Impact of CNG vehicles on Air Quality of Dhaka city

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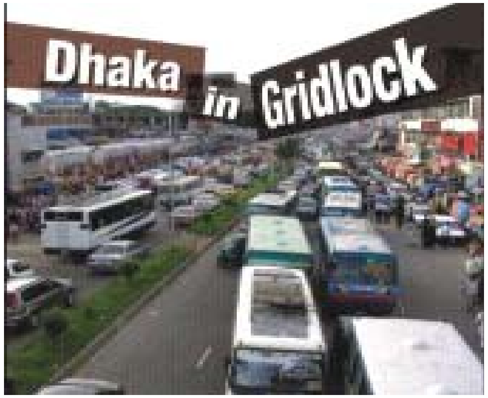
Air Quality Scenario in Bangladesh

- Major cities are highly polluted despite major efforts to-date
- PM is the most significant pollutant especially during winter season when rain fall in minimal and wind speed is low
- Known sources of air pollution are;
  i) Old and smoke-emitting diesel buses and trucks
  ii) Congested traffic in cities
  iii) Industrial emission sources including brick kiln
  iv) Many area sources of open burning, dust (construction and unpaved road), and small industries



Nature of Pollutants

Key pollutant

-*PM, SO_x, NO_x, CO, O_3 and Pb*

Sources specific Pollutants

-Motorized vehicles

visible smoke, PM, SO_x, NO_x, & toxic hydrocarbon(PAH)

-Brick kilns

PM, SO_x,

- Soil dust including road dust

PM

- Industry (Pb based battery factory, re-rolling mills, cement factory, Galvanizing factory, etc)

Control of PM is important for protection of human health and climate

National Ambient Air Quality Standards for Bangladesh

Pollutant	Objective	Average
CO	10 mg/m^3(9 ppm)	8 hours
	40 mg/m^3(35 ppm)	1 hours
Pb	0.5 µg/m^3	Annual
NO_2	100 µg/m^3	Annual
PM_{10}	50 µg/m^3	Annual
	150 µg/m^3	24 hours
$PM_{2.5}$	15 µg/m^3	Annual
	65 µg/m^3	24 hours
O_3	235 µg/m^3	1 hours (d)
	157 µg/m^3	8 hours
SO_2	80 µg/m^3	Annual
	365 µg/m^3	24 hours

Research objectives

- To assess ambient air quality particularly PM in Dhaka city
- Apportionment of potential sources of PM pollution
- Assessment of impact of different policy interventions (such as, unleaded gasoline, banning of two stroke baby taxis, CNG adaptation)
- To identify potential source locations and long range transport

Sample collection

Sampling locations

HSD: Farm Gate area in Dhaka, a hot spot with very high pollutant concentrations because of the proximity of major roadways, latitude 22.22N, longitude 91.47E)

SR: Semi-residential (AECD) area, which is located within the Atomic Energy Centre, Dhaka University Campus with relatively less traffic, latitude 23.73N, longitude 90.38E

Sampler: GENT type sampler

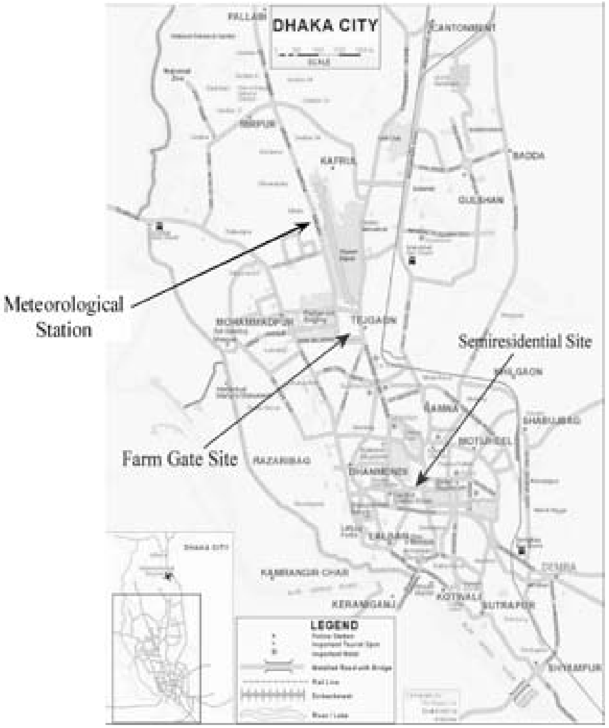
Method of Analysis

Mass by weighing

BC by Reflectance measurement

Carbon fraction analysis by carbon analyzer (USA)

Elemental Concentration by PIXE & XRF (NZ &USA)



Location of sampling site at Dhaka

Average air particulate matter mass concentration (μg/m3) and PM2.5/PM10 ratio over the collection period at the hot spot

Year	HSD				
	PM10	PM2.5	EC	PM2.5/PM10	EC/PM2.5
2000-2001	170±97.9	90.2±44.9	39.5±17.3	0.53	0.44
2001-2002	146±65.9	66.4±44.2	26.9±13.3	0.45	0.41
2002-2003	124±66.6	46.4±32.4	17.8±9.73	0.38	0.38
2003-2004	136±56.1	35.7±18.0	13.9±7.46	0.26	0.39
2004-2005	131±113	34.8±30.7	10.2±4.74	0.27	0.29
2005-2006	140±114	40.8±40.7	18.3±6.99	0.29	0.45

Average air particulate matter mass concentration (µg/m3) and PM2.5/PM10 ratio over the collection period at semi-residential site

Year	SR				
	PM_{10}	$PM_{2.5}$	EC	$PM_{2.5}/PM_{10}$	$EC/PM_{2.5}$
2000-2001	110±82.1	48.4±27.4	15.6±8.90	0.44	0.32
2001-2002	70.9±49.5	25.6±15.7	8.68±4.18	0.36	0.34
2002-2003	74.3±46.9	29.0±20.5	9.32±6.50	0.39	0.32
2003-2004	80.6±47.1	28.0±14.3	9.35±6.73	0.35	0.33
2004-2005	55.6±26.1	20.9±11.2	6.51±5.47	0.38	0.31
2005-2006	112±86.0	37.7±29.8	11.1±7.72	0.34	0.29

Average source contributions derived from the PMF modeling from 2001-2005 (SR Site)

Source	Fine sample		Coarse sample	
	%	Mass(ng/m3)	%	Mass(ng/m3)
Soil dust	14.8	2934	43.8	15055
Zn source	3.53	701	5.20	1786
Brick kiln	18.7	3709		
Road dust	3.56	707	2.21	758
Metal smelter	0.67	133	4.97	1708
Sea salt	4.34	862	5.26	1807
Motor vehicle	54.4	10797	38.6	13259
RM		19842		34373
MM		26217		44970

Average source contributions derived from the PMF modeling from 2005- 2006(SR Site)

Source	Fine sample		Coarse sample	
	%	Mass(ng/m3)	%	Mass(ng/m3)
Soil dust	9.41	2735	48.9	26392
Zn source	6.68	1943	2.03	1094
Brick kiln	38.1	11085		
Road dust	17.7	5141	12	6483
Metal smelter	6.68	1942	0.89	478
Sea salt	2.07	602	9.87	5322
Motor vehicle	19.3	5622	26.3	14179
RM		29070		53947
MM		30514		56590

Who are polluters for the environment

1. Soil dust including road dust
2. Brick kiln: EC, K, S
3. Motor vehicles: Diesel and gasoline engines or generators: OC, EC, S, NOx, Zn, Cu
4. Metal smelter: Zn, Pb, Fe etc

From Vehicular statistics

-14% of vehicles run by petrol or diesel at daytime and 28% of vehicles run at nighttime

-PM emission at nighttime is higher than at daytime

- diesel emit about 25-50%of black carbon (ref)

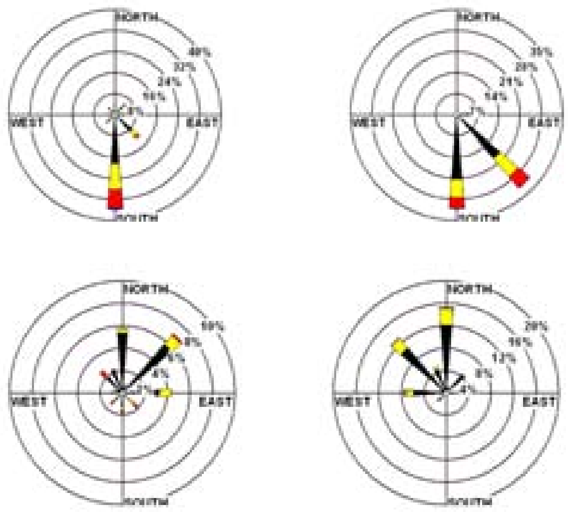
Reason of Diesel pollution

- Diesel engine

Parameter	Diesel	Gasoline
Fuel economy	30% higher	
CO	Low	High
HC	Various kinds of HC	Same HC
NO_x	High	Low
SOx	10 times higher	Low
PM	Diesel trucks and bus emits 30 to 70% more PM	Low
PM	Produce PM that are *blacker, oilier*, and have a *soiling impact* 3 to 5 times greater than typical dry airborne PM.	
Visible smoke	*Visible smoke* is produced by diesels primarily because of the elemental carbon in particulates emitted by diesel powered vehicles. About 70% of diesel particulate in elemental carbon that blocks 3 to 4 times the light compared to typical airborne particulate. Thus diesel are a major contributor to urban haze.	

The direction of wind pattern with respect to day and PM2.5 mass concentrations

Date	$PM_{2.5}$ mass (mg/m^3)		
	Wind direction	Day	Night
17/02/2010	W	116	127
18/02/2010	W	66.5	202
19/02/2010	W	63.8	272
20/02/2010	NW	113	212
21/02/2010	W & SW	135	209
22/02/2010	NW	115	260
23/02/2010	W & NW	194	161
24/02/2010	SW&W	106	102
25/02/2010	WSW	91.4	178
26/02/2010	NNW	111	232
27/02/2010	NNW	151	317
28/02/2010	W	112	278
01/03/2010	W	97.3	163
02/03/2010	W	82.5	75.8
03/03/2010	SW	70.3	75.5



Wind directional pattern

Comparison of mass concentration (µg/m3) with BNAAQS during present study (3-13 January 2010)

Parameter	Present study	BNAAQS
PM_{10}	301±35.8	150
$PM_{2.5}$	237 ±41.3	65
PM_1	148±17.5	Nil
EC in $PM_{2.5}$	39.9±11.4	Nil
OC in $PM_{2.5}$	31.2±9.15	Nil
EC in PM_1	51.7±11.2	Nil
OC in PM_1	37.0±11.7	Nil

Variation of EC/$PM_{2.5}$ ratios in different years from 1 to 14 January

Period (1-14 January)	SR site[*1]	HSD Site[*2]
2000	0.18±0.03	No data
2001	0.27±0.07	0.55±0.15
2002	0.40±0.14	0.43±0.10
2003	0.24±0.08	0.38±0.04
2004	0.33±0.05	0.36±0.18
2005	No data	0.27±0.05
2006	0.27±0.05	0.39±0.10
2007	No data	No data
2008	0.25±0.05	No data
2009	0.09±0.02	No data
2010	No data	0.17±0.03

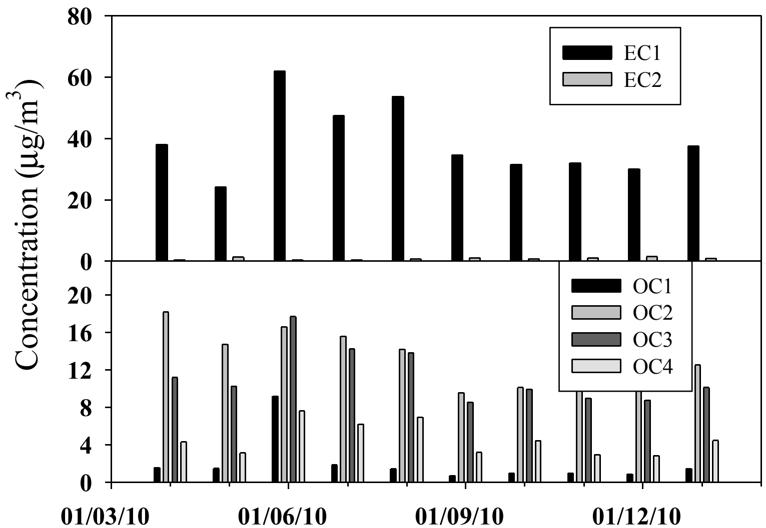
**1= Semi-residential site (SR)*
**2=Hot Spot site (HSD), proximity of major road ways*

Variation of PM mass collected by Portable and MOUDI samplers

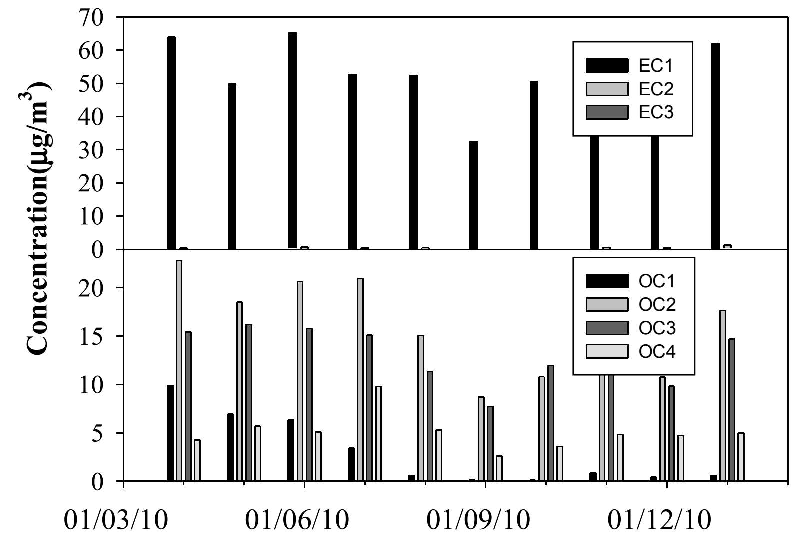
Date	Air Metrics		MOUDI	
	Mass ratio($PM_{2.5}/PM_{10}$)	EC ratio($PM_{2.5}/PM_{10}$)	Mass ratio($PM_1/PM_{2.5}$)	EC ratio($PM_1/PM_{2.5}$)
04/01/2010	0.79	1.07	0.66	1.74
05/01/2010	0.86	0.86	0.64	1.62
06/01/2010	0.92	1.20	0.50	1.24
07/01/2010	0.77	1.00	0.64	1.26
08/01/2010	0.69	1.01	0.58	1.10
09/01/2010	0.72	1.11	0.69	0.95
10/01/2010	0.77	1.01	0.68	1.70
11/01/2010	0.78	0.97	0.69	1.62
12/01/2010	0.77	0.90	0.61	1.31
13/01/2010	0.76	0.94	0.64	1.92

Micro Orifice Uniform Deposit Impactor: By using Cyclone, 18 µm to 1.78 µm sizes PM was cut off and PM samples were collected from 1.0 µm to <0.056 µm sizes

Fractions of OC1, OC2, OC3, OC4, EC1, EC2 and EC3 in PM2.5 and PM1 mass during the present study (3 January to 13 January 2010)



Air Metrics Sampler



MOUDI Sampler

Diesel: High in EC2 & OC1, Zn, Cu
Gasoline: High in EC1, OC2, OC3 & OC4
Brick kiln: EC1, K & S

Data Analysis Technique

- *Source identification by RCM method*
- *Source identification by PCA method*

Percentage of Different sources from RCM

Source	PM_1	$PM_{2.5}$	PM_{10}
Soil	7.15	9.46	**35.2**
Salt	1.94	3.47	3.4
Sulfate	9.12	**25.3**	20.5
Smoke	1.15	2.01	1.04
OC	**33.0**	25.7	15.6
EC	**46.2**	32.9	23.3
Zn	**0.55**	0.50	0.45
Pb	**0.35**	0.29	0.25

Sources from PM1 fraction by PCA method

Element	Brick kiln, Motor vehicle & Road dust	Gasoline	Pb	Residual oil	Zn
Na	0.314	0.096	-0.080	-0.136	-0.117
Mg	0.022	-0.152	-0.286	0.301	0.299
Al	0.066	-0.063	0.338	0.455	-0.081
Si	0.124	-0.364	-0.030	-0.168	0.008
S	0.223	0.020	-0.242	-0.016	-0.176
Cl	0.084	0.298	-0.010	-0.210	-0.455
K	0.350	0.011	-0.058	-0.062	0.059
Ca	0.103	-0.386	-0.083	-0.028	0.007
Ti	0.224	-0.297	-0.146	0.051	0.134
V	-0.028	-0.275	0.335	0.124	-0.060
Fe	0.344	-0.171	-0.038	-0.029	0.018
Ni	0.329	0.038	0.159	0.011	0.056
Cu	0.163	0.013	0.349	0.063	-0.392
Zn	0.260	0.236	-0.210	0.048	0.166
As	0.135	0.040	0.220	-0.419	0.328
Br	0.219	-0.052	-0.304	-0.108	-0.322
Sr	0.236	-0.126	0.335	0.033	-0.012
Pb	0.064	0.055	0.253	-0.461	0.336
OC	0.178	0.337	0.112	0.106	0.177
EC	0.112	0.318	-0.068	0.105	-0.022
Eigen value	6.91	5.32	3.89	2.02	1.92
% Varience	30.0	23.1	16.9	8.81	8.37
% Cumulative	30.0	53.2	70.0	78.9	87.2

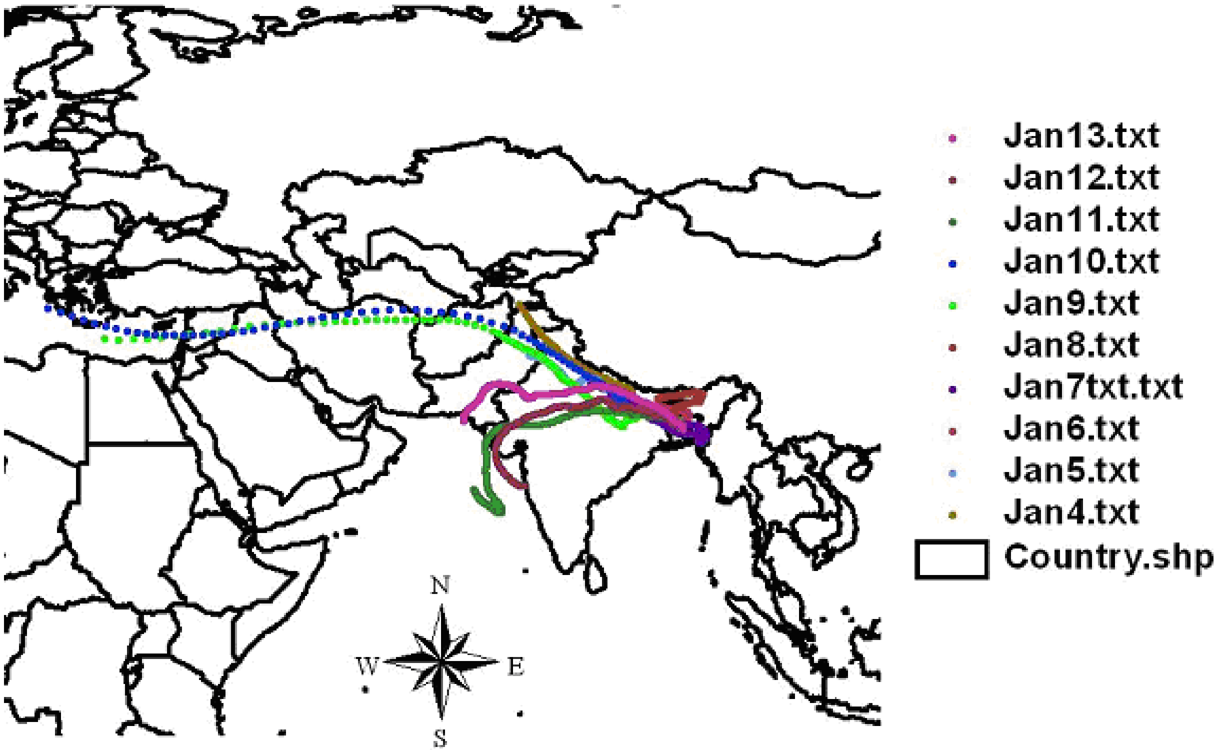
Sources from PM2.5 fraction by PCA method

Element	Road dust& Motor vehicle	Road dust	Coal	Pb	Brick kiln
BC	0.232	0.136	-0.013	-0.183	0.071
OC	0.248	-0.022	0.162	-0.098	0.010
Na	0.241	-0.046	0.043	-0.035	-0.029
Mg	0.001	0.268	-0.129	0.059	-0.660
Al	0.214	0.118	-0.277	-0.057	0.054
Si	0.053	0.336	-0.350	-0.112	0.230
S	-0.071	-0.280	0.168	-0.432	0.134
Cl	0.198	-0.144	0.293	-0.178	0.108
K	0.219	0.145	0.113	-0.088	0.005
Ca	0.240	0.130	-0.102	-0.064	-0.038
Ti	0.233	0.154	-0.138	0.007	0.086
V	-0.040	-0.400	-0.145	0.089	-0.217
Cr	0.241	-0.098	-0.084	0.160	-0.019
Fe	0.254	0.001	-0.050	-0.042	-0.070
Ni	0.215	-0.215	0.008	0.000	0.028
Cu	0.250	-0.093	-0.098	0.055	0.029
Zn	0.231	-0.103	0.111	-0.165	-0.134
As	0.080	0.208	0.426	0.340	0.205
Se	0.077	0.358	-0.173	0.036	0.171
Pb	0.072	0.185	0.397	0.430	-0.001
Eigen value	14.8	5.02	2.38	1.76	1.15
% Varience	54.8	18.6	8.81	6.52	4.26
% Cumulative	54.8	73.41	82.2	88.7	93.0

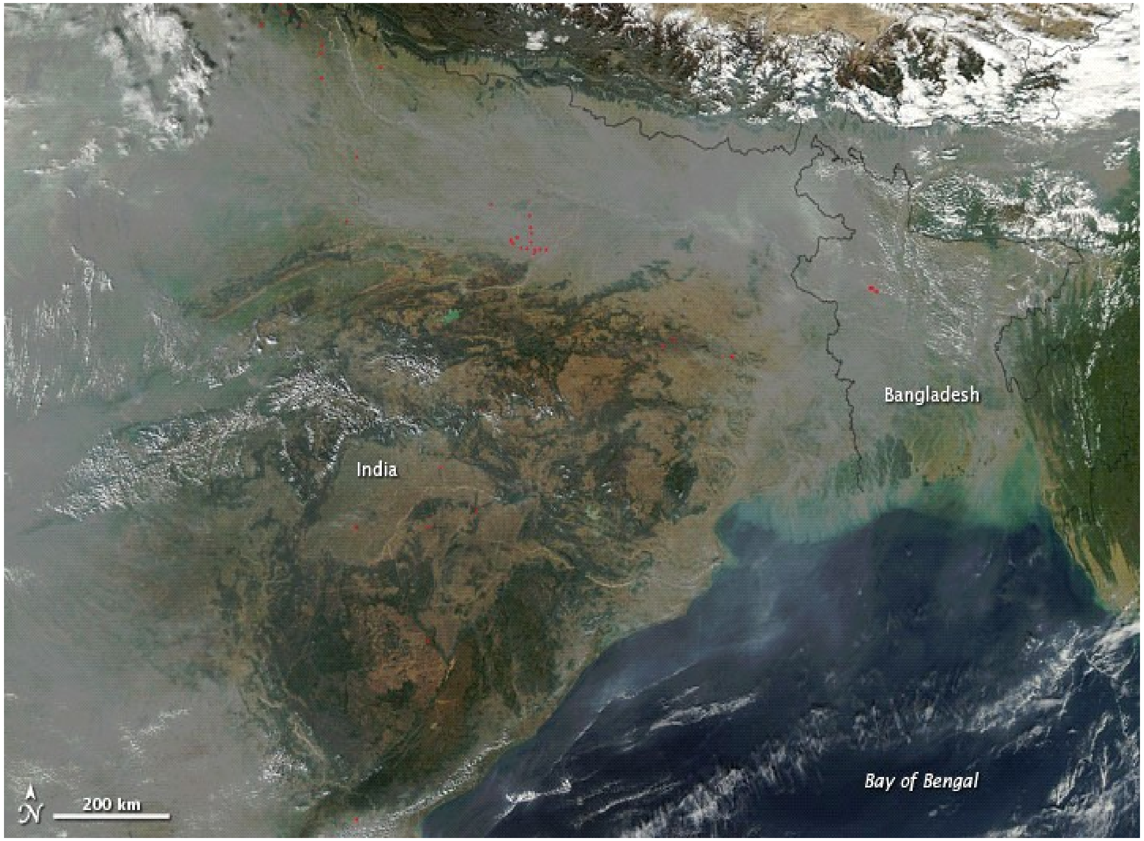
Sources from PM10 fraction by PCA method

Element	Road dust& Motor vehicle	Soil dust	Brick kiln	Pb	Diesel
BC	0.232	0.136	0.136	-0.183	0.070
OC	0.248	-0.022	-0.022	-0.098	0.010
Na	0.241	-0.046	-0.046	-0.035	-0.029
Mn	0.001	0.268	0.268	0.059	-0.660
Al	0.214	0.118	0.118	-0.057	0.054
Si	0.053	0.337	0.337	-0.112	0.230
S	-0.071	-0.280	-0.280	-0.432	0.133
Cl	0.198	-0.144	-0.144	-0.178	0.108
K	0.219	0.145	0.145	-0.088	0.005
Ca	0.240	0.130	0.130	-0.064	-0.038
Ti	0.233	0.154	0.154	0.007	0.086
Fe	0.254	0.001	0.001	-0.042	-0.070
Ni	0.215	-0.215	-0.215	0.000	0.028
Cu	0.250	-0.093	-0.093	0.055	0.029
Zn	0.231	-0.103	-0.103	-0.165	-0.134
As	0.080	0.208	0.208	0.340	0.205
Se	0.077	0.358	0.358	0.036	0.171
Br	0.226	-0.076	-0.076	-0.183	-0.084
Sr	0.208	-0.122	-0.122	0.191	-0.352
Pb	0.072	0.185	0.185	0.429	-0.001
Eigen value	14.8	5.02	2.38	1.76	1.14
% Varience	54.8	18.6	8.81	6.52	4.26
% Cumulative	54.8	73.4	82.2	88.7	93.0

Long range transport of PM in dry season



http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=41874



An evidence of Haze in the southern face of the Himalaya in mid-December 2009

Thank You

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