AIR POLLUTION IN BANGLADESH: CHALLENGES AND STRATEGIES FOR MITIGATION

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165.15 million
147,570 km²
1,160 people per km²

Natural gas,
largest mangrove forests,
biodiversity (Royal Bengal Tiger),
longest sea beach,
human resources, etc.

Top global producer of rice (3rd), tea,
potatoes (7th),
tropical fruits (6th),
jute (2nd) & farmed fish (5th)

$146 billion GDP

Become a developed country by 2041
SUB TOPIC 1:
FUNDAMENTAL IN AIR POLLUTION & AEROSOL - METEOROLOGY INTERACTIONS
Delhi most polluted capital in world, finds air report

The city is topping the list for the fourth consecutive year. Delhi topped a list of 92 capital cities in 2020, 85 such cities in 2019, and 62 such cities in 2018.

Dhaka again ranked world's most polluted city

Lahore once again sets unique record of world's most polluted city

AIR POLLUTION HOTSPOT
in South Asian Region
“Air Pollution!

Is this a new 'silent spring'

for the people in South Asia
WHAT IT IS
Air pollution occurs when harmful or excessive quantities of substances are introduced into Earth's atmosphere near surface.

HOW IT OCCURS
A mixture of solid particles, liquid particles and gases are suspended in the air.

WHICH SUBSTANCES
Substances include:
- Gases: SO₂, NOₓ, CO, O₃, Biogenic organics, hydrocarbons, etc.
- Particulate matter: smoke, dust, fumes, fly ash aerosols, BC, BrC, etc.
- Radioactive materials and many other toxic metals. Airborne pathogens.

ANNOUNCEMENT
WHO reported that 9 out of 10 people breathe air containing high levels of pollutants.

WHAT IT CAUSES
Air pollution kills an estimated 9 millions people worldwide every year. Life expectancy lost 6.7 years in Bangladesh.
(Vohra et al., 2022; HEI, 2022)
Causes of air pollution from Iran to Indonesia

Indonesia

This is daytime: bright red haze from Indonesian rainforest fires envelops city

Surreal footage shows Jambi swamped in thick cloud of pollution

BEIJING, CHINA

NEW DELHI, INDIA

JAMBI, INDONESIA

DHAKA, BANGLADESH

LONDON, UK

HAZE / URBAN SMOG
COMBUSTION GENERATED SMOKE EMISSIONS

NON FOSSIL FUEL

PEAT SOIL

COAL

PARTICULATE MATTER
- BC/EC
- OC
- BrC
- POC

GASES - INORGANIC ACIDS
- CO
- Ozone
- NOx
- SO₂
- CH₄
- CO₂

HYDROCARBONS
- BTEX
- Alkanes
- PAHs
- Dicarboxylic acid

METALS
- Pb
- Cd
- Hg
- Cs
- As
- Se

ORGANIC MOLECULES
- Aldehydes
- Phenols
- PAHs
- Biomass tracers

WILD FOREST

PEAT SOIL

COAL
Air pollution in Bangladesh:

Local or Transboundary effects???

Anthropogenic or natural causes???
The synoptic level of wind vector over the study site changes monthly in 2019:
Transport of air mass carry water vapour and pollutants

- Seasonal changes over Dhaka is very strong
- Himalaya during winter and Bay of Bengal during monsoon play significant role on the aerosol load over Dhaka
- The precursors of secondary aerosol are reported higher during dry winter months
PM$_{2.5}$ (µg/m$^3$)

PM$_{10}$ (µg/m$^3$)

NO$_x$ (µg/m$^3$)

NO (µg/m$^3$)

NO$_2$ (µg/m$^3$)

O$_3$ (µg/m$^3$)

SO$_2$ (µg/m$^3$)

CO (mg/m$^3$)

Barisal DOE Site (2020-2021)
SUB TOPIC 2: RESPIRATORY DEPOSITION DOSE (RDD)
RESPIRATORY DEPOSITION FLUX

Upper airways

Oropharyngeal region

Trachea

Bronchi

Bronchioles

Alveolar region

Nur Ain Nazirah, Undergraduate student
Mass deposition of heavy metals in the respiratory system is determined using:

\[ M_{dep} = PM \times V_m \times (DF) \]

There are three deposition factors according to the airways of particles, which are upper airway (UA), tracheobronchial region (TB) and alveolar region (AL).

• Only one deposition factor value will be obtained for each airway using PM2.5.

The deposition factor for each of the airway is determined using the following equations:

**UPPER AIRWAY**

\[ DF_{UA} = IF \times \left( \frac{1}{1 + \exp (6.84 + 1.183 \ln d_p)} + \frac{1}{1 + \exp (0.924 - 1.885 \ln d_p)} \right) \]

where IF is the inhalable fraction, estimated by:

\[ IF = 1 - 0.5(1 - \frac{1}{1 + 0.00076d_p^{2.8}}) \]

**TRACHEOBRONCHIAL REGION**

\[ DF_{TB} = \left( \frac{0.00352}{d_p} \right) \left[ \exp (-0.234(\ln d_p + 3.40)^2) + 63.9 \exp (-0.819(\ln d_p - 1.61)^2) \right] \]

**ALVEOLAR REGION**

\[ DF_{AL} = \left( \frac{0.0155}{d_p} \right) \left[ \exp (-0.416(\ln d_p + 2.84)^2) + 19.11 \exp (-0.482(\ln d_p - 1.362)^2) \right] \]
The most toxic metals with public health concerns are As, Pb, Cd, Hg, and Cr.

High deposition in UA is not very harmful because the mucus layer in UA will help to move the particles to the digestive system (Can-Terzi, Teker & Sofuoglu, 2021).

Male has higher RDD values than female. Males have a greater ventilation rate compared to females (Chalvatzaki et al., 2018).

Over 24 h, males inhale 0.578 mg of metals while female inhale 0.482 mg in Dhaka City.
Diurnal total RDD of metals (Male)

Diurnal total RDD of metals (Female)
Compositions of PM$_{2.5}$ from an urban site in Dhaka (real-time)

Compositions pose huge health concerns:
- Cr 2.01 (0.02 - 15.83) ng/m$^3$
- As 603.21 (124.5 - 3615.9) ng/m$^3$
- Pb 143.18 (12 - 2060) ng/m$^3$
- S 11258.95 (3875.8 - 28428.5) ng/m$^3$
Diurnal changes of the metals in PM$_{2.5}$

- Metals from Earth-Crust show relatively flat distribution
- Metals from anthropogenic origin peak in the middle of the day
- Changes in short interval indicate the emission from local sources
- Local meteorology also play important role to change the level of metals
SUB TOPIC 3: CHEMOMETRIC APPLICATION IN AIR POLLUTION
RECEPTOR MODELLING / CHEMOMETRIC APPROACH IN MITIGATION OF AIR POLLUTION
Air quality monitoring

Chemical analysis

Pattern recognition

Source identification

Wild fires

Vehicle emissions
Traditional Mass Closure Model

Principal Component Analysis/Absolute Principal Component Analysis (PCA/APCS)

Positive Matrix Factorization (PMF) Model for environmental data analysis
https://www.epa.gov/air-research/positive-matrix-factorization-environmental-data-analyses

Unmix 6.0 Model for environmental data analyses
https://www.epa.gov/air-research/unmix-60-model-environmental-data-analyses

Chemical Mass Balance (CMB) Model
https://www3.epa.gov/scram001/receptorcmb.htm
Source Apportionment / Chemometric Models

Traditional Methods
- Enrichment Factor (EF)
- Elemental/Diagnostic Ratio or tracer analysis
- Cluster Analysis
- Mass Closure Models
  - JR Stedman (1998)
  - Harrison et al. (2000)
  - Khan et al. (2016)

Concentration Weighted Trajectory (CWT)

Receptor Models
- PCA/MLR
- PCA/APCS
- PMF
- CMB
- Unmix

Receptor-Hysplit Coupling
- Potential Source Contribution Function (PSCF)
OUR WORK AND APPLICATION OF CHEMOMETRIC AIR POLLUTION

CHEMOMETRIC MODEL: PMF

- PMF, a robust model has been comprehensively applied to explore the southeast Asian seasonal plume.
- Reported the emission sources of PM$_{2.5}$ using metals, ions, carbon fractions, & PNC.
- Air mass plume during the moderate HAZE has been exclusively described using PMF.
- PSCF statistical function has been coupled with Factors derived from PMF to add info about source regions.
OUR WORK AND APPLICATION OF CHEMOMETRIC AIR POLLUTION

CHEMOMETRIC MODEL: PMF

PMF helps to know the contributing sources during MODERATE HAZE:

- Coal burning
- Motor vehicle
- Secondary inorganic
- Biomass burning, etc
Regional agreements and political commitments for mitigating the local air pollution

Increase awareness on air pollution for health protection

Apply 3R’s – Reuse, Reduce and Recycle to Municipal’s Solid Waste

Urgent Call for Phasing out the Old fleets

Practice carpooling and reduce number of car trips

Use public transport
In Singapore

Carbon-Tax

PSS
Hourly Pollutant Standard Index

CEMS
Continuous Emissions Monitoring System

In Ireland

Renewable Electricity
80% Conversion within 2030

Reduce Food Waste
by 50% by 2030

Organic Land
Increase to 350,000 hectares

*** Followed the EU Policies for Cleaner Europe ***

In Canada

Zero Emission
Transit Fund

CAQ-HI
Forecasting Twice a Day

Air Quality Alert
at immediate risk from air pollution

TAXES

Going ZERO WASTE
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Thank you!