CURRENT SOURCE APPORTIONMENT STUDIES IN ASIA: AN OVERVIEW

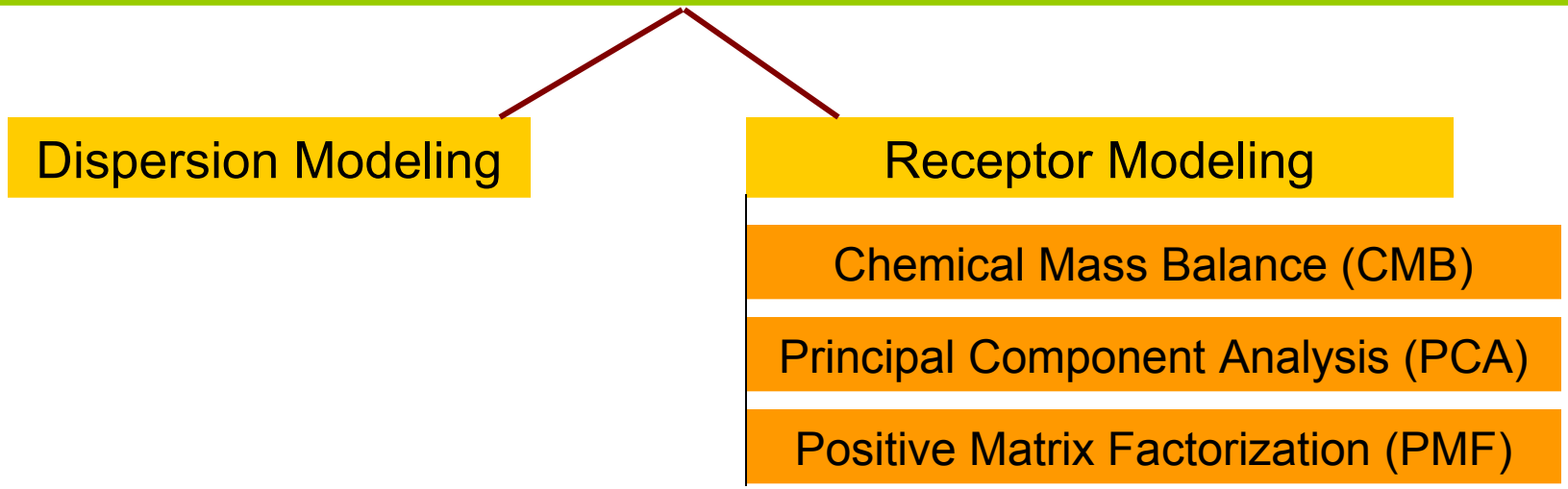
Zohir Chowdhury, Ph.D.[*1] , Abba Elizabeth[*1], Aaron Cohen, ScD.[*2], Michael Brauer, Ph.D.[*3]

*1 Graduate School of Public Health, San Diego State University, San Diego, CA 92182-4162
*2 Health Effects Institute, Boston, MA 02129-4533
*3 School of Environmental Health, University of British Columbia, Vancouver, BC V6T 1Z3

Background

- Source Apportionment review conducted as part of
  - HEI Special Report
- Only recent studies published in “English” journals included:
  - 1995-2007
  - Because of methodological differences, comparison among countries is not often as direct as desired
- Databases:
  - Web of Science
  - Pub Med
  - Google Scholar
- Outline:
  - What is “source apportionment”?
  - Source apportionment approaches
  - Source markers
  - $PM_{2.5}$ Source apportionment for major Asian cities
  - Ratio of $PM_{2.5}$ to PM_{10}

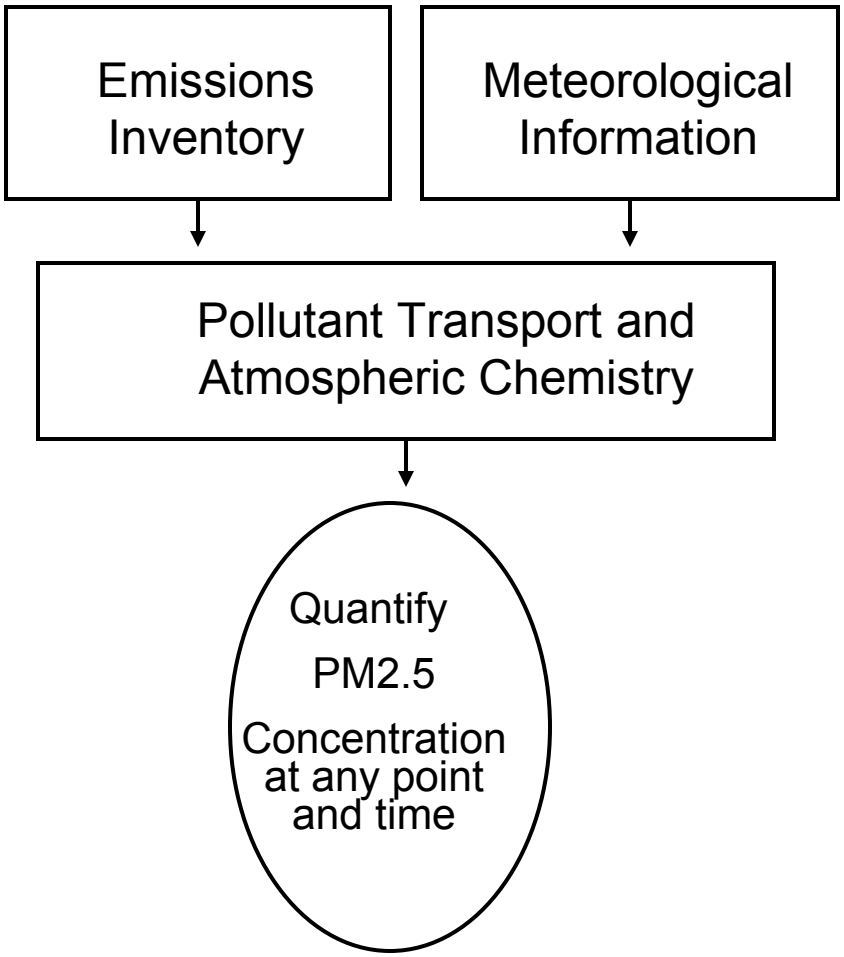
Source Apportionment

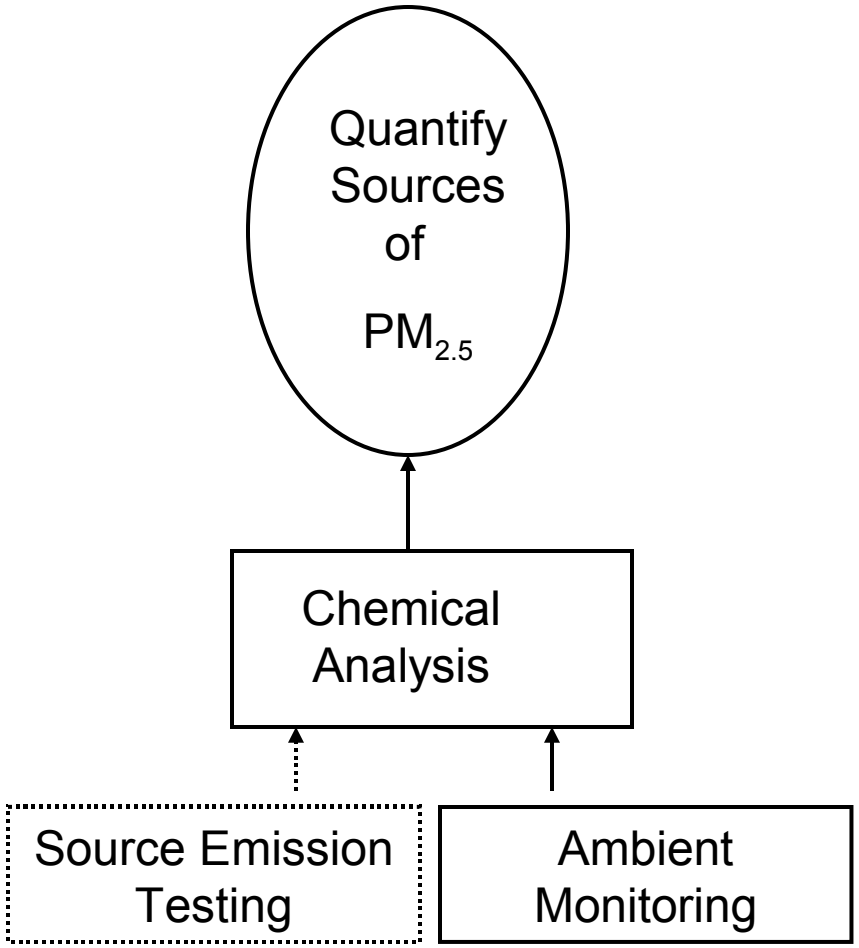


- **Source Dispersion Model**
  - A pollutant emission rate and meteorological information are inputted to a mathematical model that disperses the emitted pollutant where the pollutants may also chemically transform, generating a prediction of the resulting pollutant concentration at a point in space and time
  - A "what-if" exercise exploring consequences of different emission rates and meteorological variables. Explores the present and the future
- **Receptor Model**
  - A mathematical procedure for identifying and quantifying sources of ambient air contaminants at a receptor, primarily on the basis of concentration measurements at the receptor (ambient sampler)
  - Describes the past
  - Measurements are required

Source Modeling

Receptor Modeling





Receptor Modeling known as **"Source Apportionment"** which is the focus of this presentation

Source Apportionment Approaches

- Chemical Mass Balance
  - Ambient concentration of each tracer compound is reconstructed from the best fit linear combination of source emission profiles
  - Source contributions are estimated
  - Refer to Friedlander (1973), Watson et al. (1998) and US EPA (2006)

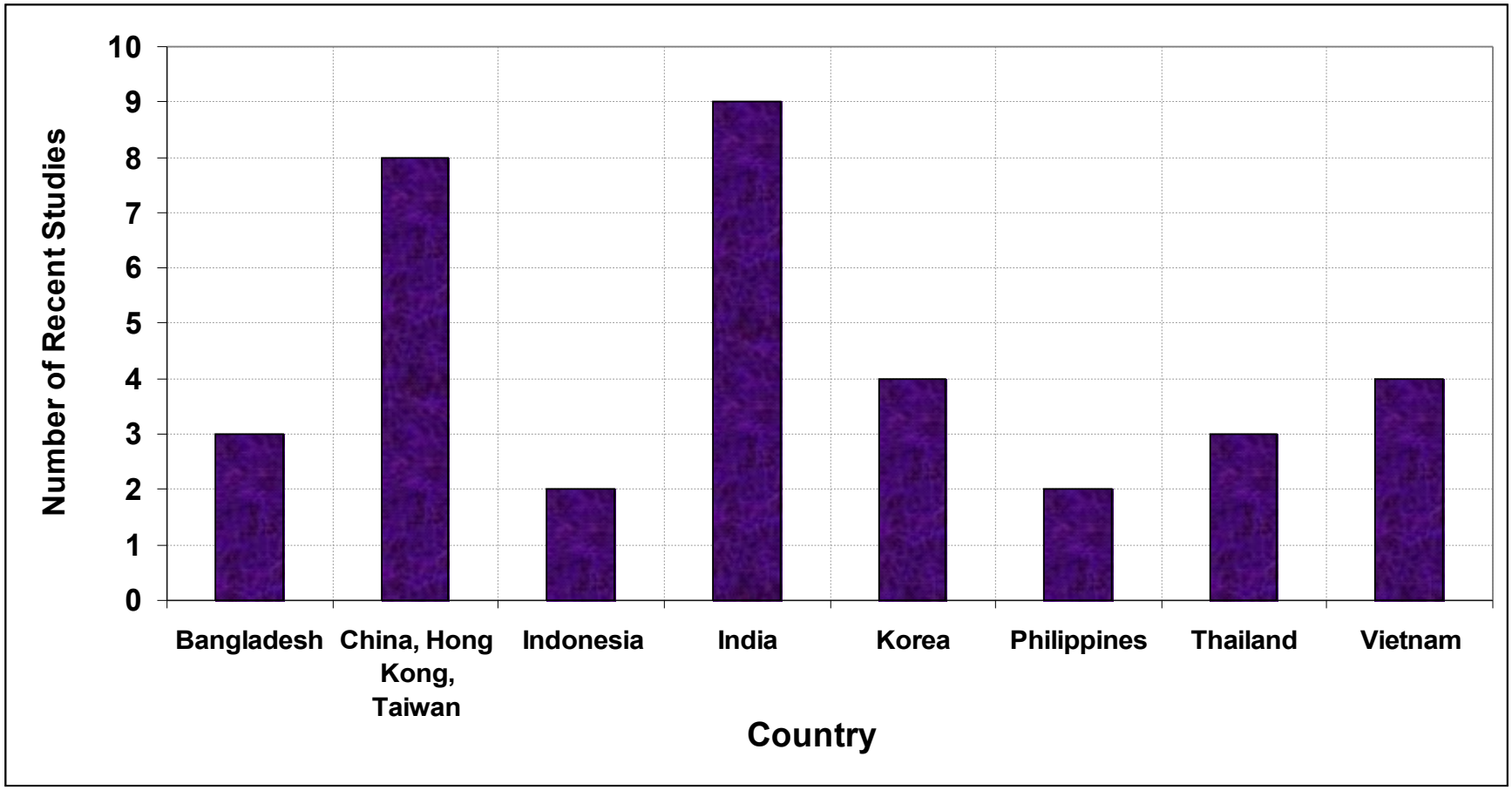
- Principle Component Analysis (PCA) and Positive Matrix Factorization (PMF)
  - Statistical procedure to estimate mix of PM sources impacting a receptor location
  - Analysis of correlation between measured concentrations of elements presuming that highly correlated elements come from the same source
  - No need for emissions testing (“source profiles”)
  - Refer to Paatero and Tapper (1993) and Hopke (2003)

Source Markers

Chemical Species	Possible Sources
Potassium, K+	Wood combustion, forest fires, prescribed burns, meat charbroiling
Sodium (Na+) and Chloride (Cl-)	Sea Salts
Nickel (Ni) and Vanadium (V)	Residual Oil combustion
Aluminum (Al), Silicon (Si), Calcium (Ca), Iron (Fe), Titanium (Ti)	Primarily from “soil” But also Smelters and Incinerators (Ca, Fe)
Lead (Pb)	Vehicle exhaust/Resuspended road dust
Bromine (Br)	Vehicle exhaust
Copper (Cu)	Smelter
Elemental Carbon (EC)	Fuel combustion and wild fires
Organic Carbon (OC)	Fuel combustion and wild fires
Hopanes and Steranes	Primarily mobile emissions
Polycycling Aromatic Hydrocarbon (PAHs)	Fuel combustion
Guaicols and Syringols	Biomass combustion

Source: Adapted from U.S. EPA (1998a, 1998b), Watson et al. (1998); Chow (1995).

$PM_{2.5}$ Source Apportionment Studies



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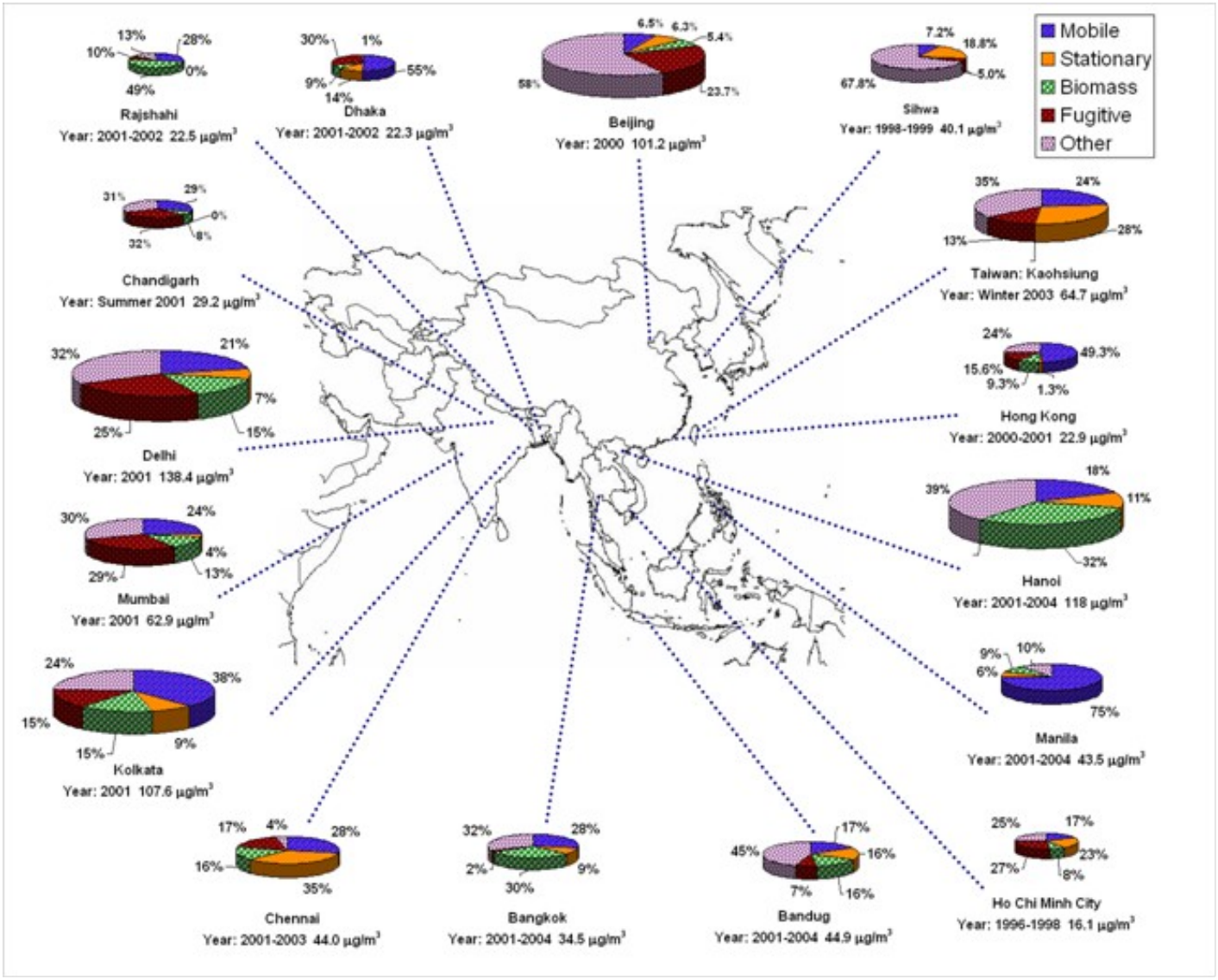
$PM_{2.5}$ Source Apportionment



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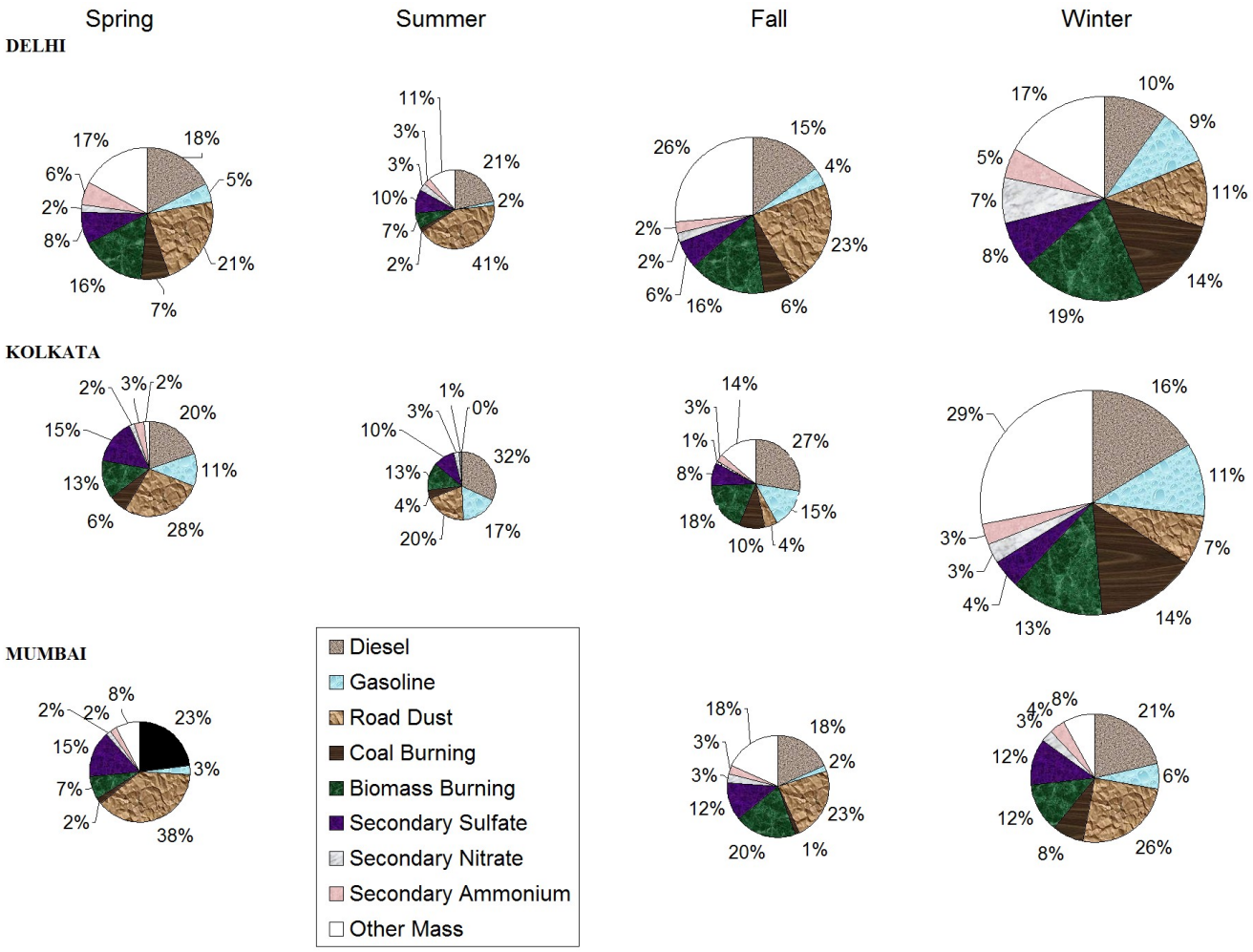
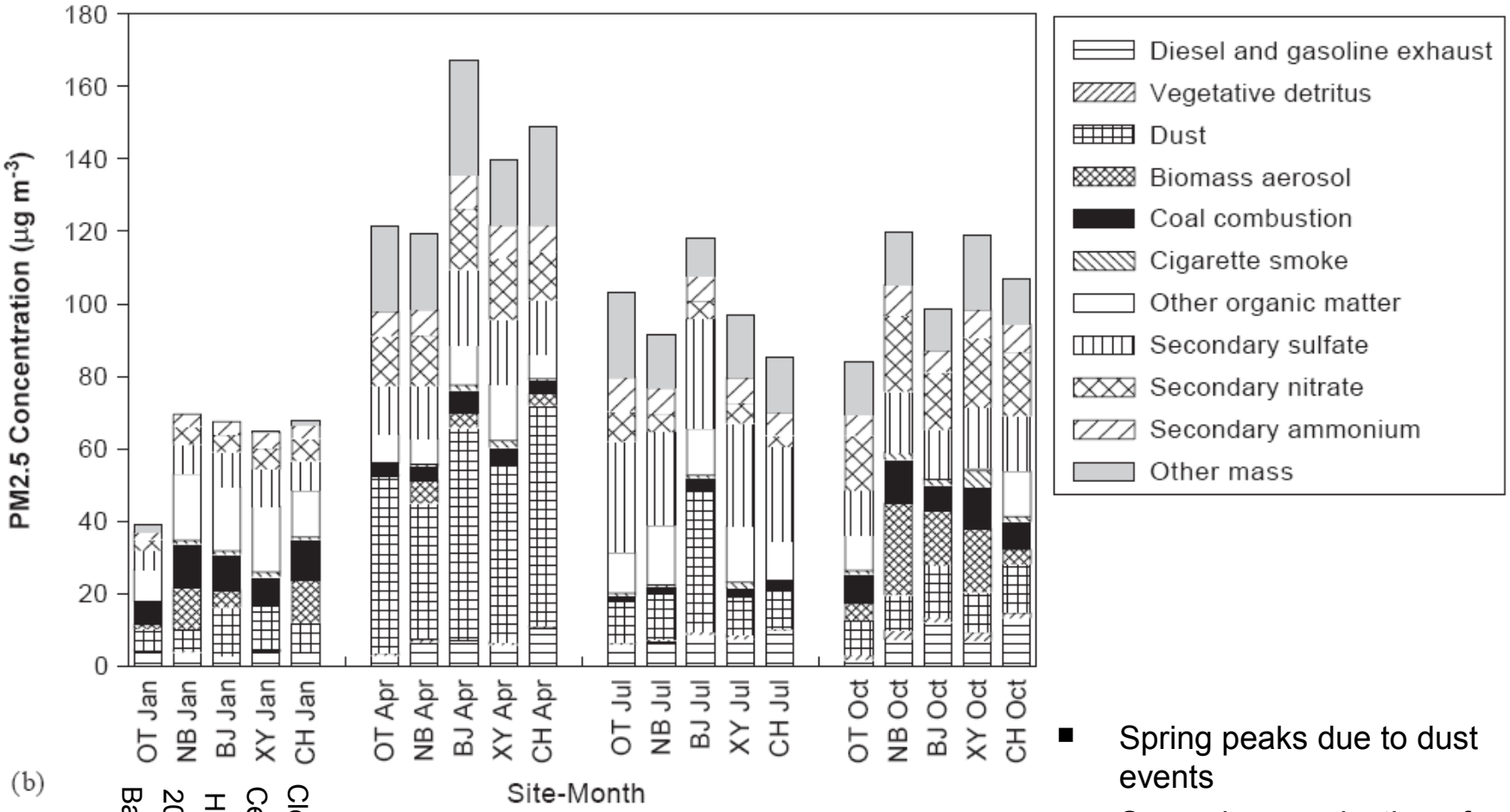
Seasonality of Sources in India



- Fossil fuel and biomass combustion dominates:
  - <u>Fossil Fuel</u>
  - Del: 25-33%
  - Kol: 37-53%
  - Mum: 21-35%
  - <u>Biomass</u>
  - Del: 7-19%
  - Kol: 13-18%
  - Mum: 7-20%
- Dust dominates during Spring and Summer
  - Long range transport and dust from local construction
- Biomass and coal are high in winter
  - Heating
  - Poor mixing and atmospheric inversion

<u>Source:</u> Adapted from Chowdhury et al. (2007).

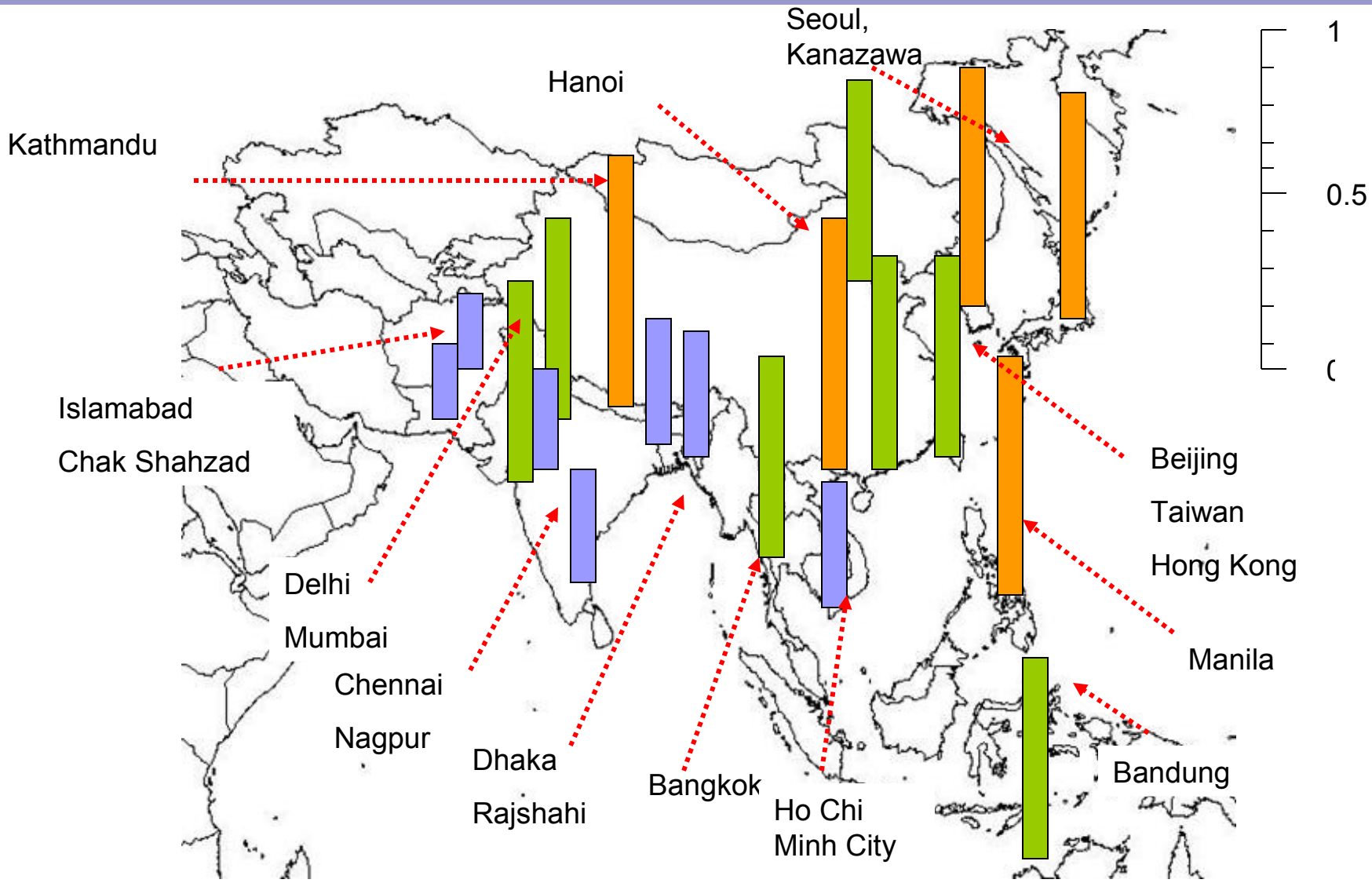
Seasonality of Sources in Beijing China



- Spring peaks due to dust events
- Secondary production of PM very important in Beijing

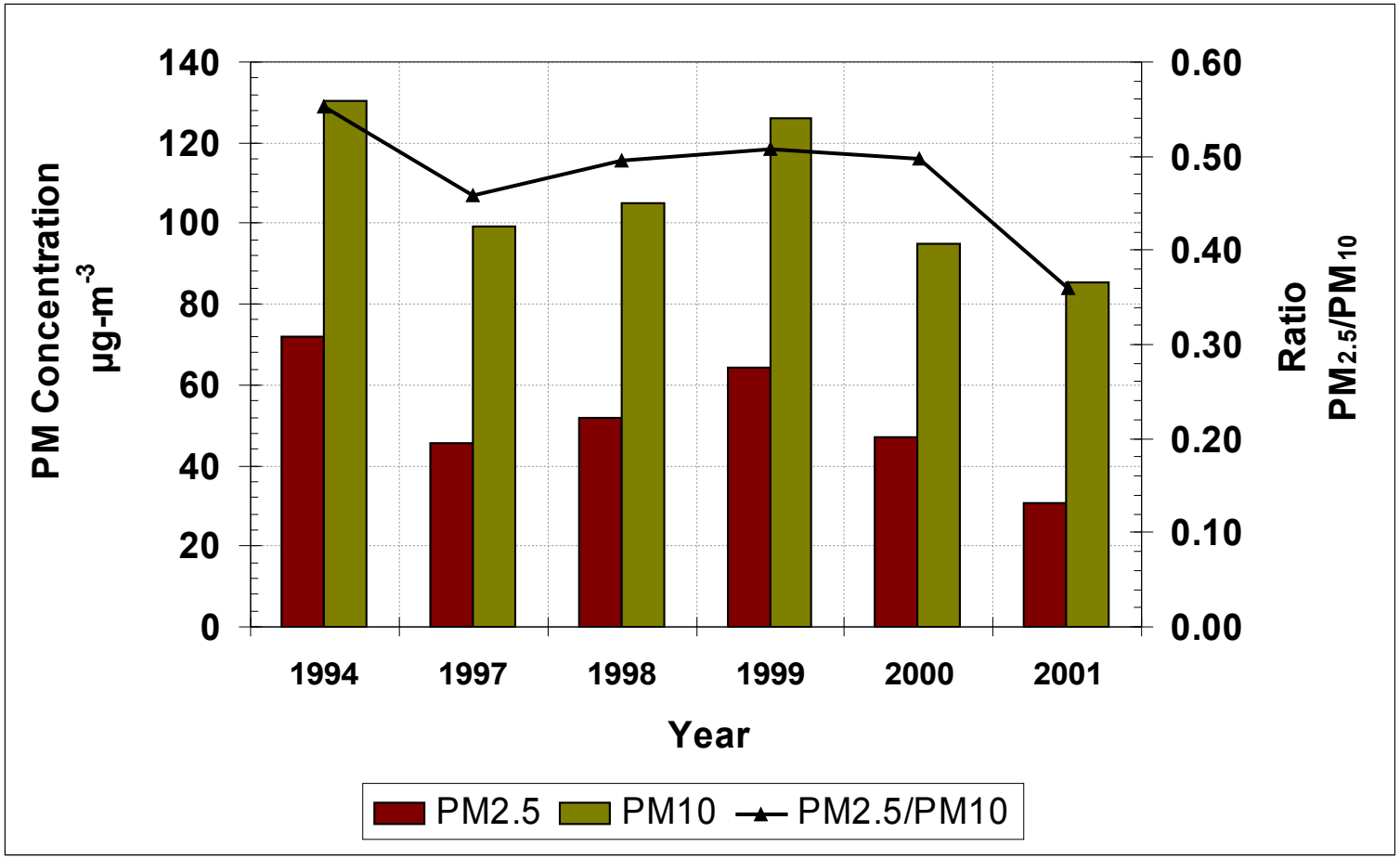
Source: Adapted from Zheng et al. (2005).

$PM_{2.5}/PM_{10}$ Ratios in Asian Cities



Sources: Agarwal et al. (2002), Begum et al. (2004, 2007), Carrico et al. (2003), Kumar and Joseph (2006), Hien et al. (2001), Ho et al. (2003), Kim et al. (2006), Oanh et al. (2006, 2007), Park et al. (2001), Shah et al. (2006), Tsai and Chen (2006), Wang et al. (2005).

Trends in $PM_{2.5}/PM_{10}$ Ratios in Bangladesh



Source: Biswas et al. (2003), Begum et al. (2004, 2007)

Conclusions

- Current Source Apportionment studies reviewed
  - For 2001-2002 major sources identified
  - Variety of sources contribute to PM2.5 problem
    - Problem not same everywhere
    - Multiple approaches for air quality management needed
- Need for new source apportionment studies to understand source contributions in Asian cities now
- $PM_{2.5}/PM_{10}$ ratios identified for many Asian cities
  - Ratio <0.6 for South Asia and South-East Asia
  - Ratio >0.7 for East Asia
  - Could potentially be used to infer $PM_{2.5}$ concentration from existing PM_{10} monitoring network available from many countrywide air pollution network sponsored by Government

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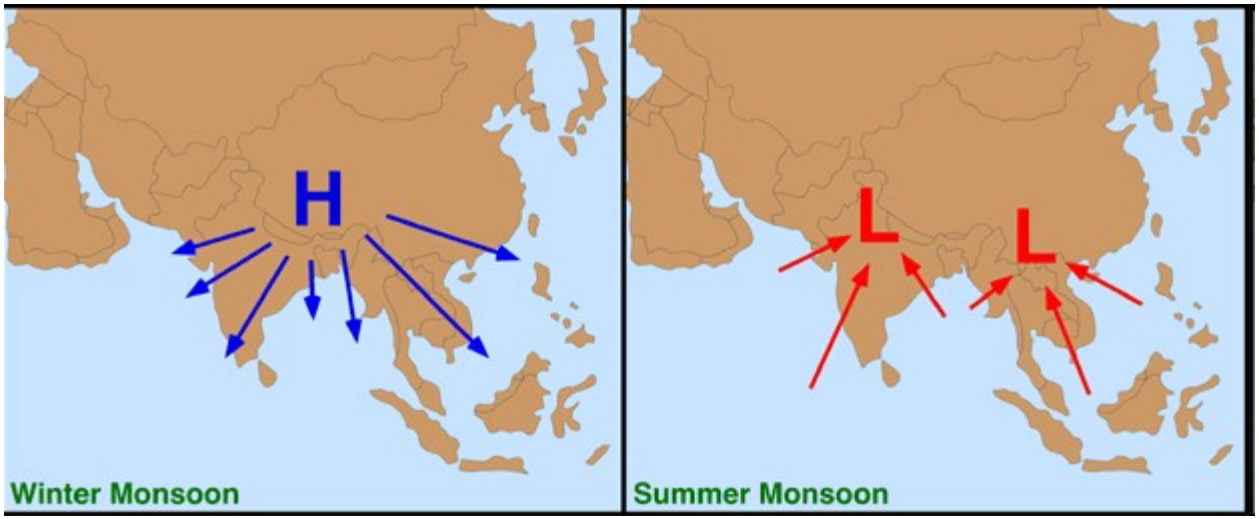
Thank You!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Winter Monsoon
L
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Summer Monsoon

PM2.5/PM10 Ratios in Asian Citis

Country	City	Average	Min	Max	References
Bangladesh	Dhaka	0.34	0.34	0.34	Begum et al. (2007)
	Rajshahi	0.35	0.35	0.35	Begum et al. (2004)
China	Beijing	0.63	0.58	0.73	Oanh et al. (2006 & 2007)
	Taiwan	0.62	0.61	0.63	Tsai and Chen (2006)
	Honkong	0.66	0.53	0.78	Ho et al. (2003)
India	Chennai	0.31	0.26	0.35	Oanh et al. (2006 & 2007)
	Mumbai	0.64	0.68	0.7	Kumar and Joseph(2006)
	Punjab	0.42			Nautiyal J.(2000)
	Delhi	0.61	0.56	0.66	Agarwal et al. (2002)
	Nagpur	0.49	0.3	0.68	Agarwal et al. (2002)
Indonesia	Bandung	0.63	0.52	0.73	Oanh et al. (2006 & 2007)
Japan	Kanazawa	0.71	0.71	0.71	Wang et al. (2005)
Pakistan	Islamabad	0.23	0.23	0.23	Shah et al. [2006]
	Chak Shahzad	0.22	0.22	0.22	Shah et al. [2006]
Philippines	Manila	0.73	0.61	0.81	Oanh et al. (2006 & 2007)
South Korea	Seoul	0.77	0.77	0.77	Kim et al. (2006)
	Busan	0.56	0.56	0.56	Kim et al. (2006)
	Sihwa	0.75	0.75	0.75	Park et al. (2001)
Thailand	Bangkok	0.59	0.47	0.68	Oanh et al. (2006 & 2007)
Vietnam	Hanoi	0.78	0.62	0.95	Oanh et al. (2006 & 2007)
	Ho Chi Minh City	0.34	0.34	0.34	Hien et al. (2001)
Nepal	Katmandu	0.76	0.7	0.81	Carrico et al. (2003)

- Ratios identify and explain what it means. High PM2.5/PM10 and how this can be used to convert
- Show a scatter plot of the range of this ratio in different region