A Brief Report on Air Pollution and Health in Thailand

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1. Introduction

Thailand locates in the heart of the Southeast Asian mainland with an area of 513,115 km^2. Thailand has borders to the Lao People's Democratic Republic, Cambodia and the Gulf of Thailand in the east, Myanmar in the west, and Malaysia in the south (Figure 1). Thailand has maximum dimensions of about 2,500 km north to south and 1,250 km. (Office of the Prime Minister, 2000).

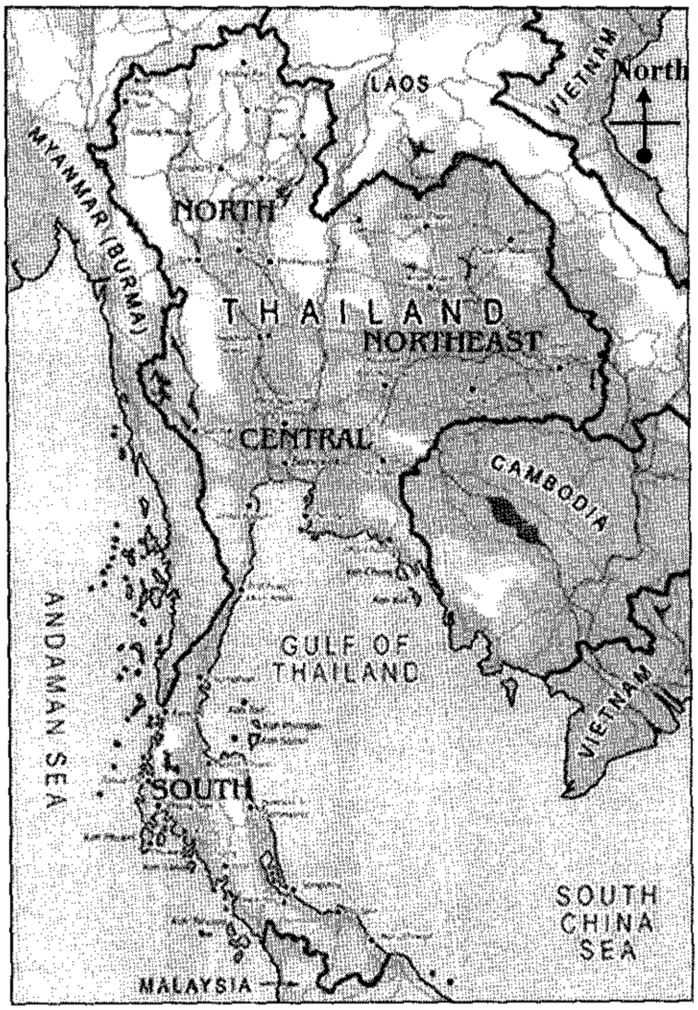

Figure 1. Map of Thailand (Source: Map of Thailand & Rob Hilken, 2003©)

Formerly known to the world as "Siam" until 1949 the name has henceforth changed to "Thailand". The word "Thai" actually means "Free". Based on geographical and cultural classifications, Thailand consists of four regions: (a) the north (a mountainous region), (b) the northeast (an arid, characterized by rolling surfaces and undulating hills), (c) the central (the basin of the Chao Phraya River including the east coast), and (d) the south (a region ranges from hilly to mountainous and the south coast).

Estimated population in Thailand is 64.86 millions in 2004, of which approximately 25% are under the age of 15 (National Statistical Office, 2004). Age and sex distribution of mid-year population in 2002 indicated that a large number of the population is in the working age with the median age of 30.5 years old (Figure 2). Current population growth rate is 0.91% and the birth rate is 16.04 per 1,000 population. While the mortality rate is 6.94 per 1,000 population, life expectancy at birth is 71.41 years. The mortality rate increased from 4.1 per 1,000 population in 1984 (Population and Social Research Institute, 2004). Figure 3 shows age specific mortality rates, which start to increase at the age of 25 years old. Three leading causes of death in general population are AIDS, traffic accidents, and stoke, respectively. Diarrhea, stomach and intestinal infections, and pneumonia are major causes of death in children with age less than five years old, respectively. A study in 2003 indicated that risk factors leading to health effects among Thais' population are unsafe sex, tobacco smoking, alcohol consumption, riding motorcycle without wearing a helmet, and high blood pressure (Population and Social Research Institute, 2004). Apart from these risk factors, air pollution is also a risk factor among general population, ranked 12^{th} equal to accident at work.

It is worst to notice that Bangkok is the capital city with the total household registration in 2002 of 5.78 millions, accounting for 10 percent of the total population of Thailand and it is largest city in Thailand. The areas of Bangkok and its vicinity are known as Bangkok Metropolitan Region (BMR), with the area of 1,569 km^2. BMR has the population density of 3,686 person per km^2 with the increase of 0.98% (BMA, 2004). Unofficial population is approximately 8.87 million inhabitants, accounting for commuters and non-registers.

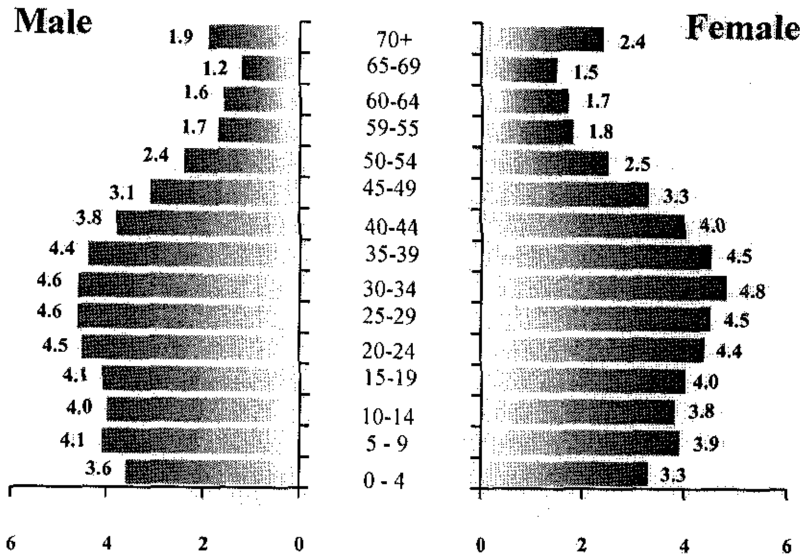

Figure 2. Age-sex structure of mid-year population 2002 (Source: Registration Administration Bureau, Department o Local Administration, Ministry of Interior, _____)

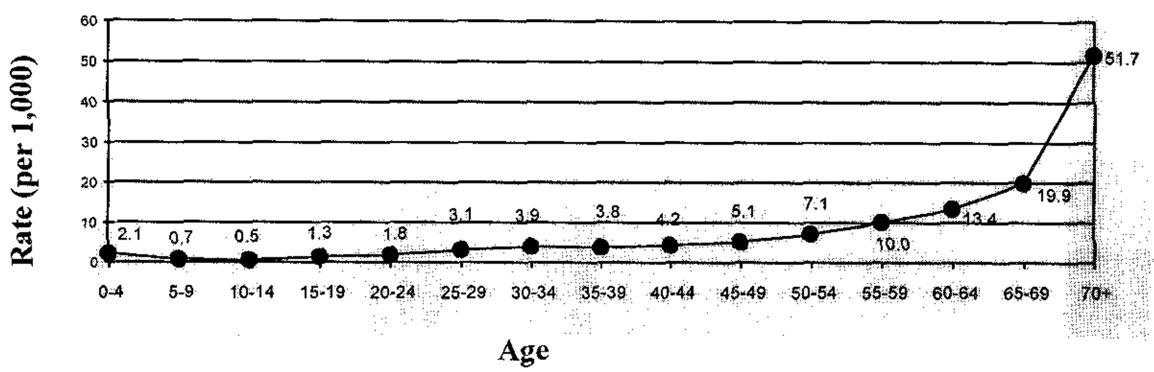

Figure 3. Age specific mortality rates (per 1,000 population) 2002, Thailand (Source: Bureau of Health Policy and Strategy, 2004).

2. Situations of Air Pollution in Thailand

Pollution Control Department (PCD) is the leading governmental agency responsible for air quality monitoring in Thailand. Most of the stations are situated in BMR, 48 from 71 stations nationwide. The rest of the stations are located in major cities in upcountry including industrial areas in the eastern seaboard. Air quality in BMR was seriously deteriorated during the rapid economic expansion in the early 1990's regarding to total suspended particulate (TSP), carbon monoxide, and lead concentrations, especially at road-site stations (PCD, 2004). Table 1 is the current NAAQS used in Thailand. Historical data shown that TSP concentrations were as high as ten times above the national ambient air quality standard (0.33 mg/m^3 for 24-hr standard). In 1996, the government implemented an aggressive emergency plan to combat PM pollution from automobiles and constructions. The latest official published report on air quality by Pollution Control Department (PCD) indicated that air quality is improving over the last decade. Data shown that air quality in Bangkok is getting better than several Asian cities, for example, Beijing, Jakarta, New Delhi and Manila (World Bank, 2003). However, problems still exist in some urban centers and near traffics.

Table 1. National ambient air quality standard of Thailand.

Pollutants	Averaging Time	Standard Values
Pb	1 month	No more than 1.50 μg/m^3
SPM or TSP	24 hours	No more than 0.33 mg/m^3
	1 year	No more than 0.10 mg/m^3
PM-10	24 hours	No more than 0.12 mg/m^3
	1 year	No more than 0.05 mg/m^3
CO	1 hour	No more than 30 ppm
	8 hour	No more than 9 ppm
O_3	1 hour	No more than 0.10 ppm
SO_2	1 hour	No more than 0.3 ppm
	8 hour	No more than 0.12 ppm
	1 year	No more than 0.04 ppm
NO_2	1 hour	No more than 0.17 ppm

Lead (Pb) phase-out campaign is an achievement in combating air pollution in Thailand. The campaign has been carried on for more than two decades, officially lunched in the mid 1980s. Lead in gasoline was phased out completely at the end of 1996 and unleaded gasoline became mandated in 1997. Prior to the campaign, monthly atmospheric lead concentrations in BMR were as high as 5.7 μg/ m^3 Significant drop of lead concentration is clearly observed from air monitoring stations, especially at road-side stations (Figure 4). Lead in the atmosphere of BMR is no longer exceeded the NAAQS for several years.

Based on PCD data, total suspended particles (TSP) was at peak in 1995, the average 24-hour of 0.53 mg/m^3. Tremendous affords have been put together to curb such pollution causing the decline in TSP concentrations, along with the economic crisis in 1997 (Figure 5). PM-10 concentrations had similar trend, steadily declining after 1997. However, PM-10 seemed to pick up in recent years (Figure 6). Data from roadside monitoring stations of BMR indicated that PM-10 concentrations posed a major threat in some areas when it exceeds the 24-hr standard, especially the inner part of BMR. In 2002, the maximum 24-hr concentration was as high as 0.30 mg/m^3 (1.5 times higher than the standards). Current data showed that PM is a major concern in many areas apart from BMR such as Saraburi, Samutprakarn, Nakhon Ratchasima, Lampang, and Chiang Mai (PCD, 2004). An adjacent province to the east of Bangkok, Samutprakarn, has approximately 30% of daily PM-10 concentrations higher that the standards. The area in Samutprakarn is highly industrialized and congested. Vehicles, dust re-suspension, construction and commerce are major sources of PM in urban areas while agricultural burning is the significant source in rural areas (World Bank, 2002). It is estimated that about 350,000 tons of PM emitted annually from agricultural burning and forest fires.

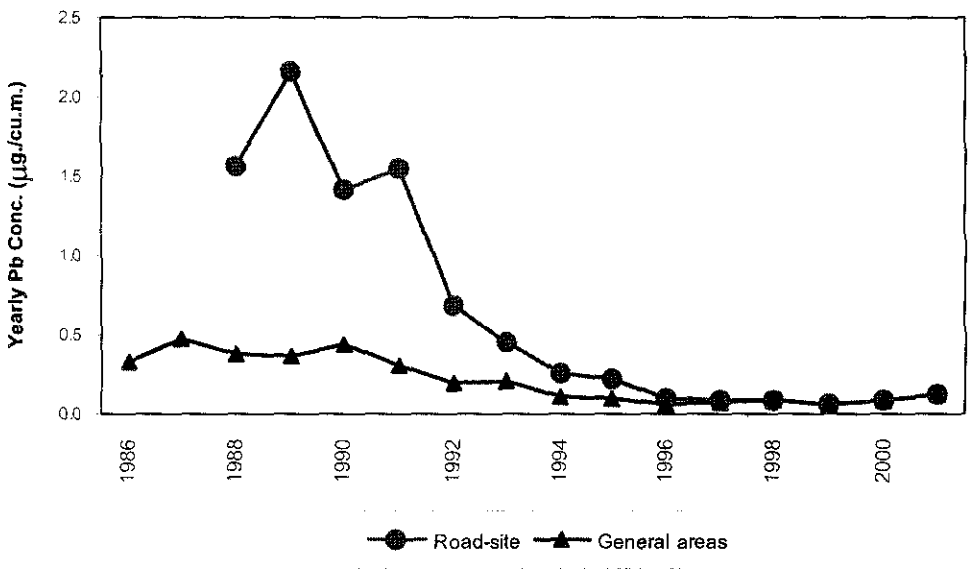

Figure 4. Yearly average Pb concentrations (µg/m^3) in BMR between 1986 and 2001 (Source: PCD, 2004).

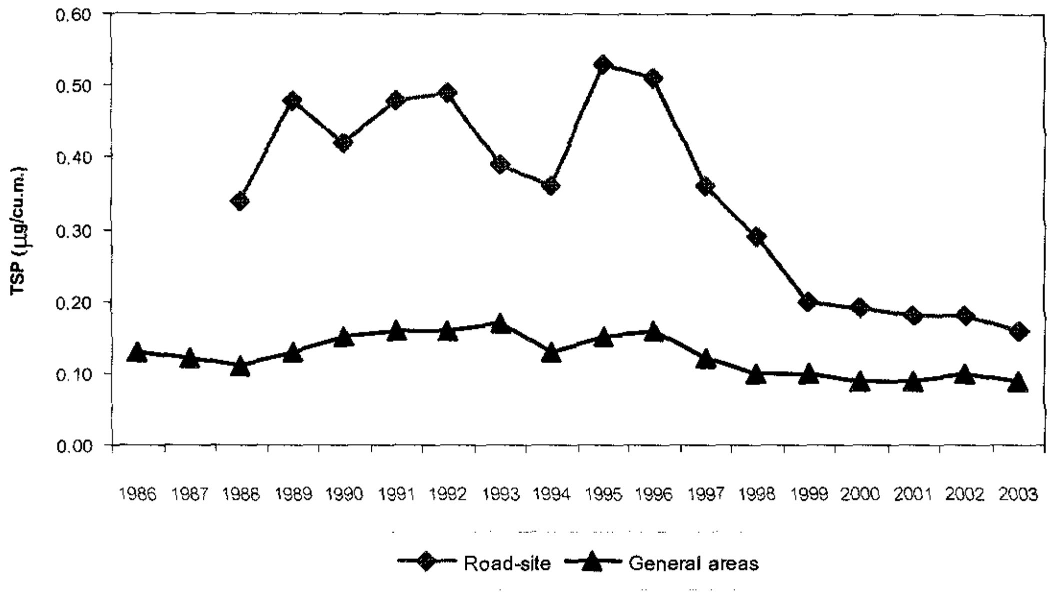

Figure 5. Daily average of TSP ($\mu g/m^3$) in BMR between 1992 and 2003 (Source: PCD, 2004).

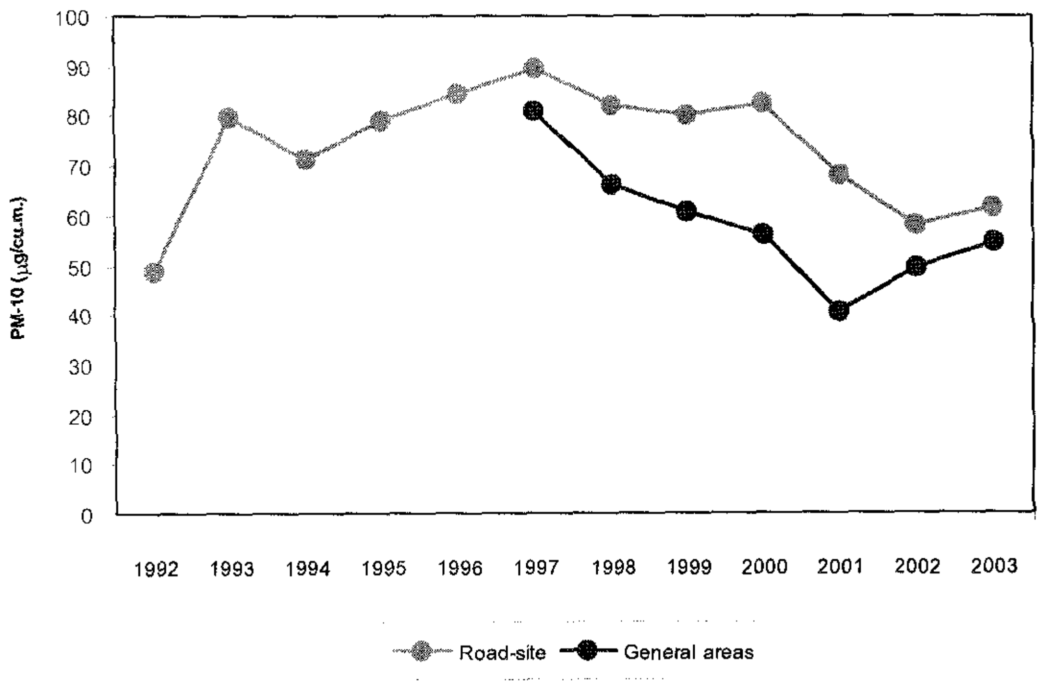

Figure 6. Daily average of PM-10 ($\mu g/m^3$) in BMR between 1992 and 2003 (Source: PCD, 2004)

Concerns over possible health effects on fine PM to the general public initiate PCD to monitor PM-2.5 in recent years. Preliminary data indicated that PM-2.5 concentrations were high at road-side stations while the general areas were similar at the stations located 10-20 km apart (Table 2). Average ratio of PM-2.5 to PM-10 in BMR ranged from 0.64 to 0.67 (Chuersuwan *et al.*, 2004). Spatial distribution of PM-2.5 levels in BMR was better than PM-10 due in part to its size. Currently, PCD is monitoring PM-2.5 at two locations in BMR due to limited monitoring equipment.

Table 2. Preliminary data for PM-2.5 in BMR during 2002 (Chuersuwan *et al.*, 2004)

Average 24-hr PM-2.5 concentrations (μg/cu.m.)				
Stations	N	Average ± σ	Minimum	Maximum
• Central BMR (road-side)	99	69.0±28.8	12.3	150.3
• Northern BMR	103	40.9±21.4	9.2	109.8
• Southern BMR	93	41.5±24.6	11.3	144.4
• Eastern BMR	88	37.9±18.9	8.0	103.9

Ozone still poses problem in general areas of BMR, unlike TSP (Figure 7). Observed high ozone often found at downwind locations from the center of Bangkok. In 2002, average one hour standard was exceeded more than 32 days and maximum concentration was as high as 169 ppb in BMR. Historical data indicated that average concentrations did not exceed the standards at all stations but maximum concentrations exceeded the standards more frequently. In Bangkok, controls of VOCs emissions seems to be the benefit to lower ozone concentrations more than the control of NO_x concentrations (World Bank, 2002).

Other conventional air pollutants do not currently pose significant problems to the public according to their concentrations. Average CO concentrations from 1994 at road-side stations were steadily declined and well below the standards (Figure 8). In the past, average 1-hr CO concentrations in the inner part of BMR were occasionally high. Other regions of Thailand have low CO concentrations and the downward trend was observed partly due to the mandated use of unleaded gasoline and the installation of catalytic converters on automobiles in 1993. SO_2 concentrations are not problems in BMR (Figure 9), but it used to be a major concern in the vicinity of a large lignite-fire power plant in the northern part of Thailand in 1992 causing health problems to nearby residences. Flue

Gas Desulfurization scrubbers are required for all the unit of the power plants to prevent such problems. Level of NO_2 in BMR is relatively stable over the years (Figure 10) and the levels account only 20% of the standards.

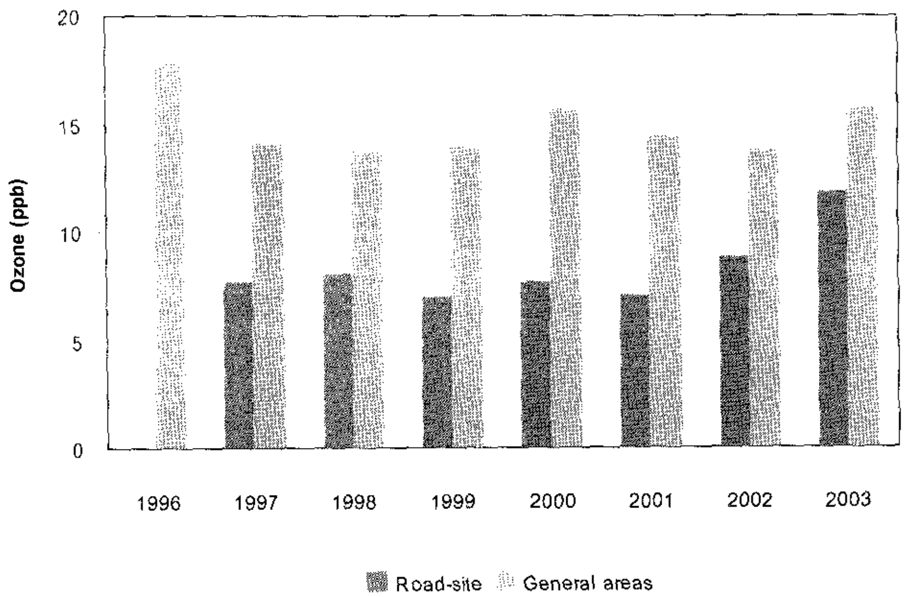

Figure 7. Average 1-hr ozone in BMR during 1996 and 2003 (Source: PCD, 2004).

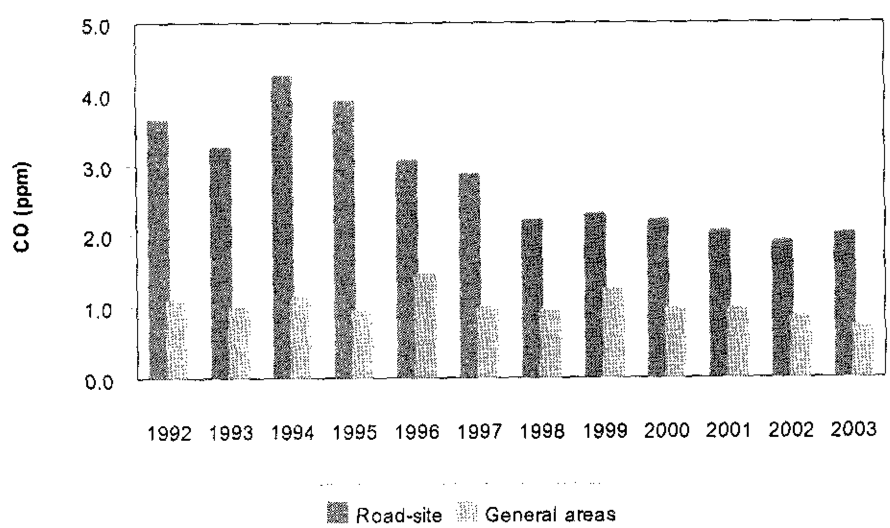

Figure 8. Average 1-hr CO concentrations in BMR during 1992 and 2003 (Source: PCD, 2004).

Several sources contribute to air emissions are motor vehicles, construction, power plants, factories, agricultural burning, forest fires, open cooking (World Bank, 2002). Approximately 60-70% of industrial emissions are in the central region. In urban areas, diesel and aging buses and trucks, two-stroke vehicles are significant for air quality.

Continuing improvement of air quality is relentless affords from PCD that have been implemented through policies and enforcement in various aspects, such as stringent emission standards, replacement of two-stoke engines with four-stroke engines, the use of EIRO II buses, etc. The power industries have shifted to more natural gas and low-sulfur coal. However, small and medium enterprises still cause air pollution problems in several regions (World Bank, 2002). With governmental report on better air quality, a survey indicated that three out of four Bangkok residents still think of air pollution as a major problem in the city. Public skeptical probably implies insufficient public participation (World Bank, 2002).

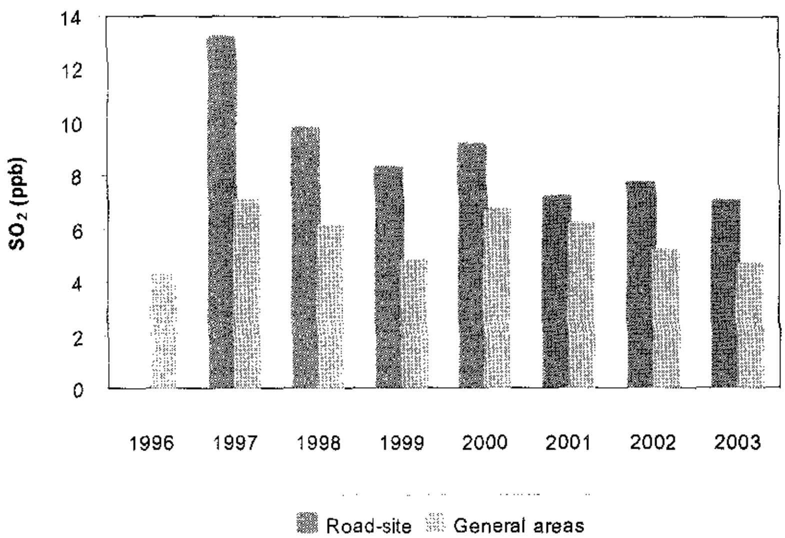

Figure 9. Average 1-hr SO_2 concentrations in BMR during 1996 and 2003 (Source: PCD, 2004).

Part of the measures to ameliorate air pollution was integrated into the socioeconomic and public participation. Empowering the public has been demonstrated in some communities in Bangkok and Chiang Mai. Public education and involvement were the keys to create awareness among the community leaders. Simple white cloths once used as an air monitoring tool for the communities in Bangkok (the darkening of the cloths simply imply bad air quality in the areas). In Chiang Mai, researchers mobilized the communities in various levels, i.e., religious leaders, students, community leaders, etc. Regular radio broadcast and field activities were part of the strategies. These projects were the contributing supports from Thailand Research Fund (TRF).

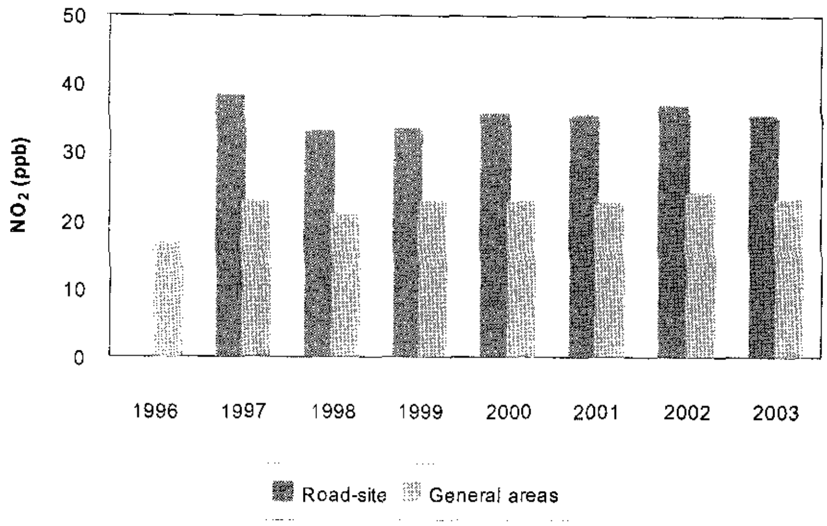

Figure 10. Average 1-hr NO_2 concentrations in BMR during 1996 and 2003 (Source: PCD, 2004).

3. Health study and air pollution in Thailand

Health study regarding to PM-10 has been conducted in the school students aged between 7 and 12 years old in Bangkok. The result reported that observed respiratory symptoms were high among the students who exposed to high PM-10 levels (Vichit-Vadakan, 1995). Rate of occurrence was corresponded to daily PM-10 levels, but PM-10 levels had no relationship with a lung function (PEFR = peak expiratory flow rate). During 1992 and 1993, the World Bank conducted a study in BMR on daily hospital admissions for respiratory and cardiovascular illnesses at five hospitals that associated with air pollution levels. The results indicated that at current PM-10 concentrations in BMR associated with 4,000 to 5,500 premature deaths each year, based on the population of 10 millions. The deaths were attributed to short-term exposures to outdoor PM. Hospital admissions causing by respiratory and cardiovascular illness are higher when PM-10 concentrations are higher (Radian, 1998).

Recently study by Vichit-Vadakan (2004) examined the relationship between daily mortality and daily mortality from 1996 to 2001. The results indicated a 10 $\mu g\ m^{-3}$ change in daily PM-10 is associated with a 0.5% increase in total mortality (95% confidence interval). The panel study examined short-term exposure to PM-10, PM-2.5, EC, OC, NO_2, SO_2, and CO for a period of 99 days in 2002. This study observed weak effect of particulate air pollution and OC component with respiratory symptoms in healthy children and adults. Exposure to lag 1 day of interquatile range (IQR) of ambient PM-2.5 was associated with wheezing in children (OR 1.37, 95%CI: 1.12, 1.68), and an IQR (3.4 $\mu g/m^3$) increased in OC was modestly associated with increased of cough (OR 1.04, 95%CI: 1.0, 1.08) and wheezing (OR 1.08, 95%CI: 0.99, 1.16) in adult. Estimated 156 cases of death from respiratory symptom in children (wheezing) can be reduced if daily PM-10 standard reduced from 60 $\mu g/m^3$ to 50 $\mu g/m^3$.

World Bank (2002) estimated health impact and cost by PM-10 for 2000 (Table 3). The methodology used in the estimates based on: an increase of 1 $\mu g/m^3$ in PM-10 was estimated to increase the mortality rate by 0.084%, chronic bronchitis cases to 3.06 per 100,000, and incidence of respiratory symptoms to 18,300 per 100,000. The World Bank report has found encouraging results in term of health and financial benefit. Fine PM is a crucial environmental risk factor for cardiopulmonary and lung cancer mortality, 6% and 8% increase for each 10 mg/m^3 in fine PM increased. Radian (1998) estimated that reduction of annual 10 $\mu g/m^3$ PM-10 would reduce adverse health effect in Bangkok: 700-2,000 premature deaths, 3,000-9,300 new cases of chronic respiratory disease, 560-1,570 respiratory and cardiovascular hospital admissions.

In term of toxic air component, a study investigated an exposure to polycyclic aromatic hydrocarbons (PAHs) among eighty-nine non-smoker traffic policemen working on Bangkok streets between 1996 and 1997. Personal air samplers were used to collect particulate PAHs. The results showed that the traffic policemen were exposed to a twenty fold higher than those who work in the office, 74.25 ng/m^3 (Ruchirawat *et al.*, 2002). This study also suggested that the use of a simple facemask helped reducing PAHs exposure, observed from the decline in a biomarker (1-hydroxypypene). However, people who work in the air conditioning office exposed to similar levels of PAHs in other countries.

Table 3. Estimates of Thailand health impact and cost by PM-10 in four cities for 2000 (World Bank, 2002).

City	PM-10 ($\mu g/m^3$)	Population (Million)	Mortality Rate	Excess deaths	Chronic Bronchitis	Cost ($ M)
Bangkok	64	5.7	0.0065	1,092	4,550	424.0
Chiang Mai	57	1.6	0.00985	390	1,080	56.8
Nakhon Ratchasima	51	2.6	0.0055	286	1,426	56.8
Songkhla	41	1.2	0.0061	104	464	21.0

Comparing blood-lead levels of 479 out of 810 subjects prior to and after the ban of unleaded gasoline in 1993 and 2000 showed blood-lead levels were significantly lower in 2000 than in 1993. Average blood-lead levels of students in 1993 was 8.56 μg/dL compared to 5.58 μg/dL in 2000 (Vichit-Vadakan and Sasivimolkul, 2003). Only 2.7% of the current students had blood-lead level higher than 10 μg/dL. Data in 1993 showed that about 26% of the students had blood-lead level above 10 μg/dL. Approximately 90% of the policemen had blood-lead levels lower than prior to ban the use of leaded gasoline. Benefit of health from the ban of leaded gasoline was estimated to be 32 times higher than the cost of retrofitting the equipment for oil refinery plants in Thailand.

A northern region in Thailand was effected by SO_2 emitted from lignite-fire power plant. A study showed that the risk to respiratory diseases of the people was three times higher than the control population (Vichit-Vadakan, 2001). A toxicological study of PM-10 and PM-2.5 on human cell has been studied in Thailand. The results indicated that collective extracts of PM-2.5 or PM-10 collected from Chiang Mai in the months of winter caused mutagenic to *Salmonella typhimurium* strain TA100 without metabolic activation. The mutagenicity appeared to track particle concentrations (Vinitketkumnuen *et al.*, 2002). It is worst notice that lung cancer incident in 2000 for Hang Dong District, Chiang Mai are very high, 45 per 100,000 population, compared to 8 per 100,000 population for the general population in Thailand.

4. Summary

Trends of air quality in Thailand are somewhat relating to economic expansion. Decade of the economic and industrial expansion came with a heavy toll on urban air pollution, especially in BMR. TSP levels, specifically, were several times above the NAAQS (0.33 mg/m^3) in 1995. Prior to the era of a massive investment in various industries air quality is not a serious concern and limited to household levels, stove cooking with charcoal, including agricultural burning in the rural areas. Public outcry was clear in BMR when the effect from air pollution was vividly on the streets and people started to feel uncomfortable and irritating from dust, smoke generated from the traffic, industries and constructions. Mitigation measures have been carried on for decade by responsible agencies to curb the air pollution that being effected millions of the residence.

Improving air quality in some areas is an achievement and hard working of responsible agencies, especially PCD, not to mention the effect of the economic crisis in 1997. Despite such achievement, air pollution still poses problems to the public for certain pollutants, fine PM and photochemical air pollutants, since the economic starts to recover. Measures used to push the policy into action, to some extent, bases upon technology and conventional approaches. A few studies from research community have been used to provide supports of such policy. Lack of funding is always an issue similar to other countries, but benefit to the public health is greater than cost of implementing mitigations measures.

5. References

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6. Acknowledgements

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