PM Concentration and Health Impacts

Atmospheric particles originate from a variety of sources and possess a range of physical and chemical properties. Collectively, particulate pollution is often referred to as total suspended particulates (TSP). Fine particulates less than 10 and 2.5 microns in size are referred to as PM_{10} and $PM_{2.5}$, respectively. These have the most significant impact on human health because they can penetrate deep into the lungs. PM emissions are a key health concern with estimated economic damage costs much higher than for other pollutants.

Ambient PM_{10} and $PM_{2.5}$ concentration and meteorological data were collected from PCD's monitoring stations in Bangkok (described in Annex B). A summary of recent data and trends in PM_{10} is described in Annex C.

Generally speaking, PM emissions are declining in Bangkok through improved mobile and other source control measures. The exceedances in PM_{10}, as measured by the number of observations exceeding the standard, are more likely to occur from November to April. Toward the end of the year, temperature inversions that trap pollutants close to the ground commonly occur due to the onset of the cool season. From February to April, the burning of rice paddy residues results in higher variability in TSP concentrations in Bangkok and other urban areas.

Maximum recorded concentrations, although lower than before, still exceed standards in many places. Longer-term trends in Bangkok's TSP concentrations (measured at the roadside) show that TSP spiked in the early 1990s, declined, and spiked again around 1996. After 1997, levels declined further, mirroring trends in ambient PM_{10}.

The negative health impacts of PM emission remain large as shown in Annex D and currently estimated to be around Bht 20 billion in 2004.

Trends in Particulate Matter in Bangkok

Source: Adapted from Thailand Air Quality Monitor, 2002

Major sources of particulate pollution in urban areas of Thailand are vehicles, re-suspension of road and construction dust, and industry and commerce. In non-urban areas, sources such as agricultural burning contribute significantly to overall particulate pollution, and their impacts are also felt in urban areas.

Average ambient measurements of PM_{10} have declined steadily in recent years as shown in Figure C.1 for Bangkok. Control measures and the Asian economic crisis of 1997 contributed to this decline. Ambient PM_{10} in other urban areas has declined steadily of late.

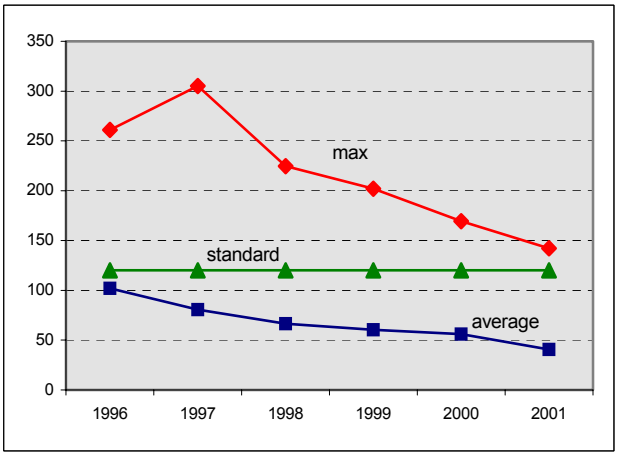

Figure C.1 - Trend of PM_{10} Concentrations in Bangkok, 1996 - 2001 ($\mu g/m^3$)

Source: PCD, 2002. Data came from 5 sites.

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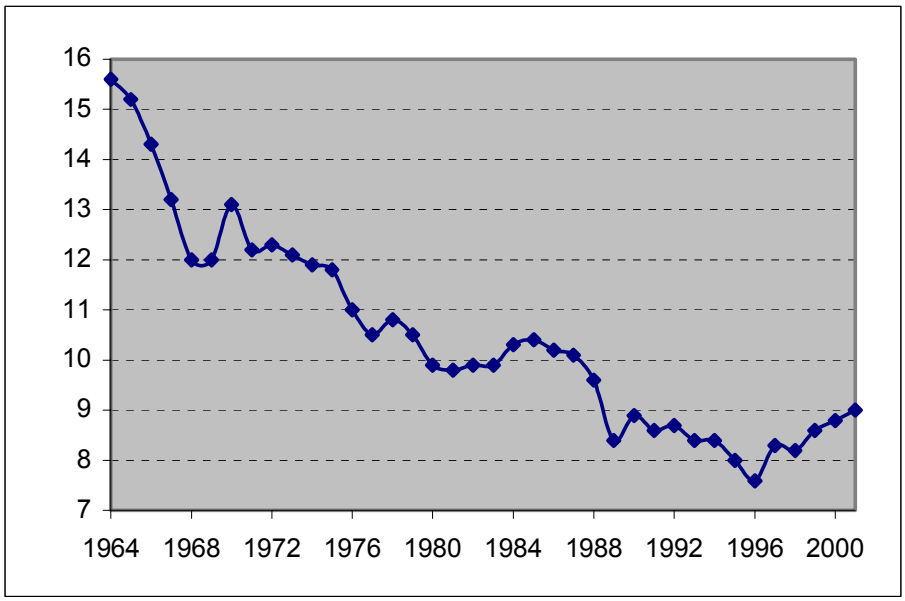
Visibility measurements recorded at Bangkok's Don Muang airport over the last four decades reveal an interesting story. While the visibility worsened steadily between the 1960s and mid 1990s, it has improved since 1996, as shown in Figure B.2. Because air pollution and reduced visibility are related, the change in the trend of visibility is similar to the PM_{10} levels measured for Bangkok reported in Figure 8. The visibility and PM_{10} measurements corroborate each other and support the expert opinion that air quality has improved in BMR in recent times. However, it also shows that there is a long road ahead which will need sustained efforts to reach visibility levels enjoyed in the 1960s and 1970s.

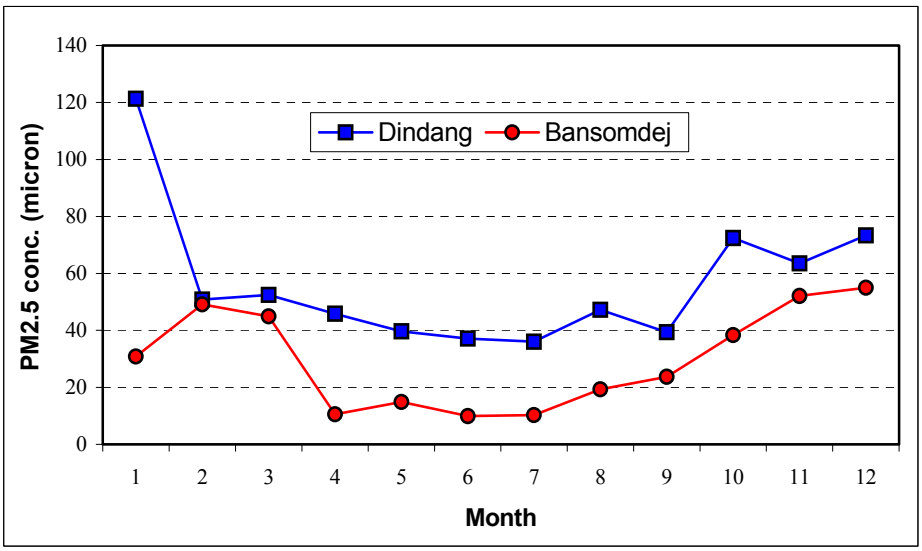
Figure C.2 - Annual Average Visibility in Kilometers at Bangkok's Don Muang Airport, 1964 to 2001

Source: Department of Meteorology, 2002.



The sample of the concentration of $PM_{2.5}$ concentrations from two stations throughout the year is presented in Figure C.3. Data from monitoring stations shows that the concentration of PM2.5 increases during October - March and decreases during April – September. Estimates of $PM_{2.5}$ source apportionment are being prepared for PCD by a Thai Research Fund project.

Figure C.3 - PM2.5 concentration (24-hr avg) at Dindang and Bansomdej station in 2002

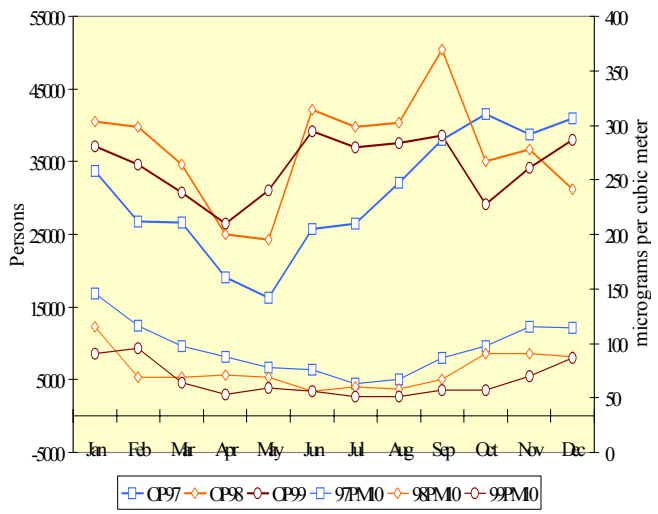


Public Health Impacts

Source: Adapted from Thailand Air Quality Monitor, 2002

Health impacts of air pollution vary based on the type of pollutant, length of exposure, and extent of interaction among pollutants. Fine particulate matter such as PM_{10} poses a serious and direct threat to human health as the particles penetrate deep into lung tissue, conveying toxic substances. Figure D.1 shows that the level of PM_{10} concentration and the number of outpatients with respiratory diseases peak during the dry season, from November until February. There is a positive correlation with the number of outpatients with respiratory diseases for these months. Although PM_{10} is not the only factor that leads to respiratory diseases, policy intervention to curb the concentration of PM_{10} during the dry season can be very beneficial and cost effective.

Figure D.1 - PM_{10} and respiratory patients



Source: PCD and BMA, 2002

Table D.1 - Estimates of Health Impact and Costs by PM10 in Six Cities for 2000

City	PM_{10} ($\mu g/m^3$)	Population (million)	Mortality Rate	Excess deaths	Chronic Bronchitis	Cost in million US$
Bangkok	64	5.7	0.0065	1,092	4,550	424
Chiang Mai	57	1.6	0.00985	390	1,080	56.8
Nakhon Sawan	51	1.1	0.0058	134	630	26.1
Khon Kaen	66	1.8	0.006	324	1,476	59.2
Nakhon Ratchasima	51	2.6	0.0055	286	1,426	56.8
Songkhla	41	1.2	0.0061	104	464	1.3
Total		**14**		**2,330**	**9,626**	**644.2**

Notes:

The PM_{10} data is the annual average and is from monitoring stations and estimates based on an air quality projection model.

1.Excess deaths and chronic bronchitis symptoms caused by PM_{10} are estimated based on simplified methodologies.

2.The total cost of deaths and chronic bronchitis caused by PM_{10} is estimated by first multiplying the unit costs with the respective cases and then adding up the costs for different categories. Since only PM_{10} related deaths and illness are included in the health damage estimation, the total costs presented in the table above are only lower bounds of the total costs caused by air pollution.

Numerous studies have attempted to estimate the health cost of PM_{10} emissions. Some of these have calculated costs on a value per ton basis, with figures ranging from US$20,000 per ton (for hospital costs only), to over US$500,000 per ton for total community costs in some high-income countries.[1] Others have attempted to put a value on mortality and morbidity, especially declining respiratory functions and other cardiopulmonary diseases.

Box D.1 - Methodology for Estimating and Forecasting Health Costs

- An increase in PM_{10} concentration by 1 $\mu g/m^3$ was estimated to increase the mortality rate by 0.084 percent, chronic bronchitis cases to 3.06 per 100,000, and incidence of respiratory symptoms to 18,300 per 100,000 adults.
- Health impacts were estimated by multiplying these dose-response coefficients with exposed populations and the PM_{10} levels above the safety threshold of 20 $\mu g/m^3$.
- In order to put a monetary value on human life, individuals in several countries are asked how much they would be willing to pay to avoid a certain symptom or illness. Per capita incomes are then used to adjust the unit values of statistical lives[1] in different cities. The corresponding value of statistical life in Bangkok and Nakorn Sawan is estimated at US$260,000 and US$43,000 respectively.
- The monetary values for health costs associated with morbidity and mortality are estimated by multiplying the health damages with the unit values.
- Projections for PM_{10} in Bangkok up to 2020 are based on assumptions made about population growth, per capita income change, and energy consumption changes, etc. Under the assumption of no new policy interventions, results indicate that PM_{10} concentration would be reduced from 60 $\mu g/m^3$ in 2002 to 50 $\mu g/m^3$ in 2020, largely due to

Valuing Health Costs

An initial analysis of the cost of health impacts of PM_{10} in six major cities in Thailand—Bangkok, Chiang Mai, Nakhon Sawan, Khon Kaen, Nakhon Ratchasima, and Songkhla[2]—was undertaken for this Monitor (Table D.1, Box D.1). Based on earlier international studies, this analysis computed the numbers of excess deaths and incidence of disease due to impacts of PM_{10}. The analysis covered the period 1996-1999, and revealed the following three important results:[3]

- *First,* the magnitude of total health costs was substantial, equivalent to 1 to 1.6 percent of the national GDP from 1996 to 1999. In 1999, for example, health costs were equivalent to the entire export value of footwear products.[4]
- *Second*, the health costs in Bangkok alone accounted for more than 65 percent of the total costs of all six cities. Since Bangkok accounts for roughly 35 percent of total GDP, the health impacts in Bangkok are equivalent to a significant proportion of the national GDP, i.e. 0.5 percent, in 1999. The average health costs of air pollution per person are estimated at US$46 (about 2,000 Baht) per year.
- *Third,* the 1997 economic crisis has caused a sharp reduction in economic activities, energy demand, and levels of PM_{10}, which directly lowers health costs of PM_{10} exposure. However, since the economic recovery in 1999, health costs have stabilized.

Forecasting Health Costs

Recent research has found that long-term exposure to fine particulate air pollution is a vital environmental risk factor for cardiopulmonary and lung cancer mortality. Each 10 $\mu g/m^3$ elevation in fine particulate air pollution was associated with approximately 6 percent and 8 percent increased risk of cardiopulmonary and lung cancer mortality, respectively (see footnote 5).

Figure D.2 shows trends in health costs associated with PM_{10} for Bangkok from 2001 to 2020, under different scenarios.[5] Under the base case scenario, health costs in Bangkok are around Bht 20 billion in 2004. Health costs decline slightly until 2009, and gradually increase thereafter for the low cost scenario. This is because the declining rates of PM_{10} during the initial period are higher than the growth rates of Bangkok's GDP. After 2009, income growth as well as the growth in value of statistical life outpaces the declining rates of PM_{10}.

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1 Parsons Internationals final report for the Air Quality Management Project to BMA, 2001.

2 The selection of these provinces is based on the availability of the ambient air quality data monitored by PCD.

3 The health costs comprise only the value of death and bronchitis costs caused by PM_{10}.

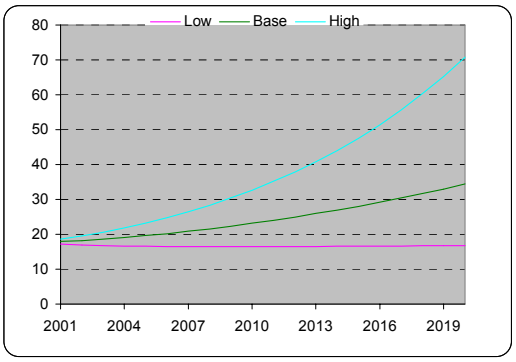
4 In 1999, the total value of footwear export was Bht32.1B (BOT, Economics & Financial Statistics, Jan 2001).

5 Low case: national GDP growth = 2 percent per annum and Bangkok GPP growth = 1.5 percent per annum.
Base case: national GDP growth = 5 percent per annum and Bangkok GPP growth = 4.5 percent per annum.
High case: national GDP growth = 8 percent per annum and Bangkok GPP growth = 7.5 percent per annum.

Another study on the benefits of air pollution management in Thailand estimated that under a medium investment scenario, the total annualized costs of implementing air pollution controls would be US$660 million in 2005 and US$1.5 billion in 2020, with corresponding benefits of US$4.7 billion and US$25 billion, respectively. The World Bank estimated benefit-cost ratio is higher for Thailand than for other countries in the East Asia region.[6]

The main purpose of such forecasting is to illustrate the potential health damage that may be prevented and substantial costs that may be saved. This can be done by designing and implementing appropriate policy interventions. These include: controlling PM emissions from buses, phasing out two-stroke motorcycles and older automobiles that lack catalytic converters, and providing appropriate fiscal and economic incentives to reduce traffic volume in cities, especially at peak hours.

Figure D.2 - Health Costs of PM_{10} for Bangkok, 2001-2020



6 World Bank (1999) Thailand: Building Partnerships for Environmental and Natural Resources Management.