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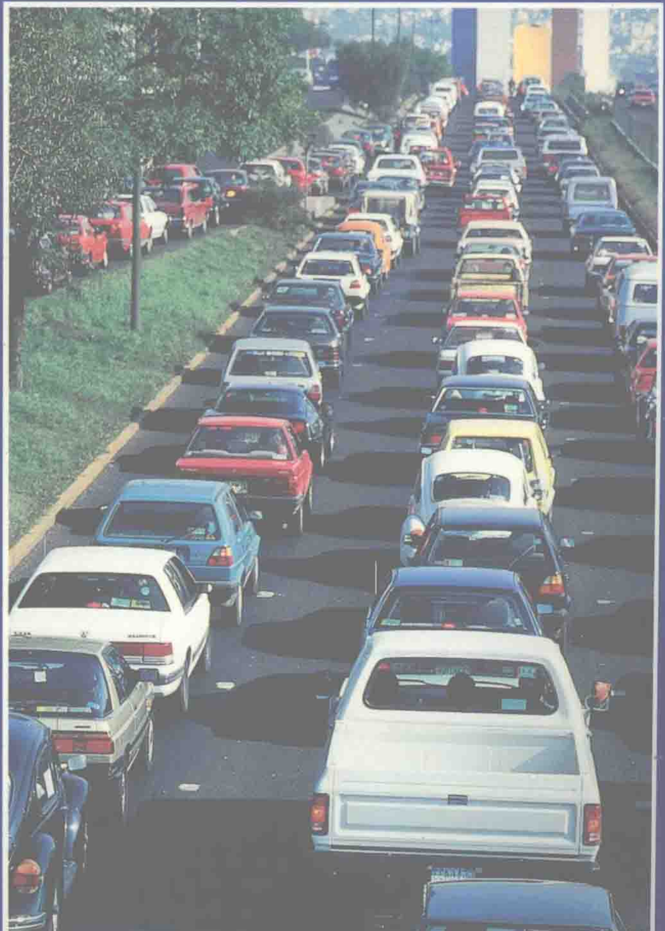
Clean Fuels for Asia

Technical Options for Moving toward Unleaded Gasoline and Low-Sulfur Diesel



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The World Bank
Washington, D.C.

FOREWORD

Air pollution has become a serious issue in many Asian cities. A major cause is the expanding motor vehicle population—with growth rates as high as 23 percent in rapidly growing economies such as China. Policymakers in Asia are beginning to review options to deal with vehicular pollution reduction. Experience worldwide has shown that the use of clean fuels—low-lead or unleaded gasoline and low-sulfur diesel—is a cost-effective way of reducing vehicular emissions.

The use of cleaner fuels in conjunction with catalytic converters would limit the total amount of emissions, thus reducing damage to human and ecosystem health. Its use would also lead to lower costs in terms of vehicle maintenance and efficiency for the individual owner.

This report describes strategies, incentives, and methods to increase the use of clean fuels. It provides policymakers with a range of alternatives that can be employed to develop a clean fuel strategy. We hope this report will assist policymakers to make informed choices among technical and financial options available for designing a clean fuels program that could ultimately improve Asian cities' air quality significantly.

The Metropolitan Environment Improvement Program (MEIP) facilitated the preparation of this publication by providing the authors with financial support, background data, and links to Asian cities participating in MEIP. We hope that this report will be widely used by decisionmakers in MEIP cities and in other cities throughout Asia.

Maritta Koch-Weser
Chief
Asia Environment and Natural Resources Division

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The authors of this report are Michael P. Walsh (consultant) and Jitendra Shah (World Bank).

In the World Bank's Asia Environment and Natural Resources Division, the Clean Fuels report was managed by Jitendra Shah, under the advice and guidance of Maritta Koch-Weser, Division Chief, and David Williams, MEIP Program Manager. Internal reviews and comments were provided by Asif Faiz, P. Illangovan, Masami Kojima, Victor Loksha, Magda Lovei, Tanvi Nagpal, Anil Somani, Gautam Surhid, Cor Van Der Sterren, Walter Vergara, Ronald Waas, L. Wijitilleke, and Yaacov Ziv. External peer reviewers were Charles Freed (U.S. Environmental Protection Agency), Bernie James (Natural Resources Canada), Gregory Rideout (Environment Canada), and Tazio Yamada (consultant). The list of international emissions and fuel standards contained in Appendix D was provided by Gregory Rideout (Environment Canada). Annice Brown was responsible for accuracy and editing. Julia Lutz provided editorial support and designed the report's layout.

Abbreviations, Acronyms, and Data Notes

AQG	Air Quality Guideline
AQIS	Air Quality Information System
AQMS	Air Quality Management System
BHP	brake horsepower
BaP	benzo(a)pryene
BTU	British Thermal Unit
CARB	California Air Resources Board
CDC	Centers for Disease Control (U.S.)
CNG	compressed natural gas
CO	carbon monoxide
DDT	dichloro diphenyl trichloro ethane
ETBE	ethyl tertiary butyl ether
EGR	exhaust gas recirculation
EU	European Union
EV	Electric vehicle
FCC	fluid catalytic cracking
FTP	Federal Test Procedure (U.S.)
GDP	gross domestic product
GEMS	Global Environmental Monitoring System
HC	hydrocarbons
IPCC	Intergovernmental Panel on Climate Change
LPG	liquefied petroleum gas
µg	micrograms (10^{-6} grams)
mg	miligrams (10^{-3} grams)
g/m^3	micrograms per cubic meter
MCPA	methylchlorophenoxyacetic acid
MEIP	Metropolitan Environmental Improvement Program (World Bank)
MMT	metylclopentadieny manganese tricarbonyl
MON	motor octane number
MTBE	methyl tertiary-butyl ether
NGO	non-governmental organization
NGV	natural gas vehicle
NH_3	ammonia
NMHC	non-methane hydrocarbons
NO_x	nitrogen oxides
NO_2	nitrogen dioxide
OECD	Organization for Economic Cooperation and Development
PAHs	polynuclear aromatic hydrocarbons
Pb	lead
PM	particulate matter
PM_{10}	particulate matter 10 microns or less
ppm	particles per million
PNA	polycyclic nuclear aromatics
RFG	refomulated gasoline
RVP	Reid vapor pressure
SO_2	sulfur dioxide
SOF	soluble organic fraction
SPM	suspended particulate matter
TBA	tertiary butyl alcohol
TSP	total suspended particulate
TWC	three-way catalyst
UNDP	United Nations Development Program
URBAIR	Urban Air Quality Management Strategy in Asia (World Bank)
USAID	U.S. Agency for International Development
USEPA	U.S. Environmental Protection Agency
VOCs	volatile organic compounds
WHO	World Health Organization

1 gallon (U.S.) = 3.785 liters
1 mile = 1.609 kilometers

Note: Except as indicated, "dollars" refers to 1995 U.S. dollars.
Except as indicated, all boxes, figures, and tables were compiled for this report by the authors.

ABSTRACT

Motor vehicles have brought increased mobility and access to employment for greater numbers of people in Asia in the last decade. However, these benefits have been partially offset by excess urban air pollution and damage to the ecosystem and human health. This report focuses on the abatement of vehicular pollution through the use of cleaner fuels, such as unleaded gasoline and low-sulfur diesel. It aims to provide decisionmakers with a methodology for making informed choices concerning the production and use of cleaner transport fuels for motor vehicles. Transport demand management, inspection and maintenance, and advancement of vehicle technology are the other components of a vehicle pollution prevention program.

This report recommends that governments adopt a strategy for the progressive elimination of lead from gasoline. In conjunction with catalytic converters, unleaded gasoline use leads to reductions in major pollutants such as hydrocarbons, carbon monoxide, and nitrogen oxides. Unleaded gasoline should be made cheaper than leaded gasoline at the pump. In addition to this priority step, it is also crucial that other clean fuels be promoted. For example, the sulfur content of diesel fuel should be reduced to control emissions of sulfur and particulates. Alternative clean fuels such as natural gas and liquefied petroleum gas should also be promoted.

Poorly maintained cars are responsible for a disproportionate amount of emissions. Regular inspection and maintenance of vehicles results in a substantial reduction in particulate, volatile organic compounds, and carbon monoxide emissions.

Contents

Boxes

Figures

Tables

EXECUTIVE SUMMARY

Motor vehicles have brought increased mobility, and access to employment for greater numbers of people in Asia in the last decade. However, these benefits have been partially offset by excess urban air pollution and damage to human and ecosystem health. Asian countries can no longer ignore air pollution, and must begin to design comprehensive air quality management systems. These systems should encompass not only transport policy but also large industries, small enterprises, and domestic sources of pollution.

This report focuses on the abatement of vehicular pollution through the use of cleaner fuels such as unleaded gasoline and low-sulfur diesel. The pollutants like lead and particulate matter (from diesel and other vehicles) are targeted because they have been identified as the largest contributors to health damage in urban areas. This report aims to provide decisionmakers with a methodology for making informed choices con-cerning the production and use of cleaner transport fuels for motor vehicles. Transport demand management, inspection and maintenance, and advanced vehicle technology are the other components of a vehicle pollution prevention program.

The report recommends the following prioritized policy options:

1. **Adopt a strategy for the progressive elimination of lead from gasoline**. Using unleaded gasoline and catalytic converters also leads to reductions in other major pollutants such as hydrocarbons, carbon monoxide, and nitrogen oxides. Unleaded gasoline use should be encouraged through clean vehicle standards and by making it cheaper than leaded gasoline at the pump. The benefits of eliminating lead outweigh the costs.
2. **Reduce the sulfur content of diesel fuels**. Reducing sulfur in diesel has the dual advantage of lowering sulfur dioxide and particulate matter emissions, and can be a cost-effective option. Lowering the fuel density is also an effective means of reducing fine particulate emissions. Other diesel fuel properties such as volatility, aromatic content, and additives may have a positive or negative effect on emissions. In addition to the adoption of mandatory limits on sulfur, tax policies can be very effective in encouraging the use of low-sulfur diesel.
3. **Encourage the use of alternative fuels**. Alternative fuels that have been proven cost-effective should be promoted through policies that encourage substitution. Conservation of oil products, energy security, and climate change or global warming are additional reasons for encouraging the use of alternatives to conventional fuels.

In addition to these three important steps, the regular inspection and maintenance of vehicles should be encouraged. Poorly maintained cars are responsible for a disproportionate amount of vehicle emissions. Semi-annual inspection and maintenance of vehicles results in a substantial reduction in particulates, volatile organic compounds, and carbon monoxide emissions. Emissions reduction can occur simultaneously with improved fuel economy and diminished need for repairs.

Asia's vehicle population is projected to continue growing well into the next century. If no action is taken now, air quality is bound to deteriorate, exacting a high toll on human health and possibly undermining many economic development gains. Based on lessons learned in other parts of the world, this report offers Asia's policymakers some valuable tools and suggestions for confronting the worsening air pollution situation now, and ensuring a cleaner environment in the future.

CHAPTER 1: INTRODUCTION

This report provides the methodology for improving air quality in large Asian cities through the use of clean fuels. This study is directed to decisionmakers whose policies have a direct impact on the production and use of cleaner transport fuels. The objective of this report is to provide a technical overview of the challenges and opportunities for lowering vehicle emissions by means of fuel modifications or substitutions. Issues receiving particular attention are **reducing** and **removing lead in gasoline** and **reducing sulfur in diesel fuel**.

BACKGROUND

In 1995, the global motor vehicle population, including passenger cars, trucks, buses, motorcycles, and three-wheeled vehicles (tuk-tuks or rickshaws) exceeded 700 million for the first time in history. While most of these vehicles remain concentrated in the highly industrialized Organization for Economic Cooperation and Development (OECD) countries, an increasing number of urbanized areas in developing countries, especially in Asia, now contain many motorized vehicles. Cities including Bangkok, Jakarta, and Seoul have some of the most congested roads in the world. While these vehicles have brought many advantages, including increased mobility and flexibility for millions of people and more jobs, and enhanced many quality-of-life aspects, the benefits have been partially offset by excess pollution and adverse effects on human health and the environment.

Motor vehicles emit large quantities of carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), and toxic substances such as fine particles and lead, as well as contributing to secondary by-products such as ozone.[1] Reducing vehicular pollution usually requires a comprehensive strategy encompassing the following elements:

- automobile demand management (incentives to reduce automobile use such as road tolls, parking restrictions, area licensing schemes, mass transit availability, etc.);
- inspection and maintenance;
- advanced vehicle technology; and
- clean fuels.

This report focuses primarily on clean fuels. It starts with a brief summary of the air pollution problem in selected Asian cities, followed by the challenges and opportunities for lowering vehicle pollution through greater use of clean or alternative fuels. The remainder of the report explores some of the pollution control efforts underway in the region.

THE AIR QUALITY SITUATION IN ASIA

Over the course of the past two decades, there has been an explosive growth in many Asian countries' motor vehicle populations. As a result, serious air pollution exposure problems caused by vehicle emissions are emerging. The section below takes a brief look at nine Asian cities.

Bangkok, Thailand

Eleven years of air quality monitoring indicate that the air pollutants of greatest concern in Bangkok are suspended particulate matter (SPM), especially respirable particulate matter (PM_{10})[2], CO, and lead, caused mostly by the transport sector. Current SPM levels in Bangkok's air, especially along congested roads, far exceed Thailand's primary ambient SPM air quality standard. In 1993, curbside 24-hour average concentrations exceeded this standard on 143 out of 277 measurement days. Mobile sources continue to be the Bangkok population's biggest source of exposure.

Beijing, China

In spite of a relatively small vehicle population, air pollution problems caused by motor vehicles have started to emerge in major Chinese cities, especially Beijing. The number of automobiles in Beijing is almost 10 percent of the total in all of China (19 million), and many Chinese-made vehicles still use 20-year old designs, resulting in CO and HC emissions rates that are 10–20 times the levels emitted by modern engines. According to an air quality survey, motor vehicles contribute about half of the total CO, HC, and NO_x emissions coming from all pollutant sources. Lead is another pollutant of concern; concentrations of lead in Beijing are 1–1.5 $\mu g/m^3$, and have reached 14–25 $\mu g/m^3$ in extreme cases.

Ho Chi Minh City, Vietnam

Although available air quality data are limited, the Institute of Hygiene and Public Health conducted a monitoring study in 1993. Results showed that particulates, or dust, are a very serious problem at present, and that CO and nitrogen dioxide (NO_2) also exceeded current Vietnamese standards. The study demonstrated that although many sources certainly contribute to these problems, vehicle emissions seem to dominate.

Hong Kong, China

Particulates are Hong Kong's most serious pollution problem at present, and motor vehicles are estimated to be responsible for approximately 50 percent of PM_{10} emissions. Using the methodology developed by the California Air Resources Board, the Hong Kong Environmental Protection Agency estimates that particulates from diesel vehicles alone cause approximately 290 premature deaths from lung cancer each year.

Kuala Lumpur, Malaysia

Based on available 1992 data, it was concluded that the air pollution problem is relatively serious in comparison with accepted air quality guidelines.[3] Annual and daily PM_{10} averages regularly exceeded guidelines, as did CO and ozone. Follow-up studies in 1994 continued to show serious problems, as particulates routinely exceeded guideline limits and appeared to be worsening. NO_2 and particulate matter were the most pervasive air pollutants, and motor vehicles were again found to be the main source of air pollution.

Manila, the Philippines

In Metro-Manila, air quality data are available, and measured concentrations of PM_{10} routinely exceeded acceptable levels by a factor of more than three. Measured total suspended particulates (TSP) exceeded acceptable levels by even larger percentages. Lead concentrations also exceeded Government standards.[4] Monitoring indicates that both CO and NO_2 occasionally exceed standards. Measurement for sulfur dioxide (SO_2) and total oxidants indicated concentrations, at present, were within acceptable standards. Motor vehicles were found to contribute over 40 percent of PM_{10}.[5]

Jakarta, Indonesia

During the ten-year period between 1981 and 1991, Jakarta's population doubled; there was also a tremendous rise in the number of vehicles, from approximately 900,000 to 1,700,000, making Jakarta's growth rate one of the highest in developing countries. These changes are reflected in the city's poor air quality. Overall, traffic and industry are Jakarta's main sources of air pollution. TSP emissions are estimated at 96,733 tons per year, PM_{10} emissions total 41,369 tons per year, and NO_x emissions are calculated at 43,031 tons per year. Annual TSP averages in the most polluted areas are 5–6 times the national air quality guidelineand varied from 180 to 600 $\mu g/m^3$. Motor vehicles were found to contribute 40 percent or more to PM_{10}.[6]

Mumbai, India

Greater Mumbai's population grew 38 percent between 1971 and 1981, and another 20 percent by 1991, reaching 9.9 million. The expansion of industry, increased production, and a 103 percent increase in the number of motor vehicles has led to a severe air pollution problem. Diesel trucks and three-wheel vehicles contribute significantly to air pollution. The annual TSP concentration increased from 180 $\mu g/m^3$ to approximately 270 $\mu g/m^3$ between 1981 and 1990, an increase of almost 50 percent. Total annual emissions of TSP and PM_{10} are estimated at 32,000 and 16,000 tons, respectively, per year. World Health Organization (WHO) air quality guidelines and national guidelines for TSP are frequently exceeded in Mumbai. Of the population, 97 percent lives in areas where the WHO guideline is exceeded. Measures to reduce air pollution in Mumbai must focus on the most important source—traffic—which contributes about 50 percent of PM_{10}.[7]

Kathmandu, Nepal

Kathmandu Valley's population grew 44 percent between 1980 and 1990. In 1992, its population was estimated at 1,060,000, of which 54 percent was urban. The growth in population has been accompanied by a doubling in the number of motor vehicles in the past decade, which can be seen in increases in the use of gasoline (150 percent), motor diesel (175 percent), kerosene (250 percent), and fuel oil (580 percent) during 1980–93. Air pollution measurements show that particulate pollution is the most significant problem in the Kathmandu Valley. Total TSP emissions per year amount to 16,500 tons. PM_{10} emissions are 4,700 tons per year. WHO guidelines for TSP and PM_{10} are often substantially exceeded. TSP concentrations have been measured at above 800 $\mu g/m^3$ (WHO TSP guidelines are 150–230 $\mu g/m^3$). Visibility in the Valley has been reduced substantially, which has impacted tourism, one of Nepal's major sources of revenue.[8] Motor vehicles and scattered small brick manufacturers were found to be the largest source of human exposure to air pollution.

CONCLUSIONS

As the above examples illustrate, many major Asian cities' current air quality levels already reflect serious air pollution, with the transport sector contributing about 50 percent of PM_{10}.

Because the vehicle populations in most of these cities continue to grow, often at rates exceeding 10 percent per year, future air pollution problems will be even more serious unless aggressive control efforts are undertaken. Fortunately, several countries in the region have developed significant pollution control efforts, which are the subject of chapter 5.

ENDNOTES

1. See appendix A for a detailed review of adverse health affects associated with vehicular air pollution.
2. PM_{10} refers to particles in the size range of 10 microns or less. All of these particles are con-