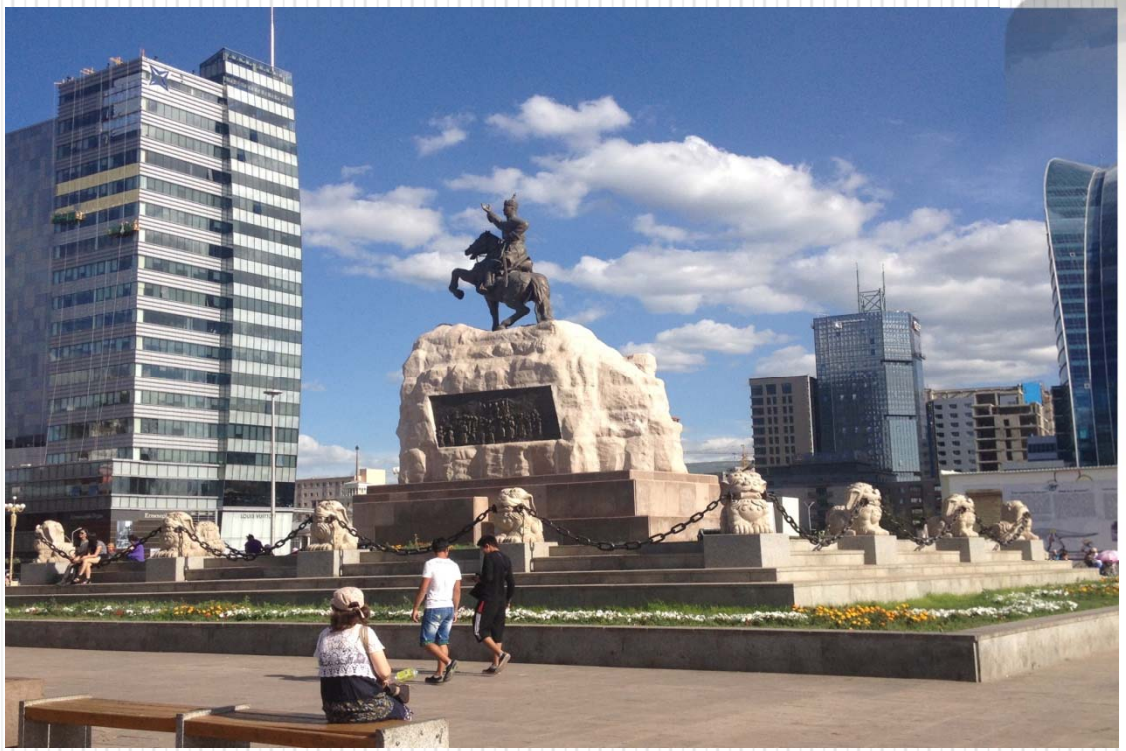
ULAANBAATAR CITY'S PM AIR POLLUTION AND BLACK CARBON STUDY



S. Lodoysamba,
D. Warburton,
D. Shagjjamba,
I. Tserenkhand
N. Warburton,

Contents

- Why is PM pollution important?
- PM Air pollution levels in Ulaanbaatar City
- What Are the main sources of PM pollution?
- Stove testing laboratory
- Managing the mitigation of UB air pollution
- Some results of air pollution mitigation
- Black Carbon Study Results

Why PM Air Pollution is important?

Terminology

Black Carbon = Particles largely black in colour

CO = Carbon monoxide

MNS = Mongolian National Standard

NO_2 = Nitrogen Dioxide

0_3 = Ozone

PM = Particulate matter

$PM_{2.5}$ = Particles smaller than 2.5 microns

PM_{10} = Particles smaller than 10 microns

SO_2 = Sulfur Dioxide

WHO = World health Organisation target

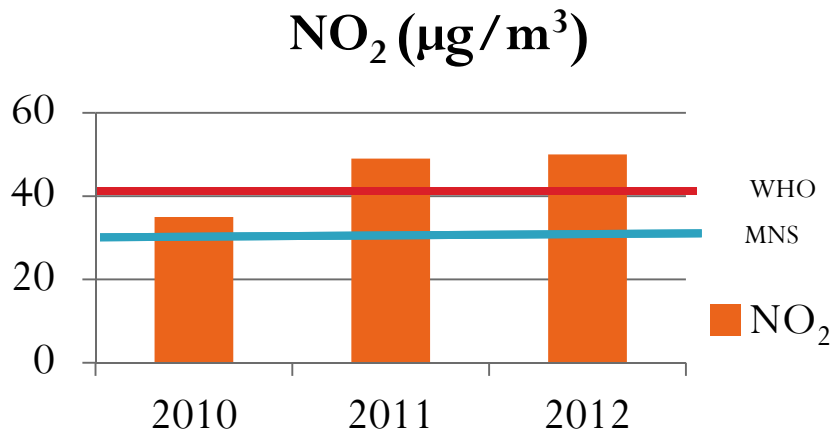
Main Air Quality Indicators (MNS 4585) 2007

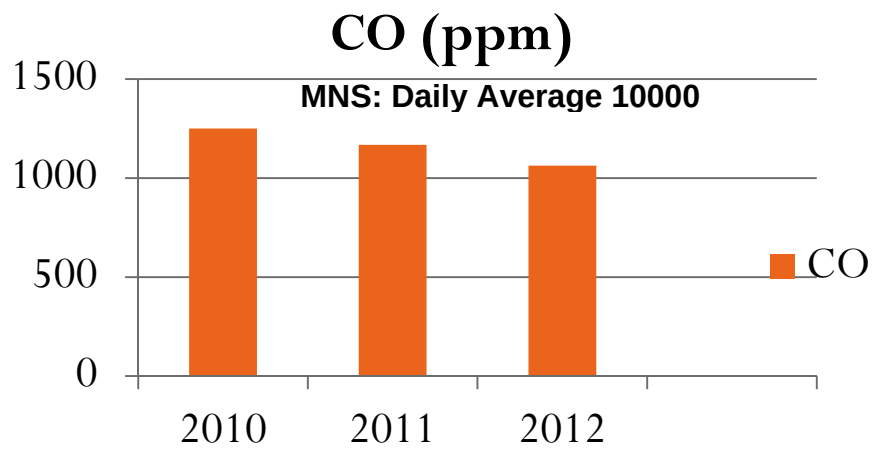
- SO_2 (10µg/m^3 annual, 20µg/m^3 daily)
- NO_2 (30µg/m^3 annual, 40µg/m^3 daily)
- H_2S !!! (Dangerous and unknown)

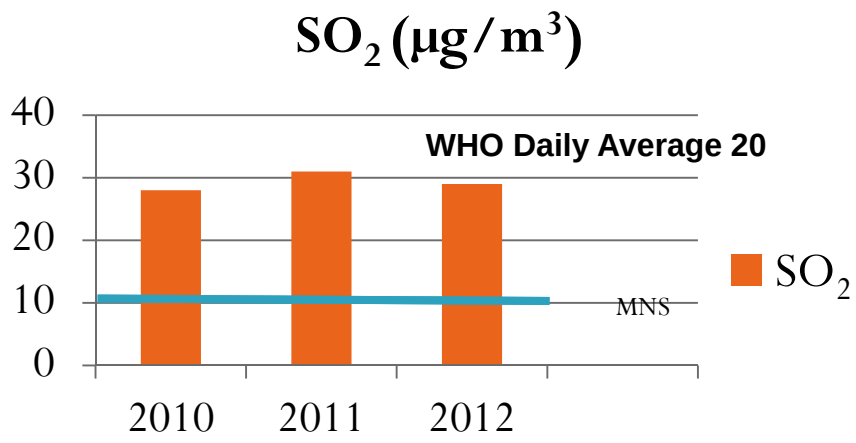
- PM_{10} (50µg/m^3 annual, 100µg/m^3 daily)
- $PM_{2.5}$ (25 µg/m^3 annual, 50µg/m^3 daily)

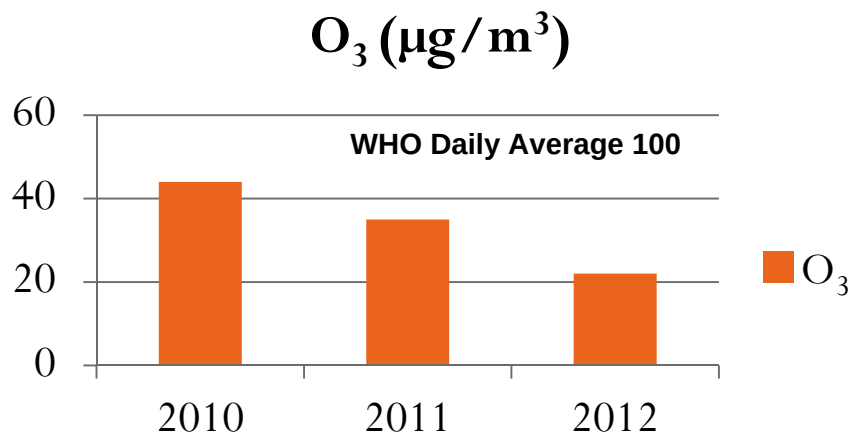
- CO (10000 ppm? 8 hours)
- O_3 (100 µg/m^3 8 hours)

Air pollution Indexes (μg/m³)



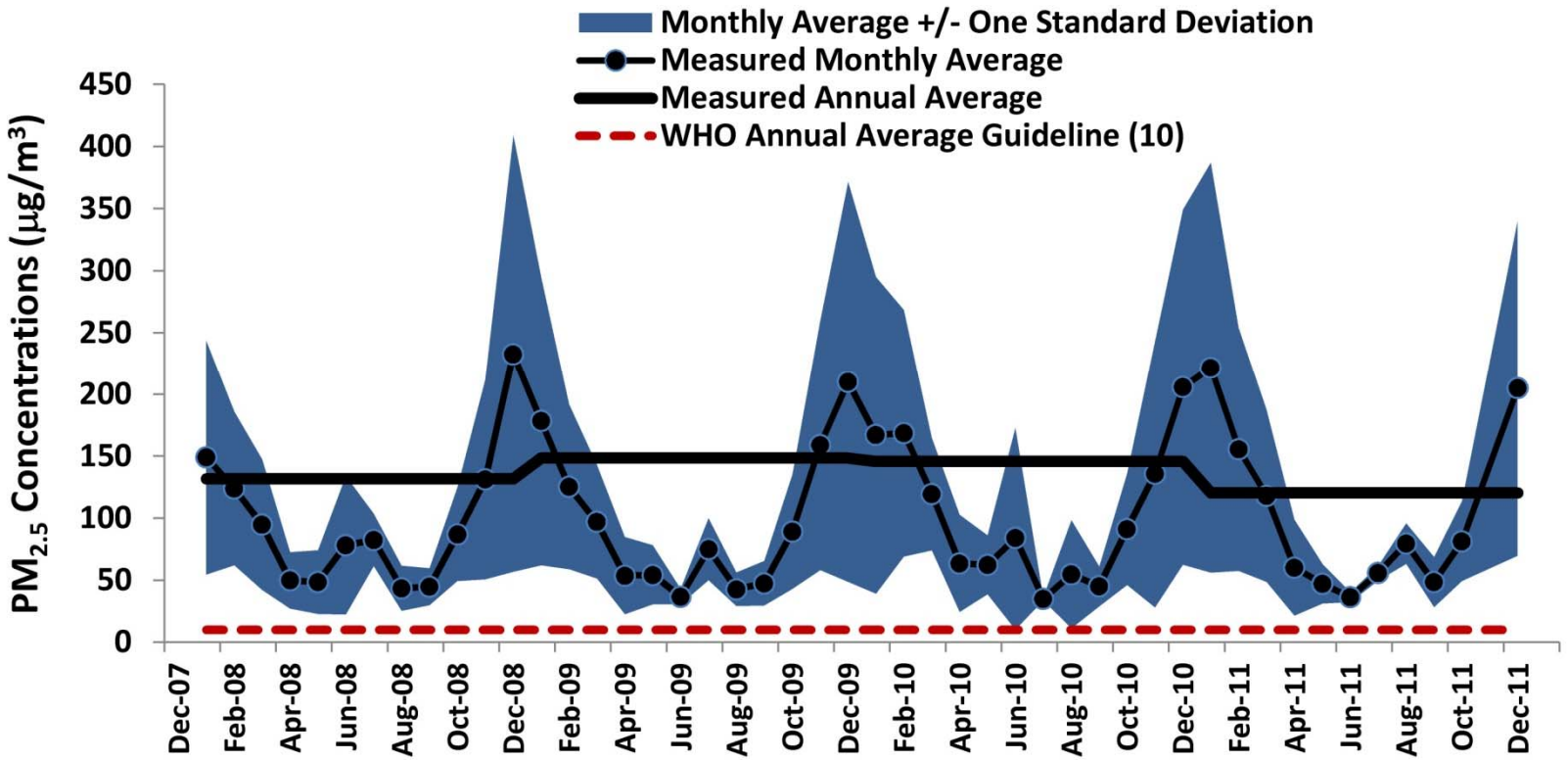




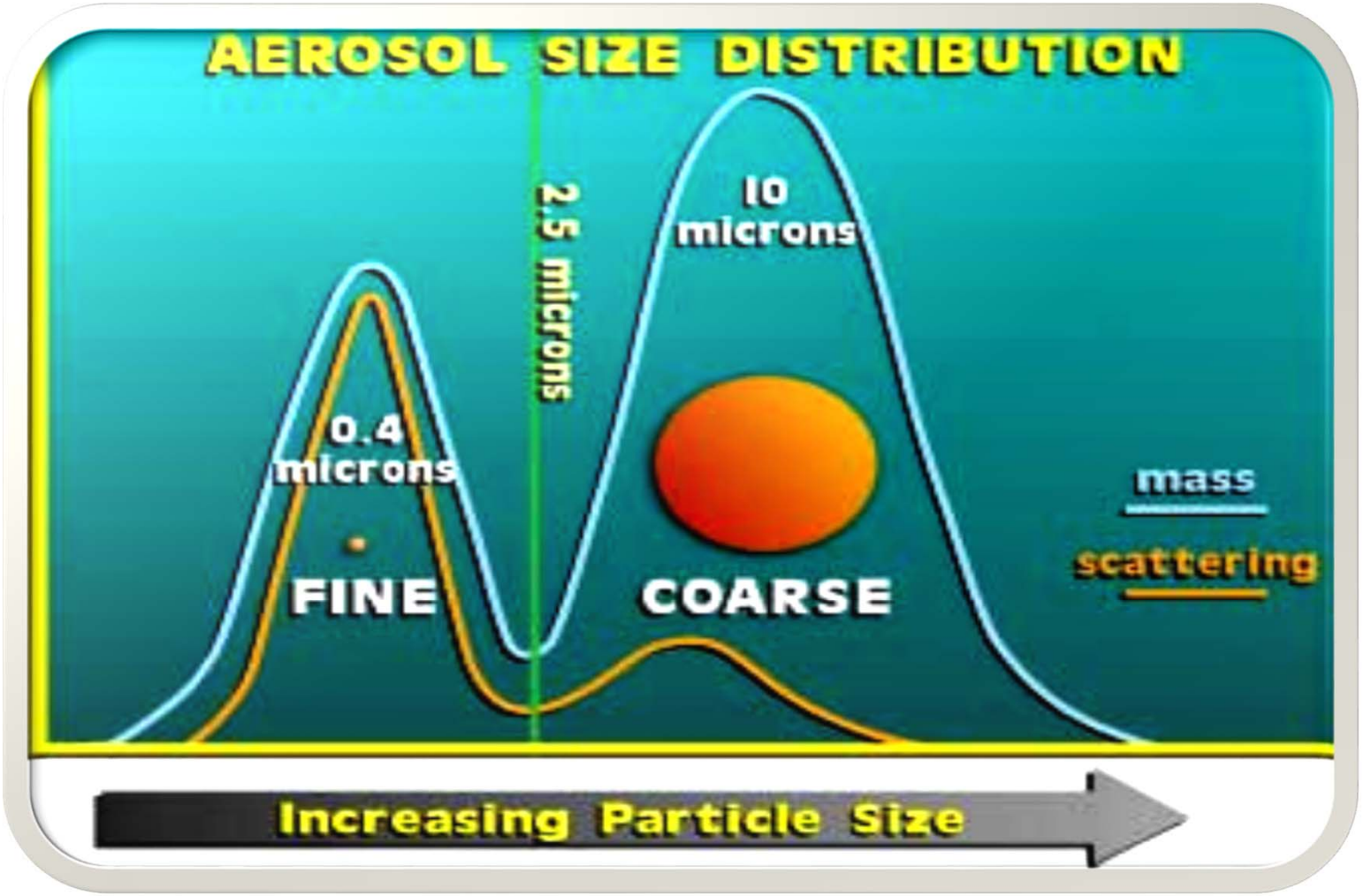


***NAMEM Air Quality Agency Data averaged from 9 monitoring stations**

PM2.5 concentrations by month from the NAMEM air monitoring station in Ulaanbaatar



Particulate Matter Distribution



Methodology

- Position of sampler:

  UB City — Nuclear Research Center
  Zuun Ail
  3 Horoolol

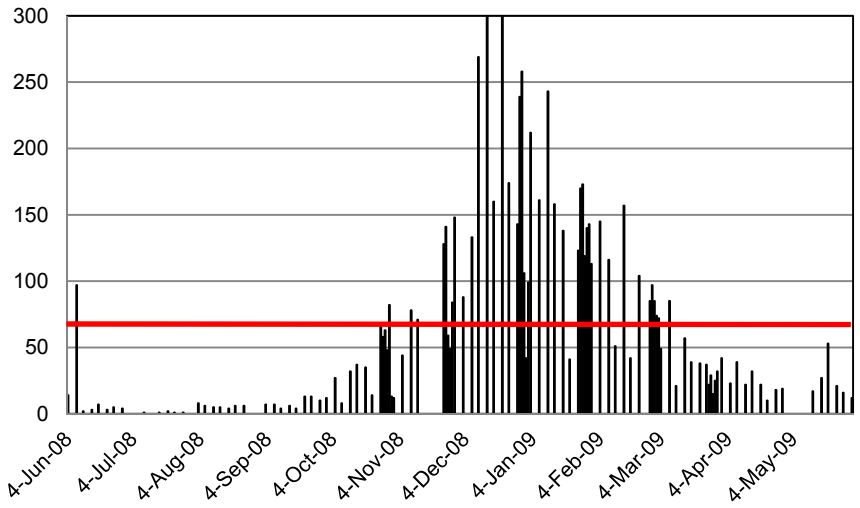
- Duration: 2004.10 – 2013.6
- Height of sampling: 1.6м, 4m, 6m.
- Sampling frequency: Twice a week
- Sampler: GENT Sampler with Polycarbonate filters , Dusttrak
- Type of analysis: PIXE, XRF
- BC measurement: Reflectometer, MicroAethalometer
- Data interpretation was made using software EPA PMF1.1(USA)

PIXE analysis were done in the New Zealand Institute of Geosciences and Nuclear Sciences, 30 elements were analysed

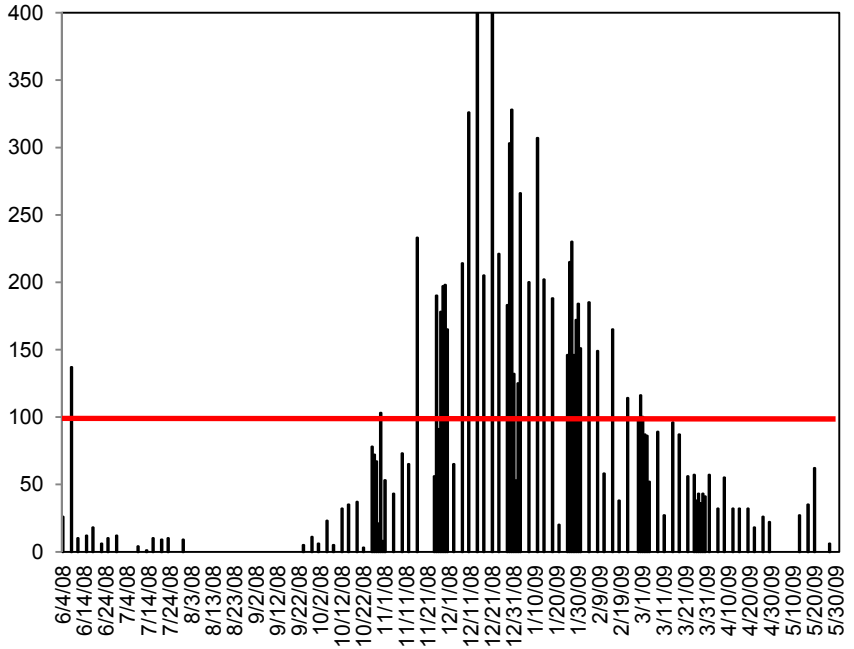
Sampling Sites

Typical seasonal time series of PM daily concentration (μg/m^3)

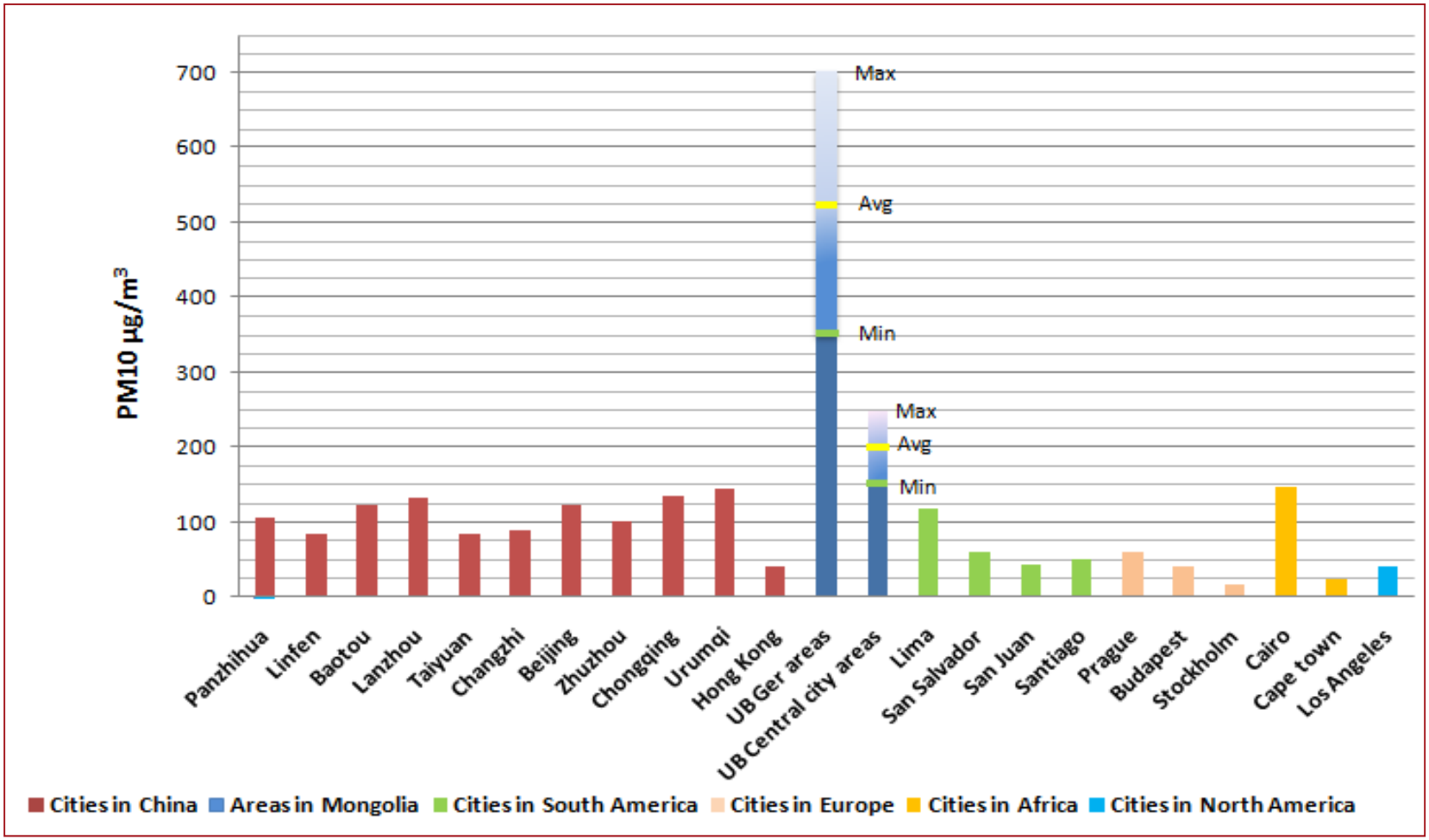
Timeseries PM2.5(NAMHEM)



Timeseries PM10 (NANHEM)



Yearly Average Concentrations



WorldBank 2011

What are the Sources of Pollution?

Pollution Source Apportionment

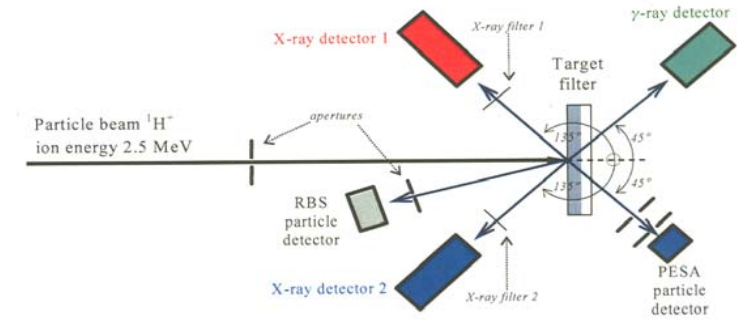
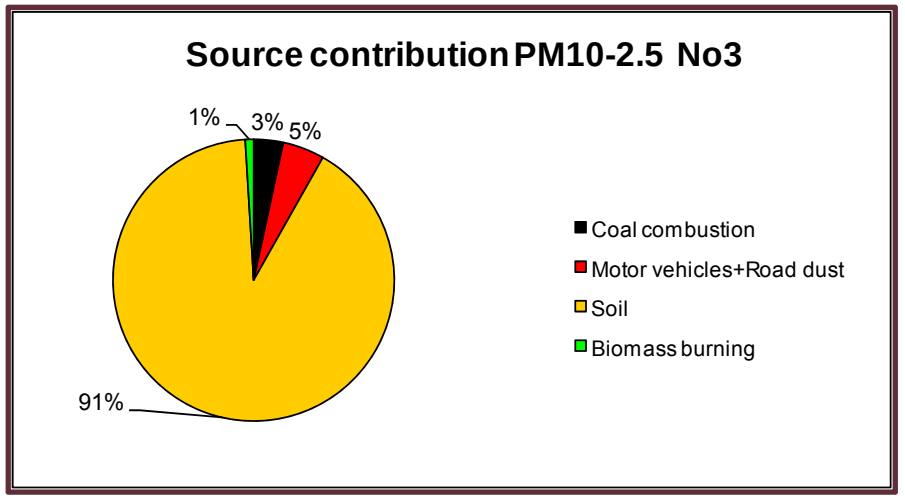


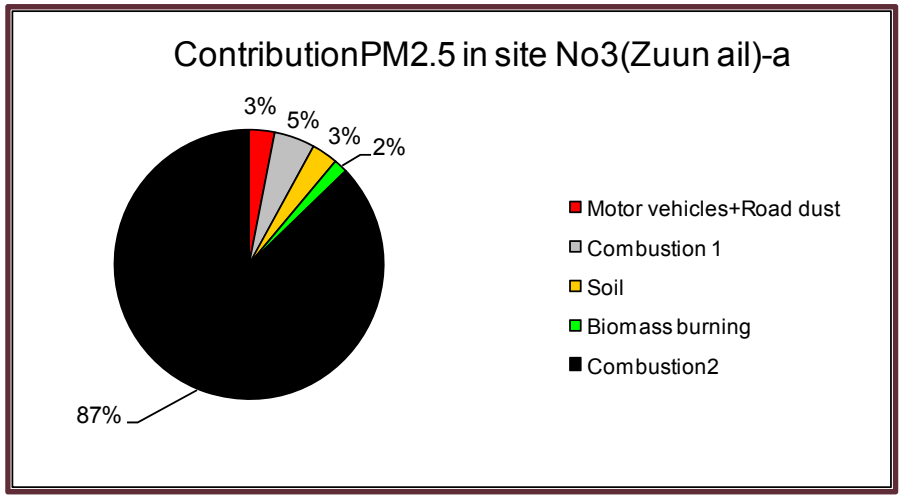
Fig. 1 Schematic of a typical experimental setup.

Experimental setup of the New Zealand Institute of Geosciences and Nuclear Sciences

XRF Spectrometer "SPECTRO XEPOS"
Nuclear Research Center, NUM, Ulaanbaatar

S.Lodoysamba, et.al,2011.



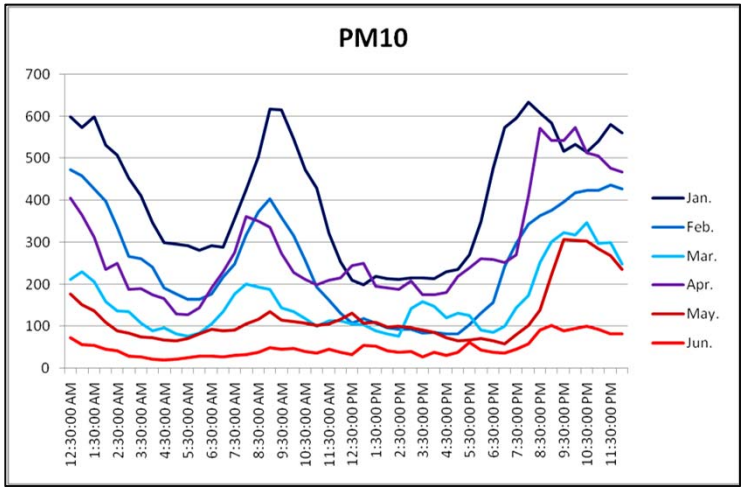


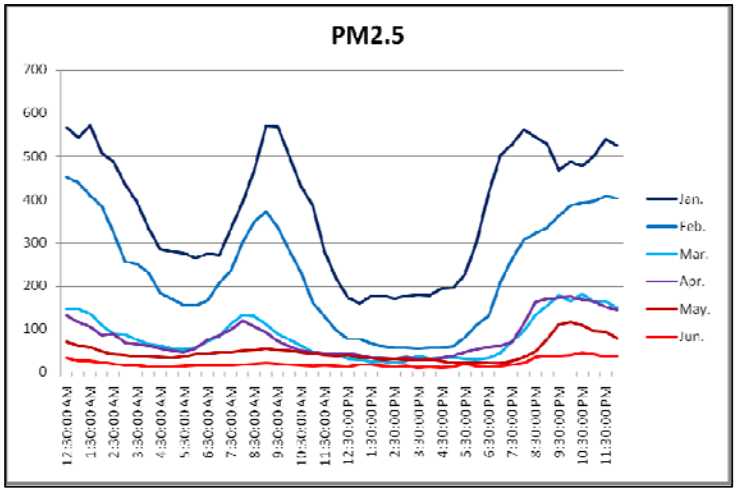
Elemental Concentrations (μg/m^3)

Elements	Arithmetic Mean	StdDev	Median	Maximum	Minimum	Samples > LOD[a]	S/N
PM 2.5	51800	91400	28200	1210000	5700		
BC	7290	10454	4242	94206	680	235	2.75
Na	290	425	112	2642	0	88	0.13
Mg	326	276	235	2083	31	200	0.62
Al	1150	1224	745	7627	0	227	0.81
Si	2305	1740	1871	10554	129	236	17.2
S	1969	3978	900	40079	125	236	17.55
Cl	139	133	88	849	12	236	2.14
K	324	239	243	1558	35	235	7
Ca	789	559	652	3194	50	236	11.92
Ti	37	33	28	156	0	191	0.27
Mn	15	14	11	65	0	178	0.18
Fe	523	388	416	2150	26	236	0.62
Cu	10	29	3	373	0	105	0.21
Zn	44	54	30	400	0	213	0.55
Pb	31	73	7	525	0	50	0.08

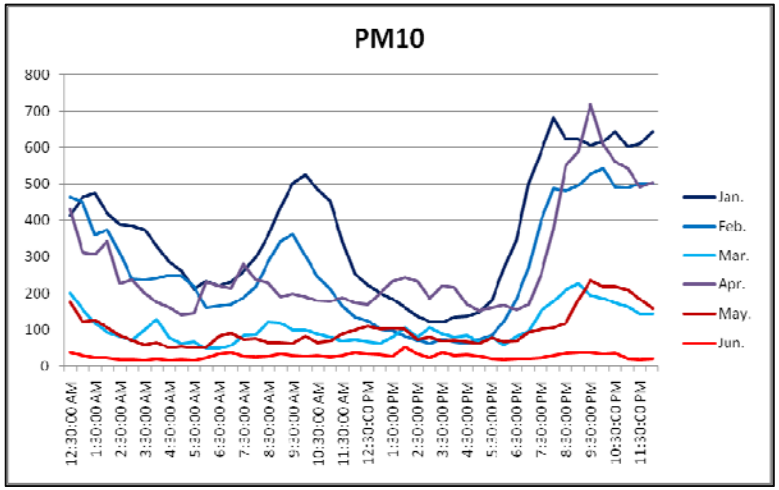
Diurnal time Series of PM concentrations
(Example TV site, GTZ station)

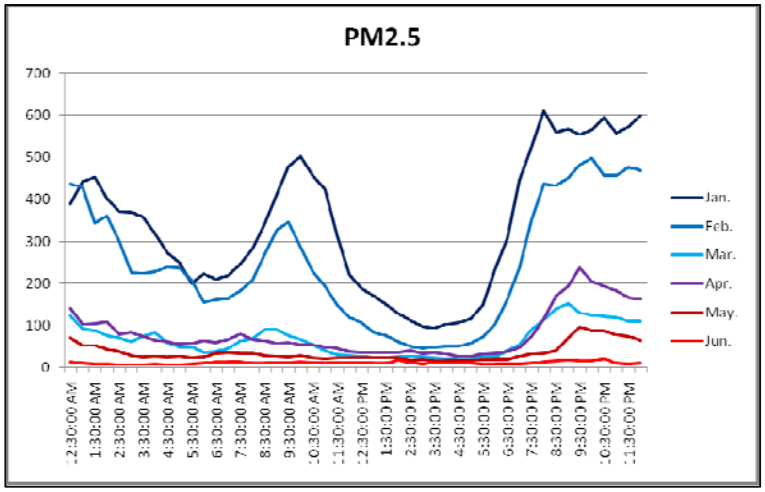
Working days





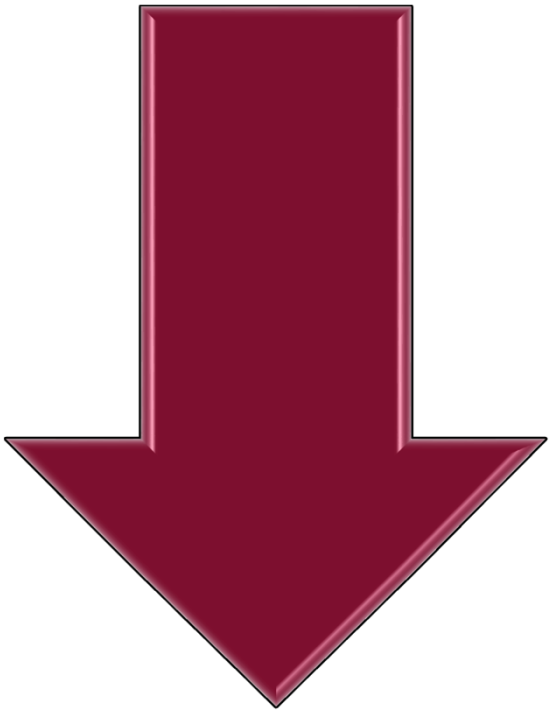
Weekend





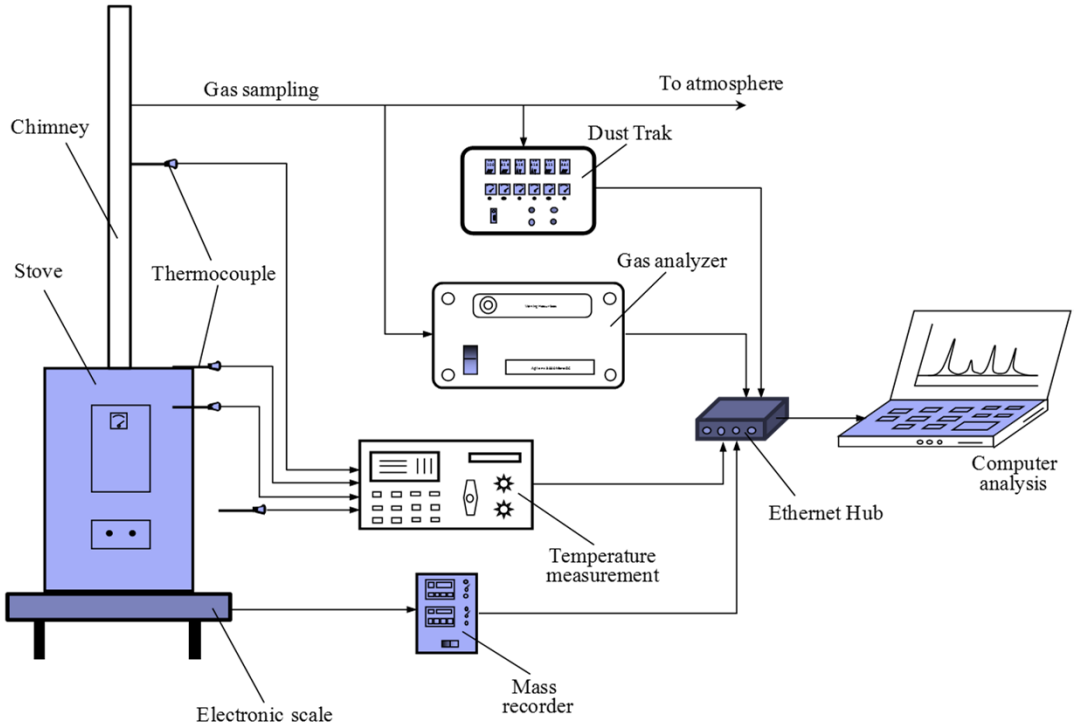
Sources and Content of Pollution

- Main pollution sources are:
  - PM_{10}- Soil erosion, Coal combustion, Motor vehicle, Biomass burning,
  - $PM_{2.5}$- Coal combustion, Motor Vehicle+Road dust, Biomass burning, Soil
- Ulaanbaatar is the most polluted capital city of the world.
- 50% of PM concentration corresponds to ignition phase (cold start) and reloading of stoves.
- Presence of toxic elements in air: Hg, Ni, V, F, Cl, Br, As.
- Pb (Lead) in the air is below the Mongolian standard.



What to do?

Stove Testing Laboratory

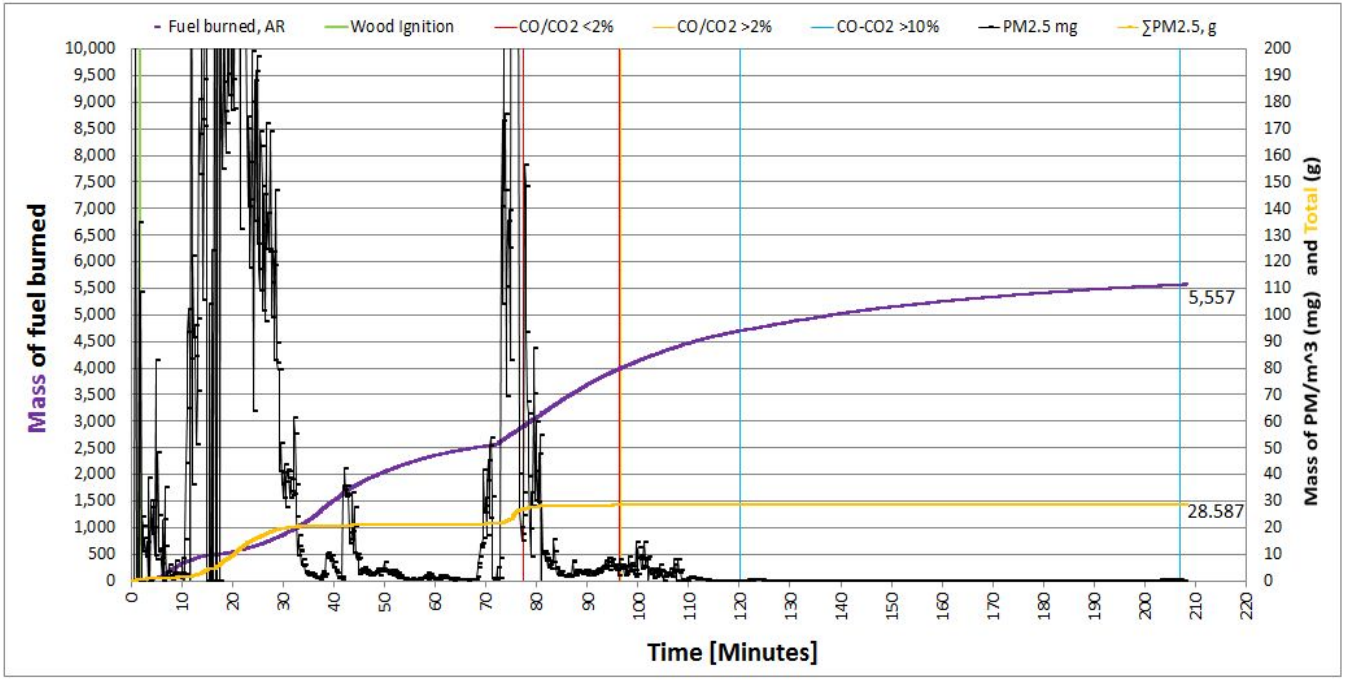


Mongol stove

Stove Manufacturer	Ulaanbaatar	Test date	22/Aug/2010
Stove Model	Traditional stove, traditional fire	Type of Fuel	Nalaikh

Coal, v. 2.58

PM 2.5 and Mass Burned 10.4.1 Traditional stove, traditional fire 22/08/2010 Test No. 081



Note: The ash is still in the stove.
The heat value/kg considers this.
The test ends when 90 % of the fuel loaded (total) has been burned.

Average particulate emission		
PM2.5	388.358	mg per MJ

Average CO emission		
	8.161	g per MJ

Traditional stove, traditional fire

This test includes a refuelling episode. For a front lit traditional stove, the performance is typical showing that PM production is highly dependent on the lighting method. The peak power was 18 kW reached when first lighted or when refuelled.

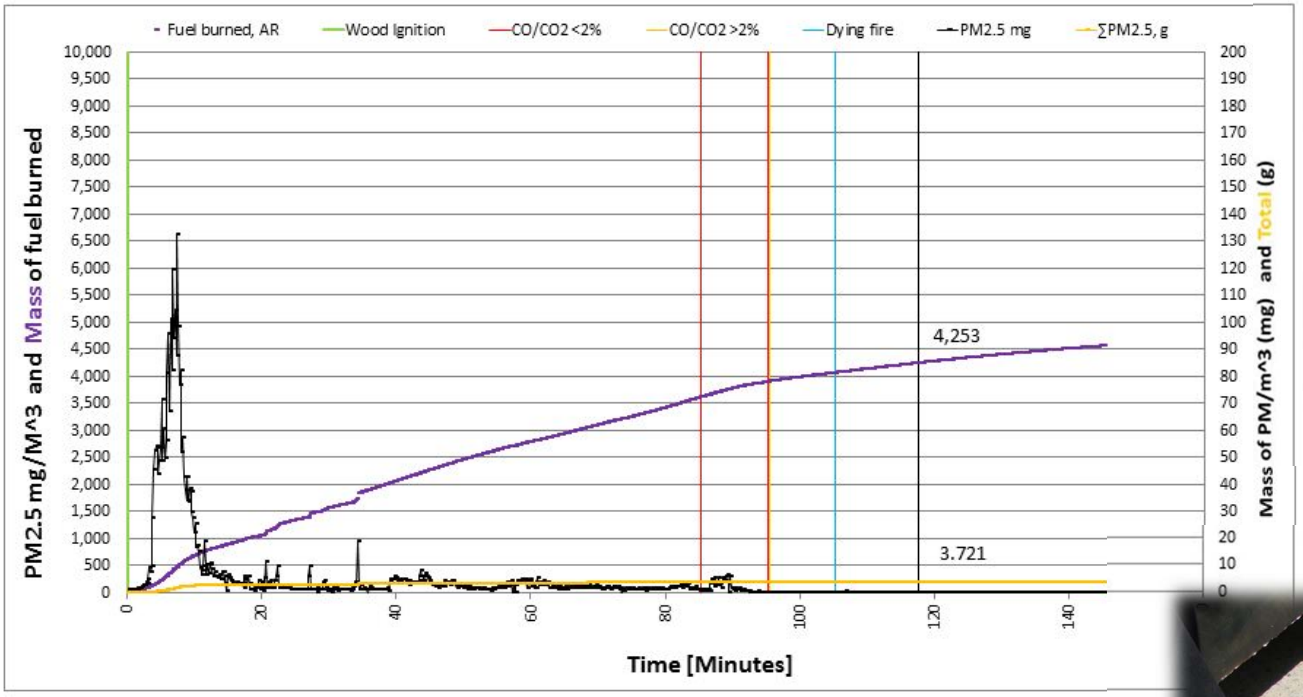
Modified Mongol Stove

Stove Manufacturer Street
Stove Model MM-0

v. 2.53

Test date 30/Nov/2010
Type of Fuel Nalaikh Sept '10

PM 2.5 and Mass Burned 10.4.1 MM-0 30/11/2010 Test No. ELCD Long Test



Average particulate emission
PM2.5 66.994 mg per MJ

Average CO emission
3.598 g per MJ

MM-0

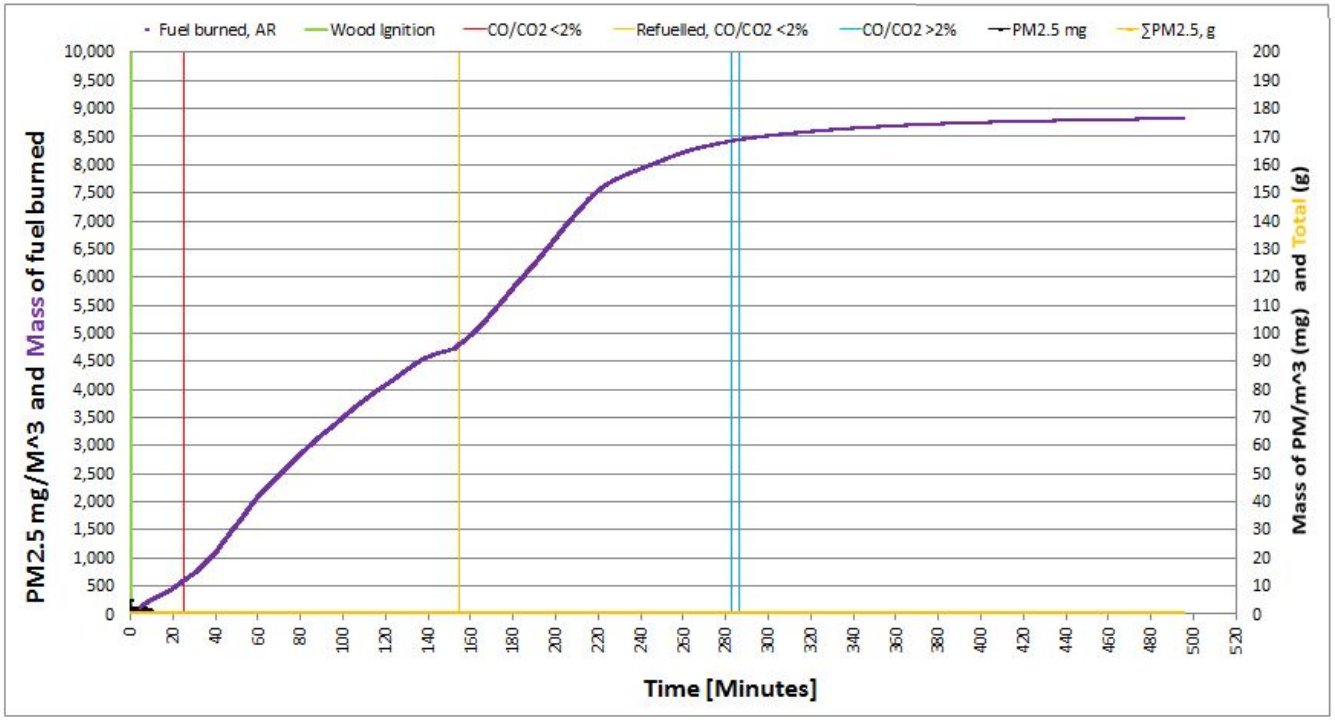
No refuelling, just light at the far end of the combustion cvhamber and burn 90% of the fuel.

Prototype Stove

Stove Manufacturer GTZ's contractor
Stove Model GTZ 7.5

Coal, v. 2.58

PM 2.5 and Mass Burned 10.4.1 GTZ 7.5 18/12/2010 Test No. 117



Note: The ash is still in the stove.
The heat value/kg considers this.
The test ends when 90 % of the fuel loaded (total) has been burned.

Average particulate emission		
PM2.5	0.363	mg per MJ

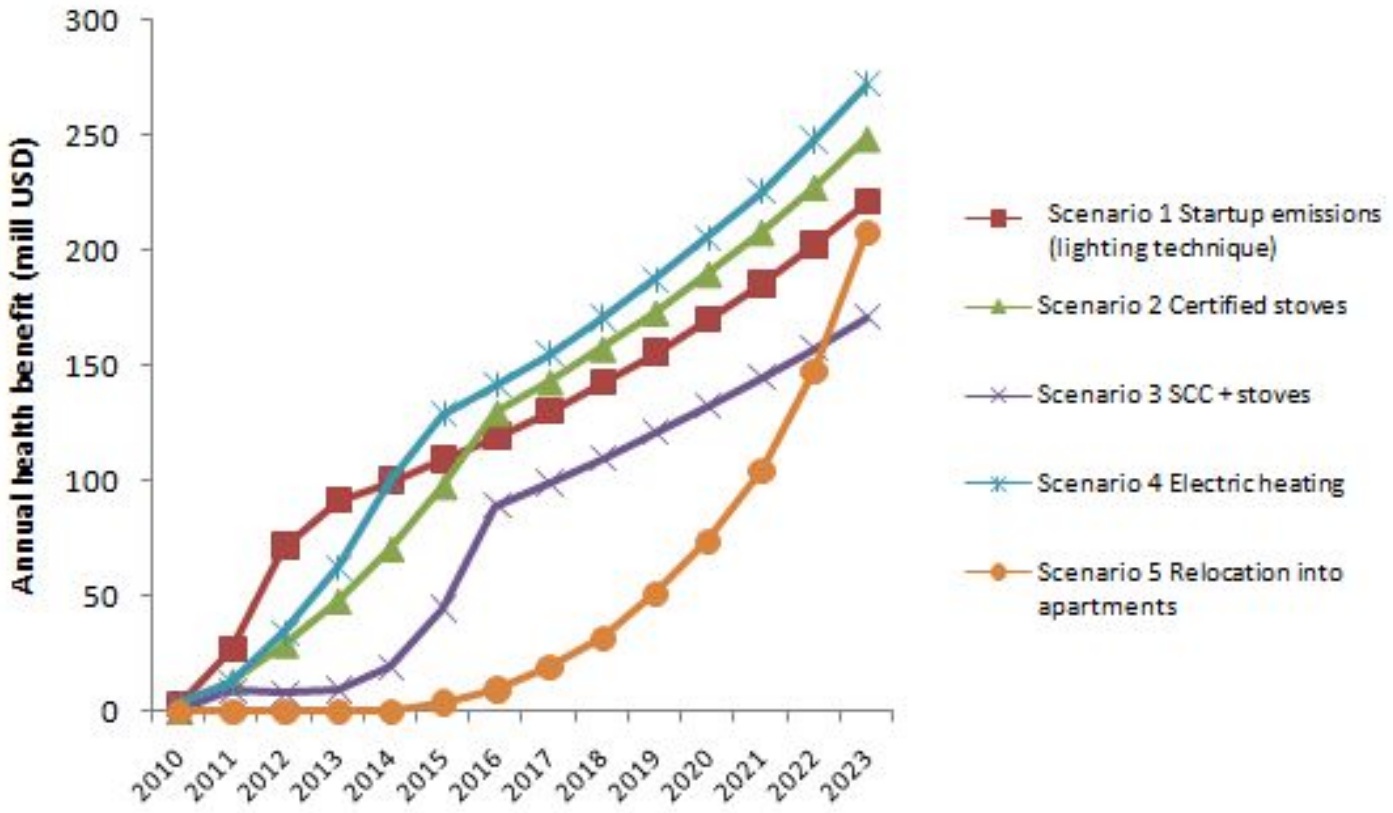
Average CO emission		
	0.528	g per MJ

Comparative stove efficiency

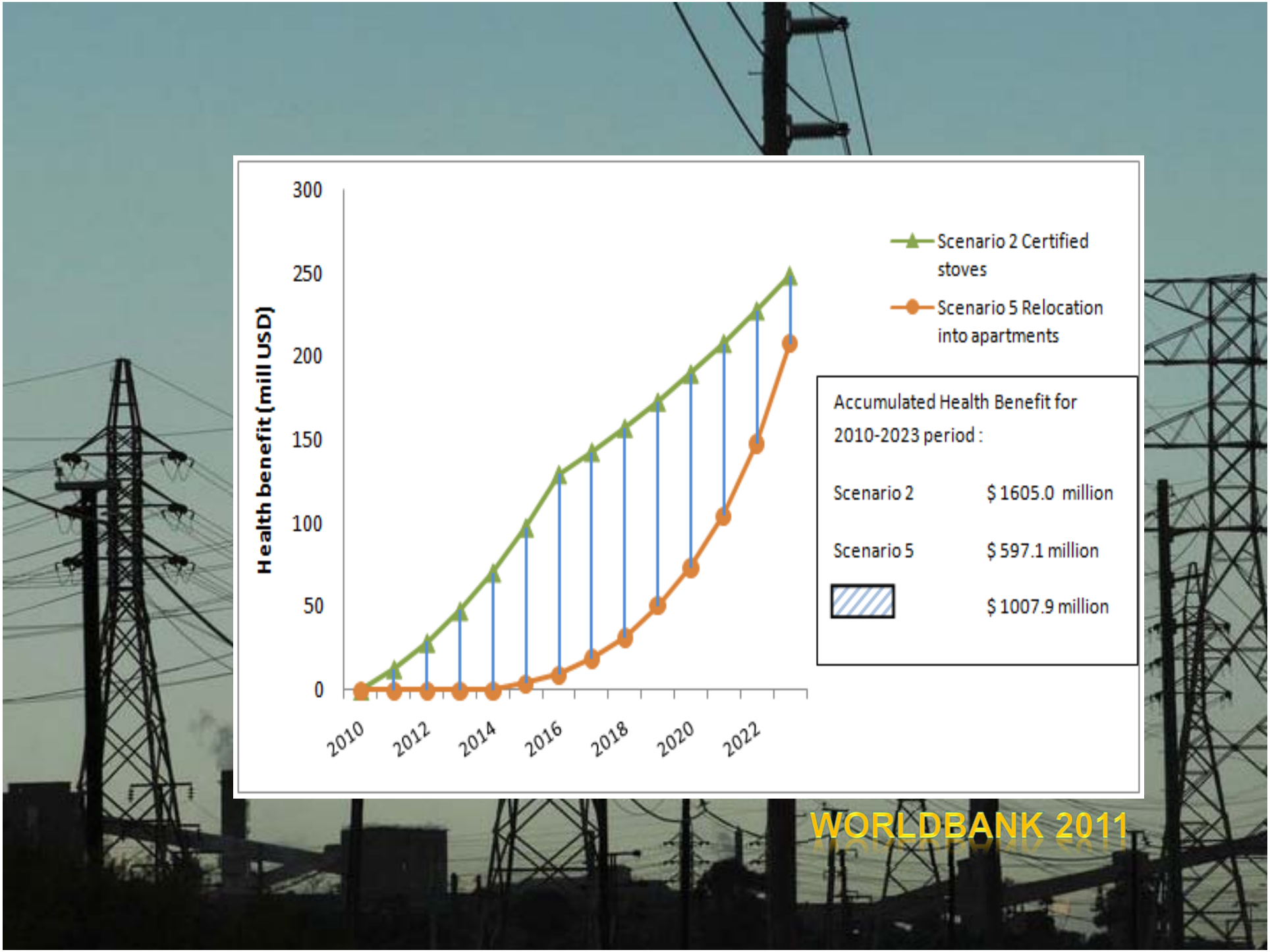
- Traditional stove has high emission and low efficiency, due to inefficient combustion and being lined with bricks and clay to increase lifetime
- Prototype stoves reduce PM Emission per MegaJoule of heat delivered more than 99% while still using raw coal
- Prototype stove is so efficient that it substantially cleans the ambient air that passes through the fire.

Management

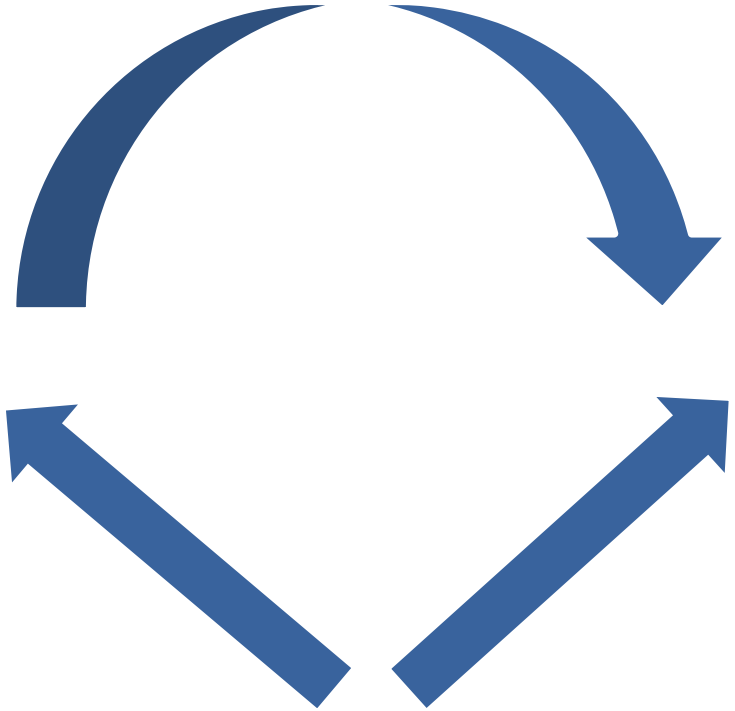
Annual Health Benefits From Abatement Scenarios
- benefits of different solutions accrue at different times.



World Bank 2011


300
250
200
150
100
50
0
Health benefit (mill USD)
2010
2012
2014
2016
2018
2020
2022
Scenario 2 Certified stoves
Scenario 5 Relocation into apartments
Accumulated Health Benefit for 2010-2023 period :
Scenario 2 $ 1605.0 million
Scenario 5 $ 597.1 million
$ 1007.9 million
WORLDBANK 2011

153,000 (82%) stoves were changed for improved stoves



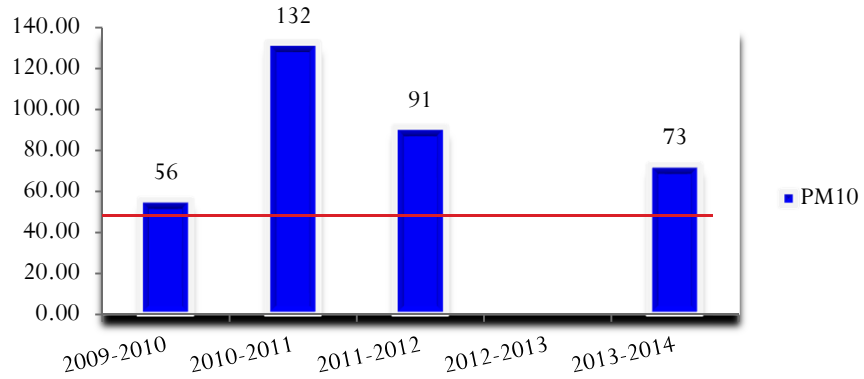
Change in emissions and fuel consumption		
Coal consumption	Stack gas (PM2.5)	(SO2)
-16%	-80%	?

Insulation materials, Saw Dust Briquette were distributed to the household

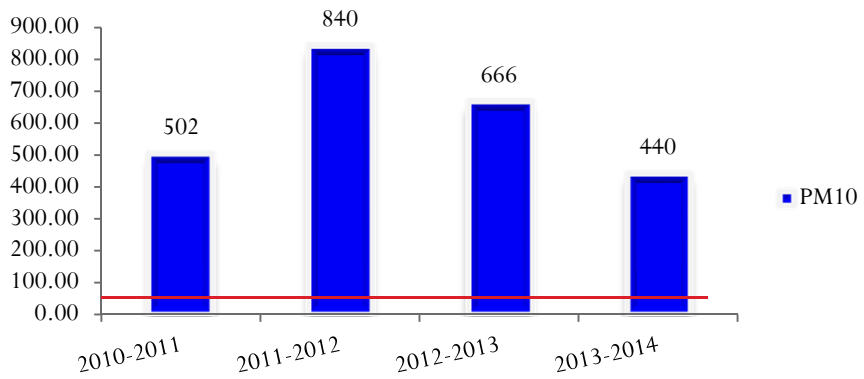
10 percent of HOB's were improved.

Winter Months PM_{10} Pollution Through The Years ($\mu g/m^3$)

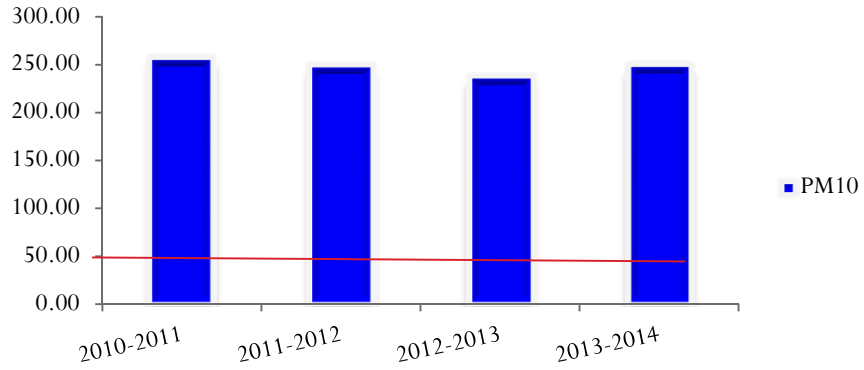
CLEM UB1



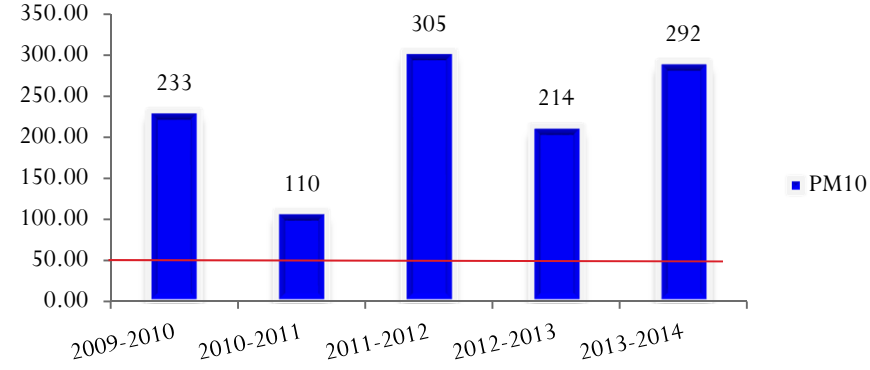
Zuun Ail UB5



West Cross UB2



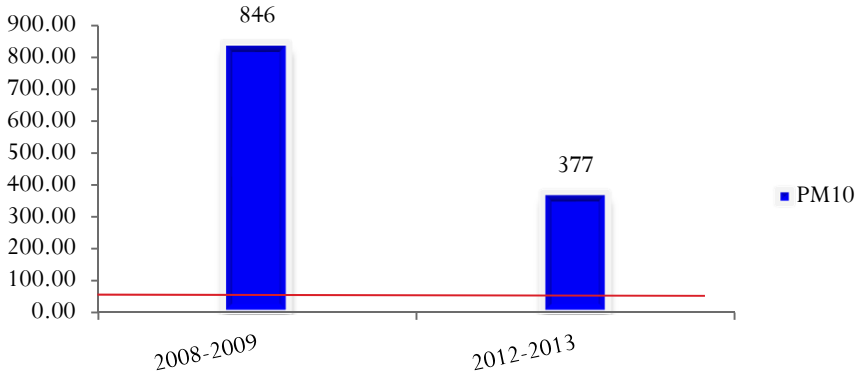
13 Dist. UB4



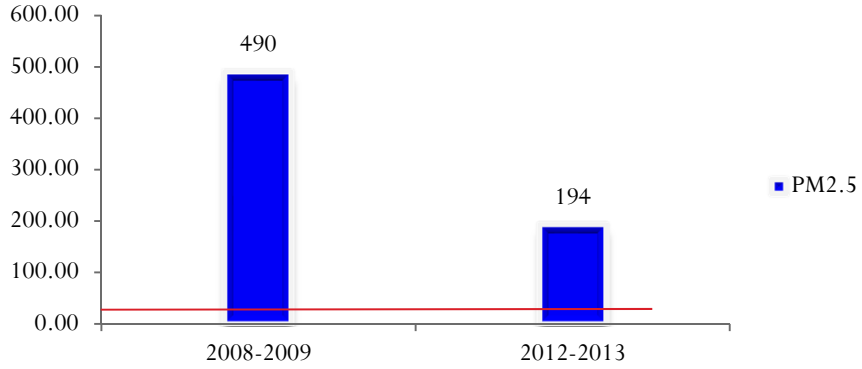
NAMEM 2014

$PM_{2.5}$ Pollution In Winter Months ($\mu g/m^3$)

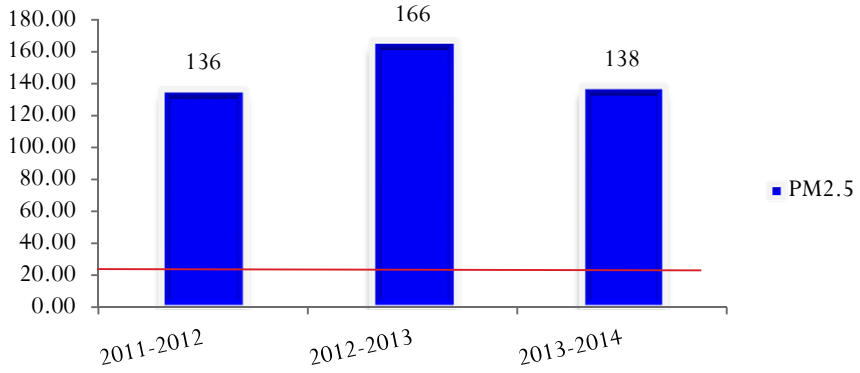
Zuun Ail UB5



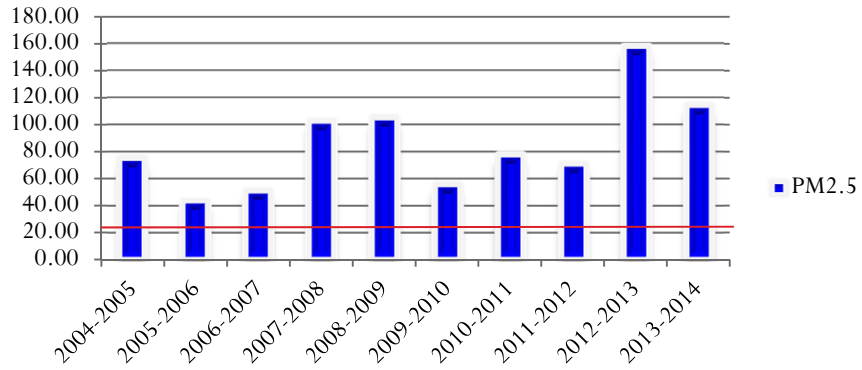
Zuun Ail UB5



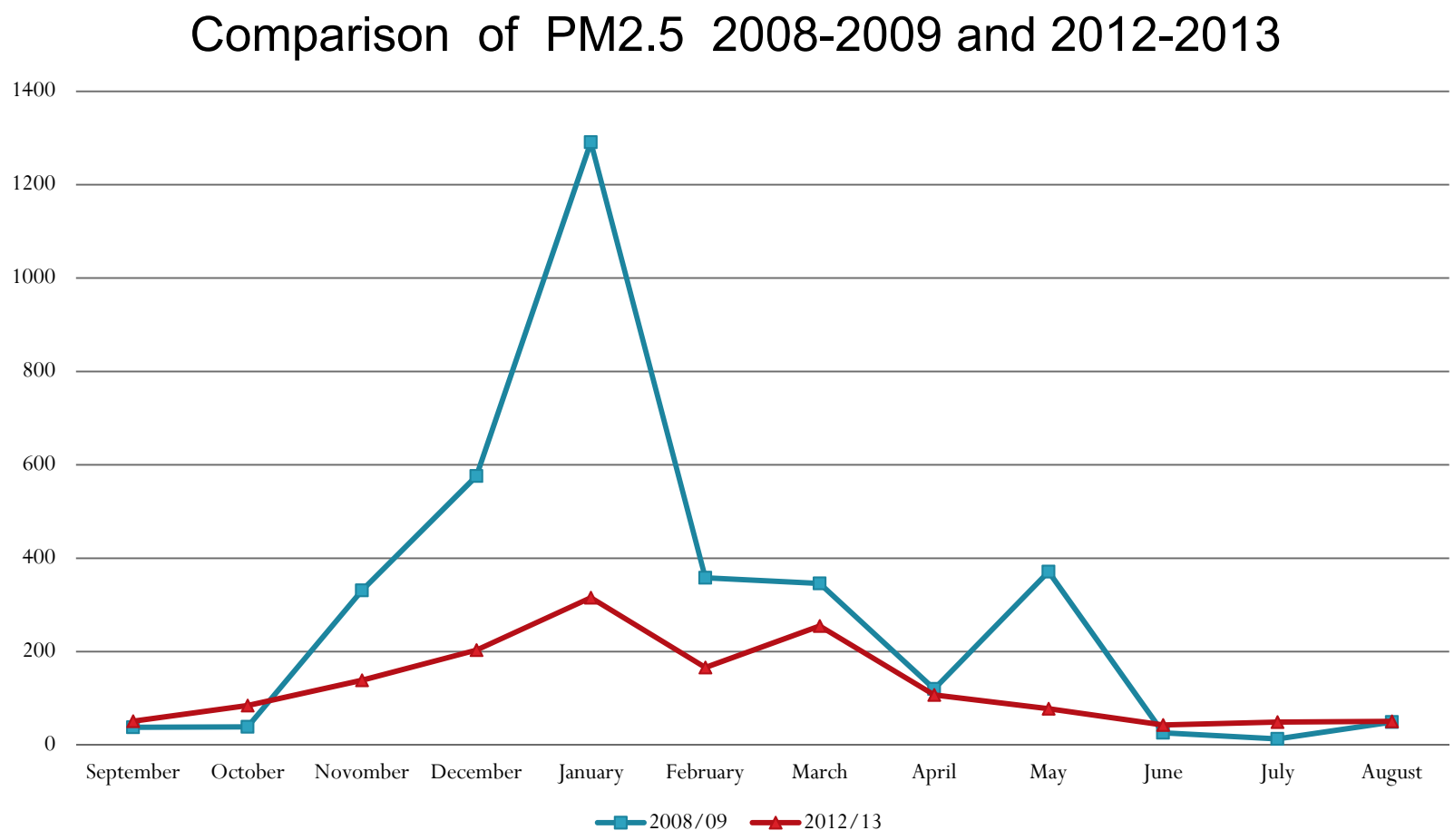
West Cross UB2



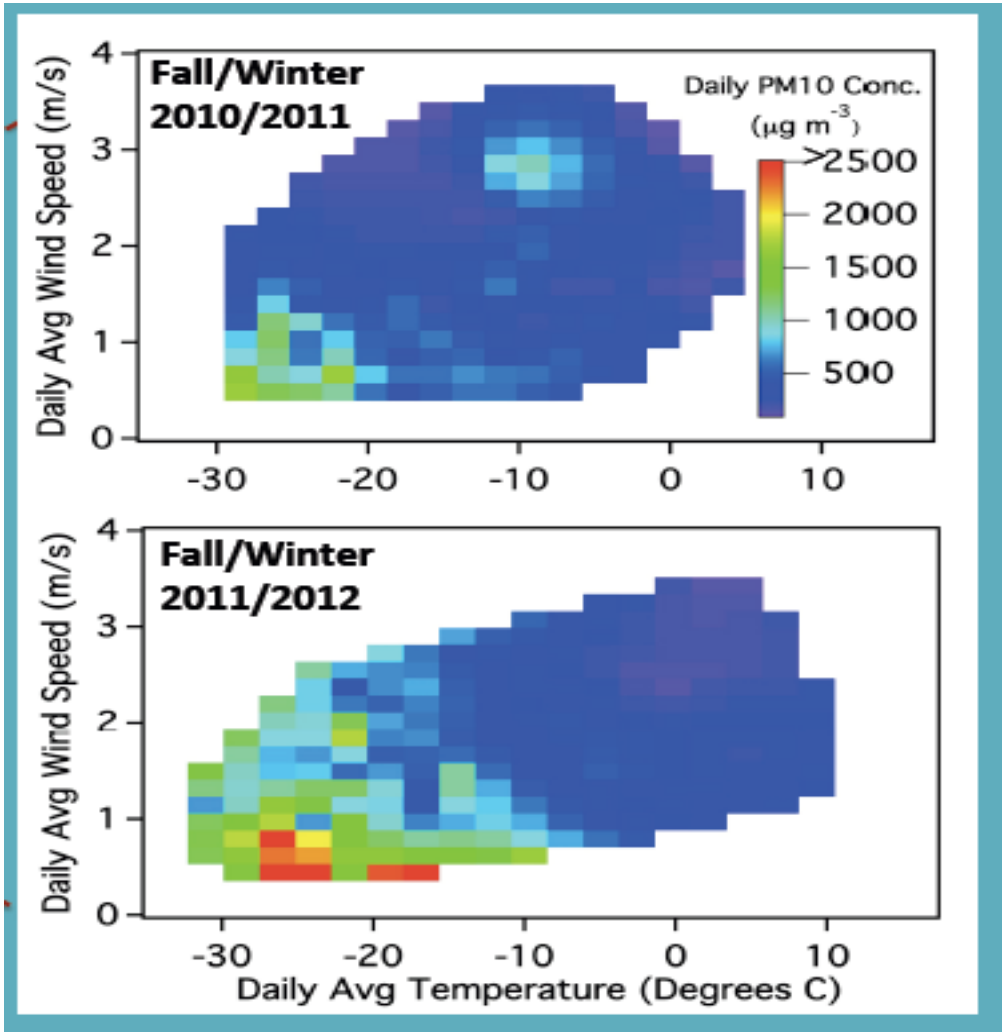
NRC UB6



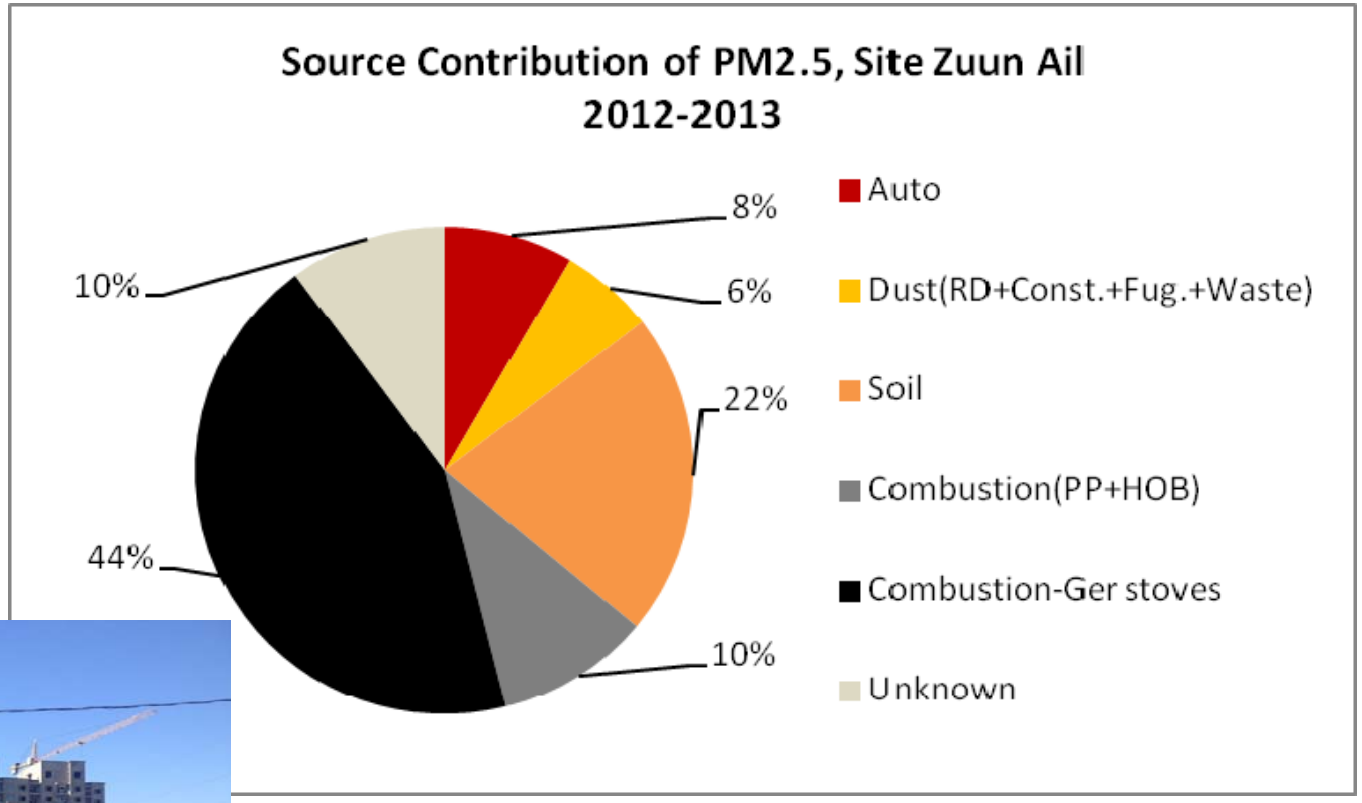
Comparison PM2.5 Concentration at Zuun ail



PM_{10} VS Wind and Temperature



New Source Apportionment Result



Discussion

- PM Air pollution reduction varies from site to site:
  - 57% decrease at Zuun Ail in 2012-2013 versus 2008-2009 (high stove uptake)
  - 30% reduction in overall UB pollution (AQA 2012-2013 versus 2011-2012)
  - 2012-2013 and 2013-2014 winter PM2.5 air pollution decreased some places (Zuun Ail, Western Cross) but increased in some places (13 District, Academy Town)

Discussion

Reason of reduction of $PM_{2.5}$:

- Sale of 145,000 improved household stoves
- Paving more roads
- Weather conditions, especially inversions, wind direction and speed, temperature

Reason for increase of $PM_{2.5}$:

- Use of Baganuur coal instead of Nalaikh coal in the winters of 2012-2013 and 2013-2014
- Increasing population, vehicles and homes
- Weather conditions, wind direction and speed, especially inversions, temperature

Conclusion

- $PM_{2.5}$ air pollution in UB City has been reduced overall since 2011/12
- 2012-2013 and 2013-2014 winter reduced only in some places
- $PM_{2.5}$ concentration in ambient air is highly dependent on not only stoves, but also the type of fuel used and firing behavior of the users
- H_2S should be measured and controlled

Conclusion (Cont.)

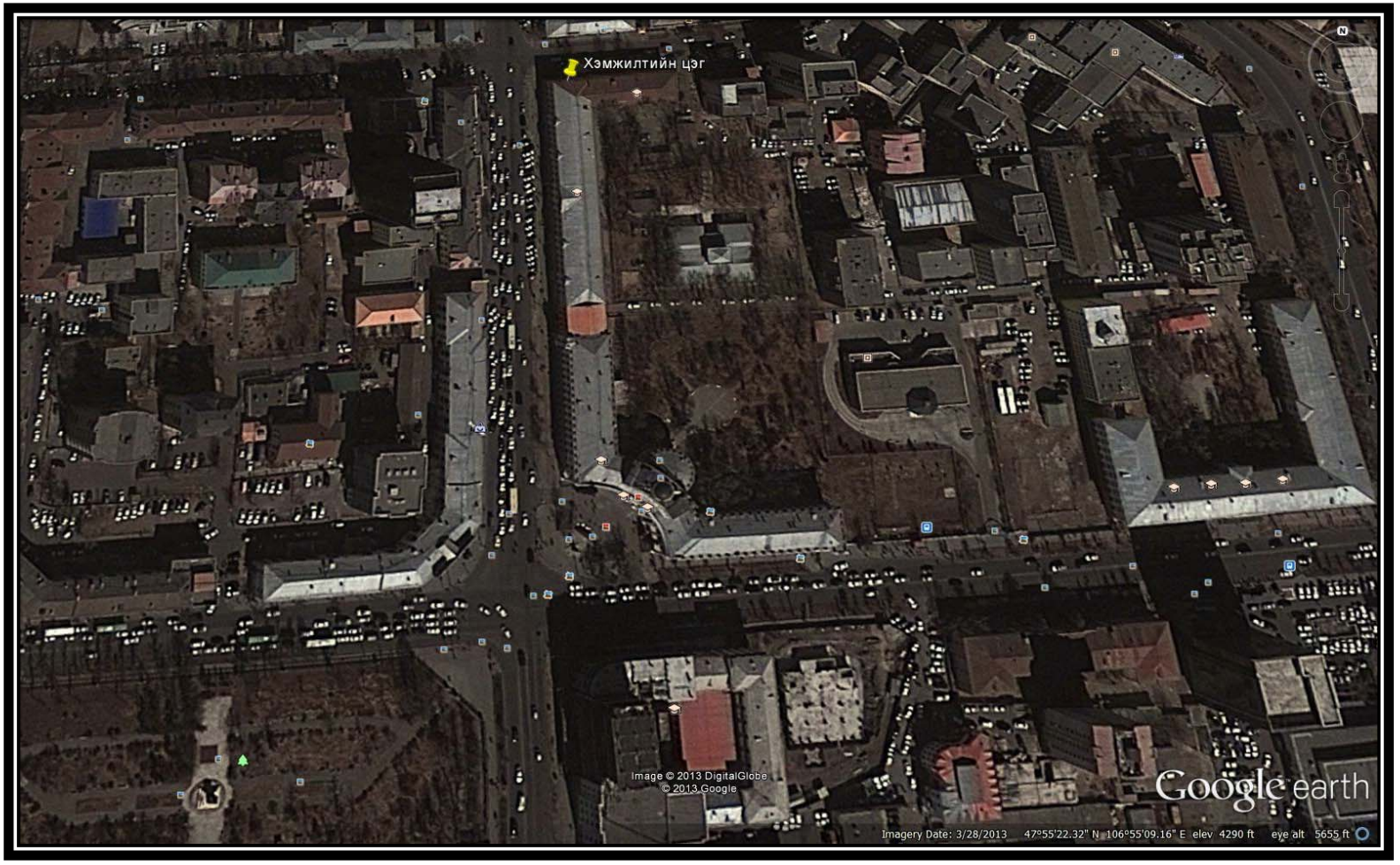
- Fuel for households should be carefully selected and tested in common stoves using common behavior
- In more air pollution monitoring stations should measuring $PM_{2.5}$ pollution (at least 6)
- Source apportionment work should be done for more sites for future policy making of reduction of air pollution as current information is limited

Black Carbon Study

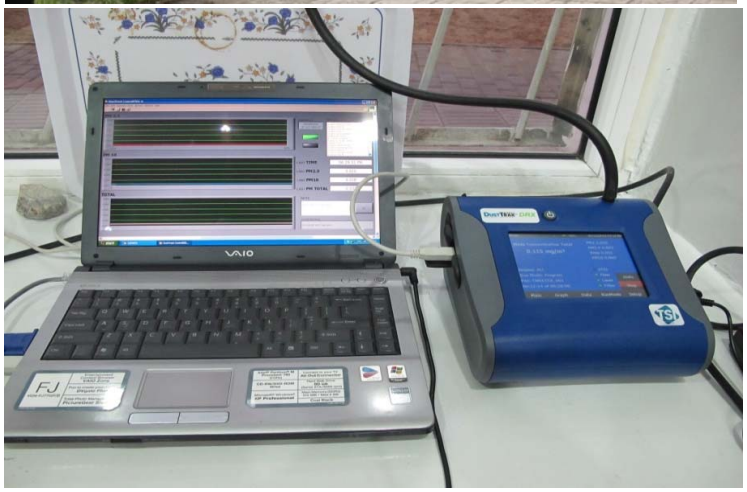
Aim of the study is:

Evaluation of BC in central Ulaanbaatar and possibility of use of MicroAethalometer to assess personal dose of PM2.5 pollution

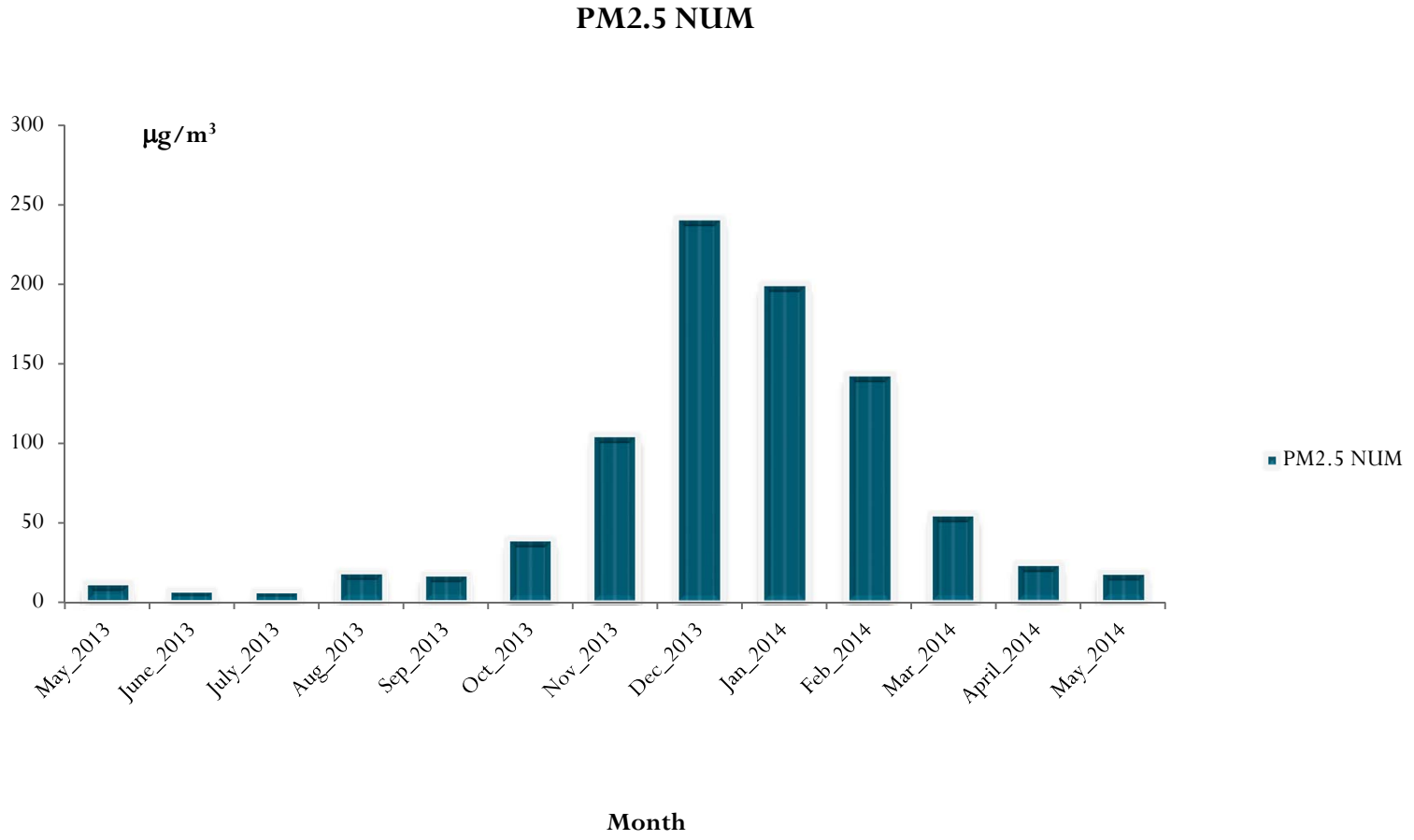
Black Carbon Study



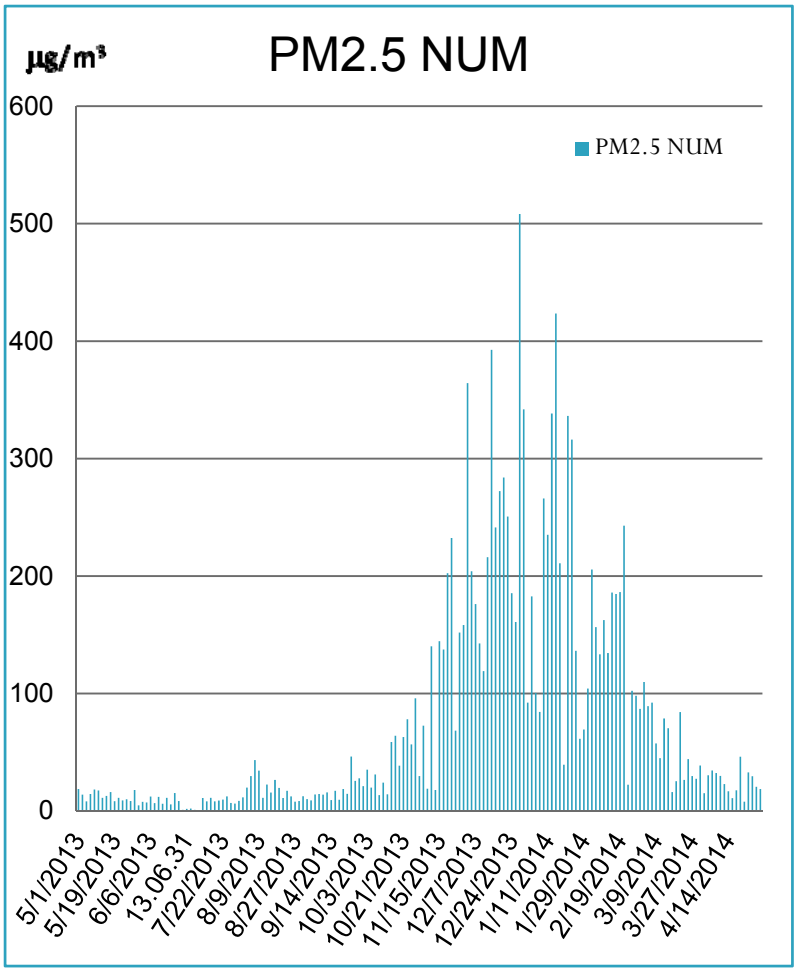
PM2.5 Measurement – Dusttrak DRX- 8533, TSI,USA,
Black Carbon Measurement- Microathalometer, MicroAeth AE-51, USA
Measuring Site, Building 3 NUM, United Nations Street Cross Road

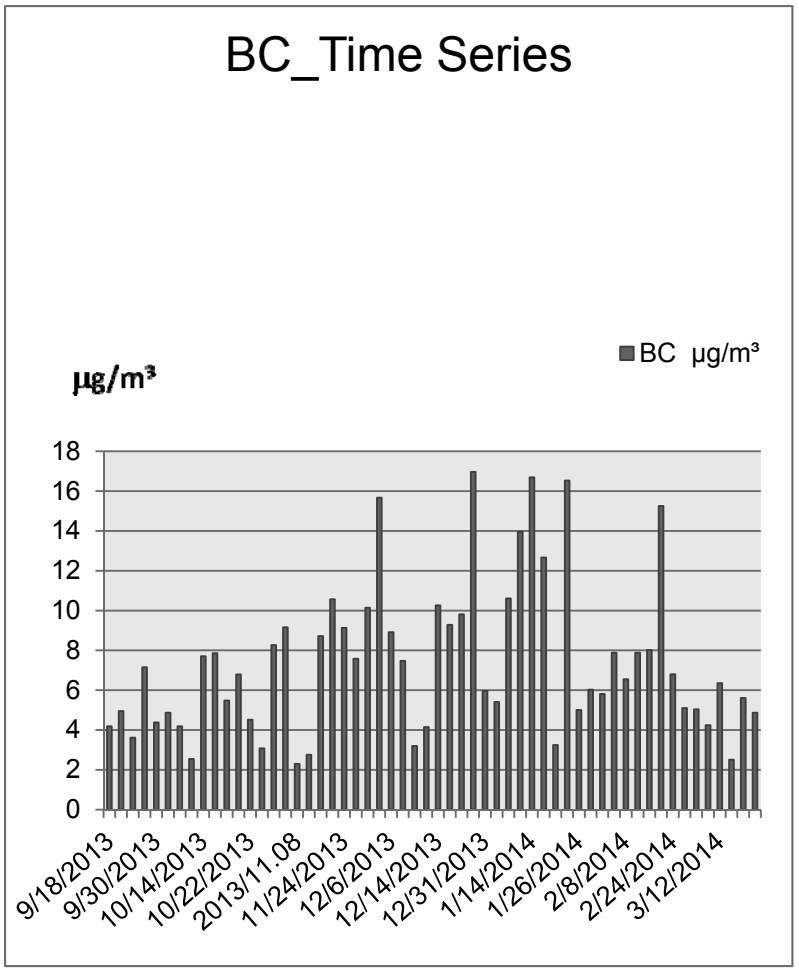


Monthly Average PM2.5 at NUM



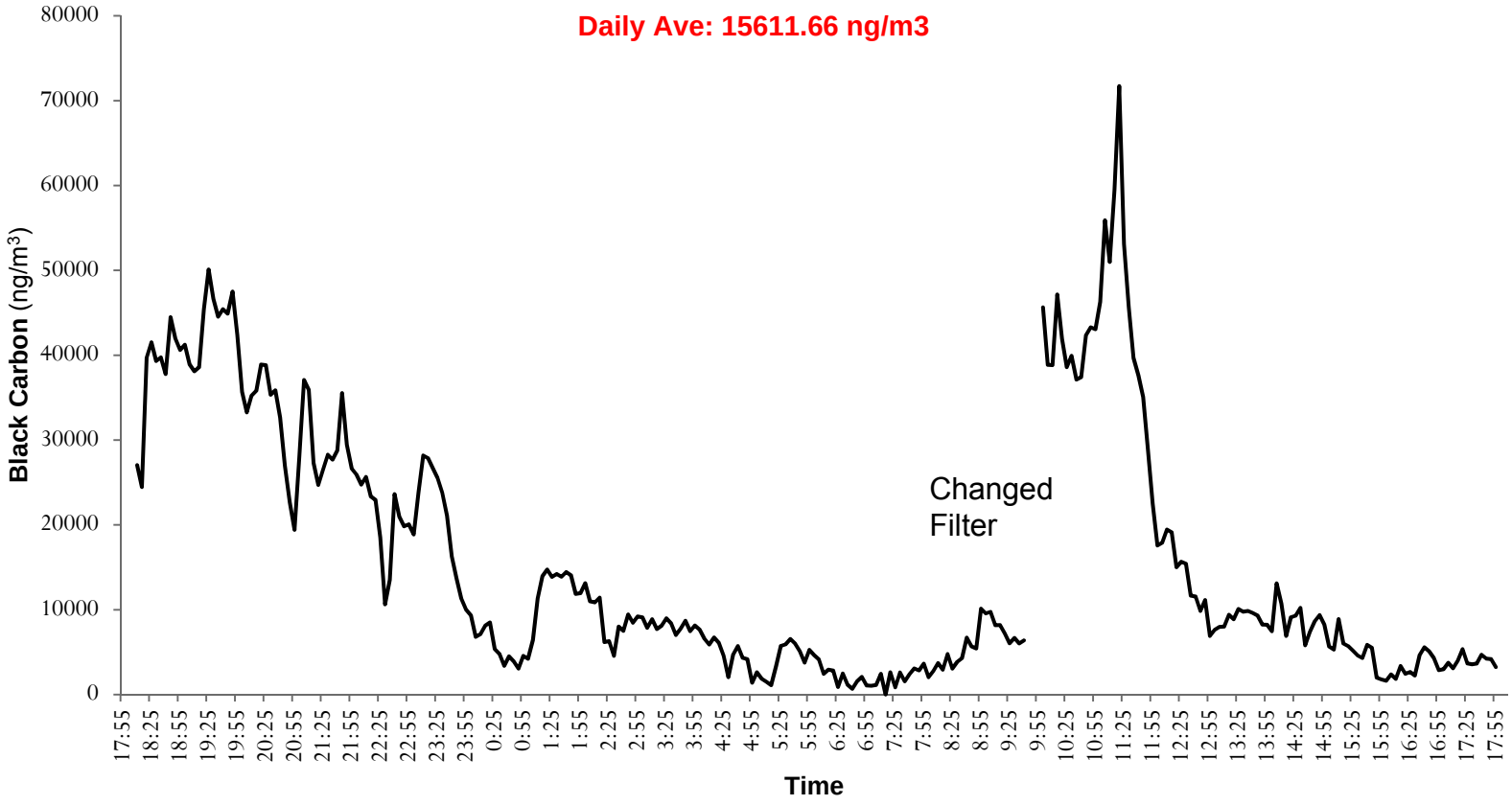
Time Series of PM2.5 and BC at NUM



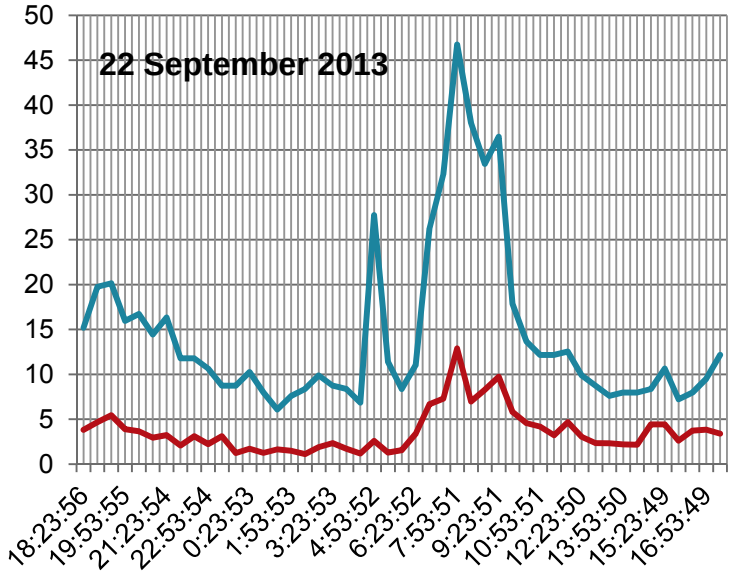


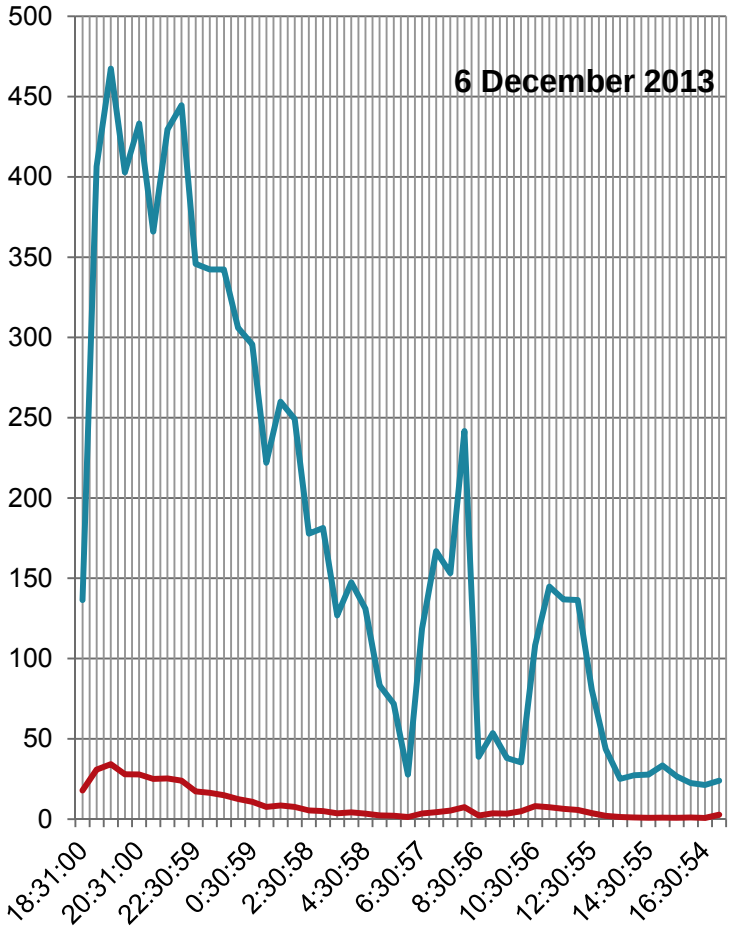
Filter is blocking

2013/12/02

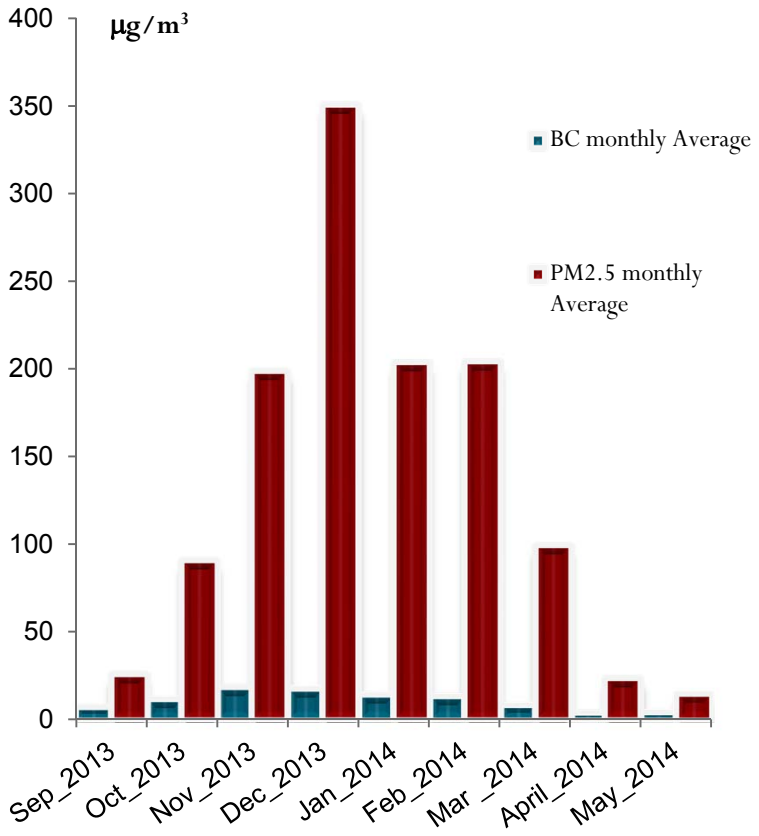


PM2.5 and BC (μg/m³)





BC/PM2.5 Ratio

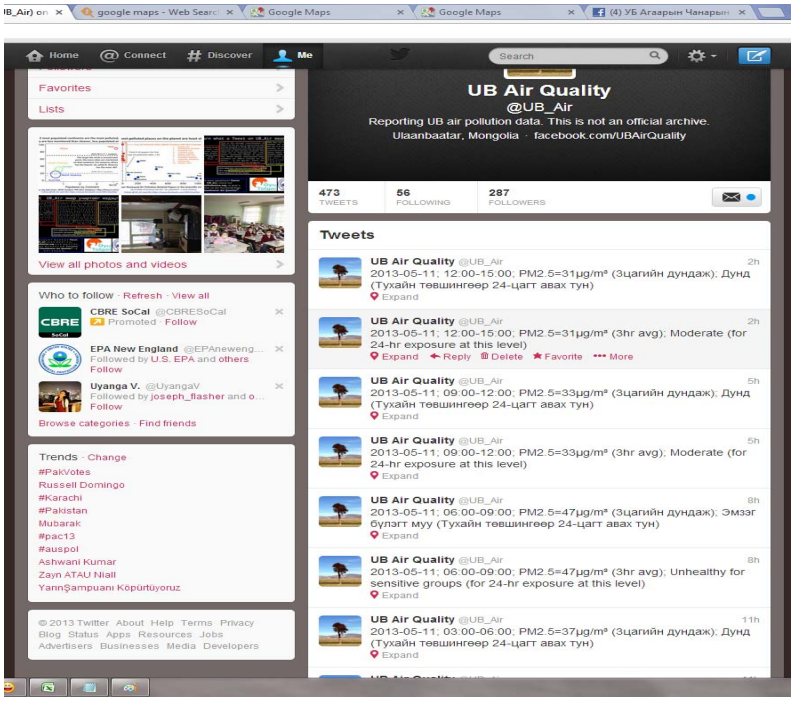


Months	BC/PM2.5
Sep_2013	0.29
Oct_2013	0.13
Nov_2013	0.10
Dec_2013	0.05
Jan_2014	0.07
Feb_2014	0.07
Mar_2014	0.09
April_2014	0.19
May_2014	0.31

Conclusion: Black Carbon Study

- Black Carbon measurement can be done not for more than 6 continuous hours in November-February in Ulaanbaatar, due to filter saturation
- $PM_{2.5}$ pollution can be estimated using Black Carbon by MicroAethalometer measurement. Monthly calibration factor should be applied, as BC/PM2.5 ratio is not linear from month-to-month
- This Non-linear ratio can be explained by the presence of water droplets and ice on cold days and because dominating BC source at the site is vehicles. It should be studied more in future.

Twitter and FaceBook air quality



https://twitter.com/ub_air and https://www.facebook.com/UBAirQuality

Please visit our Twitter and FaceBook sites to see the air pollution in Ulaanbaatar on-line.

lodoysamba@gmail.com

Acknowledgement

- B.Batmergen,
- Crispin Pemberton-Pigott
- S.Enkhmaa
- G.Gerelmaa
- Christa Hasenkopf
- B.Tuvshintur and many others

THANK YOU FOR YOUR ATTENTION