Development of Stove Emission and Efficiency Testing Laboratory

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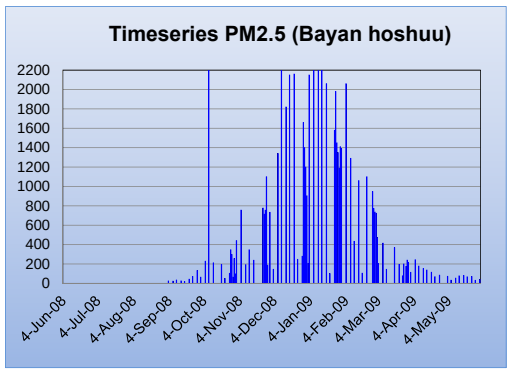


In this paper the stove emission and efficiency testing laboratory developed in Ulaanbaatar by the ADB and WB is described. The extremely high air pollution in Ulaanbaatar, the capital city of Mongolia often exceeds the WHO guidelines for respirable airborne particulate matter by a factor of 35. According to a pollution source apportionment study conducted by the National University of Mongolia it is mainly emitted by domestic cooking and heating stoves. More than 90% of the annual average PM2.5 is generated by simple wood stoves poorly suited to burning lignite, the preferred urban fuel.

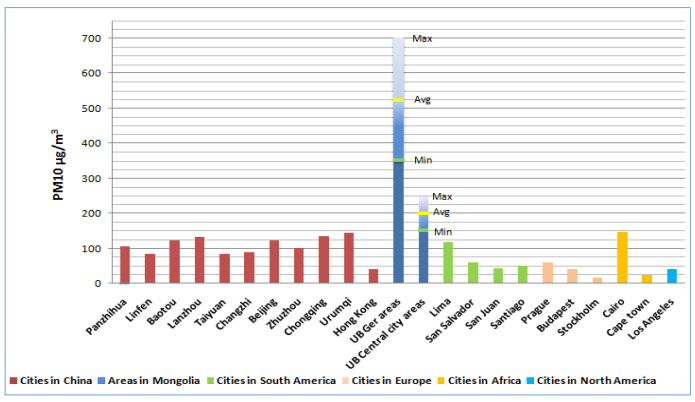
The Stove Efficiency and Emission Testing (SEET) laboratory was established in Ulaanbaatar to develop, test and rate low emission, high efficiency stoves as part of an air pollution reduction program. The equipment includes an Emerson X-Stream dual channel gas analyser (CO, O_2, CO_2, CO_2x2), Dusttrak DRX particle counter, 150 kg x 2 g Adam electronic mass balance monitored using novel desktop software and an Agilent 34972A multiplexer fitted with an Agilent 34901 thermocouple card. A novel particle dilution tunnel system avoids condensing water vapour from the stack. It is supplied with CO_2-free dry air from a Twin Towers Engineering cycling adsorber. Gas sample drying in achieved using a vortex tube chiller and Nafion dryers. The variable dilution of the particle concentration, including condensable volatiles, is factored to its undiluted state by continuously logging the ratio of the CO_2 concentration in the stack and that of the CO_2 at in the diluter. Dilution can be manually varied as required from 3:1 to 300:1 keeping the PM concentration within the particle counter's 150 mg/m^3 limit from a source as high as 45,000 mg/m^3.

Data analysis is performed using the SeTAR Centre's (University of Johannesburg, South Africa) Heterogeneous Test Protocol and analytical methods. More than 200 tests were carried out for development of new stoves and product selection for Ulaanbaatar's Clean Air Program (UBCAP). The laboratory shows this methodology can serve as important instrument for the development, testing and selection of improved stoves.

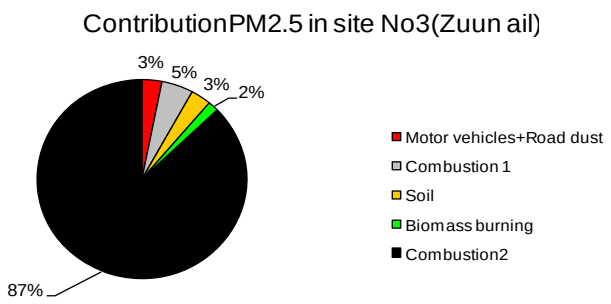
Keywords: Stove Testing, Efficiency, Emission, PM2.5, Heterogeneous Test Protocol, Ulaanbaatar, condensable volatile particles

Tag: Low Emissions Urban Development

Average Concentration Calculated			
Area	**PM10 (mg/m^3)**	**PM2.5 (mg/m^3)**	**Exceedence**
Central part UB	300	150	6
Ger area UB	350-900	300-620	7-18



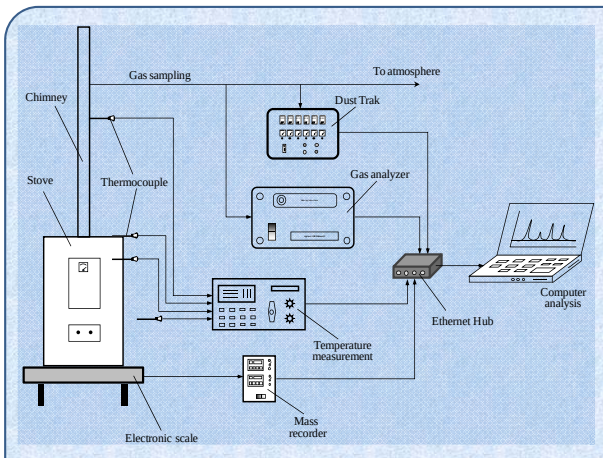
Ulaanbaatar is most polluted capital in the world



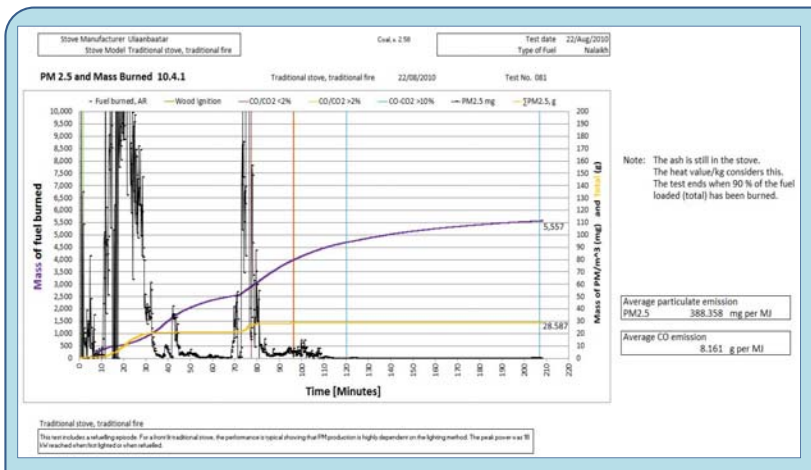
Main pollution source (87%) is coal burning in inefficient stoves

Ulaanbaatar residential area in winter

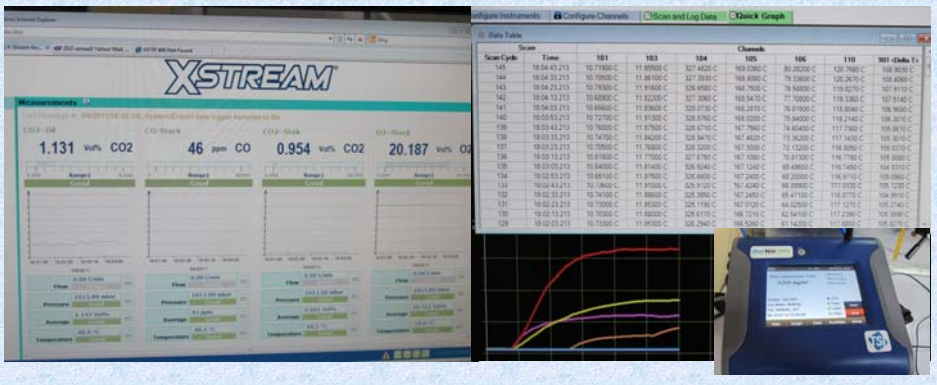
Stove Emission and Efficiency Testing Laboratory was established to develop low emission high efficiency coal stoves for cooking and space heating.

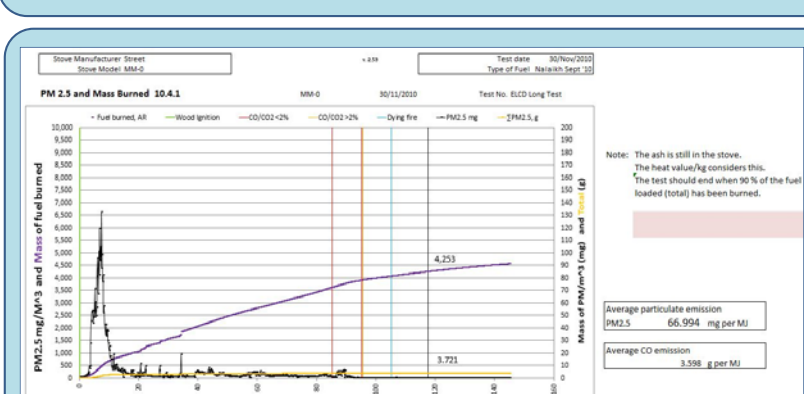


Schematics of the laboratory



PM2.5 Emission measurement of inefficient stove





Simple change of firing technique gives much improvement in emission

SEET Laboratory Test Single Test Analysis xxx.10.5 Test No. 081 Analysis Sheet: Coal, v. 2.58

Stove Manufacturer Ulaanbaatar Stove Model Traditional stove, traditional fire

Traditional stove, traditional fire Report		Date 22/08/2010	Time 10:50 AM	Fuel Coal	LHV, MJ/kg 13.0	Analysed by -			Colour Coding
Enter line numbers in Column C to divide the test into relevant sections. The last line is auto-set on Test Info page	Event Occurs on Line Number:	Stove Power per section Watts	None None Water Eff %	Average CO/CO2 ratio	CO_2 Emitted /kg burned g	CO Emitted /kg burned g	CO emitted during this portion, g	H_2O Delta T during this section	Combustion efficiency
Wood Ignition	16	8,371	0.0%	6.2%	1,944	71	207.2	0	MJ related
CO-CO_2 reaches 2%	469	Minutes of burn	75.52	VALID	This cooking section can overlap other sections				Mass related
									Section 1
CO/CO_2 <2%	470	12,233	0.0%	1.5%	2,033	19	19.7	0	Section 2
CO-CO2 reaches 2%	583	Minutes of burn	18.85	VALID					Section 3
									Section 4
CO/CO_2 >2%	584	6,433	0.0%	5.1%	1,965	59	41.0	0	Whole test
CO-CO2 reaches 10%	728	Minutes of burn	23.58	VALID					
CO-CO2 >10%	729	2,161	0.0%	15.7%	1,785	165	142.5	0	
90% fuel burned	1,249	Minutes of burn	86.73	VALID					

		Adjusted to 80 deg	COOKING	Whole Test	Beginning line	16
Initial Mass of Water Boiled, g	-				Ending line	1,249
Time to Boil, minutes (Green section above)	75.52	N/A	N/A minutes/Litre		Fuel burned, g	5,555.4
Fuel used to Boil, g (Green section above)	2,909.58	N/A	N/A g/minute		Minutes of test	205.2
Specific Fuel Consumption to boil, g/litre	N/A	N/A	N/A g/minute/litre		Avg g/minute	27.08
Energy to boil 1 litre, MJ	N/A	N/A	N/A Eff v.s. theoretical need		Max Min ratio	5.66
CO emitted to boil 1 litre, g	N/A	N/A				

Stage	CO, g Per hour	CO/CO_2	CO, g/MJ	CO g/kg AR	CO_2 g/MJ	CO_2 g/kg AR
CO-CO2 reaches 2%	164.7	6.2%	5.46	71.22	149	1944
CO/CO2 <2%	62.6	1.5%	1.47	18.54	156	2033
CO/CO2 >2%	104.4	5.1%	4.51	58.78	151	1965
CO-CO2 >10%	98.6	15.7%	12.67	165.19	137	1785
Whole Test	172.8	9.6%	8.16	106.38	145	1884

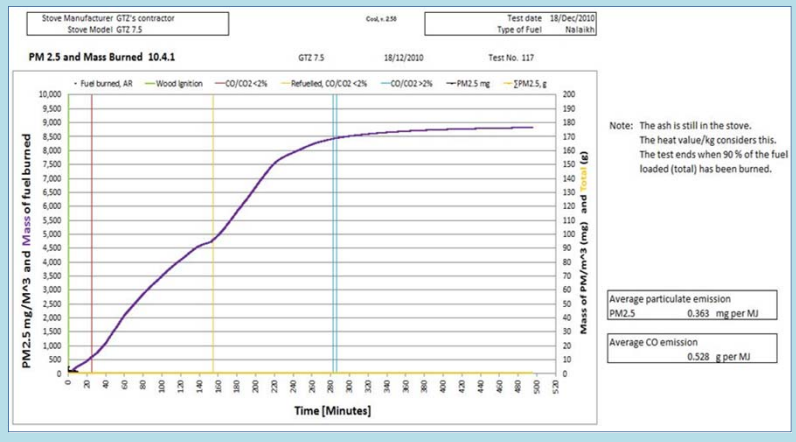
Check for ash correction

Stage	PM 1.0 g	PM 2.5 g	PM 4.0 g	PM 10 g	PM2.5 mg/MJ	PM2.5 g/kg AR	PM10 mg/MJ	PM10 g/kg AR
CO-CO2 reaches 2%	26.242	26.260	26.260	26.260	692.337	9.025	692.348	9.025
CO/CO2 <2%	1.503	1.504	1.504	1.504	108.731	1.417	108.739	1.418
CO/CO2 >2%	0.322	0.323	0.323	0.323	35.453	0.462	35.458	0.462
CO-CO2 >10%	0.001	0.000	0.000	0.000	0.041	0.001	0.038	0.000
Whole Test	28.105	28.125	28.126	28.126	388.358	5.063	388.366	5.063

Stage	MJ Yielded	Fuel, kg/hr AR	Thermal Eff	Heat, kW	Net heat, kW	Time, Hrs	Net KWHours
CO-CO2 reaches 2%	37.93	2.31	71.8	8.37	6.01	1.26	7.56
CO/CO2 <2%	13.84	3.38	66.1	12.23	8.09	0.33	2.64
CO/CO2 >2%	9.10	1.78	62.6	6.43	4.03	0.39	1.58
CO-CO2 >10%	11.25	0.60	53.9	2.16	1.16	1.45	1.68
Whole Test	72.42	1.62	62.6	5.88	3.68	3.42	12.60

Note: Net Heat is the same as the electric power needed for the same amount of heat to be delivered into the home.

Totals ignore section overlaps/underlaps



The laboratory helps to develop ultra low emission high efficiency stove.