State of Air Quality and Noise Pollution
The status of air quality problems in Thailand in 2003 continued to be particulate matter in size smaller than 10 micron (PM$_{10}$), which exceeded standards in many locations similar to the preceding year. Most of these were the same places, such as Samutprakarn, Bangkok, and Chalerm Prakeat District, Saraburi province.

Secondary issues were ozone gas ($O_3$), which was found to exceed standards in some areas, i.e., Bangkok and surrounding provinces, and eastern region. Carbon monoxide gases (CO) exceeded standards in areas located near certain Bangkok roadsides. Other air pollutants, i.e., sulfur dioxide (SO$_2$) and nitrogen dioxide (NO$_2$), were within limits.

Air Quality in Bangkok

Air pollutants found to have exceeded standards in the City of Bangkok were particulate matter (PM), ozone gases, total suspended particles (TSP) and carbon monoxide. Compared to the previous year, these problems became more degraded. Other pollutants were within limits, however. The main cause of PM has always been vehicular traffic, which increases every year. Data obtained from Department of Land Transportation indicate that the total number of registered vehicles until 2002 was 5.4 million. In 2003 alone, there were 514,530 new registrations. As a result, locations by major streets experienced worse air pollution problems than residential areas.

1. General Areas

Bangkok-wide there were 10 air quality monitoring stations in total. Continuous monitoring showed that particulate matter and ozone gases had increased compared to the previous years. Other pollutants, such as TSP, sulfur dioxide, nitrogen dioxide and carbon monoxide, were within limits (see Table 1 in Index).

The 24-hour particulate matter averages, measured at 20.5 - 189.0 µg/m$^3$, exceeded standards 36 times from a total 1,680 readings, or 2.14% (standard of 120 µg/m$^3$). Locations with the most serious PM problem were Bangkhuntien District and Singharaj Pittayakom School.

The 1-hour ozone averages, measured at 0 - 169.0 parts per billion (ppb), exceeded standards 155 times from a total 61,789 readings, or 0.25% (standard of 100 ppb). The highest levels found were near Ramkamhaeng University, frequently exceeding the standard limits.

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$O_3$ Ozone gas is the secondary pollutant that formed in the chemical reactions between hydrocarbon and nitrogen oxides sunlight as catalyst.
2. Roadside Locations

There were 7 monitoring stations, plus an additional 21 temporary stations, monitoring air quality around Bangkok roadsides. Field measurements showed that major problems of roadside areas were PM and TSP. Furthermore, carbon monoxide and ozone gases also exceeded standards at times around particular streets. Sulfur dioxide and nitrogen dioxide, on the other hand, remained below standards (see Table 2 in Index).

2.1 Air Quality Monitoring Stations

Air quality near roadside locations sampled and measured continuously all year round at 7 stations found 24-hr particulate matter averages at 12.7 - 208.9 µg/m³, which exceeded standards 108 times from 2,152 readings in total, or 5.02%. The highest levels were detected on Rama IV Road next to the Ministry of Science and Technology.

The 1-hr ozone averages were detected at 0 - 145.0 ppb, which exceeded standards 13 times from 24,905 total readings, or 0.05%. Most exceedances were near Indrapitak Road, Thonburi power sub-station.

2.2 Temporary Air Quality Monitoring Stations

Field measurements of air quality by roadsides with heavy traffic using 21 temporary stations, conducted 2-3 times a week on 3 parameters, namely PM, TSP and CO, found particulate matter to exceed standards at several locations. TSP and CO exceeded standards on some streets (see Table 3 in Index).

The 24-hr PM averages was detected at 39.2 - 241.0 µg/m³. The highest levels measured were by Sukhumvit Street close to Soi Onnuch. In addition, Rama III at Tok intersection had PM exceedances daily. Furthermore, several other streets had PM problems, i.e., Lanluang at Man-sri Intersection, Rajavitthi at Victory Monument, Pitsanulok at Yommaraj Intersection, Samsen at Sri-yan Intersection, Yaowaraj at Rajawong Intersection, Sathupradit at Sathupradit Post Office, Rama I at Mahboonkrong. All were due to heavy and congested traffic (Figure 1).

The 24-hr TSP averages were detected at 0.06 - 0.48 mg/m³. The highest levels were found at Sathupradit Road near the post office. In addition, exceedances were detected at times on some streets (standard of 0.33 mg/m³), i.e., Sukhumvit at Soi Onnuch, Rama I at Mahboonkrong, Ratchaprarop at Pratunam, Samsen at Sri-yan, Rama III at Tok Intersection, and Pitsanulok at Yommaraj Intersection (Figure 2).

The 1-hr CO averages were within limits. However, the 8-hr averages exceeded standards at times on some roadsides due to heavy traffic resulting in a collection of this gas. Concentration readings were 0.3 - 13.0 parts per million (ppm). Locations where exceedances were found (standard of 9 ppm) were Prachatipok Road at Taksin Monument, Sukhumvit near Onnuch, Bangkok-Nonthaburi Road at Wongsawang Intersection, Si-praya Road at Si-praya Intersection, Lanluang at Man-sri Intersection, and Rama I at Mahboonkrong.
Considering the air pollution trend in Bangkok, it is evident that PM has continued to be a major problem in roadside locations more than in other areas. Though data show that PM quantity has been clearly declining, however in 2002-2003, the trend has started to rise once again (Figure 3). It is also expected to pose a serious threat in the future if not seriously handled.
Ozone gases posed another significant air pollution problem since they exceeded standards several times in the various areas of Bangkok, and were also increasing continuously (Figure 4). Thus, protective and control measures are needed to keep within standards.

Solutions to air pollution from vehicles, another major source for Bangkok, are more stringent emission standards for new and old motor vehicles, petrol improvement by means of reducing sulfur content, inspection and law enforcement of violations, and enhanced emission control on public buses, etc.

Air Quality in Surrounding Provinces
Continuous monitoring in the Bangkok’s 4 surrounding provinces - Samutprakarn, Samutsakorn, Pathumthani and Nonthaburi - at 10 stations found that PM and ozone gases posed significant problems, and that they were more serious than the previous years. Other pollutants remained within standards, however (see Table 4 in Index).

The 24-hr PM averages were measured at 11.6 - 331.4 µg/m³. The most problematic location was Samutprakarn with exceedances of 458 times from a total of 1,533 readings, or 29.9%. This figure is higher than the previous year of 18.4% exceedance rate (Figure 5). In addition, comparing the annual averages indicates that there is also an increasing trend (Figure 6).
The 1-hr ozone averages were higher than standards several times at all monitoring stations with readings at 0 - 187.0 ppb. Maximum readings were at Samutsakorn Highway Department Office, Kratumban District, Samutsakorn.

Air Quality in other Provinces

Outer provinces of Thailand had PM as the main problem. Compared to the previous years, most locations did not change very considerably, except Chalerm Prakeat District, Saraburi, whose PM problem became slightly more severe. Secondary pollutant was ozone, with all others remaining within standards (see Table 5 in Index).

The 24-hr averages of PM were measured at 10.9 - 388.5 µg/m³. The highest readings were recorded at Chalerm Prakeat District, Saraburi with 46 exceedances of all 307 readings, or 15.0%. This was because the area features a lot of stone crushing and grinding facilities, and cement plants, which may have been the main PM contributors. In light of the situation, responsible agencies have proposed action plans to alleviate the problem. Other locations with less severe PM problems included Sriracha District, Chonburi, Lampang, Nakorn Ratchasima, and Chiang Mai, etc.

The 1-hr averages of ozone gases were measured at 0 - 134.8 ppb. Most exceedances were found in the eastern region of Chonburi and Rayong provinces. The provinces of Ratchaburi, Saraburi, Chiang Mai and Nakon Sawan, however, had exceedances at a few intervals only.
Inspection and Ban of Black-Smoke Emitting Vehicles

The Traffic Police Department in cooperation with Bangkok Metropolitan Administration and Pollution Control Department conducted inspections and issued bans on vehicles emitting black smoke in accordance with the Enhancement and Conservation of National Environmental Quality Act B.E. 2535 (1992). Only vehicles covered by the Law on Motor Vehicles, i.e., pickup trucks and passenger vans, were tested. Inspections were launched on Taksin Road for 3 months from September 18 - December 17, 2003 in order to prepare related agencies and publicize measures to the general public. In conclusion, from all 631 vehicles inspected, 321 were temporarily banned from use. These vehicles would have to be re-tuned and brought in for re-inspections within 30 days. Should they be caught again without removing temporary bans, permanent use prohibited orders will take effect. Records obtained from the re-inspection checkpoints at the Elevated Highway Police Station, Barom Ratchachonani Road, during the period of September 18 - December 31, 2003, show that a total of 288 vehicles, or 90%, came back in for re-inspection and successfully removed the temporary bans. Thus, there are 33 vehicles, or 10%, remaining to be followed up. Pollution Control Department has issued warrants to the owners of those remaining vehicles for prompt re-inspection. So far there have been no permanent bans issued as no vehicles have been found in use with temporary violations.
In addition, Land Transportation Department and Bangkok Metropolitan Administration along with Pollution Control Department conducted inspections and issued bans in accordance with the Land Transportation Act B.E. 2522 (1979) on large vehicles, particularly public buses, 3 times a week on Mondays, Wednesdays, and Fridays. “Use Prohibited” marks were sprayed onto the vehicles with black smoke emissions exceeding standards. During the period of Sep. 18 - Dec. 17, 2003, of all 953 vehicles inspected, a total of 120, or 12.6, were spray-painted with “Use Prohibited”. In all, there were 111 public buses, 2 trans-province buses, and 7 others. Follow-up did not find second-time violations.

In 2004, to comply with the Enhancement and Conservation of National Environmental Quality Act B.E. 2535 (1992), related agencies set up plans to expand the scope of inspections to cover the entire city of Bangkok at approximately 30 traffic police inspection points. Re-inspection points were also added to as many as seven at Pollution Control Department, Elevated Highway Police Station, and all 5 Mechanical Department offices of Bangkok Metropolitan Administration. With regard to compliance with the Land Transportation Act B.E. 2522 (1979), Pollution Control Department solicited additional cooperation from Bangkok Mass Transit Authority (BMTA). With Land Transport Department orders to prohibit use, public buses commissioned by private parties who are contracted by BMTA would have to re-tune the engines, or otherwise risk getting operation contracts revoked.
Sulfur Reduction in Diesel Fuel

Bangkok and its outlying provinces still experienced air pollution problems, specifically PM matter, with vehicles being the main sources responsible for as much as 54% of total PM emission (Figure 1). Diesel vehicles, in particular, emit PM as much as 83% of all vehicular emissions (Figure 2).

Vehicular particulate matter is produced by incomplete combustion of carbon and hydrocarbon atoms, components in diesel fuel. These atoms form larger molecules, agglomerate and become sulfate compounds, a result of sulfur in the fuel and liquid hydrocarbon, turning into small soot particles (Figure 3).

Studies on the effects of sulfur content in diesel fuel as manufactured according to EURO II and EURO III standards (the latter of which is more stringent and will be in effect in mid-2004) on pollution from diesel vehicles found that levels of all pollutants tend to decline when sulfur content is reduced (Figure 4).
Nonetheless, the aforementioned study had procedural limitations as it was not able to find test vehicles with the same engine system. EURO II vehicles employ direct injection engines with higher compression ratios, which result in very high level of heat in combustion, producing a large quantity of NOx and very low CO. Hence, CO from EURO II test vehicles was much lower than indirect injection EURO III engines.

In light of enforcing EURO III standards on diesel vehicles, the National Environment Board at its 6/2546 convention on October 30, 2003, agreed to raising emission standards for new vehicles. Small-size, level-6 diesel and level-7 gasoline vehicles would have to comply with EURO III standards later to be promulgated by Thai Industrial Standards Institute (TISI). In order to comply with new EURO III standards, small-size, level-6 diesel vehicles would require fuel to have sulfur content reduced from 500 ppm to 350 ppm. Therefore, the Department of Energy Business must require sulfur content in commercial diesel fuel to be below 350 ppm and to take effect on January 1, 2004.

Reducing sulfur content in diesel fuel from 500 ppm to 350 ppm will have the following benefits on the environment and human health:

1. Environment: Particulate Matter Reduction
   1.1 It is estimated that vehicular emissions of particulate matter in Bangkok and its surrounding provinces are 13,985 tons in 2003. However, because 83% of particulate matter was produced by diesel vehicles, they generated 11,608 tons of particulate matter a year. A decrease in sulfur content in diesel fuel will help reduce particulate matter emitted by diesel cars, most of which comply with EURO II standards, by 15.6%, or 1,741.3 tons per year.

   1.2 From 1997 baseline data, emissions of particulate matter from various sources in Bangkok and surrounding provinces were 38,192 tons, and the 24-hr average concentrations along roadside in Bangkok was 89.32 µg/m³. Therefore, if PM emissions are reduced by 1,741.3 tons a year from limiting 500 ppm of sulfur content in diesel fuel to 350 ppm, atmospheric concentrations of PM will reduce to 85.29 µg/m³. (This equals to a reduction of 4.07 µg/m³).
2. Human Health: Decreasing the human health impacts

The 1998 study on effects of PM to the health of population living in Bangkok and surrounding provinces found that every 10 \( \mu g/m^3 \) reduction of PM would significantly lower health problems. Nonetheless, decreasing sulfur content in diesel fuel from 500 ppm to 350 ppm and having 4.07 \( \mu g/m^3 \) less PM would also lower health problems of the population. Table 1 compares health benefits received from PM reduction.

<table>
<thead>
<tr>
<th>Health Benefits</th>
<th>PM Reduction by 10 ( \mu g/m^3 )</th>
<th>PM Reduction by 4.07 ( \mu g/m^3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Reduced premature death rate</td>
<td>700-2,000 cases per year</td>
<td>285-814 cases per year</td>
</tr>
<tr>
<td>- Reduced chronic respiratory patients</td>
<td>3,000-9,300 cases per year</td>
<td>1,221-3,785 cases per year</td>
</tr>
<tr>
<td>- Reduced admission rate in respiratory and coronary problems</td>
<td>560-1,570 cases per year</td>
<td>228-638 cases per year</td>
</tr>
<tr>
<td>- Fewer days with severe respiratory problems that hinder daily activities</td>
<td>An average of 0.52-16.29 days per person per year, or 2,900,000-9,100,000 days/year</td>
<td>An average of 0.21-0.66 days per person per year, or 1,180,300-3,703,700 days/year</td>
</tr>
<tr>
<td>- Fewer days with mild respiratory problems</td>
<td>An average of 3.9-13.25 days per person per year, or 22,000,000-74,000,000 days/year</td>
<td>An average of 1.6-5.39 days per person per year, or 8,954,000-30,118,000 days/year</td>
</tr>
<tr>
<td>Monetary costs of health</td>
<td>56,000-140,000 million baht/year</td>
<td>22,792-56,980 million baht/year</td>
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</tbody>
</table>
Levels of noise in 2003 along roadsides in Bangkok and surrounding provinces mostly exceeded standards as a result of traffic. Other areas in general did not have exceedances. Nonetheless, the average noise levels in 2003 did not differ from the previous year, except areas with new activities, which caused more noise. Noise measurements along roadsides and canals in Bangkok, surrounding provinces and 9 provincial centers were as follows:

Noise Levels in Bangkok and Surrounding Provinces

The 24-hr average roadside noise levels were 66 - 86 decibel A (dBA) with a mean value of 73 dBA. It also had an exceedances rate of 88% (70 dBA standard). Locations most seriously affected are Chokchai Police Station, Ladprao Rd. with the 24-hr average measuring 86 dBA, and temporary checkpoints on Mahaisawan, Rama IX, Arunamarin-Prannok, Sukhumvit, and Bamrungmaung having a 24-hr average exceeding 80 dBA daily (Figure 1 and Table 6). Compared to data collected in 2003, the 24-hr noise level average differed slightly (Figure 2). On the other hand, areas located 50 meters away from main roads had a 24-hr average of 54 - 71 dBA and a mean value of 60 dBA. Exceedances were less than 1% at Ramkhamhaeng University and Singharaj Pittayakom School (Table 7). Comparing data collected in 2003 to the previous years found that the 24-hr average was slightly lower (Figure 3).

Communities along Saensab Canal had a 24-hr average of 57 - 63 dBA, which met the standard. The mean 24-hr average was at 61 dBA with Eakamai Soi 30 having the highest noise level.

Noise Levels in other provinces

The 24-hr roadside average measured 54 - 90 dBA with a mean of 64 dBA and an exceedances rate of 11%. Location most seriously affected was Na Pralan School, Saraburi with 93% exceedances rate. The highest 24-hr reading of 90 dBA was found at Had Yai Municipality Office, Songkhla Province, which had a combination of traffic and construction noises of nearby sites (Figure 4 and Table 9). Comparing 2003 data to the previous year, it was found that 24-hr averages were similar (Figure 5). Other locations, on the other hand, had a 24-hr average of 52 - 72 dBA, and a mean of 59 dBA. The exceedances rate was less than 1% (Figure 4 and Table 10). Comparing 2003 data to the previous year, the 24-hr averages were not different (Figure 6).
Figure 1. Noise Level in Bangkok Metropolitan area 2003

Figure 2. Roadside 24 hour average Noise level in Bangkok Metropolitan area 1997-2003

Figure 3. General area 24 hour average Noise level in Bangkok Metropolitan area 1997-2003
Figure 4. Roadside 24-hour average noise levels in the outer provinces 1997-2003.

Figure 5. General area 24-hour average noise level in the outer provinces 1997-2003.

Figure 6. Noise standard = 70 dBA.

Noise level = 70 dBA.

Noise standard = 70 dBA.

24-hour Average Noise Level (dBA)

4-hour Noise Levels (dBA)

4-hour Noise Levels (dBA)

4-hour Average Noise (dBA)

4-hour Average Noise (dBA)

4-hour Average Noise (dBA)