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Brief overview of researches on traffic induced air pollution in Dhaka, Bangladesh

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Abstract

Dhaka, the capital of Bangladesh, and one of the fastest growing megacities of the world, has been well known for being over-populated, traffic congested and polluted (emission). It was termed as the most polluted city in the world in the 90's because of the presence of high level of lead in air. Pollution from traffic and brick kilns has been identified as two of the most significant of all the factors by the studies. In order to improve the severe situation, the authorities took some decisions (e.g. banning two stroke engines, introducing Compressed Natural Gas (CNG) etc.). There has been little systematic research on air pollution of Dhaka resulting from traffic. There have been some estimations of emission from different sectors (e.g. transport, industry, residential etc.). The pollutants in consideration were NOx, SOx, CO, CO2, $PM_{2.5}$, and PM_{10} etc. In spite of few projects in the 90s and 2000s, the air quality monitoring data are rare and mostly unavailable due to limited measuring facilities, economic constraints and lack of initiatives etc. This paper uses the traffic and air quality data which have been estimated, collected and analyzed by previous studies, reports and researches. It attempts to summarize and depict the research results on air pollution of Dhaka, especially from traffic, with brief description of the transport system.

Keywords: Air pollution; Dhaka; traffic problems; developing cities.

1. Introduction

Dhaka, the capital of Bangladesh, and eight largest city in the world, in terms of population (Begum et al. 2013), has been well known for being over-populated, traffic congested and polluted (emission). It was termed as the most polluted city when lead in the air was reported higher than in the atmosphere of any other place of the world (Ahmed 1997). Pollution from traffic and brick kilns has been identified as two of the most significant of all the factors by the studies. In order to improve the severe situation, the authorities took some decisions (e.g. banning two stroke engines, introducing Compressed Natural Gas (CNG) etc.). But, other than numerous sporadic systematic and recent studies and projects, there has been little research on air pollution of Dhaka resulting from traffic. This paper tries to comment and overview the results from various studies, projects and policy decisions regarding the topic.

2. Major Facts

2.1 Population

With a current population of 17 million, Dhaka (location 23.42N and 90.22E) has been growing at astonishing levels since the independence. Its metropolitan area is home to almost 15 million people in an area of 1,528 km² (about 17 million in the Greater Dhaka). The megacity's population is expected to rise to 20 million people by 2020. With more than 45,000 people per square meter in the core area, it is also one of the most densely populated cities in the world (ADB 2011). It is among the only seven cities which experienced urban population growth higher than 2.4% in between 1975-2005 (UN 2006). Per capita income averages around USD 900 per year, and around 30% of the population lives in miserable conditions, with very poor access to transport services (Ministry of Finance GoB 2012).

2.2 Weather

The weather of Dhaka is tropical with lowest temperature varying between 54-79F and highest between 77-95F. According to meteorological condition, a year can be divided into four seasons, pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-November) and winter (December-February) (Salam et. al. 2003). During monsoon (June-August), there is very high precipitation of rainfall being on the average greater than 30 cm per month. During winter (November-January), there is hardly any rainfall (<2 cm per month) and there is very little wind (Sarker and Alam 2001). In general, October to April can be termed as dry season.

2.3 Traffic situation

In Bangladesh, like any other developing economies, motorized traffic is growing rapidly; around 300 new motorized vehicles are coming to road every day. The number of registered motorized vehicle grew from 7,37,400 in 2003 to 17,51,834 in June, 2012. More than 40% of all registered vehicles (7,08,197) are in Dhaka (BRTA 2012). The number of motor vehicles per 1000 people rose from 1.4 in 1982 to 2.28 in 1991, and to 2.72 in 1995 (BBS 1995). Motor vehicles are classified in the following major categories: heavy truck, tractor, bus/minibus, car, jeep, trailer, auto-tempo (three wheeled scooter, 9 seated), auto-rickshaw (three wheeled scooter, 4 seated), and motor cycle. Nearly one third of motor vehicles (mainly trucks and buses) are run by diesel, which results in greater amount of urban SPM, SOx and NOx.

It can be observed that, the number of privately owned motor vehicles particularly motorcycles and cars are growing rapidly which increased by 200% and 250% respectively over the period of 8 years (2003-11). Public transport such as buses and minibuses has not grown substantially despite the demand for public transport has increased considerably. There are 11,060 buses and 8,583 minibuses plying on roads which represent only about 3% (buses and minibuses combined) of total motorized traffic. On the contrary, motorcycles constitute around 42% of total motorized vehicles (Hoque et al. 2012).

In an ideal city, 25% of the surface area should be used for constructing roads and lanes, (Hossain 2006) but Dhaka has only 8% (DCC, 2002). Moreover, like most of the developing cities, Dhaka's road network hierarchy is poorly defined, with very limited number of arterial and main roads. The prevailing situation is even worse when taken into account the fact that, this inadequate road space is shared by both motorized and non-motorized traffic (heterogeneous traffic mix) and vehicles with varying characteristics (e.g. three-wheelers, human haulers, pickups, vans etc.) (Barua et al. 2013).

2.4 History

Environmental problem in Bangladesh was a relatively new concern in the late 80’s or early 90’s. The Department of Environment (DoE) was established in 1989 (18 years after the emergence of the country) as the sole official agent dedicated to the scientific and regulatory measures. It conducted a National Environment Monitoring and Pollution Control Project (NEMAP), funded by Asian Development Bank in 1990. It monitored ambient air quality of SPM, SO2 and NOx at three locations of Dhaka City. Before, during and after that, several other monitoring and surveys on ambient concentration of oxides of nitrogen (NOx), lead (Pb), particulate matter (PM), carbon monoxide (CO) and black smoke have been carried out by various individual researchers, institutes, organizations, authorities and government, in some cases with financial and/ or help from developing partners, in Dhaka.

For example, (Karim 1999) determined some black spots with respect to different pollutants (Black spot locations are those where pollutant concentration exceeded the ambient standard level); a 17 month survey study by Bangladesh Atomic Energy Commission (BAEC) scientists detected 463 ngm/m3 of lead in air over Dhaka, Bangladesh during the dry months (November 1995-January 1996) etc. The overviews of these studies are summarized in the following sections organized with respect to various pollutants.

3. Air pollution and the pollutants

Generally, some of the causes for air pollution can be stated as large numbers of high polluting vehicles, impure fuel, inefficient land use and overall poor traffic management (Karim et al. 1997). One of the dominating factors of Dhaka's traffic pollution was the number of auto-rickshaws and auto-tempos.

Table 1
Baseline vehicular emissions inventory in Dhaka, 1996; Unit: 1,000 tons

	Particulate matters (PM_{10})	Hydrocarbons	Carbon monoxide	Nitrogen oxides	Lead	Carbon dioxide	Methane
Light vehicles	0.26	3.70	24.91	1.63	0.012	309	0.04
Minibus	0.21	0.12	0.30	0.58	0.003	115	0.02
Diesel bus	0.64	0.42	1.40	2.65	0	324	0.02
Diesel truck	1.11	0.74	1.91	3.61	0	563	0.03
3-wheeler	0.93	13.52	16.37	0.07	0.011	147	0.19
2-wheeler	0.55	3.31	5.81	0.02	0.011	50	0.11
Total	3.70	21.80	50.70	8.55	0.037	1507	0.40

(Ahmmed and Begum 2010)

Their increase was most remarkable in Dhaka as the proportion of such two stroke engine vehicles in the total vehicle population rose from 2.2% in 1982-83, to 18% in 1990-91, and as high as 23% in 1996-97 (Karim et al. 1997). It was estimated that an auto-rickshaw emitted 30 times more pollutants than a normal car (Karim 1997). The annual fuel consumption by the vehicles in Dhaka metropolitan was 77% diesel, 18% petrol, and 5% octane before the introduction of Compressed Natural Gas (CNG) (Sarker and Alam 2001).

Table 2
Ambient air quality of Dhaka City

Location	Pollutant's Concentration				
	CO (µg/m3)	NOx (µg/m3)	SO2 (µg/m3)	PM_{10} (µg/m3)	CO2 (ppm)
Mohakhali	2519	376	Trace	547.66	435
Farmgate	7730	752	Trace	289.92	590
Mogbazar	5726	339	Trace	383.53	475
Sonargaon	3435	75	Trace	161.93	500
Science Lab	5726	113	Trace	167.64	500

Note: Amended Bangladesh Standards (ECR,2005)
SO2: 365 µg/m3 (24-hour average)
CO: 10000 µg/m3 (8-hour average)
NOx: 100 µg/m3 (Annual)
PM_{10}: 150 µg/m3 (24-hour average)
(Ahmmed and Begum 2010)

The most important pollutants with respect to transportation systems can be identified as Carbon monoxide (CO), Sulfur dioxide (SO2), lead (Pb) Nitrogen oxides (NOx), Ozone (O3), Hydrocarbons (HC) and Suspended Particulate Matter (SPM) (Karim 2001). In the late 1970s, environmental Protection Agency (EPA) of USA added lead (Pb) to this list. Particulate matter with an aerodynamic diameter of less than or equal to 10µm (PM_{10}) was added to the list in 1987 (Ahmmed and Begum 2010). Observing from (Nasiruddin 2001), the trend for concentration of SO2, O3, CO and NOx, their values go up in dry season significantly. The same has been also true for $PM_{2.5}$ and PM_{10} (their concentrations increases by 5-7 folds) (Begum et al. 2010).

3.1 Suspended Particulate Matter (SPM), Particulate Matter (PM), PM_{10}, $PM_{2.5}$ and Black Carbon (BC)

It was observed that from January to April (dry and calm season) the ambient concentration of Suspended Particulate Matter (SPM) exceeded the WHO standard for daily average hourly concentration of 150-230gm/m3. Average SPM levels were about double than the Bangladeshi standard of 200 µg/m3 in residential areas and are more than 10 times higher than the WHO guidelines of 120 µg/m3 (24 hours) in commercial areas (Sarker and Alam 2001). The maximum daily average hourly concentration of SPM observed was 570 gm/m3 at Motijheel in January (Islam and Islam, 1990). Interestingly, this study did not show any alarming situation for ambient SO2 and NO2 concentrations.

Table 3
Concentrations (µg/m3) of PM_{10} $PM_{2.5}$ BC during rainy season at Farmgate

Parameters	Day time			Night time		
	PM_{10}	$PM_{2.5}$	BC	PM_{10}	$PM_{2.5}$	BC
Average	55.8	24.4	15.6	63.6	25.2	10.9
95% confidence interval	48.5-63.2	11.8-37.0	12.9-18.3	56.5-70.7	21.0-29.4	8.85-13.0
Geomean	54.3	23.1	14.6	62.3	24.0	10.1
95% confidence interval	53.7-55.0	22.4-23.8	13.8-15.4	61.6-62.9	23.3-24.8	9.29-10.9
Max	82.5	43.1	24.1	87.3	39.1	17.2
Min	36.4	11.5	5.99	46.5	12.5	3.24

(Begum et al. 2013)

The estimated PM emissions from different modes indicated that around 54% emission contribution is from bus/minibus, followed by truck and tanker (26%). The black spot areas for PM were located in the intercity routes and the major bus terminals. The bus terminals (Gabtoli and Sayedabad) showed average estimated values above 110 μg/m^3 of PM. Locations with highest concentrations of PM are Sheraton, Farmgate, Sonargaon, Mohakhali-Gulshan intersection and Banglamotor. (Karim 1999).

3.2 Black smoke, Volatile Organic Compounds (VOCs)

A report from DoE indicates that between 1982 and 1988, 19,757 vehicles (of all categories) nationwide were checked for subjective assessment through vehicle counts for environmental pollution (black smoke and noise). Of them, 13,308 vehicles (67.4%) were found to be emitting excessive amounts of black smoke (DoE 1990). Many surveys may have been undertaken along the years by the DoE to count the black smoke emitting vehicles. Black smoke measurement using scientific smoke meters was done for the first time in 7-16 May 1990 (Bashar and Reazuddin 1991). The result has been presented in Table 1. A similar study was performed between 25 January-24 August 1996 jointly by the DoE and traffic police, not only covering Dhaka, but also Chittagong, Khulna and Rajshahi metropolis. The study surveyed 814 vehicles and 297(36%) of them were found emitting black smoke and other emissions (The Independent 1996).

A representative assessment black smoke emission through vehicle count at Farmgate intersection was performed in December 1992 under the Dhaka Integrated Transport Study (DITS). Movement of vehicles was observed for black smoke emission during peak hours. Five categories of vehicles were surveyed: bus/minibus, truck, car, auto-tempo and auto-rickshaw. Auto-rickshaw and auto-tempo were observed to have the maximum emission (90% and 80%, respectively), followed by bus and truck (75%) (DITS 1994).

Ambient air samples were collected by (Hussam et al 1998) for 30-45 min by solid phase micro-extraction (SPME) at four locations near Shewrapara, Dhaka. Two samples collected near an auto-rickshaw stand contained 7, 83,000 and 1,479,000 μg/m3 of Volatile Organic Compounds (VOCs). These values are almost 4 and 7 times higher than the then accepted normal value (1,93,000μg/m3), respectively. In particular, the concentration of toluene (a known carcinogen) was 50-100 times higher than the threshold limiting value of 2000μg/m3. Two other samples collected under normal traffic conditions at the mentioned site showed 1,35,000and 1,80,000μg/m3 of total VOCs.

3.3 Oxides of Nitrogen and Sulfur (NOx and SOx)

Oxides of nitrogen include nitric oxide (NO) and nitrogen dioxide (NO2). The calculation of NOx indicated that bus and minibus (diesel operated) and motor car have the significant contribution of NOx (30%), followed by heavy-duty vehicles (truck and tanker) (28%). On the other hand, three wheelers are the least contributing modes of NOx in Dhaka City.

In November 1996 and February-March 1997, (Karim 1999) performed field studies to measure ambient NO2 concentration in 51 street locations, one residential area and 4 personal exposures. The street locations had been divided in two zones to identify the severity of the problem of NO2. The high concentration location (blackspots) is zone I and low concentration location is zone II. Zone I is identified as the location where NO_2 concentration exceeded 40ppb and zone II is those locations less than this level. Among 51 street locations 35 of them are identified as the blackspots. In 10 street locations concentration of NO_2 exceeded 60 ppb. Most polluted locations of NOx were Syedabad bus stand, Sheraton hotel roundabout, Sonargaon hotel roundabout, Farmgate intersection and Moghbazar intersection.

The bus terminals (Gabtoli and Sayedabad) showed average estimated values above 70 ppb of NO_2. Another study on emission source inventory performed in winter 1995 at Dhaka found total emissions of SO2 and NO2 to values 70 and 72 ton/day, respectively (Azad and Kitada 1996). (Karim et al. 1997) assessed the total emissions from different energy consumption sectors and emission factors to transportation energy use in Bangladesh. They found that NOx and SOx emissions from transportation systems in national pollution averaged 34% and 47%, respectively. In case of SO2 in Dhaka, the contribution is mainly coming from high sulfur content in the diesel fuel. It was estimated that buses powered by diesel fuel contribute 58% SO_2 emission followed by trucks and tankers 34%. (Karim 1999)

Table 4
Comparison of present and past SO2 concentration

Place	SO2 concentrations, µg/m3	
	Year 2000	Year 2010
Mohakhali	152	Trace
Farmgate	121	
Mogbazar	146	
Sonargaon	393	
Science Lab	146	

(Begum 2004)

3.4 Carbon Monoxide and Hydro Carbons (CO and HC)

During December 1991-January 1992, 9h instantaneous average concentration varied between 10-11 ppm (weekdays) and between 5.4 to 5.6 ppm (weekends) (Karim 1999). The weekday's 9h instantaneous average concentration exceeded the then international standard of 10 ppm (WHO/UNEP 1989). Considering CO emission by each transportation mode for the year 1996, it was estimated that auto-rickshaws and cars are the major contributors (35%), followed by Motorcycles (24%). It has also been noted that auto-rickshaw is the major contributor of HC emission (56%), followed again by motorcycle (26%). Mass transit had little contribution of HC emission. (Karim 1999). The five locations severely polluted by CO were Moghbazar, Kakrail, Bijoynagar, Mohakhali rail crossing adjacent road, and Mohakhali (Amtala). In addition, the 5 locations polluted by HC were Moghbazar, Kakrail, Bijoynagar, Mohakhali rail crossing adjacent road, and Sonargaon hotel roundabout (Karim 1999).

4. Conclusion

Emissions in metropolitan Dhaka have been increasing at a steady rate for more than three decades. Annual average increases of 6.5% in NOx, 5.8% in HC, 5.9% in CO, 5.6% in PM and 6% in SOx emissions were observed from 1981 to 1996 (Karim et al. 1997). This paper summarizes and depicts the research results on air pollution of Dhaka, especially from traffic, with brief description of the transport system. It also explains impacts of some of the projects and policy decisions. The past experiences and information will be helpful for emission control strategies and decision-making processes as there is still only a couple of active air quality monitoring station. It may also act as a baseline study for estimating present and future air quality and emission from different sources.

References

Asian Development Bank (ADB), (2011),"Preparing the Greater Dhaka Sustainable Urban Transport Corridor Project", Consultant's Report.

Ahmed, N., (1997),"Air Pollution in Dhaka City", Key note speech at Chemical Engineering Division of Institute of Engineers Bangladesh (IEB), Dhaka, Bangladesh; May.

Ahmmed, K. M. Tanvir and Begum, D. A., (2010),"Air Pollution Aspects of Dhaka City", Procedure of International Conference on Environmental Aspects of Bangladesh (ICEAB10), Japan, pp. 129.

Azad, A. K., and Kitada, T. (1998),"Characteristics of the Air Pollution in the City of Dhaka, Bangladesh in winter", Atmospheric Environment; 32, 1991—2005.

Bangladesh Bureau of Statistics (BBS), (1995),"Statistical Yearbook of Bangladesh", Bangladesh Bureau of Statistics, Government of Bangladesh.

Bangladesh Road Transport Authority (BRTA), (2012),"Number of Yearwise Registered Motor Vehicles in Dhaka", Available at: http://www.brta.gov.bd/images/files/motor_v _dhaka_05-08-12.pdf.

Barua, S., Alam, D., and Seraj, M.(2013),"Conceptual Physical Design of Bus Rapid Transit (BRT) in Dhaka", Urban Public Transportation Systems 2013: pp. 285-295.

Bashar, S.H.M.A., Reazuddin, M.(1991),"Toward Sustainable Development: Issues of environmental Pollution in Bangladesh", Ministry of Environment and Forests (MOEF), Dhaka.

Begum, D. A. (2004),"Air pollution: A Case Study of Dhaka City", In: Better Air Quality conference '(BAQ)-2004', Society of Indian Automobile Manufacturers, Agra, India; December.

Begum, B. A., Hossain, A., Saroar, G., Nahar, N., and Nasiruddin, M.(2013),"Impact of Vehicle Fleet Characteristics on Ambient PM Concentrations during Rainy Season at Farm Gate (CAMS-2) in Dhaka", Bangladesh Journal of Science and Research; 48, 143-150. Available online at www.banglajol.info.

Begum, B. A., Biswas S. K., and Hopke P. K. (2011),"Key issues in controlling air pollutants in Dhaka, Bangladesh", Atmospheric Environment; 45, 7705-7713.

Dhaka City Corporation (DCC).(2002),"Structure plan, master plan and detailed area plan for Dhaka city", Volume. 1, Dhaka City Corporation, Bangladesh.

Dhaka Integrated Transport Study (DITS).(1994),"Air and noise pollution", Working Paper No. 8, Planning Commission and Department of Economics and Social Development, Government of Bangladesh, and United Nations Development Program (UNDP).

Hoque, M. M., Ahsan, H. M., Barua, S., and Alam, D. (2012),"BRT in Metro Dhaka: Towards Achieving a Sustainable Urban Public Transport System", Proceedings of CODATU XV: The Role of Urban Mobility in reshaping Cities, Addis Ababa, Ethiopia.

Hossain, M. (2006). "The Issues and Realities of BRT Planning Initiating in Developing Cities", Journal of Public Transportation, 2006 BRT Edition.

Hussam, A., Alauddin, M., Khan, A.H.(1998),"Air pollution in Dhaka city: measurement of Volatile Organic Compounds (VOCs)", Paper presented at a seminar in Atomic Energy Commission, Dhaka, Bangladesh. A press report on the presentation was published by the daily The Independent, 27 August.

Islam, A.K.M.R., Islam, M.A. (1990),"Ambient Air Quality in Dhaka", Department of Environment, Government of Bangladesh.

Karim, M.M. (1997),"Traffic Pollution in Bangladesh & Metropolitan Dhaka a Preliminary Investigation", Article published in AMITECH's news page, 9 October.

Karim, M. M. (1999),"Traffic Pollution Inventories and Modeling in Metropolitan Dhaka", Bangladesh, Transportation Research Part D 4, 291-312

Karim, M. M. (2001),"Status of Air Quality and State-of-art Control Measures in Dhaka, Bangladesh", 94th Annual Conference and Exhibition of Air and Waste Management Association, Orlando, Florida, USA, June 24-28.

Sarker, M. Z. A., and Alam, M. (2001),"Air Pollution Due To Vehicle Exhaust in Dhaka City", 4th International Conference on Mechanical Engineering, Dhaka, Bangladesh, pp. 37-42;, December 26-28.

The Independent.(1996). "36 percent vehicles emit black smoke" (19 September 1998 issue) An English Daily of Bangladesh.

United Nations (UN).(2006),"World Urbanization Prospects: The 2005 Revision", Working Paper No. ESA/P/WP/200, Department of Economic and Social Affairs, Population Division.