Science of the Total Environment 409 (2011) 1774–1785

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Assessing the co-benefits of greenhouse gas reduction: Health benefits of particulate matter related inspection and maintenance programs in Bangkok, Thailand

Ying Li [a,*,1], Douglas J. Crawford-Brown [b]

[a] Department of Public Policy, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA
[b] Cambridge Centre for Climate Change Mitigation Research, University of Cambridge, Cambridge, UK

ARTICLE INFO

Article history:
Received 28 September 2010
Received in revised form 25 January 2011
Accepted 26 January 2011
Available online 21 February 2011

Keywords:
Health benefits
Ambient particulate matter
Inspection and maintenance programs
Motor vehicles
Bangkok

ABSTRACT

Since the 1990s, the capital city of Thailand, Bangkok has been suffering from severe ambient particulate matter (PM) pollution mainly attributable to its wide use of diesel-fueled vehicles and motorcycles with poor emission performance. While the Thai government strives to reduce emissions from transportation through enforcing policy measures, the link between specific control policies and associated health impacts is inadequately studied. This link is especially important in exploring the co-benefits of greenhouse gas emissions reductions, which often brings reduction in other pollutants such as PM. This paper quantifies the health benefits potentially achieved by the new PM-related I/M programs targeting all diesel vehicles and motorcycles in the Bangkok Metropolitan Area (BMA). The benefits are estimated by using a framework that integrates policy scenario development, exposure assessment, exposure-response assessment and economic valuation. The results indicate that the total health damage due to the year 2000 PM emissions from vehicles in the BMA was equivalent to 2.4% of Thailand's GDP. Under the business-as-usual (BAU) scenario, total vehicular PM emissions in the BMA will increase considerably over time due to the rapid growth in vehicle population, even if the fleet average emission rates are projected to decrease over time as the result of participation of Thailand in post-Copenhagen climate change strategies. By 2015, the total health damage is estimated to increase by 2.5 times relative to the year 2000. However, control policies targeting PM emissions from automobiles, such as the PM-oriented I/M programs, could yield substantial health benefits relative to the BAU scenario, and serve as co-benefits of greenhouse gas control strategies. Despite uncertainty associated with the key assumptions used to estimate benefits, we find that with a high level confidence, the I/M programs will produce health benefits whose economic impacts considerably outweigh the expenditures on policy implementation.

1. Introduction

Urban air pollution associated with transportation is currently a major public health concern in many large developing metropolitan areas as rapid expansion of vehicle use is a common feature in these areas, and scientific studies have found suggestive evidence relating adverse human health effects to exposure to primary traffic-generated air pollution (HEI, 2010). Although the negative health impacts of urban air pollution have been widely investigated, the link between specific traffic-related emission control policies and associated health benefits has not been well characterized and rarely been integrated into policy analysis in a developing country context. This issue is especially germane under the emerging Copenhagen Accord, because policies aimed at reducing greenhouse gas emissions find weak support in developing nations faced with needed economic growth, but gain in support as the co-benefits of greenhouse gas reductions are included in financial analyses. One co-benefit of greenhouse gas reduction in the transportation sector is reduced emissions of particulate matter, leading to improved health and economic performance.

This paper studies the capital city of Thailand—Bangkok, a megacity that has been suffering from severe adverse health effects attributable to ambient particulate matter (PM) for more than a decade. To mitigate the serious urban air pollution and promote sustainable transportation development in Bangkok, a justified goal in its own right but also a co-benefit of climate change policies, enhanced inspection and maintenance (I/M) programs targeting PM emissions from in-use diesel-fueled vehicles and motorcycles have been proposed to be adopted. These are relatively new types of I/M programs distinct from traditional I/M programs that focus primarily on other pollutants from gasoline-fueled vehicles. At present, PM-oriented I/M programs have gained a growing interest due to the public concern over the health threat posed by fine PM emitted from

* Corresponding author at: Department of Public Policy, University of North Carolina at Chapel Hill, CB# 3435, Chapel Hill, NC 27599-3435, USA. Tel.: +1 919 360 0636; fax: +1 315 684 6588.
E-mail address: liying@email.unc.edu (Y. Li).
[1] Present address: 20 Carriage Lane, Apt.12, Cazenovia, NY 13035, USA.

0048-9697/$ – see front matter
doi:10.1016/j.scitotenv.2011.01.051

in-use vehicles. In particular in less developed nations, vehicles are often poorly maintained—leading to both PM emissions and fuel inefficiency—and there are still many old vehicles running on roads. PM control policy options have been proposed as imperative solutions to the air pollution resulting from mobile sources in these regions in addition to setting new vehicle emissions standards and enforcing fuel quality regulations. The goal of this research is to understand the health benefits potentially achieved by enforcing these programs so better cost–benefit assessments can be developed.

An integrated procedure is used here that combines exposure assessment, exposure–response assessment and economic valuation. Our methods are based on those used by the U.S. EPA in making regulatory decisions based on cost–benefit comparisons (USEPA, 1999), and others to assess the benefits of reducing ambient air pollution (e.g. Ostro and Chestnut, 1998; Levy and Spengler, 2002; Wang and Mauzerall, 2006; Cifuentes et al., 2001). While most previous studies either focus on the health benefits from achieving a target air quality standard, or the health related environmental costs attributable to a particular sector of energy use, fewer studies have examined specific control policy scenarios targeting emissions from the transportation sector. This study provides a systematic evaluation of the health benefits resulting from new PM-related vehicle I/M programs to evaluate the benefits of air pollution control policies.

The paper is organized as follows. Section 2 describes the methods used to quantify the health benefits of PM-related I/M programs in the study area, including policy scenario development, exposure assessment, exposure–response assessment, and economic valuation. Section 3 presents estimates of health damage costs attributable to vehicle PM emissions in the base year and benefits of the I/M programs in future years, and also compares the health benefits with the costs of implementing the programs. Section 4 summarizes the major conclusions of this study.

2. Methods

2.1. Policy scenario development

This study uses the year 2000 as the base year to establish the emission baseline. This year was chosen because in the late 1990s, in confronting severe PM pollution in the Bangkok area, the Thai government implemented a series of cost-saving mitigation measures, such as providing car engine tune-up service to the public for free, paving street shoulders to reduce road dust, etc. Although these measures did significantly contribute to preventing Bangkok's air quality from getting worse, ambient PM concentrations continue to exceed the air quality standards. There remains, therefore, significant pressure to bring about further reductions. An additional advantage of this base year selection is that the Bangkok Air Quality Management Project sponsored by the World Bank, conducted during the late 1990s through early 2000s, has provided reliable data for the year 2000 required to estimate the local public health benefits of emission control policies. These data are rare in less developed countries.

We consider both a business-as-usual (BAU) scenario, i.e. the scenario with no further control policies relative to the base year 2000, and a hypothetical abatement policy scenario enforcing enhanced PM-oriented vehicle inspection and maintenance (I/M) programs targeting all diesel-fueled vehicles and motorcycles in the Bangkok area. The programs are assumed to start in 2008 and target a total reduction of 25% in PM_{10} emissions (all particulates with an aerodynamic diameter of less than or equal to 10 μm) from all diesel-fueled vehicles and motor vehicles relative to the baseline. We also test the sensitivity when the I/M programs do not accomplish the emission cut target, i.e. achieving less than 25% PM_{10} emission, which is very likely in reality and will result in smaller benefits from the programs.

2.2. Simulation of changes in human exposure to ambient particulate matter due to policy implementation

To estimate the changes in ambient PM concentrations under a policy scenario, we began by defining the modeling domain and obtaining PM monitoring data. The modeling domain of this study is the Bangkok Metropolitan Area (BMA), which includes Bangkok and its surrounding five provinces, Samut Prakarn, Nonthaburi, Pathum Thani, Nakhon Pathom and Samut Sakhon, altogether covering an area of 7761.50 km^2 (the area of Bangkok is 1568.20 km^2), or about 1.5% of the area of Thailand, and with a population of 12 million (as of 2008). The reason that Bangkok's peripheral provinces were also included is that these areas are closely linked in terms of traffic and economic development (Oanh and Zhang, 2004). We limited the impacts of the I/M programs on PM air quality within metropolitan Bangkok due to the reason that, unlike particulates from industrial point sources or natural sources, which may be transported over very long distances with high stacks or climate conditions, the particulate emissions from vehicle exhaust considered here are expected to have much greater impacts at the local scale than at the regional scale. Nevertheless, we are aware that ignoring the impacts in the larger region may slightly underestimate the total benefits resulting from policy implementation.

Daily monitored PM_{10} data were obtained from the Pollution Control Department (PCD), Thailand. Of the 17 permanent air quality monitoring stations in the BMA operated by PCD, 8 have daily PM_{10} data in the base year 2000, with all these stations located in Bangkok. In the case of missing monitoring data, daily PM_{10} concentrations on these days were estimated based on data of the previous and next days using linear interpolation. If monitoring data were missing for ten or more continuous days, the seasonal average PM_{10} level was utilized as an approximation of the daily concentrations to reflect the possible significant difference among seasons (including Winter, Summer and Rainy) throughout a year.

To estimate the ambient PM_{10} concentrations attributed to mobile sources, it was assumed that the shares of different source categories for monitored PM_{10} concentrations are proportional to their relative contribution to the emissions inventory of PM_{10}. For example, if PM_{10} emitted from mobile sources account for 50% of the total PM_{10} emissions from all man-made sources, then 50% of the total anthropogenic ambient PM_{10} concentrations, defined as a monitored concentration less the regional background of PM_{10}, are contributed by these sources. It was not judged feasible to attempt a more precise allocation of the relationship between emissions and concentration for each source. Therefore, the reduction in ambient PM_{10} concentrations attributed to mobile sources is also proportional to the projected emission reduction in these sources. In addition, it was assumed that except for mobile sources, all other PM_{10} emission sources will not be affected by I/M programs considered. This approach allows us to calculate the daily PM_{10} concentrations at monitors in the base year attributable to mobiles sources, and to predict the future changes in concentrations observed at monitors that reflect the hypothetical imposition of the I/M programs by using Bangkok's PM_{10} emission inventory and daily monitoring data in the year 2000.

The best available PM_{10} emission inventory information in the BMA was examined, and it was found that in this area there still exists significant uncertainty in the relative share of contribution to the total PM_{10} emissions by different source categories, including mobile (motor vehicles), industrial, road re-entrainment and construction. For example, a World Bank (2002) publication stated that emission inventories in the BMA prepared and reported by different organizations can differ by a factor of twenty. In order to reduce the possible biases introduced by a single study on the emissions inventory in the BMA, this study collected all available studies and averaged the results. We estimate that in the base year 2000, there were 15,650 tons of PM_{10} emitted from motor vehicles in the BMA, accounting for 32% of total anthropogenic PM_{10} emissions in that year. In uncertainty analysis, we represent the uncertainty of this variable as a Uniform distribution, with a lower