road network of bus routes</td>
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Source: Taipei City Government Bureau of Environmental Protection

**PROSPECTS FOR THE FUTURE**

In addition to the continual strengthening of emission controls for various air pollutants, the air pollution control strategy in Taipei city will also be required to address the emissions of greenhouse gases (GHGs). The EPB will increase citizens awareness of climate change issues in order to reduce GHG emissions. Because mobile sources are the primary cause of air pollution in the city, the EPB will co-operate with the other city authorities concerned in order to increase the control of mobile sources and co-ordinate activities. Furthermore, due to advances in technology and lifestyle changes, the EPB is examining the most appropriate management and control measures. The aim of such actions is to maintain citizens’ health, enhance quality of life and protect the environment.
REFERENCES


Air Protection Department of the Environmental Protection Administration (1999) Notion of Control Point Source