Initiative for Policy Dialogue
Based at Columbia University

Working Paper Series

Urban Air Pollution, Health and Policy Instruments

Alan J. Krupnick

Task Force on Environmental Economics

1. Introduction

Many developing countries have experienced increased urban population and economic growth over the last few decades. This trend brings about increased pressure on public health through air pollution that results from the growth in mobile and stationary sources. At the same time, economic growth may improve the health care system and may result in greater expenditure on cleaner technologies and better pollution abatement equipment, which reduces emissions per unit output. Further, as a country's economy matures, it relies less on manufacturing and more on service sectors, which are less polluting.[1]

The purpose of this chapter is to examine the record of urban population growth, health, and health care spending in developing countries, describe the linkage between urban air pollution and health,[2] and weigh policy responses to reduce stationary and mobile source air pollution, illustrating options through case studies.

2. The Situation in Urban Areas of Developing Countries

2.1 Urban Population Growth

Global urban populations have been growing steadily, irrespective of income group, since 1960. The pace has been particularly rapid, however, in the developing countries (low income and lower middle income countries, see Figure 1).[3] Underlying this trend are both increases in the general population and an increases in the urban share of the national population. The urban population share appears to have leveled out in the high income countries at about 78%. The urban share for the upper middle income group, while starting from a much lower base in 1960, increased at a much faster rate to also reach 78% by 2001 (Figure 2). Urban shares for developing country groups are much lower than those for higher income countries, and their trends are quite different from each other. Urban population shares increased from 25% to 45% over 1960-2001 in the lower middle income group but only from 18% to 31% in the low income group.

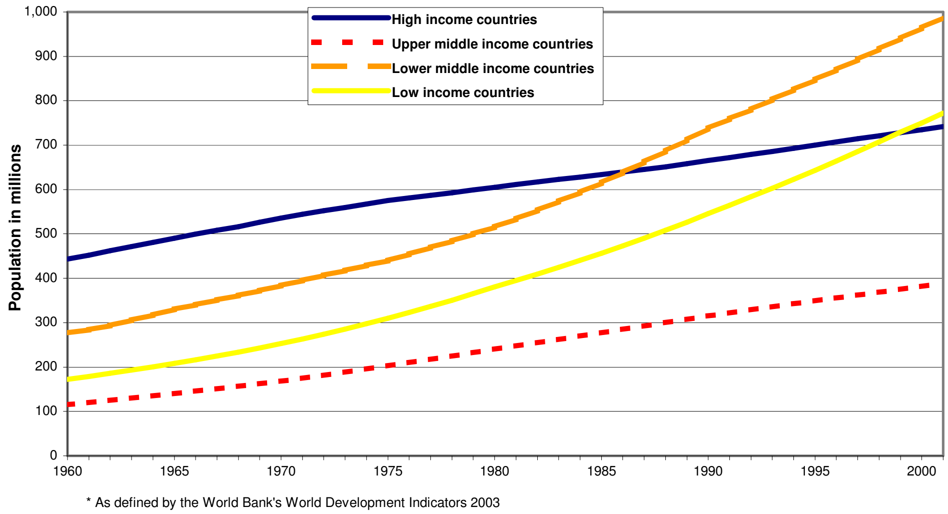
Figure 1.

[1] These factors can be summed up in the environmental Kuznets curve (Andreoni and Levinson, 2001; Millimet, List and Stengos, 2003), which portrays total emissions rising with economic output to a point, where it tops out and then begins to fall as the economy matures further.

[2] The focus on outdoor air pollution should not be interpreted as a judgment that indoor air pollution is less of a problem or a more expensive problem to address. As will be seen below, indoor air pollution is probably a greater problem (and certainly a greater problem for the poor) and there are many low cost ways of reducing it, including through education, increasing ventilation in the home, and stove adaptations.

[3] From World Bank 2003: Low-income countries: Afghanistan, Guinea, Nigeria, Angola, Guinea-Bissau, Pakistan, Azerbaijan, Haiti, Papua New Guinea, Bangladesh, India, Rwanda, Benin, Indonesia, Sao Tome and Principe, Bhutan, Kenya, Senegal, Burkina Faso, Korea, Dem Rep., Sierra Leone, Burundi, Kyrgyz Republic, Solomon Islands, Cambodia, Lao PDR, Somalia, Cameroon, Lesotho, Sudan, Central African Republic, Liberia, Tajikistan, Chad, Madagascar, Tanzania, Comoros, Malawi, Timor-Leste, Congo, Dem. Rep, Mali, Togo, Congo, Rep., Mauritania, Uganda, Cote d'Ivoire, Moldova, Uzbekistan, Equatorial Guinea, Mongolia, Vietnam, Eritrea, Mozambique, Yemen, Rep., Ethiopia, Myanmar, Zambia, Gambia, Nepal, Zimbabwe, Georgia, Nicaragua, Ghana, Niger. Lower-middle income countries: Albania, Guatemala, Romania, Algeria, Guyana, Russian Federation, Armenia, Honduras, Samoa, Belarus, Iran, Islamic Rep., Serbia and Montenegro, Bolivia, Iraq, South Africa, Bosnia and Herzegovina, Jamaica, Sri Lanka, Brazil, Jordan, St. Vincent and the Grenadines, Bulgaria, Kazakhstan, Suriname, Cape Verde, Kiribati, Swaziland, China, Macedonia, FYR, Syrian Arab Republic, Colombia, Maldives, Thailand, Cuba, Marshall Islands, Tonga, Djibouti, Micronesia, Fed. Sts., Tunisia, Dominican Republic, Morocco, Turkey, Ecuador, Namibia, Turkmenistan, Egypt, Arab Rep., Paraguay, Ukraine, El Salvador, Peru, Vanuatu, Fiji, Philippines, West Bank and Gaza.

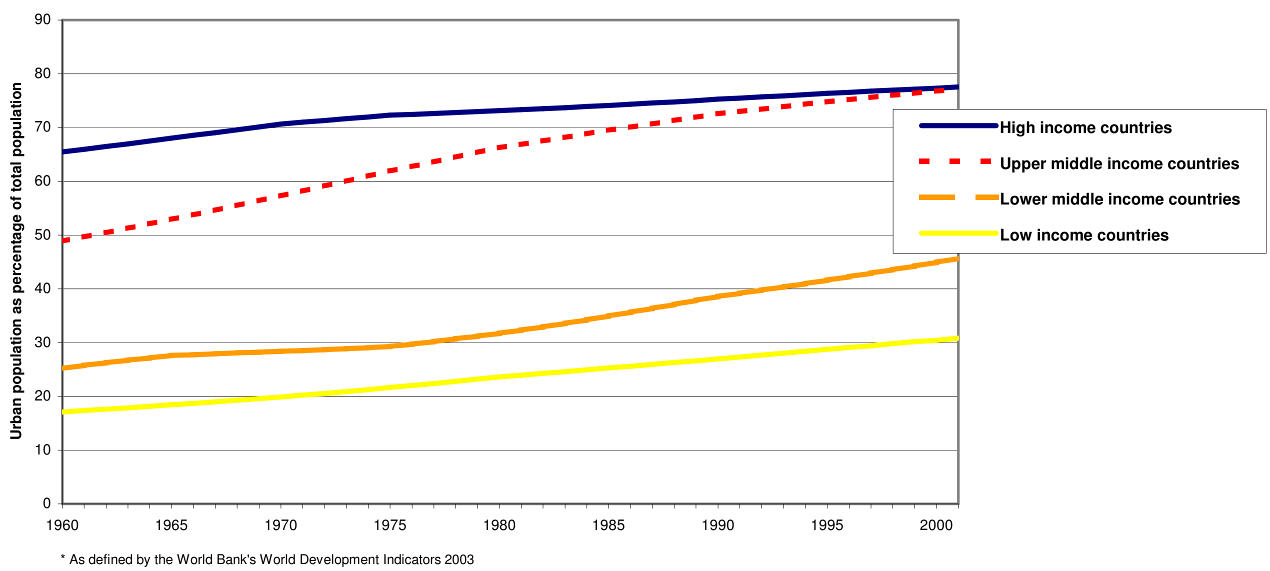
Urban Population by Income* 1960-2001



Source: World Bank 2003a

Figure 2.

Urban Population Share by Income* 1960-2001

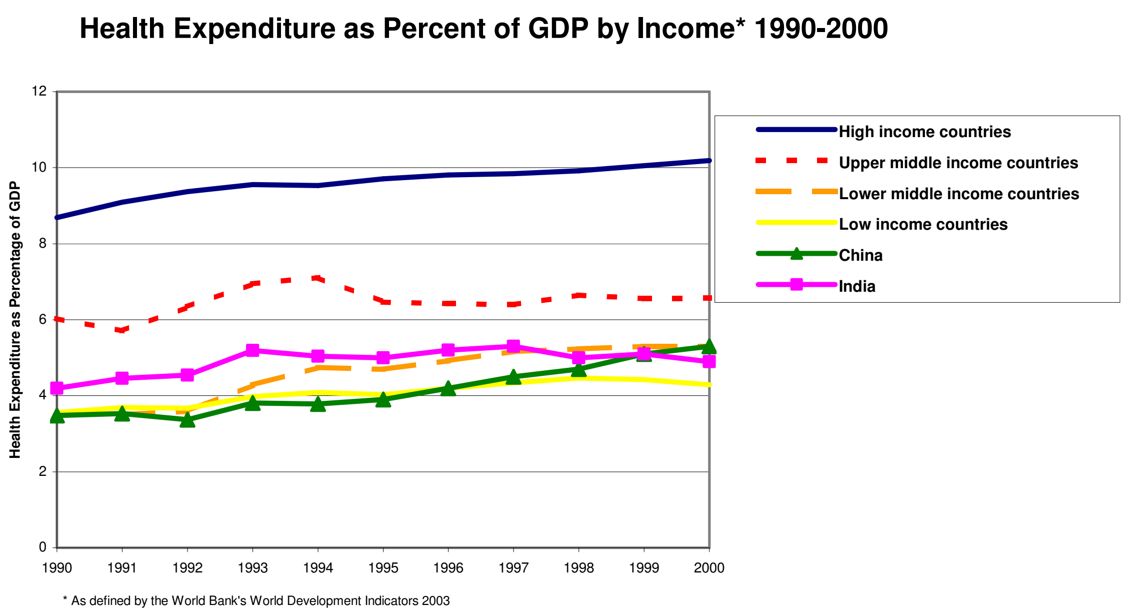


Source: World Bank 2003

Health Care Spending

Data on health care spending for the income groups discussed above are only available from 1990 to 2000 (Figure 3). These data give some indication that rising incomes are leading to a rising share of health care expenditures, but the trend is weak. With GDP rising throughout the decade in the low income countries, health care expenditures rose only slightly faster, with the share rising from about 3.5% of GDP in 1990 to 4.2% in 2000 (a period when expenditures in India were basically flat). In the lower middle income group, however, bolstered by China, expenditure shares rose from 3.5% to 5.5%. It might be argued that health care expenditures are driven more by increasing population than economic growth in these countries. Expenditures per capita, however, were basically flat for the lowest income developing countries and increased only moderately for the lower middle income group.

Figure 3.



Source: World Bank 2003a

Health Indicators

The most comprehensive analysis of health in the developing world, but one unfortunately not restricted to urban areas, is the recent World Health Organization (WHO) study on the Global Burden of Disease (WHO, 2003). This report describes mortality and "burden" (life-years, adjusted for disability, or DALYs) for regions throughout the world in 2000 and attributes these losses to specific risk factors, including outdoor air pollution and indoor exposure to air pollution from burning solid fuels.

The diseases related to air pollution include chronic obstructive pulmonary disease (COPD), asthma, acute respiratory disease, and ischaemic heart disease, with links to cancer, fetal abnormalities, low birth weight, and other less documented effects. In the high-mortality developing countries, DALYs from respiratory infections are rated the second highest cause of burden (at 8.2%) behind HIV/AIDS, with ischaemic heart disease ranked 8th (3%) (Table 1). The other diseases mentioned above fall far below 1%. In the lower-mortality developing countries, respiratory infections slide to third place (4.1%) with COPD (3.8%) and ischaemic heart disease (3.2%) making it into the top ten leading diseases (Ezzati et al. 2003).

Table 1. Top Ten Leading Diseases by Percentage of Regional Disease Burden

High-mortality developing regions		Lower-mortality developing regions	
HIV/AIDS	9.0%	Unipolar depressive disorders	5.9%
Lower respiratory infections	8.2%	Stroke	4.7%
Diarrhoeal diseases	6.3%	Lower respiratory infections	4.1%
Low birthweight	5.0%	Road traffic accidents	4.1%
Malaria	4.9%	Chronic obstructive pulmonary disease	3.8%
Unipolar depressive disorders	3.1%	Ischaemic heart disease	3.2%
Measles	3.0%	Birth asphyxia and birth trauma	2.6%
Ischaemic heart disease	3.0%	Tuberculosis	2.4%
Tuberculosis	2.9%	Alcohol use disorders	2.3%
Birth asphyxia and birth trauma	2.7%	Hearing loss	2.2%

Source: adapted from Ezzati et al. 2003

The Role of Air Pollution

How does urban air pollution fit into this story? On one hand, the health effects associated with air pollution are arguably the best documented of any *environmental* problems. For instance, a number of unusually comprehensive and careful epidemiological studies have constructed a link between fine particulate pollution and shortened life expectancy – studies that form the backbone of the U.S. EPA's recently implemented fine particulate matter ambient air quality standard. The concentration-response coefficients from these studies (such as Pope et al, 1995) indicate that mortality rates fall by about 3% for every 10 $\mu g/m^3$ annual average reduction of this pollutant. For example, for an urban center with a death rate of 1200 per hundred thousand people and a population of 10 million, this reasonable reduction could result in the reduction of 3,600 deaths per year. Since these health effects appear to be concentrated in the very young, the old, and the sick, they translate into very high benefits to these groups. Add to these the benefits from reduced hospital and emergency room visits, doctor visits, asthma and other respiratory sickness days, missed work and school, and other effects that must be far larger to lead to such a large death rate reduction, and the scope of these health improvements may be significant to the general population.

On the other hand, it would not be surprising to see a relatively small role for air pollution in any story about urban health in low income groups. For one thing, other risk factors, such as HIV/AIDS and smoking, may have a more significant effect. And, in countries with low life expectancy, people may die of other causes before their air pollution exposure catches up to them.

Even here, however, the interaction between various health effects points to a larger role for air pollution. For instance, if one is already sick due to a pollution-induced respiratory disease, the probability of getting sick in other ways may rise. Ozone exposure, for example, has been linked to impaired immune response. Additionally, the relationships can go the other way. If one is already sick from some disease, such as TB, one may be more likely to be affected by air pollution, by, for instance, developing or exacerbating an asthma condition. Further, living in a poor country without good health care means that pre-existing conditions are likely to be more prevalent relative to a developed country.

Based on standard, mostly western, epidemiological relationships, the WHO data presented in Ezzati et al. (2002) show a very small role for outdoor air pollution in the burden of disease in developing countries. They instead target the role of indoor air pollution from burning solid fuels for cooking and, in some areas, heating. Indoor air pollution is a problem for very poor people in rural areas and possibly a problem for developing countries in cold climates (e.g., China). Then again, outdoor air pollution may be tied more closely to economic growth, concentrated in the cities, and relevant primarily for countries with a high reliance on coal (e.g., China). Specifically, in Africa, deaths from outdoor air pollution are estimated to be only 0.5% of total mortality, whereas deaths from indoor smoke make up 4%. In the poorest of the poor African countries (with the highest adult death rates), this disparity is even greater. In contrast, in the Western Pacific region which includes China (and has low mortality rates), men are more likely to die from outdoor air pollution than indoor, while women are more likely to die from indoor smoke exposure. In total for that region, deaths from outdoor air comprise 3% of total mortality with indoor air at 4.8%.

Although urban air pollution plays a relatively small role in affecting health, it is does not follow that countries should not take action to control air pollution. One important criterion for priority setting may be the size of the risk. But another surely is efficiency, i.e., the net social benefits from reducing the risks, which depends on marginal costs and marginal benefits from reducing pollution. Air pollution reductions may be far easier and less expensive to achieve than some higher ranking causes of disease burden, such as HIV/AIDS, smoking cessation, and mental illness. More will be said on this topic later in the chapter.

2.5 What are the Most Serious Air Pollution Problems?

The contribution of various types of sources to creating emissions, the process transforming those emissions to air pollutants, and the effects of pollutants on health are reasonably well understood in developed countries, but little evidence exists specifically for developing countries.[4] Since the effects of air pollution are probably less potent in developed countries due to better health care, we can assume that the scientific understanding from developed (and some developing) countries holds in general for the rest of the world, but is a conservative estimate for developing countries.[5]

---

[4] Eastern European countries have been included in the Air Pollution on Health: A European Approach (APHEA) project and Health Effects Institute's major concentration-response function studies are beginning in Asia (Health Effects Institute 2003).

[5] This assumption needs one significant qualification. If elderly people are particularly at risk from air pollution and few people live to be elderly in these developing countries, then the public health impact may be relatively low even though the slope of the C-R function may be steeper for developing countries.

2.5.1 Pollutant Categorization

The pollutants of potential concern can be classified into conventional pollutants (sulfur dioxide (SO_2), particulates (total – TSP, particulates with a diameter 10 microns or less – PM_{10}, and fine particulates – $PM_{2.5}$), ozone (O_3), nitrogen dioxide (NO_2), and carbon monoxide (CO)), air toxics (including lead, benzene, a number of the diesel particulates), and global pollutants (carbon dioxide, chlorofluorocarbons, and others). Because global pollutants do not harm health directly, they are not addressed in this chapter.

The remaining pollutants mentioned above have all been implicated in health effects of one type or another and to one degree or another. Currently, attention is focused on particulates, particularly $PM_{2.5}$ and several of its constituents, including sulfates (SO_4), nitrates (NO_3) and carbon compounds. Sulfates have been significantly linked to mortality and morbidity risks, as have $PM_{2.5}$, PM_{10} and TSP. Sulfur dioxide has also been linked to health effects, but because the sulfate particles are formed from reactions involving SO_2 gas; it may be impossible to identify separate effects of SO_2 as a gas versus the sulfate particles that result from it. There is very little evidence of links to health effects involving other particulate constituents.

Ozone, which is formed from volatile organic compounds (VOCs) and NO_2 in the presence of sunlight and heat, has been found to affect morbidity endpoints, such as acute respiratory disease symptom days and hospitalizations, but the evidence of a mortality effect is neither strong nor frequent (Figure 4). NO_2 is primarily of concern because of its conversion to the particulate NO_3, which counts as a fine particulate and, if one is concerned about ozone, through its conversion to ozone. CO is primarily of concern in enclosed spaces, such as parking garages and, of course, indoors. The air toxics are of concern because of their links to cancer, low birth weight and other diseases. With the possible exception of diesel particulate emissions and lead, toxic pollutants are far less ubiquitous and less concentrated in the environment than the conventional pollutants. Lead, even in low doses, has been shown to cause learning disabilities in children and high blood pressure in adults. The U.S. EPA's action level for lead has become increasingly more restrictive as additional epidemiological findings are made.

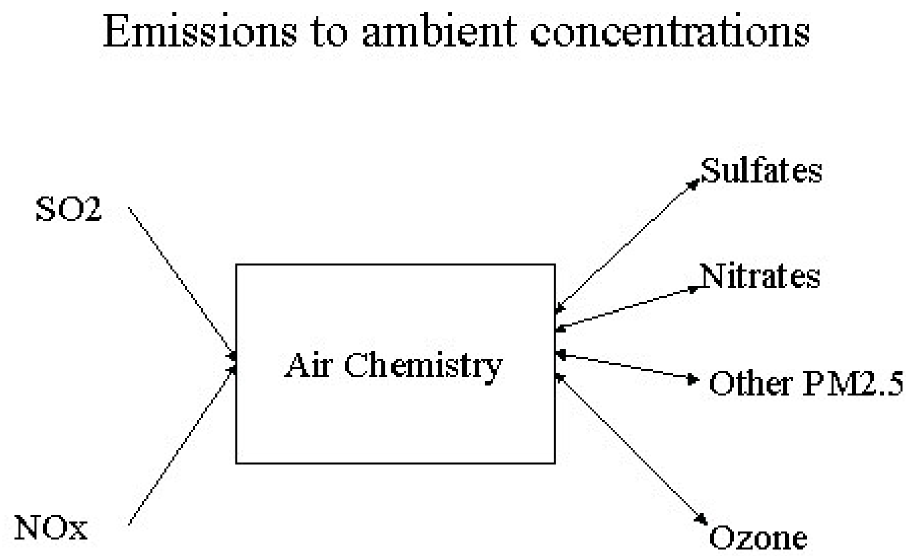
2.5.2 Pollutants Sources of Concern

There are three major categories of sources of air pollution in urban areas: point sources (industrial emissions, power plants), mobile sources (autos, buses, mopeds, motorcycles), and residential and area sources (home heating and cooking, emissions from small businesses, such as dry cleaners and paint finishers).

In developing countries, particularly China and India, coal burning for electricity generation is a major source of particulates and SO_2. Industrial emissions of SO_2 and particulates also come from smelters, coke ovens, and other steel-making operations. Additional, residential and area sources can, in the aggregate, contribute to a large share of these pollutants.

Mobile sources contribute a growing share of the most troublesome pollutants. Buses and trucks in developing countries have very high per-kilometer emissions of all types of pollutants and, if run on diesel or leaded gasoline, are of particular concern. Low, but rapidly growing, auto ownership, will likely raise VOC and NO_2 emissions from gasoline, raising concerns about ozone and, if the fuel is still leaded, lead.

Figure 4.



2.5.3 Evidence on Concentrations

There is surprisingly limited evidence on concentrations of air pollutants in urban areas of developing countries. WHO is the only multi-country source of time-series information, and their data collection efforts are spotty and reporting is late. The current system, Air Management Information System (AMIS; WHO 2001), replaces the previous system, Global Environment Management System (GEMS; WHO 1987). Both involve setting up monitors in industrial, commercial and residential areas in each city to measure concentrations of a variety of pollutants. The pollutants measured vary by city, but most measure TSP (and increasingly finer particulates (PM_{10})) and SO_2; some measure NO_2, lead, and ozone. High income countries, as expected, tend to have the most comprehensive reporting of pollutants. There has been some backsliding in terms of the database's coverage. For example, GEMS contained very good data on China in the 1980's, but the AMIS data end for Chinese cities in 1994. In addition, GEMS comprehensively reported the number of days with violations of air quality standards, while AMIS does not.

Thus, to get as complete a picture as possible of the progress (or lack thereof) by urban areas in developing countries in reducing air pollution, we supplemented the AMIS data with country-specific sources where available. Then, we computed annual average values for the periods of 1986-92 and 1993-00 for each country and took the differences; reporting average differences by pollutant in Table 2. For ease of reporting, countries were classified into four categories (according to GDP per capita from the World Bank). Over the two time periods, the poorest countries gained very little ground or got worse. An example is PM_{10}, with annual average PM_{10} concentrations *increasing* by about 26 $\mu g/m^3$ in the low income countries, while all the other countries gained ground. This situation may not be as dire as it seems. With some economic growth and an increasing population in many of these countries, even holding the line on emissions is an achievement. Interestingly, the largest gains – 20 µg/m^3 reduction in PM_{10} -- were experienced by cities in the second poorest group of countries.

Table 2. Air Pollution Change by Income

Pollutant by country income category*	Average for 1993-2000	Difference between averages for 1986-92 and 1993-2000**	# cities w/data in both periods
Sulfur Dioxide Annual Mean (µg/m^3)			
A (low income)	15	3	10
B (lower middle income)	61	16	26
C (upper middle income)	25	13	14
D (high income)	16	13	46
Nitrogen Dioxide Annual Mean (µg/m^3)			
A (low income)	26	0	10
B (lower middle income)	62	-15	12
C (upper middle income)	42	2	14
D (high income)	42	5	42
PM10 Annual Mean (µg/m^3)			
A (low income)	127	-26	10
B (lower middle income)	66	20	8
C (upper middle income)	61	4	1
D (high income)	34	13	14
Lead Annual Ambient Mean (µg/m^3)			
A (low income)	0.14	0.05	10
B (lower middle income)	0.37	0.05	8
C (upper middle income)	0.29	0.20	11
D (high income)	0.10	0.13	30
Ozone Annual Mean (µg/m^3)			
A (low income)	79	-	0
B (lower middle income)	48	-11	3
C (upper middle income)	48	5	3
D (high income)	38	-3	35
SO_2 # days guideline exceeded			
A (low income)	2	1	7
B (lower middle income)	9	2	5
C (upper middle income)	4	16	3
D (high income)	2	7	32
NO_2 # days guideline exceeded			
A (low income)	2	0	8
B (lower middle income)	25	-15	4
C (upper middle income)	11	-17	2

D (high income)	4	3	29
Ozone # days guideline exceeded			
A (low income)	90	-	0
B (lower middle income)	9	-1	2
C (upper middle income)	28	-13	2
D (high income)	18	5	24

*'Income categories are based on World Bank World Development Indicators
http://www.worldbank.org/data/countryclass/classgroups.htm
**Negative difference implies that air quality worsened over the time periods compared.
Source: WHO 2001, Air Management Information System

What are the best solutions?

It is one thing to illuminate the key urban air pollution problems; but quite another to identify the best interventions for addressing them –a task beyond this paper. Still, a few comments are appropriate. First, defining what is best is not easy task, with the efficiency and equity perspectives being the two most easily articulated. However, even if we confine ourselves to an efficiency perspective, what is best can be viewed from a net benefits or a cost-effectiveness perspective. The former involves choosing interventions with the largest net benefits; the latter, choosing an appropriate effectiveness metric and then rank ordering interventions according to costs per unit of effectiveness. Second, in a limited sense, the choice of policy intervention can be a choice to avoid having to do such rankings. In particular, economic incentive policies can be designed to create incentives for the regulated parties to discover the cheapest ways of reducing emissions (if emissions is the effectiveness measure), or reducing whatever effectiveness measure is operative. For instance, a tradable permit policy with a cap on aggregate emissions will lead to the cheapest interventions per unit of emissions reduced being adopted. This approach is limited, though, because some interventions may need to occur in the public sector or in sectoral areas that do not lend themselves to the application of incentive policies.

For health, a promising effectiveness measure for use in cost-effectiveness analysis is the QALY or DALY, mentioned above. Indeed, the WHO has developed software called WHO-CHOICE, with the purpose of making a wide range of cost-effectiveness calculations and comparisons for each WHO region using the DALY metric (http://www3.who.int/whosis/menu.cfm?path= evidence,cea&language=English). Unfortunately, for this paper, WHO has not yet developed the tool for air pollution interventions. However, they have developed the tool for childhood illness interventions; among them case management options for addressing childhood pneumonia, which could be related to air pollution. Table 3 provides an example of the model's output for countries in the Southeast Asia Region with high adult and child mortality (Category D). This example shows that extending case management to higher numbers of children has only a modest affect on costs and that the cost-effectiveness is extremely promising. For comparison, table 4 shows some of the interventions to reduce DALYs from poor water quality and highlights how relatively expensive these options are.

Table 3. Region: WHO South-east Asia Region (SEAR) – High Adult and Child Mortality
Category: Childhood Pneumonia

		Average Year Cost (in international [I$])			Effectiveness (DALYs averted: average 1 year)	
Cluster	Intervention	Programme	Patient	Total		Average Cost-Effectiveness
UFV	Case Management of childhood pneumonia (CM), 50% coverage	38,135,366	176,465,572	214,600,938	2,646,618	81
UFV	CM, 80% coverage	63,218,585	282,387,697	345,606,282	4,234,588	82
UFV	CM, 95% coverage	98,629,429	335,428,693	434,058,123	5,028,574	86

Table 4. Region: WHO South-east Asia Region (SEAR) - D
Category: Unsafe Water Supply, Sanitation and Lack of Hygiene Related Risk

		Average Year Cost (in international [I$])			Effectiveness (DALYs averted: average 1 year)	Cost Effectiveness	
Cluster	Intervention	Programme	Patient	Total		Average	Incremental
WS	Disinfection at point of use with education	523,019,455		523,019,455	3,248,440	161	161.01
WS	Halving the population without improved water supply	585,826,305		585,826,305	951,318	616	Dominated

WS	Halving the population without improved water supply and sanitation	5,907,522,335		5,907,522,335	4,908,162	1,204	Dominated
WS	Improved water supply and sanitation (98%)	11,578,743,777		11,578,743,777	9,627,739	1,203	Dominated
WS	Improved water supply and sanitation with disinfection (98%)	14,184,319,328		14,184,319,328	25,443,560	557	615.51
WS	Piped water supply and sewage with treatment (98%)	39,689,844,066		39,689,844,066	38,442,566	1,032	1962.11

The World Bank has also periodically developed cost-effectiveness measures using DALYs. In The World Bank's *Environmental Health Report* (2003b), a variety of interventions to improve health are examined and cost per DALY is estimated. Most of these interventions are low cost, for instance, developing water connections in rural areas at $35 per DALY, instituting malaria controls at between $35 and $75 per DALY, and improving stoves and fuels ranging from $50 to $200/DALY. But, for reducing urban air pollution, all that is said of the cost-effectiveness of interventions is that they vary from the negative (electronic ignition systems in two-stroke vehicles) to US$70,000 per DALY or more for some pollution control measures.

3.0 Policy Response

The purpose of this section is to identify attractive, i.e., efficient and equitable, policies for mitigating the urban air pollution problems caused by point, mobile and residential/commercial sources (not indoor air). This is done by first considering the different types of policies available and then matching the requirements of the various policies to the unique economic, institutional and environmental features of developing countries (what we term stylized facts).

3.1 Policy Types

In the space of three decades, the popularity of economic incentive approaches to controlling air pollution has gone from virtually nil (i.e., policy dominated by "command and control" approaches) to the point where, at least in developed countries, tradable permit policies are often the first approach considered by policymakers. In the early 1970's, the only example of economic incentive approaches in the U.S. was the unsuccessful attempt by the Nixon Administration to tax sulfur in fuels. Today, however, there are dozens of examples of serious attempts to implement tradable permit and emissions tax approaches in the U.S. and elsewhere, particularly in Sweden. While most successful implementations of these approaches have occurred in the developed world, increasingly developing countries are turning to them. In spite of the efficiencies such instruments promise, their successful implementation will be a challenge, due to the complexities of implementation and need for institutional capacity. In addition, these instruments may come with high expectations, being wrongly viewed by politicians as actually lowering pollution, as opposed to reducing the costs of any given pollution reduction.

The available options, as discussed in other chapters, include direct regulation - sometimes termed command and control (CAC), tradable permits, fees or taxes, subsidies and deposit refund systems, voluntary and informational approaches, or the creation of property rights and legal liability. In an air pollution context, command and control policies would include regulations requiring catalytic converters on vehicles and regulations requiring firms to meet certain emissions standards. Note that the latter approach affords more flexibility, giving firms the option of finding the cheapest way to meet the standards, while the former approach is a technology standard.[6] Regulations on vehicle fuel and on fuel economy are other examples of CAC policies associated with air pollution.

Tradable permit (TP) approaches differ from these CAC approaches because they provide more of an economic incentive for firms to find cost-effective methods to reduce pollution. Firms with lower pollution abatement costs find it in their interest to reduce pollution and sell their surplus permits to other firms. Technological change is boosted by TPs because the firm's incentive to innovate extends beyond any given emissions standard, and by reducing emissions firms can actually get paid for their actions by other firms.[7] Probably the best-known TP air pollution example in the world, and the first fully specified and well functioning policy, is the U.S. EPA's SO_2 Allowance Trading Program under Title IV of the Clean Air Act.[8]

---

[6] Another argument sometimes made for CAC standards approaches is called the Porter Hypothesis, which asserts that a country's tight environmental standards may actually increase competitiveness in the world market. See (Ambec and Barla, 2002; Smith and Walsh, 2000).

[7] CACs can also boost technology change, however, through their technology-forcing provisions. For instance, by requiring that all cars have catalytic converters, the market and competition to produce such devices cheaply grows.

[8] Title IV of the 1990 Clean Air Act Amendments initiated an SO_2 emission allowance cap and trade program as a strategy to reduce regional SO_2 emissions from power plants by 50%. It is widely believed that Congress would not have imposed the same amount of reductions if not for the prospective cost savings from trading. The program combines an aggregate cap on annual allocation of emission allowances at all large fossil-fired electricity generation facilities with nearly unfettered opportunities to trade or bank allowances. The success of this program stems from

Fees to raise the price of polluting can be placed on inputs to the polluting process, on outputs produced concurrently with the pollution, or on pollution emissions themselves. By raising the price of polluting (either directly or indirectly), the polluting activity becomes less attractive. Moreover, unlike TPs (if the TPs are distributed for free rather than auctioned), revenues are raised for use elsewhere. This approach can be efficient because firms have the incentive to minimize the cost of reducing their pollution, rather than being subject to arbitrary pollution limitations through standards. Of course, standards and fees can be combined, such as when payments have to be made for any emissions above the standard. The fee in this case functions much like a fine. Examples of fees associated with air pollution are gasoline taxes (a fee on an output with emissions as a joint product), a broader-based fee like an energy tax, fees on fuel sulfur content (as in Sweden), and fees on coal at the mine mouth (a fee on an input).

Subsidies are the opposite of taxes in that polluters are paid not to pollute or are encouraged to produce a less-polluting output by subsidizing the price of that output. Reducing a tax can be thought of as a form of subsidy. Given that there are substitutes for highly polluting activities, one can think of using taxes, subsidies or both to create price gaps between the more- and less-polluting products. Subsidies to transit (an output-based subsidy) reduce reliance on the more-polluting passenger vehicle (per passenger mile). Subsidies to renewable energy discourage producing energy with the more-polluting fossil fuels. Taxing unleaded or low sulfur fuel less than leaded or high sulfur fuel encourages purchase of the former. Reducing existing subsidies on highways and on oil production (e.g., the oil depletion allowance in the U.S.) raises the cost of driving and producing oil, relative to less-polluting (but formerly higher cost) alternatives.[9]

Voluntary and informational approaches are particularly appealing for a developing country because they do not require as sophisticated a monitoring and enforcement infrastructure as other policies. These approaches may rely on public goodwill to push polluters to action. Requiring firms to submit estimates of their emissions for public disclosure can lead to firms abating their pollution to avoid being branded a bad polluter. These programs may be defined in voluntary terms from the beginning. Industry associations may collaborate, with or without government involvement, to change their polluting processes in order to "spruce up" their image or perhaps to improve the health of their workers. A good example is the attempt by brick kiln

---

the program's simplicity, effective monitoring through continuous emissions monitors, definite penalties and the opportunity for banking.

The cost of the program will be just over $1 billion per year by 2010, but it enabled the industry to fully capitalize on advantageous trends in coal transport and other technology changes, due to the flexibility inherent in allowance trading. Compared to an approach that mandated a specific emission rate at every facility, the allowance trading program is estimated to have reduced program costs by 30-50% (Carlson et al. 2000; Ellerman et al. 2000). However, compared to a prescriptive technology approach, such as a requirement of scrubbers at a certain class of facilities, the savings are perhaps 200% of actual costs.

[9] Deposit-refund approaches involve requiring payment up front with the payment refunded once the desired action is taken. This approach is especially applicable to cases where there is a time lag between the purchase of a product and pollution arising from it, such as the purchase of an air conditioner that will eventually leak freon into the atmosphere. Most conventional air pollutants are produced contemporaneously with consumption of the product, so this approach rarely applies.

manufacturers in Ciudad Juárez, Mexico to change their fuel source from scrap tires to the much cleaner propane (Blackman and Bannister 1998).

Finally, the creation of legal liability and property rights where none existed can clarify responsibilities and result in pollution reductions.

4.0 Point Source Policies

Policies that are appropriate for developed countries may not be appropriate in developing ones. They may require an infrastructure or a legal system that a developing country doesn't have, or they may emphasize technologies that are too expensive for developing countries. Any discussion of treating developed and developing countries differently, however, runs into a "political incorrectness" problem for suggesting that developing countries could be satisfied with lower technology and less environmental cleanup because they need to focus more on economic growth. Yet, there is no reason why all types of countries should use a certain set of policies any more than there is a reason to use the same type of policy to address every type of environmental problem. Adaptation and working within the limitations of each country is a must. In this spirit, there are several stylized facts that separate typical developed and developing countries and give rise to a means of notionally ranking some policy types above others.

Stylized facts. Of the many general differences, six are of particular importance to air pollution policy in developing countries (relative to developed countries): (i) concerns about minimizing costs overshadow concerns about reducing air pollution to a greater extent; (ii) capital is more scarce, relative labor; (iii) baseline emissions control is lower; (iv) market distortions are more pervasive; (v) the infrastructure for implementing an air pollution control system is minimal and transactions with that infrastructure marred by corruption; and (vi) revenue needs of governments are more pressing.

What do these differences imply about air pollution policy choice, in theory? Other things equal, the greater ability of incentive approaches to reduce abatement costs argues for their preference over CAC policies. Tietenberg (1985) and many others find such savings in policy simulations and cost-benefit analyses of real programs, with the amount depending on the sophistication of the CAC policy in the comparison. Beyond this distinction, a pricing policy would be favored over a quantity-constrained policy, based on Weitzman (1974), because the former constrains costs while the latter constrains damage.

Having scarce capital and cheap labor in developing countries implies that simple, labor-intensive approaches to reducing air pollution may be more attractive than in developed countries. Additionally, fairly modest incentives (such as a low emissions fee) could bring about emissions reductions at low cost. Other low-cost options could include keeping up with maintenance schedules, purchasing spare parts in advance, and improving worker training. CAC approaches are ill suited to providing incentives for operations and maintenance improvements because companies have an enormous range of existing conditions and control options. That developing countries have low baseline emissions control reinforces the need for a choice of low-cost approaches; because of rising marginal costs of abatement, the scope for reducing emissions cheaply will be large initially.

Market distortions are more pervasive in developing countries. In particular, energy prices are often kept below market rates.[10] This subsidy exacerbates the lack of internalization of the air pollution externalities and encourages undue reliance on energy-intensive processes. The implication for policy is the need for the removal of such subsidies, but of course that action is rarely easy from a political standpoint.

The very existence of taxes creates a market distortion (called the deadweight loss of taxation), which has implications for the use of emissions taxes and marketable permits. Recent research emphasizes that marketable permits should be, at least partly, auctioned off, with the revenues used to offset some of these pre-existing distortionary taxes (Parry 1995 and Parry et al 1999),[11] and that emissions tax revenues should also be at least partly used in the same way. In practice, however, the ability of governments to initially distribute marketable permits for free is one of the main attractions of this approach. And revenues from environmental taxes are most likely to be used (in developing countries) to support cash-strapped environmental protection agencies rather than to offset distortions.

Weak institutions probably result in the most important differences for policy prescriptions between developed and developing countries. Irrespective of the policy type, strong institutions are needed to carry out basic governmental functions - fighting for scarce resources, writing regulations, establishing an emissions baseline, tracking changes in emissions over time, enforcing the regulations, and monitoring air quality to determine if regulations are effective and at the correct level of stringency. Where strong institutions are lacking, a government can invest resources towards bolstering them before committing to or implementing a policy, or can work with the institutional resources available to craft policies that require less-strong institutions. The latter approach could be preferable since establishing strong institutions takes significant time and many environmental problems cannot afford to be ignored in the meantime (Sterner 2003).

One example of such a policy is voluntary, informational policies, such as PROPER, Indonesia's Public Disclosure Pollution Control Program. Another is setting emissions baselines at default values (say from U.S. AP-42 documents) to be changed only with a showing by the regulated entity that these defaults are in error. However, this short cut may blur the distinction between incentive and CAC policies. An alternative option is to focus the policy on the point in the production chain that is overseen by the strongest institutions. In developing countries, the Ministry of the Interior or Commerce is often one of the stronger ministries, with taxing and enforcement powers over the companies it regulates. Thus, using "blunt instruments," such as taxes on energy inputs, may be a viable alternative, while sacrificing some efficiency for the gain in enforcement. For instance, a tax on the sulfur content of coal can reduce SO_2 emissions and is easy to document and enforce. Such an approach, however, provides incentive only to reduce sulfur content, not directly to reduce SO_2 emissions, which might more cheaply be reduced at the point of release.

---

[10] Generally, damages from pollution are not internalized into the costs of market goods. To internalize the costs from air pollution a tax or other policy can be used to make these damages part of the input costs.

[11] A complementary argument is that auctioning emission permits may help correct distortions away from economic efficiency stemming from noncompetitive market structure, especially in the electricity sector (Burtraw and Palmer 2004).

Weak institutions argue against complex, but conceptually efficient, approaches to reducing air pollution, such as tradable permits. Simpler variants, such as intra-firm bubbles,[12] have some of the advantages of a TP system, although they limit abatement effort allocation changes to within the firm. Simply letting prices rise or adding taxes to highly polluting joint products or inputs seems like the simplest solution if taxing authority and enforcement systems are already in place. Simple, transparent rules may also have the virtue of limiting unpleasant surprises when there is so much uncertainty in how a policy will be implemented and responded to.

On the other hand, incentive approaches are favored because weak governments cannot hope to collect and process the information needed to set efficient CAC regulations. Decentralized incentive-based policies that do not require such information have the advantage.

In the end, efficiency is but one criterion in deciding the best possible policy for each situation – equity, politics, enforceability, and the need to encourage cooperation and involvement are also important factors (Sterner 2003).

4.1 Recent Examples

Tradable permits for point source SO_2 emissions in Taiyuan, China

As part of a loan for air quality improvement in Shanxi Province, the Asian Development Bank, in cooperation with the Shanxi Planning Commission, initiated a Technical Assistance (TA) grant in March 2001 to enhance the use of market-based instruments (MBIs) for air quality management in Shanxi. [13] The Provincial capital city of Taiyuan was selected as the site for a demonstration of the use of MBIs for SO_2 control – specifically a cap and trade program involving large stationary point sources.

Taiyuan, with a population of 2.7 million, is located five hundred kilometers southwest of Beijing. Topographically, mountains surround Taiyuan on three sides, resulting in a natural smog trap in which air pollutants tend to accumulate. The annual average of daily SO_2 concentrations in Taiyuan was 200 $\mu g/m^3$ in 2000, much higher than the People's Republic of China (PRC)'s Class II annual standard (600 $\mu g/m^3$) and far higher than the U.S. SO_2 standard of 80 $\mu g/m^3$.

The Taiyuan city government had proposed more than a 50% reduction in SO_2 emissions as part of its five-year environmental plan ending in 2005. MBIs, such as emissions trading, have the potential to facilitate achievement of this very ambitious goal at lower cost than alternative approaches.

[12] An approach that permits a plant or multi-plant firm to meet its stack-by-stack emissions reduction responsibilities in total rather than at each specific stack.
[13] Resources for the Future led this TA, in cooperation with Resource Consulting Associates, Inc, the Norwegian Institute for Air Research, and the Chinese Research Academy for Environmental Science. Information in this example is based on the project's final report to the Asian Development Bank. In addition, the U.S. Environmental Protection Agency (EPA) provided extensive assistance in the areas of training and capacity building.

Among developing countries, the PRC has been a pioneer in the use of certain economic instruments, most notably the pollution levy system. Although the pollution levy system serves as an integral component of environmental management in the PRC, its principal aim is to fund the regional and local Environmental Protection Bureaus (EPBs) and help finance pollution control measures. In the early 1990s the PRC began to require emission offsets[14] at selected new facilities. These pilot projects revealed that emission trading was feasible, at least in this primitive form.

The adage that ‘Rome wasn’t built in a day’ aptly describes the challenges involved in introducing a rigorous environmental management system such as emissions trading in Taiyuan. Establishing a program of emissions trading is somewhat like building a complex mosaic: a large number of intricate elements must be fit together. These range from technical components like air quality monitoring to policy-relevant and sometimes politically sensitive issues such as developing a viable system design and establishing an appropriate legal framework. The exercise is not merely a matter of mechanically assembling pieces into a working whole. There are a variety of stakeholders and constituents who must understand how such a program might work, who must agree it is in their interests to be part of the effort, and who must be trained to do their share in making it a reality. Thus, an important part of the demonstration in Shanxi Province included capacity building for and with the people, the institutions and the myriad potential participants in the trading program, to develop fluency with and support for the principles involved.

In response to the Taiyuan EPB’s limited capacity, the TA implemented major improvement to the Taiyuan EPB’s emissions monitoring and enforcement system, the heart of any emissions control function. Thus began a multi-year process of establishing facility-specific emission caps for large emission sources for the years 2002-2005, as well as development and demonstration of various computer-based tools designed to facilitate emissions monitoring and verification (the Emissions Tracking System - ETS).

The ETS collects data on fuel inventories and fuel consumption as a basis for calculating total emissions during the compliance period. In addition to calculating emissions from mass balance formulas, the ETS collects data from the monitoring bureau to facilitate comparison of each enterprise’s emission measurements. Data about production levels are also collected to establish emission rates (e.g., emissions/unit of output) that the EPB can use to identify possible discrepancies in an enterprise’s submission.

A number of additional steps were necessary to move the Taiyuan EPB towards trading: education of the government and industry leadership about the benefits of adopting emissions trading in Shanxi province and Taiyuan city (including an initial simulation of emissions trading among selected facilities - two large power plants, a small power plant and a heavy machinery manufacturer) as well as on the theory, practice, and management of emissions trading systems; promulgation by the city of Taiyuan in October 2002 of a formal regulation on emissions trading and the administrative framework to support the regulation; and
the building of a computerized Allowance Tracking System (ATS).

---

[14] This is an approach requiring new polluting sources in a region to obtain emissions reductions from existing sources in the region before they (the new sources) can begin operating.

The ATS application facilitates allowance accounting, including the creation of allowance accounts, issuance/allocation of allowances to the enterprises, transfer of allowances among enterprise accounts, and allowance deductions to offset emissions during the compliance year. In addition, the data and reports from the ATS can be used to publicize the results of the trading program.

The real challenge is to apply these techniques in a nation where legal and institutional arrangements for environmental management are still in their formative stages. Although the PRC is a rapidly evolving market economy, there is little experience with rigorous environmental monitoring and enforcement or with the trading of intangible commodities like pollution credits. Steady, reliable, fair enforcement and a well-constructed program to detect and act on violations are the basic building blocks of any environmental management system, whether that system uses conventional tools or MBIs. At the same time, analysts from developed countries and western cultures should be alert to the many "non-policy" avenues (e.g., moral suasion, pressure on Party leaders at the firm, etc.) that a government has to influence firm behavior.

Whether or when a TP system "in the Chinese style" becomes fully operational remains to be seen. Continued support by both domestic and international experts to facilitate the initial operation and help ease the "growing pains" of the system is recommended, as is a further evaluation of the system when it reaches full-scale operation.

There are many steps still to be taken before Taiyuan has a well-functioning monitoring and enforcement system and before Taiyuan will be able to appropriately use emissions trading. These steps may be divided into technical adjustments, institutional strengthening, and improved coordination and information flow. For illustration, we include three examples of possible steps below.

Increase compliance incentives by lifting the cap on total penalties. Article 23 of the *Administrative Regulation on* SO_2 *Emission Trading in Taiyuan City* sets a yearly cap of 30,000 Yuan on the total penalties that can be assessed against polluters. The obvious difficulty with this provision is that in instances in which the cost of compliance (either installing technology, making process changes or purchasing allowances) is greater than the maximum stipulated by the penalty cap, the incentives for enterprises to come into compliance are dramatically reduced, as the cap limits their overall penalty payments.

Allow banking of surplus permits without TEPB approval. The emission trading regulation specifies that enterprises must apply to the TEPB for approval before using banked allowances to cover emissions during the compliance period. However, because an enterprise will not know the outcome of its application until after the compliance year is over, there is no opportunity to further reduce emissions or purchase allowances from other enterprises if the request is denied. Therefore, this provision effectively prevents banking of excess allowances. Limiting the use of the banking provision in this manner will raise the costs of meeting the caps without any significant environmental benefits. Concern that the banking provision may allow emissions to increase beyond acceptable levels does not seem warranted.

Establish realistic but firm emissions reduction targets for sources in Taiyuan. More than two years of the five-year plan in which SO_2 emissions were to be reduced by more than 50% have passed. To date there has been only limited progress in reducing total emissions. This slow progress should be evaluated and a realistic timetable developed. Without certainty about the outcomes of regulatory, environmental progress will be hampered.

Emissions fees for stationary source emissions control in Metro Manila

The Asian Development Bank has supported various initiatives to address the serious air quality problems in Metro Manila, culminating in a multi-component loan and a technical assistance grant (TA) that together make up the Metro Manila Air Quality Improvement Sector Development Program. The Program commenced in 1999 and was originally planned to run for 4 years (1999 to 2002). Previous studies under the TA have recently assessed a broad range of market-based instruments (MBIs) for air pollution control in the Philippines (e.g., Ruzicka et al., 2002). However, it was thought that a research effort was needed to define very specific policies to be applied in Manila. Accordingly, researchers at RFF[15] developed a design methodology for implementing an emissions fee program for stationary sources and a sulfur tax for diesel fuel (discussed in section 5.0, below). The intent of the program is to offer efficient financial incentives to reduce particulate emissions and precursors, as well as to raise revenues for important air pollution monitoring and enforcement activities. We recommended beginning immediately with a straightforward fee program, initially targeting the most important emitters, recognizing that the fee level may not reflect full marginal costs. To the extent possible, we felt that distributional concerns should be addressed by means such as standard credits, or investment credits, that allow marginal fees to provide stronger incentive effects. These recommendations have not yet been implemented.

Particulate matter (PM) is the main pollution problem in Manila, and monitored readings show some of the highest PM concentrations in the world. Ambient ozone is a lesser problem, with few violations of guidelines/standards. Reducing NO_x and SO_2 emissions is also potentially important since they are precursors to $PM_{2.5}$.

An emissions fee policy is recommended because of its efficiency and its ability to generate revenues to fund pollution control activities. Revenue needs include, but are not limited to, administrative costs of stationary source permitting, monitoring and enforcement. Emission fees are intended to be a major revenue source for the Air Quality Management Fund (AQMF), which has a broad mandate for restoration, research, outreach, and technical assistance, as well as for regulatory activities. Therefore, in designing the fee, we focus first on the direct effects—the marginal incentives and the administrative burdens—and then on the revenue and cost impacts. In principle, efficiency reasons should determine the tax rate, and equity and revenue concerns should determine the exemptions.

We felt that such a proposal was realistic because of Manila's experience with The Laguna Lake Development Authority (LLDA). The LLDA successfully implemented an Environmental User Fee System to reduce the biochemical oxygen demand (BOD) of industrial effluents flowing into

[15] This example is based on Fischer et al. 2002.

Laguna de Bay, the second largest freshwater lake in Southeast Asia. The total annual fee paid by a facility equals a fixed charge (based on a range of the daily wastewater flow rate) plus, for each pollutant, a variable fee multiplied by the annual load. Emissions are determined using limited sampling and presumptive factors, leaving the firms with the burden of proving actual loads are lower with continuous monitoring.

The program was phased in, initially limited to the top dischargers in the major BOD-contributing industries. It has been credited with helping to reduce the annual BOD inflows to the Lake by almost 75% from 1993 to 2000, although the extent to which the reduction can be attributed to the fee has not been formally evaluated.

Legal basis. The Philippines Clean Air Act (CAA) of 1999 (Republic Act No. 8749), explicitly provides for economic incentives as a part of environmental policy. The Declaration of Principles recognizes that "polluters must pay,"[16] and the Declaration of Policies encourages the use of market-based instruments.[17] Specifically, an emission fee system is mandated for industrial dischargers as part of the regular permitting system,[18] although the Implementing Rules and Regulations remain broad enough on this point to leave room for interpretation. Fees collected are to be deposited in a special account (the AQMF) established by the National Treasury and administered by the Department of Environment and Natural Resources (DENR). The CAA further identifies the Environmental Management Bureau as the administrator of the AQMF, with funds to be used for environmental restoration and environmental management by DENR, other agencies, and management of local airsheds.

With the legal authority already in place per the CAA, the practical barriers to implementing the emission fee system will be administrative in nature. Capacity must be built so that DENR can perform certain key functions: compiling the specific data needed to calculate the fee; validating the data provided by the firm; billing, collecting, and enforcing penalties for failure to pay the fee; and providing dispute resolution for conflicts emanating from fee computation methods and data inputs. Furthermore, internal accounting procedures will need to be established to earmark revenues for environmental management, program administration, restoration, and rehabilitation.

The other challenges are informational and political. Considerable uncertainty remains over the precise extent and distribution of stationary source and other emissions in Metro Manila. Additionally, although we determined that emissions controls were relatively inexpensive for many of the point sources of particulates and SO_2 in Manila, we could not determine the level of compliance with existing regulations. Perhaps the first challenge to putting the program in place is building support among stakeholders. The fee level, participation rules, and exemptions each have important impacts on the competing interests of government for revenues, of firms for their costs, and of the public interest for the efficiency and efficacy of the program.

Emissions Fee Calculation. In the basic design, total emission fees assessed for any plant would equal

$$\text{Total Fee Payment} = \tau_P \text{PM}_{10} + \tau_S \text{SO}_2 + \tau_N \text{NO}_x + X \ ,$$

[16] Ch. 1, Art. 1, Sect. 2.
[17] Ch. 1, Art. 1, Sect. 3c.
[18] Ch. 1, Art. 1, Sect. 13.

where the τ 's represent the fee rates for each pollutant, and *X* represents an optional fixed component, which may be positive (a fixed fee, like the current charge for permit processing) or negative (a standard credit or exemption). The fixed component, if needed, represents an adjustment mechanism to achieve the targeted revenue goals.[19] The fee rates will depend on the relative contribution of the different emissions to PM_{10} concentrations, as well as the corresponding costs in terms of abatement opportunities or health damages.

Both marginal damages and marginal costs seem to lie in the same range of $2000 or more per ton. Given the uncertainty surrounding these numbers in the Philippines case, we hesitate to recommend a marginal fee that fully reflects these cost estimates. Furthermore, we realize that a fee of this size is not likely to be tenable, given concerns for economic development and the need for stakeholder acceptance of the program. While efficiency should be a goal, it is more important to begin implementing the program. Once started, one will be able to observe how firms actually react to the fee and how the environment is affected by the corresponding changes in emissions. After learning from the responses over time and gathering better monitoring, health, and cost data, the fee can be adjusted in the future to better reflect the policy targets.

Monitoring. When properly maintained, continuous emissions monitoring systems (CEMS) are the most accurate means of calculating emissions; however they are also the most costly. The Clean Air Act requires the installation and operation of CEMS for new and modified sources that have the potential to emit more than 100 tons per year of any pollutant. Currently, only the major power plants (Pabilao, Mauban, and First Gas) are equipped with CEMS. Discussions with the Pollution Control Officer of Pagbilao and Mauban Quezon Power Plants estimates the capital and annual operating costs of CEMS at P2.5 million and P1.0 million, respectively. These CEMS are capable of monitoring SO_x, NO_x, and PM emissions. For medium and small sources, it may not be practical to install CEMS. Thus, most emissions will have to be estimated using emission factor methodology.[20] For those firms not installing CEMS we recommend that a special emissions tracking system (ETS) be developed and implemented in the Metro Manila airshed, as was done in Taiyuan.

---

[19] The fixed fee can be made to vary according to firm characteristics as well, without compromising the incentive effect of the marginal rate. Differentiation of the fee can make allowances for different abilities to pay of smaller versus larger stationary sources. Another option is to make the fixed fee conditional on certain behavior, e.g., offering rebates for installing pollution control equipment or continuous monitoring systems. This structure would help firms defray fixed capital costs and would be an alternative to funding such projects through the AQMF.

A standard exemption helps mitigate the cost impact while retaining the strong marginal incentive to reduce emissions, particularly if emissions reduced below the exemption are credited. Given the large variation among the sources, we recommend allocating a firm-specific (or possibly industry-specific) exemption based on a share of its historical emissions. If historical emissions data is unavailable or of poor quality, average industry data may have to be used to calculate the fixed exemption.

[20] The legal basis for the fee assessment is provided in Section 13 of the CAA " to include, but is not limited to, the volume and toxicity of any emitted pollutant." There is no prohibition on the use of presumptive emission factors to estimate emissions.

For a credible emissions fee system, the data reporting requirements must be explicit and standardized.[21] Something like an "emissions tax return" form could be sent out, that would provide the net emissions, fee liability, and the source data used to calculate them. Quarterly self-monitoring reports currently submitted by Pollution Control Officers contain basic information, including data on materials (e.g. fuel) use and production outputs. When coupled with applicable emission factors these reports could serve as a basis for calculating facility-specific emissions fees.

Selection criteria for participants. Participation criteria determine which permitted industrial sources are assessed for emissions fees. Different designs for the participation requirement have different revenue implications. For instance, firms below an emissions quantity cutoff could be exempt from full reporting and fee payments, reducing the cost burden, but at the same time creating a financial incentive to stay below the cutoff. Or they could be assessed a reasonable presumptive charge, allowing them to undertake full reporting if they can show their emissions fee payments would be lower.

One could also target sources based on geography. While conditions do seem to vary considerably within the defined Metro Manila airshed, we do not at this point propose differentiating the fee or participation rules within the airshed. The additional administrative complexity is too burdensome. However, geographic variation could be used to prioritize and target enforcement efforts. Furthermore, the fee is not the only emissions policy, and other regulations are available to cope with highly localized hot spots.

Enforcement. Previous assessment of the Environmental Management Bureau's (EMB's) enforcement capability (IEMP 1997) revealed that fines by themselves were rarely used to leverage compliance. Further, this assessment revealed that even when assessed, fines were rarely collected. Reasons for low fines collection include: a) the absence of guidelines on setting fines to account for the seriousness of the violation or the violator's ability to pay, and b) the lack of institutional incentives for collection since revenues from fines and penalties do not revert back to EMB. However, discussions with two Regional EMB Offices indicated that this trend may be changing, at least for the environmental impact assessment program. The creation of the Environmental Revolving Fund under this program allowed EMB to retain revenues from administrative fines, and assessment and collection of administrative fines and penalties has more than doubled since the Fund's creation.

A review of 33 pollution adjudication cases revealed that it takes EMB an average of 8 months to serve a cease-and-desist order (CDO) from the date of detection, and 15 months for firms to comply from the date compliance activities are initiated. Exceptional cases were documented where it took EMB more that 150 months from the date a violation was detected to serve a CDO. Of the 33 cases reviewed only 7 cases were considered resolved. The types of delays observed in the present system would seriously diminish the effectiveness of the emissions fee system of the type proposed herein.

---

[21] The U.S. EPA has developed Procedures for Preparing Emission Factor Documents (http://www.epa.gov/ttn/chief/efdocs/procedur.pdf). These procedures may be overly complex for the Philippines case, so opportunities for streamlining EMB guidelines should be assessed, especially for smaller sources.

Timing and phasing in. A phase-in period, where the fee program is announced but collections are not yet begun, can be used to promote understanding among the business community and allow them to take actions that will reduce their emissions and, consequently, their fee payments. For example, in the first year, one could implement the emissions reporting component alone. Firms then learn how to comply with the fee program and observe how it will impact their costs. During this time they can assess and implement ways to reduce those costs through abatement. The following year, the fee payments would be required.

Over time, as the actual impact on emissions is revealed, the fee can be adjusted to reach ambient concentration targets. Better information about the levels, composition, and consequences of emissions can also lead to adjustments in the fee structure. The standard exemption could also be phased down over time as transitional costs pass and emissions fall. Later, the program could be expanded by reducing the participation threshold or expanding to other airsheds, taking local conditions into account in adapting the program.

5.0 Mobile Source Policies

Vehicles in the developing world's megacities, such as Mexico City, Sao Paulo, Santiago, Bangkok, Bombay, Delhi, Manila, Jakarta and Seoul, have been found to contribute to 40 to 99 percent of some air pollutants (Sterner 2003). Thus, mobile source control policies must be a part of any urban air pollution strategy.

The data in Table 5 illustrate the increasing trend worldwide of vehicle use, as well as the great disparities between income groups. Growth in vehicles has taken off in the middle income developing countries, but is essentially flat in the poorest. Thus, the concern is that unless ownership can be slowed or at least emissions in new vehicles reduced, air pollution is likely to get much worse in these countries. At the same time, ownership in these middle income countries lags far behind that in the high income countries. Another disturbing trend for air pollution is the gradual increase in the share of passenger vehicles in the vehicle fleet (and the corresponding reduction in buses). In China, for example the percentage of passenger cars in the total vehicle fleet increased from 31% in 1990 to 49% in 1996, the most recent year that vehicle data are available for China.

Table 5. Vehicles and Passenger Cars 1990-2000

	Vehicles per 1,000 population		Passenger cars per 1,000 population	
Income category	1990	2000	1990	2000
Low income	9	10*	6	9*
Lower middle income	19	32	11	23
Upper middle income	127	193	114	153
High income	514	586*	396	443*
China	5	8*	1	7
India	4	8*	2	5*

* data for most recent year available
Source: World Bank 2003a

Fortunately, the policy menu for reducing mobile source emissions is long and varied. In addition to direct abatement measures, there are transportation control measures (i.e., measures to reduce vehicle miles traveled and trips) to address congestion externalities (that indirectly reduce emissions) and options to change fuel quality, vehicle design, bus quality, the price of driving, the price of fuel and vehicles, the price of parking, and bus fares, to name just a few.

Most of the stylized facts applying to point sources also apply to mobile sources. Several additional stylized facts that apply to mobile sources include: (i) leaded fuels and high sulfur diesel fuels are used in higher proportions in developing countries; (ii) buses are currently a much more important (but declining) part of the urban transportation fleet than they are in developed countries; (iii) vehicles tend to be older and not as well maintained in developing countries.

We emphasize lead and sulfur in fuels because these pollutants are particularly damaging to human health based on extensive epidemiology research. Since approximately 90 percent of all lead emissions into the atmosphere are due to the use of leaded gasoline, it has become a worldwide public health priority to eliminate lead from gasoline (Lovei 1997). Developed countries have already phased out lead gasoline, beginning with the U.S., in the late 1970s and early 1980s. Many developing countries, such as Bolivia, Colombia, El Salvador and Guatemala, have done so as well, and many more are in the process. In countries where lead has been phased out, dramatic reductions in both blood lead and atmospheric lead have been observed (Table 6). Unleaded gasoline is only available in two of 52 African countries, however, and these countries along with oil-rich areas like the Middle East and Venezuela, have yet to eliminate the use of leaded gasoline (IOMC 1998).

Table 6. Summary of Studies on Lead in Blood, Gasoline and Air

Location	Year	Blood lead (µg/dL)	Lead in gas (g/L)	Atmospheric lead (µg/m^3)	Population age range tested
Athens, Greece	1982	16.0	0.40	1.76	adults
	1993	5.5	0.14	0.43	
Caracas, Venezuela	1986	17.4	0.62	1.9	15+
	1991	15.6	0.39	1.3	
Mexico City, Mexico	1988	12.2	0.2	NA	0.5-3
	1993	7.0	0.06	NA	
Turin, Italy	1980	21.0	0.6	3	18+
	1993	6.4	0.11	0.53	
United Kingdom	1979	12.9	0.42	NA	Adults & children
	1995	3.1	0.055	NA	
United States	1976	15.9	0.465	0.97	1-74
	1988-1991	2.8	0.00	0.07	

Source: Thomas, et al 1999; appearing in WRI 2001

There are many policy options for phasing out leaded gasoline, and determining which is optimal depends on each country's available technologies, markets, vehicle fleet, and politics. The U.S. phaseout, for example, utilized tradable emission permits whereby refineries that could afford to change their technology did so, and then sold the permits to refineries that could not. Other approaches include direct regulation, eco-labeling, and preferential tax treatment. Many of the eastern European countries, for instance, are using taxes on leaded gasoline to encourage production and use of unleaded gas (Sterner 2003). Some alternative policies with respect to reducing sulfur in diesel fuel are discussed in the example in this section on Metro Manila.

The current low ratio of autos to total vehicles in lower income countries (Table 3) means that there may be opportunities to develop transportation control strategies that might be less accepted once car-commuting habits are formed. The low value of time in developing countries also suggests that the focus should be on transportation controls rather than on new vehicle investment or high cost rail systems. Such controls promise reductions in congestion, an increase in capacity utilization of roads and the vehicle stock, and possibly a reduction in total trips, all of which will reduce pollution. These controls can be CAC, such as banning vehicles from driving on certain days as in Mexico City or placing a quota on new cars as in Singapore; incentives, such as congestion tolls and increased parking fees; or planning, such as designing an efficient mix of public and private transportation routes and urban infrastructure. The city of Curitiba, Brazil, for example, implemented a long-term transportation plan in 1974 that included at its core a privatized express bus service, complemented by designated arteries for traffic into and out of the city. Curitiba now has a high rate of car ownership but no serious congestion, and public transportation carries more than two thirds of the population each day with an estimated fuel consumption savings of 25% (Sterner 2003).

Stemming the conversion to single occupancy vehicles with rising incomes should be an important part of an emissions reduction strategy. Improving the quality of bus service will be important for this task as incomes rise. While fare increases are always an option, subsidies could also be warranted because of the positive externalities to congestion and pollution bus use has in comparison with autos – such goes the conventional wisdom.

Nevertheless, if buses use diesel fuel and are substituting for gasoline-powered automobiles, the effects on health are unclear. The generally higher sulfur content of diesel fuel as well as the presence of very fine particulates, some of which are carcinogenic, in this fuel argue for caution in making this particular switch. Conversion of buses from diesel to natural gas, such as the recent program in Delhi (see below), is one method for retaining buses as cheap mass transportation with fewer emissions, although such programs have uncertain effects on costs. On the gasoline side, emissions are mainly VOCs and NO_x, both of which contribute to ozone formation; however ozone appears from the epidemiological literature to be less damaging to health than the particulates from diesel.

Vehicle maintenance is critical to keeping emissions low, yet bus and vehicle inspection programs are virtually non-existent or largely unenforced in some developing countries. In addition, the average age of the fleet of vehicles in developing countries is 12 to 15 years, compared to 6 to 8 years in OECD countries (US-DOT 1996). Older vehicles increase emissions by having lower initial design standards, by increasing emissions with age, and by being more likely to be poorly maintained. One of the first steps toward fixing this problem is to remove perverse subsidies, such as tax breaks for older vehicles, and encourage engine replacement, retrofitting of catalytic converters, and "scrappage" programs to get rid of old cars (Sterner 2003).

Following are two examples of applied mobile source emissions reduction policy.

5.1 Recent Examples

Mobile sources emissions control in Metro Manila

Several recent analyses in Manila (Ruzicka et al. 2002, Larssen et al. 1997 and ENRAP 1996) develop a menu of economic incentive and command and control approaches that could be applied to mobile sources to begin to lower their emissions. Based on these studies and our own analyses, the RFF team[22] proposed a Mobile Source Control Action Plan involving a pilot diesel retrofit program for utility vehicles (including jeepneys) and a charge on the sulfur content of diesel fuel to encourage meeting the 500 ppm standard and to push refineries harder to reach sulfur content levels compatible with more advanced particulate trap technologies. Here we discuss only the latter recommendation.

Particulate matter is the main pollution problem in Manila, with ambient ozone being a lesser problem. Thirty-nine thousand tons of PM_{10} are emitted by mobile sources. Forty-nine percent of mobile source PM_{10} comes from diesel utility vehicles, 22% from motorcycles and tricycles using gasoline/oil mixtures in 2-stroke engines, and 23% from trucks and diesel buses (Fischer, et al, 2003). Out of 1.7 million vehicles in Metro Manila, diesel vehicles make up about one-third (543,000), with another third being gasoline autos and the remainder gasoline utility vehicles and gasoline/oil motorcycles. Consequently, a focus on direct diesel emissions (as opposed to gasoline emissions), particularly from non-bus sources, seems necessary and appropriate.

Assigning a low priority to NO_x control in our Plan is a critical element for a diesel emissions control strategy because it permits a way out of the so-called “diesel dilemma.” Simply stated, the physics of diesel engines creates a tradeoff between reducing PM emissions and reducing NO_x emissions. To get both requires very complex and expensive abatement technology, as well as very low sulfur fuel—conditions that are simply not yet practical in the Philippines.

There are several reasons to recommend a sulfur charge aimed at reducing the sulfur content of automotive diesel. Given industry pressure to relax targets for meeting new lower standards, the charge would offer financial, if not mandatory, incentives to meet them. The tax could also encourage overcompliance with the standard, which is desirable because the lower the sulfur content, the more effective the diesel catalyst. Furthermore, to the extent that compliance with the diesel standard is achieved by switching to low-sulfur crude oil imports, the sulfur content of other oil-based fuels (including kerosene and bunker fuel) would be improved as well.

Experience with lead in the Philippines suggests this approach is feasible. The phase-out of lead in gasoline was accomplished quickly with the aid of tax restructuring to offer incentives for consumers to switch fuels. A tax differential equal to the production cost differential of 4.5 cents per gallon was created, with a charge of 2 cents per gallon levied on leaded gas and unleaded gas subsidized by the same amount from an oil price stabilization fund, when prices were still

[22] Fischer, C., A. Krupnick, R. Morgenstern, K. Rolfe, R. Rufo, J. Logarta. 2002.

regulated. Upon price deregulation, the excise taxes were restructured to give unleaded gasoline a four-cent per gallon edge at the pump. Started in 1994, the phase-out was complete in 1999. Concurrently, oil prices were deregulated and all prices fell.

The energy department is also concerned about the impacts of new fuel standards and taxes on the viability of the local oil refiners. Figures show that compliance with the current standard of 2000 ppm sulfur (from 5000 ppm prior to January 2001) diesel was achieved mainly through dilution with imported 500 ppm sulfur diesel. If standards can only be met with imported oil, this could drive down local refinery profits.

Some oil companies have officially written the energy department seeking its support for a deferment of the new standard to either 2006 or 2007 (requiring an amendment to the Clean Air Act). If the government is eventually persuaded to defer the new standard on limited protectionist grounds, then imposing a tax differential (between a high-sulfur and low-sulfur grade) would be an attractive option to move policy in the same direction. If transition costs for refineries are a concern, especially for obtaining industry acceptance of the policy, rebates toward installing desulfurization capacity could help defray those costs initially. Alternatively, a type of standard exemption could be included in determining the base for the charge. A fixed exemption would mean that fees would have to be paid on total sulfur exceeding a certain fixed amount. This reduces the total tax liability for the producer while maintaining the marginal incentives (fully so, if the charge is refundable for sulfur levels below the exemption). However, building in such an exemption risks creating a transfer to producers that persists beyond the transition period.

Accordingly, we proposed restructuring the excise tax on diesel fuel into two parts, a base rate and a charge based on the sulfur content. In other words,
Total tax per liter = base excise tax + charge*sulfur rate
Thus, the lower the sulfur content of the fuel, the lower the taxes paid for every liter sold.

In contrast with the recent lead phaseout, consumers will not choose between different grades and prices of diesel at the pump. Rather, producers have the choice of how much sulfur to remove from the diesel fuel that they sell at retail. If a refinery can lower sulfur cheaply, it can do so, and pay less tax; if another finds more desulfurization too expensive, rather than raise its production costs, it can choose to pay more tax.

As with the stationary source fee described in the previous section, the sulfur charge should reflect the costs of sulfur and its removal. A problem common to both designs is a lack of information. One would need to know the marginal reduction costs of all the major participants to determine the tax rate that would achieve the desired reduction (average content=standard).

Making the sulfur charge additional to existing excise taxes, instead of lowering the base, would raise additional revenue and raise retail prices. The sulfur charge revenues could be used in many ways, such as to create a fund that can help subsidize purchase of the particle traps for utility vehicles that we advocated in our Plan.

An additional effect of the corresponding price increase would be to reduce some of the differential between gasoline and diesel prices. The relative price change, over time, could induce a switch to gasoline vehicles for new vehicles, or perhaps even engine replacements on old vehicles that, while exacerbating VOC emissions, would result in a large drop in PM emissions. However, if the stock of diesel vehicles improves over time, upgrading to Euro 3 and 4 standards, and sulfur content becomes low enough to make catalysts effective, this switch may not be as desirable given concerns over carbon emissions.

Alternatively, one could retain the current excise tax and structure the charge to be paid on sulfur content exceeding some percentage standard (and also credited if below), in effect creating a rate-based exemption. In theory, the price and revenue effects would be the same as in the previous example.[23]

A key question is where the tax should be levied. We recommended that it be levied at the point where the refined products enter the market: sales by refineries and importers of refined products. These actors are limited in number (3 refineries, and at least five major importers of automotive fuels). They also have pre-existing regulatory burdens and relationships with enforcement agencies. This "upstream" point of compliance thus minimizes the administrative and enforcement burden, and has been noted by other researchers such as Harrington and McConnell (2003) as a viable option for some mobile source pollution problems. The price incentives would be similar regardless of the point of compliance. Lower-quality fuels are made more costly, creating pressure to consume and produce higher-quality fuels.

Administratively, the sulfur-content charge should not present much of an increased burden over current practice. Excise taxes are already collected on the volume of diesel sales, and sulfur contents must be certified, so additional reporting requirements are not imposed. It does, however, increase the financial importance of fuel sampling and reporting; thus, verification and monitoring will require greater attention.

Imposing and altering the diesel tax requires legislative approval, so it may be harder to phase it in or adapt it once it is in place. Still, adjustments could be made over time; the reform could perhaps give the Department of Energy (DOE) or another agency with the relevant authority to adjust the sulfur charge on their own. Initially imposed to speed compliance to the 500 ppm standard, the charge will also help provide information regarding the costs and cost-effectiveness of further lowering sulfur in fuels.

By recommending a diesel retrofit program and sulfur charge we are not suggesting that the many other options for reducing mobile source emissions be ignored. With air pollution problems as serious as those faced in Manila, many points of attack are needed. Nevertheless, limited administrative resources demand prioritization, such as putting off consideration of alternative fueled vehicles. Alternative fuel technologies are expensive and not cost-effective, and a policy to promote them will take a long time to pay off. We feel the Philippines should wait for less expensive technologies.

Similarly, we did not recommend immediately bolstering the gasoline vehicle inspection and maintenance program. Improving enforcement of this program will take a huge administrative

[23] The danger here is that unintended tax credits could be created; in the U.S. lead phasedown policy, which used tradable performance standards (another rate-based scheme), some companies blended otherwise uneconomic fuels (like ethanol) with a little leaded gasoline, just to generate tradable credits.

commitment and the pollutants emitted may not be contributing very much to Manila's most serious pollution problems. We also recommend putting off consideration of changing vehicle registration fees to make them more environmentally responsive. While responsiveness is a good idea, these fees have just recently been reformed and it may be politically difficult to change them again so soon.

Conversion of buses to CNG in Delhi, India[24]

Delhi is one of the many mega-cities of the developing world struggling with very high levels of pollution from industrial, residential, and transportation sources. In particular, the latest census shows that the population has grown to 14 million and the number of motorized vehicle registrations grew three times as rapidly as population between 1980 and 2000.

Vehicles were powered largely by highly polluting engines, including buses trailing plumes of black smoke from their diesel engines. In 2002, Delhi's commuters used buses often enough to rank the city in the world's top 20 for use of public transportation. Private vehicles were powered by diesel, gasoline, or two-stroke engines, which use a combination of gasoline and motor oil. The city's huge fleet of "three wheelers" (small vehicles used as taxis or for light hauling) also used two-stroke engines. Taken together, a 1992 World Bank study estimated Delhi's annual health costs of ambient air pollution to be 10 billion Indian Rupees (about US $200 million).

The Delhi government had passed a Clean Air Act in 1981 that authorized a Central Pollution Control Board to "lay down standards for the quality of air;" "advise the Central Government on any matter concerning the improvement of the quality of air and the prevention, control, or abatement of air pollution;" and "perform such other functions as may be prescribed." Yet, the government was not implementing the Act. Following a 1985 filing by attorney M.C. Mehta, who asked the Court to order the Delhi Administration to enforce its existing laws to reduce air pollution in the city, the Indian Supreme Court began a long process with the government on many pollution fronts, culminating in its now famous July 1998 Order requiring that public diesel vehicles and three-wheeled vehicles with two-stroke engines be converted to compressed natural gas (CNG). Contrary to popular belief that the Court originated this idea, the idea had been is discussion at least as far back as 1988.

In any event, the order began to be implemented in early 2002, with the Supreme Court ordering the immediate installation of 1,500 CNG buses and the replacement of 800 diesel buses per month. It also set up daily fines for buses ignoring the Order and fined the central government 20,000 Rs. (about US$476) for repeatedly delaying the process. By November of 2002 diesel city buses, diesel taxis and two-stroke three-wheelers were completely phased out. Since then, there has been a slight reduction in monitored respirable particulate concentrations in the city. However, a big increase in concentrations the year before makes if risky to attribute such improvements to the policy.

The Court's decision to convert to CNG has been criticized from numerous angles - that it was not cost effective; that the Court did not conduct an adequate inquiry about fuels and ultimately

---

[24] Information for this example is taken from Bell, Mathur and Narain (2004) and on the web at: http://www.rff.org/rff/News/Features/Clearing-the-Air.cfm

selected the "wrong" fuel; that rather than set policy, the Court should have set emissions norms and then allowed for multi-fuel and multi-technology options for meeting those norms; and finally that the Court overstepped its bounds by making policy. In addition to fending off fiercely defended positions from powerful interest groups, the Court faced possible policy trade-offs between cost-effectiveness and enforceability: rigid technology standards are likely to be more expensive, but more flexible performance standards could have been more problematic to implement and enforce. The illegal use of kerosene to adulterate the fuel if price instruments were used instead was a major factor in the Court's decision to force the conversion.

Perhaps the most important issue concerning the Delhi program is whether this approach is exportable. Bell et al (2004) draw out several factors that should be taken into account. First, there must be a "dependable decision-maker," a public body, such as the Indian Supreme Court, that is respected by the population, operates independently, and is willing to enforce policy reforms. Second, countries should consider only tools consistent with their institutions and technical capabilities. The Indian court's decision to order a diesel ban was based on the lack of enforcement institutions to limit fuel adulteration. And third, even with an independent and active judiciary, reforms will not happen unless other institutions support it. In India, a free press and independent NGO community helped keep the spotlight in the conversion issue.

6.0 Conclusions

Compared to developed countries, which already have relatively clean water and face arguably less intense tradeoffs between economic growth and environmental protection, air pollution may be a lower priority in the developing world. While improving health care systems can result in people living longer and healthier lives, as income grows, energy use grows and along with it, air pollution.

Yet, even this attenuated tradeoff is not inevitable. The tools and understanding to address air pollution problems in urban areas of developing countries already exist. In developing countries, large stationary sources of air pollutants are easy to identify, document, and target. The stylized facts in developing countries argue for a preference towards applying economic incentive approaches to stationary source problems, but only ones that are sensitive to and accommodate institutional deficiencies in these countries. The growing role of mobile sources is perhaps more troubling, because it brings congestion along with environmental externalities and is more closely tied to income growth. Yet, here, a variety of incentive and CAC policies are available to reduce emissions; those helping to produce cleaner fuels being among the more promising. Further, with the vehicle fleet growing in at least the middle income developing countries, some options exist to embed newer technologies in the fleet at relatively modest cost. In addition, improvements in public transit may slow substitution to private vehicular use.

Lacking, however, are a solid factual basis for defining the type and extent of the air pollution problem – i.e., the poor state of air pollution monitoring, and the infrastructure to set air quality goals and implement measures to attain them. The case studies presented here show that NGO's (in this case the Asian Development Bank) have a willingness to bring about such implementation and that analysts can design policies that address to some extent the shortcomings in laws, funding, and experience that afflict developing countries. But, in the end, it is the local and national governments that must be responsible for such goal setting and implementation. The enviable performance of many developing countries in banning lead from gasoline is evidence that progress can be made.

References

Ambec, Stefan and Philippe Barla. 2002. "A Theoretical Foundation of the Porter Hypothesis," *Economics Letters* 75 (3): 355-60 (May).

Andreoni, James and Arik Levinson. 2001. "The Simple Analytics of the Environmental Kuznets Curve" *Journal of Public Economics* 80(2): 269-86. (May).

Bell, Ruth, Kuldeep Mathur and Urvashi Narain. 2004. "Clearing the Air: How Delhi Broke the Logjam on Air Quality Reforms" *Environment,* April.

Blackman, A. and G. Bannister. 1998. "Community Pressure and Clean Technology in the Informal Sector: An Econometric Analysis of the Adoption of Propane by Traditional Mexican Brickmakers." *Journal of Environmental Economics and Management.* 35(1):1-21.

Burtraw, Dallas and Karen Palmer, 2004. "Distribution and Efficiency Consequences of Different Approaches to Allocating Tradable Emission Allowances for Sulfur Dioxide, Nitrogen Oxides and Mercury," Resources for the Future Discussion Paper.

Carlson, Curtis, Dallas Burtraw, Maureen Cropper, and Karen Palmer. 2000. SO_2 Control by Electric Utilities: What Are the Gains from Trade? *Journal of Political Economy* 108(6): 1292–326.

Ellerman, A.D., Paul L. Joskow, Richard Schmalensee, Juan-Pablo Montero, and Elizabeth Bailey. 2000. *Markets for Clean Air: The U.S. Acid Rain Program.* Cambridge: Cambridge University Press.

ENRAP. 1996. Philippines Environmental and Natural Resource Accounting Project, Phase III. Manila, funded by the Asian Development Bank

Ezzati, M., S. Vander Hoorn, A. Rodgers, A. Lopez, C. Mathers, C. Murray, and the Comparative Risk Assessment Collaborating Group. 2003. "Estimates of global and regional potential health gains from reducing multiple major risk factors." *The Lancet*. 362:271-80.

Ezzati, M., A. Lopez, A. Rodger, S. Vander Hoorn, C. Murray, and the Comparative Risk Assessment Collaborating Group. 2002. "Selected Major Risk Factors and Global and Regional Burden of Disease." *The Lancet*. 360:1347-60.

Fischer, C., A. Krupnick, R. Morgenstern, K. Rolfe, R. Rufo, J. Logarta. 2002. *Air Pollution Control Policy Options for Metro Manila.* Draft report to the Asian Development Bank. Manila, Philippines: Asian Development Bank.

Harrington, W., and V. McConnell. 2003. *Motor Vehicles and the Environment*. RFF Report. Washington, DC: Resources for the Future.

Health Effects Institute. 2003. "Update on HEI's Interational Project in Asia – June 2003". Accessed online at: http://www.healtheffects.org/International/Papa-update2.htm.

Inter-Organization Programme for the Sound Management of Chemicals (IOMC). 1998. *Global Opportunities for Reducing the Use of Leaded Gasoline*. Geneva, Switzerland: United Nations Environment Programme (UNEP Chemicals).

Larssen, S., F. Gram, L. Hagen, H. Jansen, X. Olsthoorn, R. Lesaca, E. Anglo, E. Torres, R. Subida, and H. Francisco. 1997. "Urban Air Quality Management Strategy in Asia: Metro Manila Report." Jitendra Shah, Tanvi Nagpal, and Carter J. Brandon, eds. World Bank Technical Paper No. 380. Washington, DC: The World Bank.

Lovei, M. 1997. *Phasing Out Lead From Gasoline: Worldwide Experience and Policy Implications.* World Bank Technical Paper No. 397. Washington, DC: The World Bank.

Millimet, Daniel L., John A. List, and Thanasis Stengos. 2003. "The Environmental Kuznets Curve: Real Progress or Misspecified Models?" *Review of Economics and Statistics* 85(4):1038-47 (November).

Parry, Ian W. H.. 1995. "Pollution Taxes and Revenue Recycling." *Journal of Environmental Economics and Management* 29:S64-77.

Parry, Ian W.H., Roberton C. Williams and Lawrence H. Goulder. 1999. "When Can Carbon Abatement Policies Increase Welfare? The Fundamental Role of Distorted Factor Markets." *Journal of Environmental Economics and Management* 37(1): 52-84 (January).

Pope, CA, MJ Thun, MM Namboodiri, DD Dockery and JS Evans. 1995. "Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults." *American Journal of Respiratory Critical Care Medicine.* 151:669-74.

Ruzicka, I., A.L. Indab and C.M. Rufo Jr. 2002. "Coughing up for Clean Air: Incentive-based approaches to controlling air pollution in Metro Manila." Manila, Philippines: Asian Development Bank.

Smith, V. Kerry, Randy Walsh. 2000. "Do Painless Environmental Policies Exist?" *Journal of Risk and Uncertainty* 21(1): 73-94 (July).

Sterner, T. 2003. *Policy Instruments for Environmental and Natural Resource Management*. Washington, DC: Resources for the Future.

Thomas, V., R. Socolow, J. Fanelli, and T. Spiro. 1999. "Effects of reducing lead in gasoline: An analysis of the international experience." *Environmental Science and Technology.* 33(22):3942-3948.

Tietenberg, T. 1985. *Emissions Trading: An Exercise in Reforming Pollution Policy.* Washington, DC: Resources for the Future.

U.S. Department of Transportation. 1996. Transportation Statistics Annual Report, An International Comparison of Transportation and Air Pollution, Chapter 9. Washington, DC: USDOT Bureau of Transportation Statistics.

Weitzman, M. 1974. "Prices vs. Quantities." *Revue of Economic Studies*. 41/4.

World Bank. 2003a. *World Development Indicators on CD-ROM*. Washington, DC: World Bank.

World Bank. 2003b. *Environmental Health Perspectives.* Washington, DC: World Bank.

World Health Organization. 2003. *World Health Report* Geneva: http://www.who.int/whr/2003/en/

World Health Organization. 2001. *Air Quality and Health: Air Management Information System 3.0 CD-ROM*. Geneva: World Health Organization.

World Health Organization. 1987. Global Environment Monitoring System, *Global Pollution and Health.* Geneva, Switzerland: World Health Organization.

World Resources Institute. 2001. "Laden with Lead." *World Resources 1998-99*. Originally published 1998, updated October 2001. Accessed online at: http://earthtrends.wri.org/pdf_library/features/ene_fea_lead.pdf