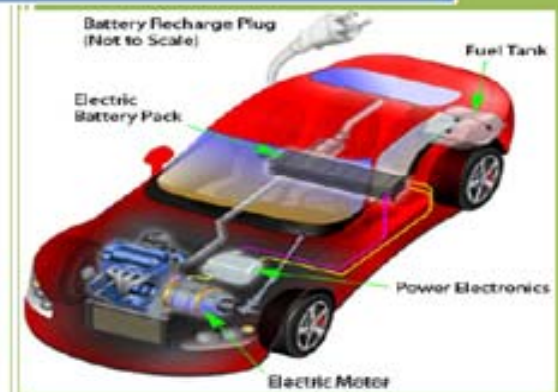


Final Draft Report on Pilot Global Fuel Economy Initiative Study in Ethiopia

Part IV

IMPACT OF VEHICLE EMISSIONS ON AIR POLLUTION IN ADDIS ABABA

ADDIS ABABA INSTITUTE
OF TECHNOLOGY



10/4/2012



Outline

- Air pollutants associated with vehicular emissions
- Air quality measurement
- Methodology
- Pollutant measurement sites
- Determination of air quality and impact evaluation
- Mitigation measures

Air Pollutants Associated with Vehicular Emissions

- **Pollutants**
 - Carbon monoxide, CO
 - Hydrocarbons, HC
 - Nitrogen oxides, NO_x
 - Sulfur oxides, SO₂
 - Particulate Matter, PM_{2.5}
 - Ozone (O₃)



Air Quality Measurement and Impact Evaluation

- **Pollutants Considered**
 - Carbon monoxide, CO
 - Particulate matter, PM_{2.5}
 - Nitrogen dioxide, NO₂
 - Sulfur dioxide, SO₂



Methodology

- Literature review
- Selection of measuring sites
- Collection of primary data
- Evaluation of the data on the basis of the WHO and ETH-EPA ambient air quality guidelines

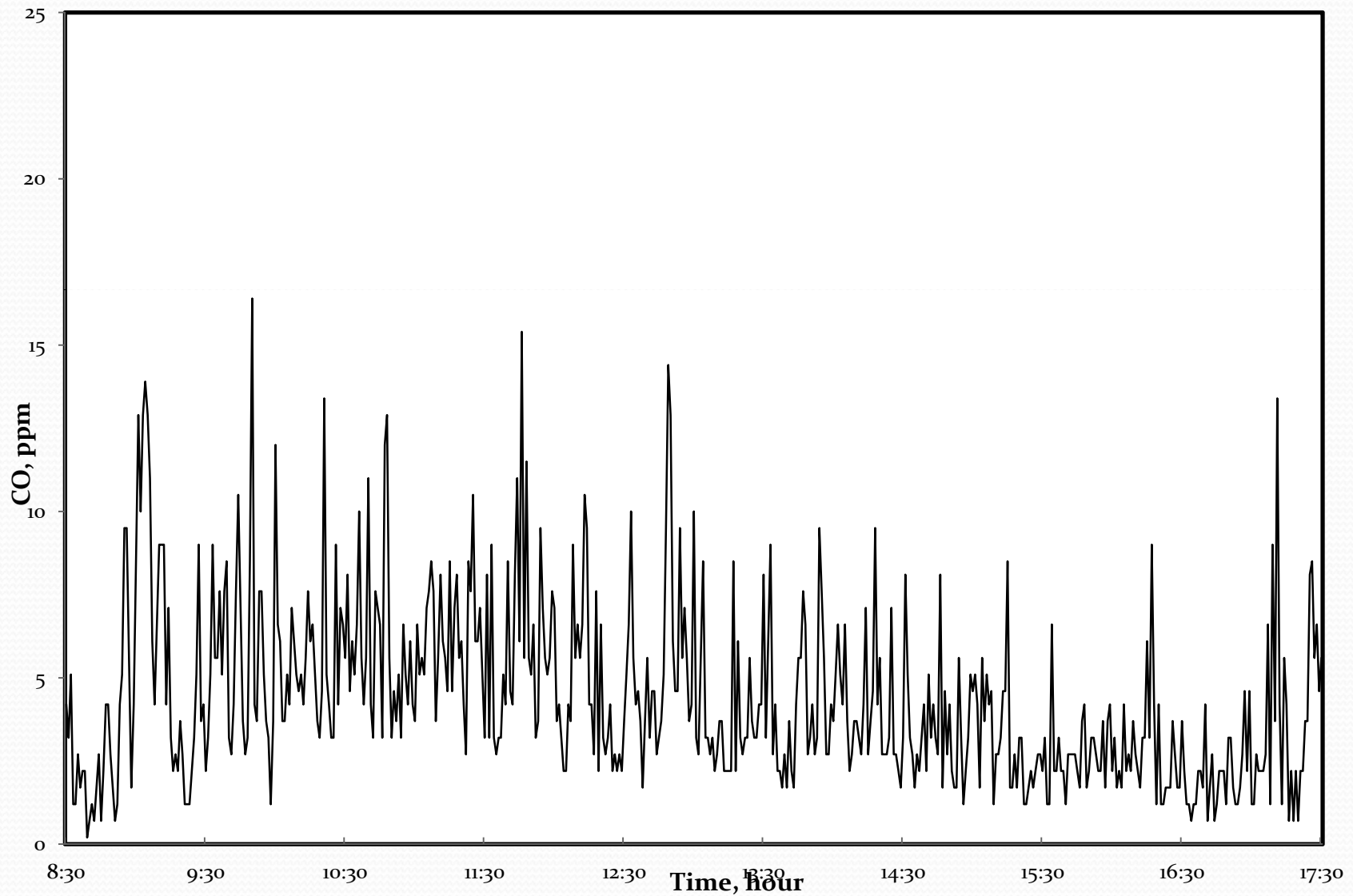
Measurement Site

Site		GPS location
Code	Name	
S1	Aduwa Square (Megenagna)	N 09° 00.145'; E 038° 47.560'
S2	Arada (Arada building)	N 09° 01.977'; E 038° 45.187'
S3	Betel	N 09° 00.225'; E 038° 41.515'
S4	Bob Marley Square (Imperial Hotel)	N 09° 00.156'; E 038° 48.005'
S5	Bole Bridge	N 08° 59.351'; E038° 47.550'
S6	Bus Station (Addis Ketema)	N 09° 02.038'; E038° 43.947'
S7	Entoto (St. Mary Church)	N 09° 05.182'; E 038° 45.735'
S8	Kaliti Road Intersection (Traffic light)	N08°55.967'; E038°46.002'
S9	La gare Traffic Light	N 09° 00.701'; E 038° 45.192'
S10	Mexico Square	N 09° 00.638'; E 038° 44.699'
S11	Teklehaimanot Square	N 09°01.728'; E038°44.583'
S12	Urael Traffic Light	N 09° 00.659'; E 038° 46.503'

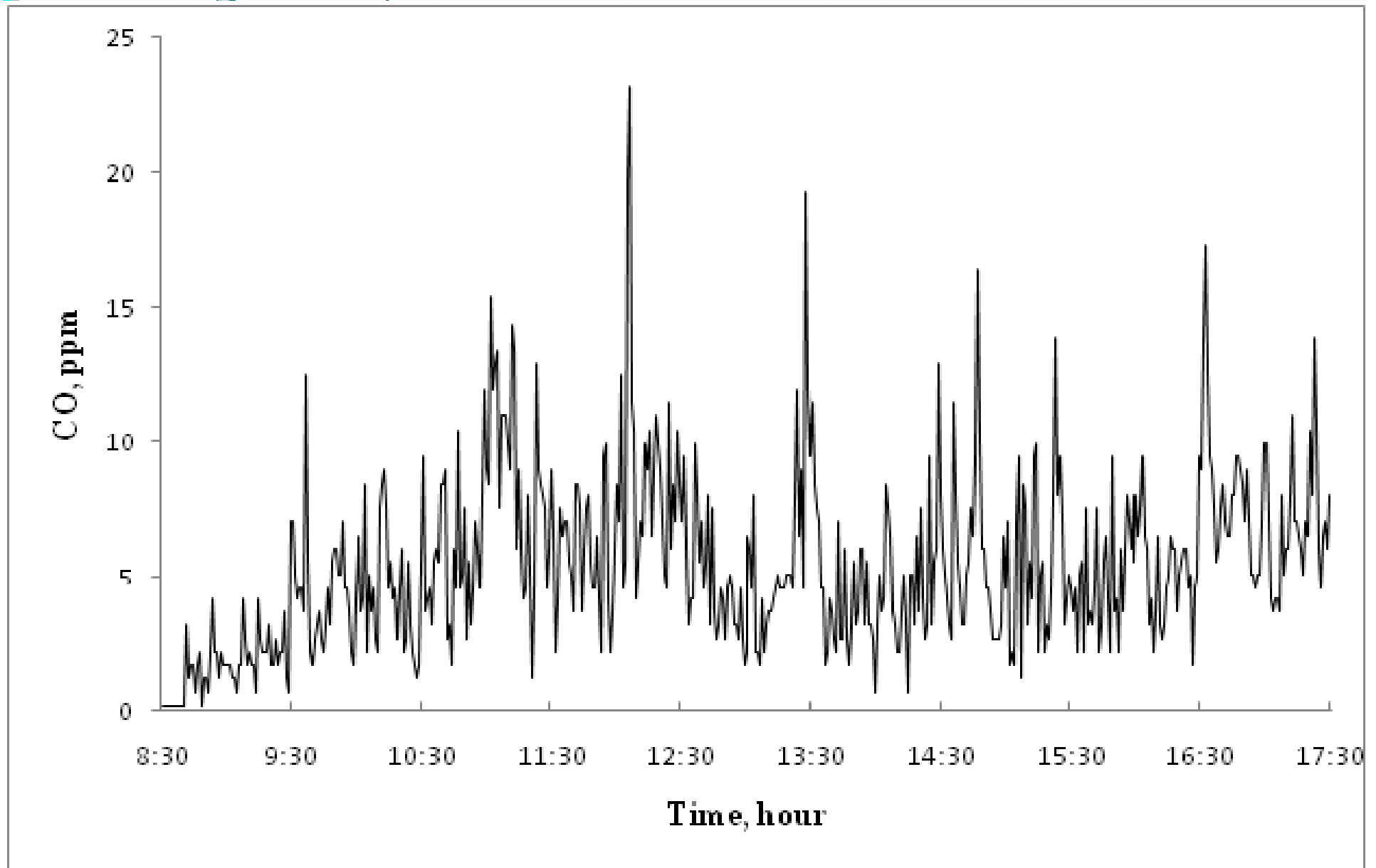
Determination of Quality and Impact Evaluation

- **Determination of Carbon Monoxide, CO concentration**
 - CO concentration levels in the ambient air at all selected sites were measured and determined .
 - Measured data are presented graphically and in tabular form
 - Example graphical data

Measured CO concentration at Bole bridge during the dry season



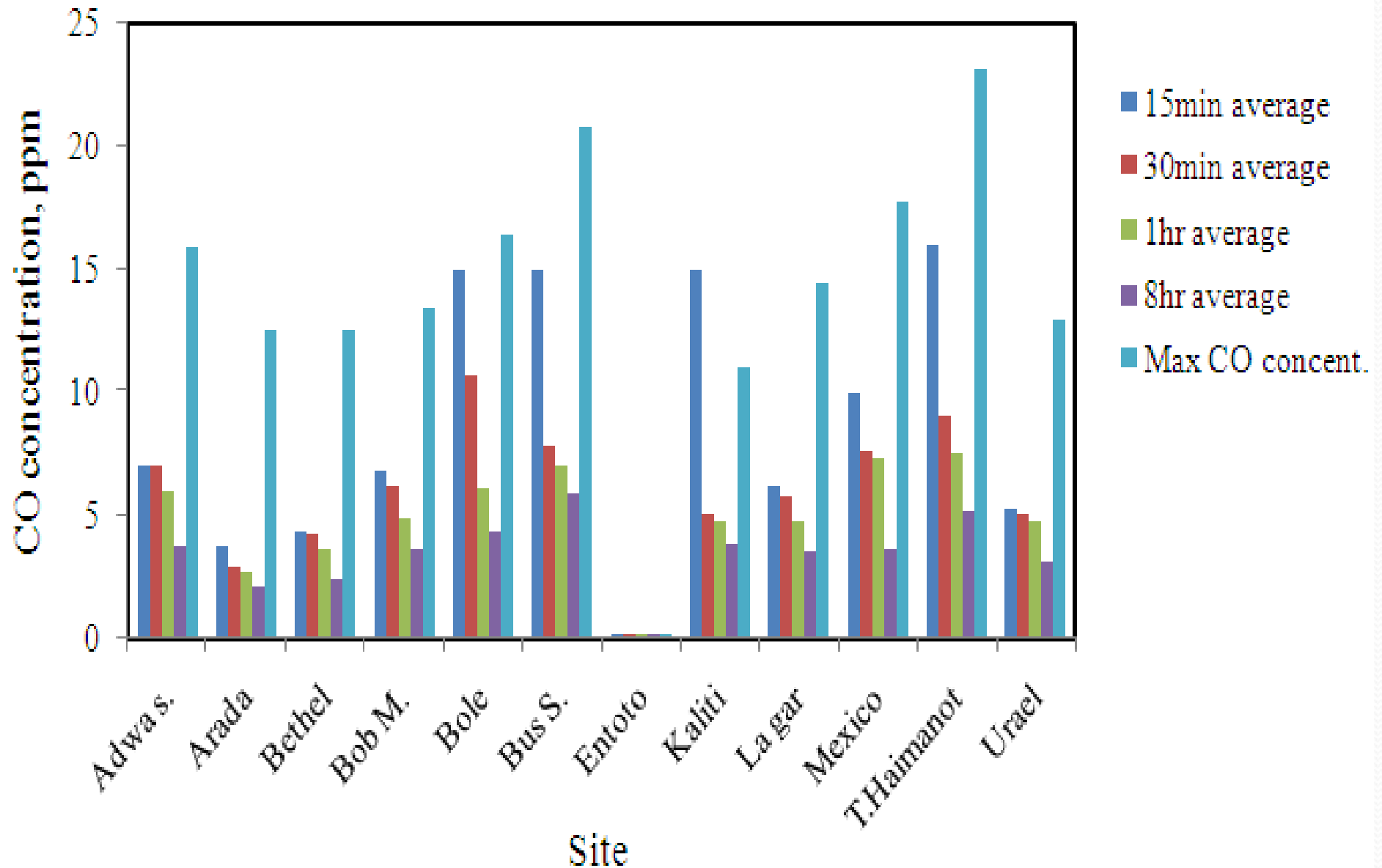
Measured CO concentration at Teklehaimanot Square during the dry season



CO concentrations at different sites collected during the dry season

Site		CO Concentration, ppm				
Code	Name	Max 15-minute average	Max 30-minute average	Max 1-hour average	8-hour average	Maximum
S ₁	Aduwa Square (Megenagna)	7.1	7.1	6.0	3.8	15.9
S ₂	Arada (Arada building)	3.8	3.0	2.8	2.2	12.5
S ₃	Betel	4.4	4.3	3.7	2.5	12.5
S ₄	Bob Marley Square (Imperial Hotel)	6.9	6.3	4.9	3.7	13.4
S ₅	Bole Bridge	15.0	10.7	6.1	4.4	16.4
S ₆	Bus Station (Addis Ketema)	15.0	7.8	7.1	5.9	20.8
S ₇	Entoto (St. Mary Church)	0.2	0.2	0.2	0.2	0.2
S ₈	Kaliti Road Intersection (Traffic light)	15.0	5.1	4.8	3.9	11.0
S ₉	La gare Traffic Light	6.3	5.8	4.8	3.6	14.4
S ₁₀	Mexico Square	9.9	7.6	7.3	3.7	17.7
S ₁₁	Teklehaimanot Square	16	9.0	7.5	5.2	23.2
S ₁₂	Urael Traffic Light	5.3	5.1	4.8	3.2	12.9
Average		8.7	6.0	5.0	3.5	14.2

CO concentrations at different sites



Wet season CO concentration level at different sites

Site	CO concentration, ppm				
	Max 15-minute average	Max 30- minute average	Max 1-hour average	8-hour average	Max.
Bus station (Addis Ketema)	37.4	23.4	17.2	2.8	44.2
Mexico Square	14.5	13.1	8.1	4.9	22.7
Teklehaimanot Square	17.2	13	8.0	1.5	24.2



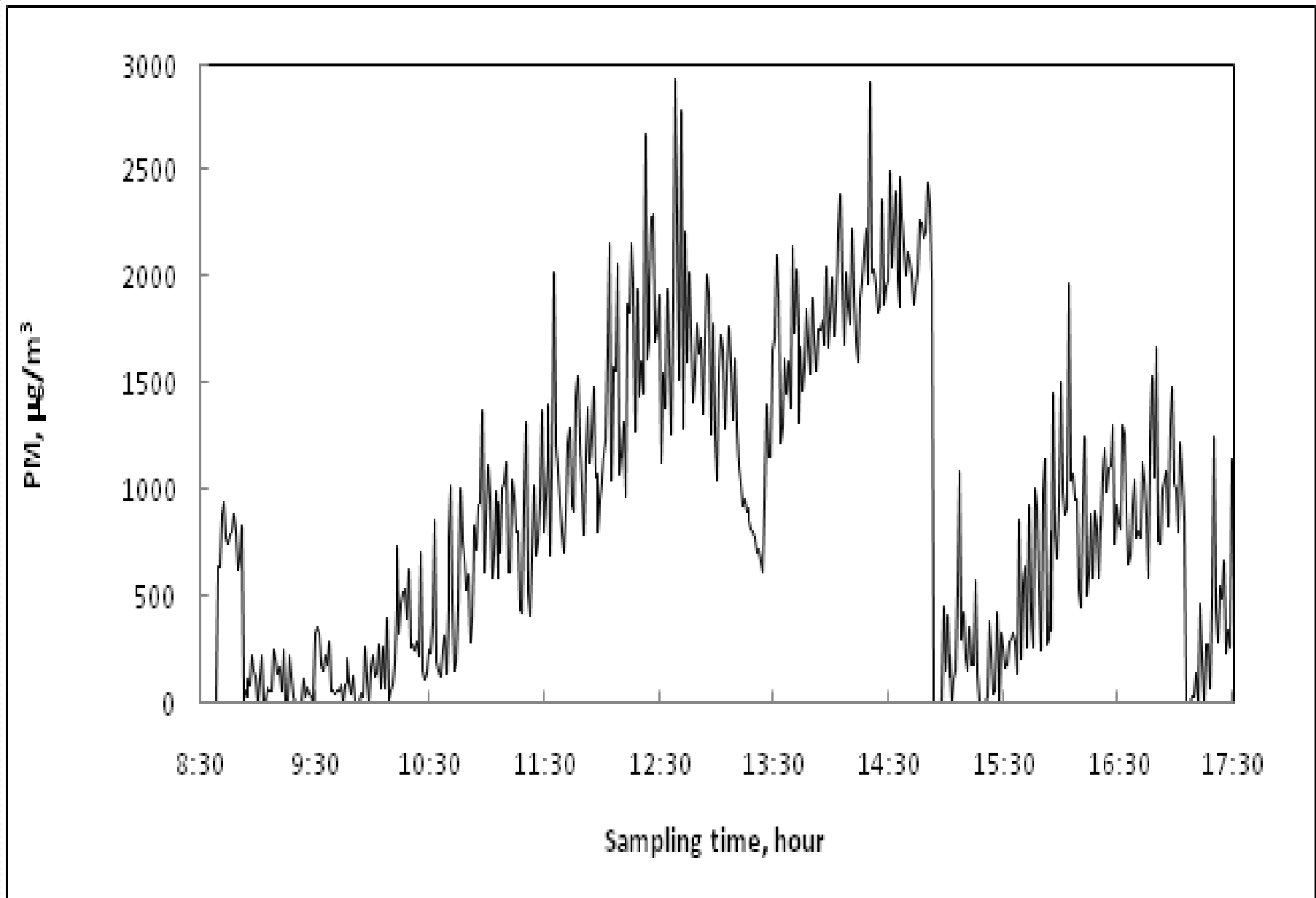
Evaluation of CO Impact

- Results obtained were evaluated.
- CO concentration level in the ambient air is below both the WHO and ETH-EPA guideline limits
- Impact can be considered insignificant

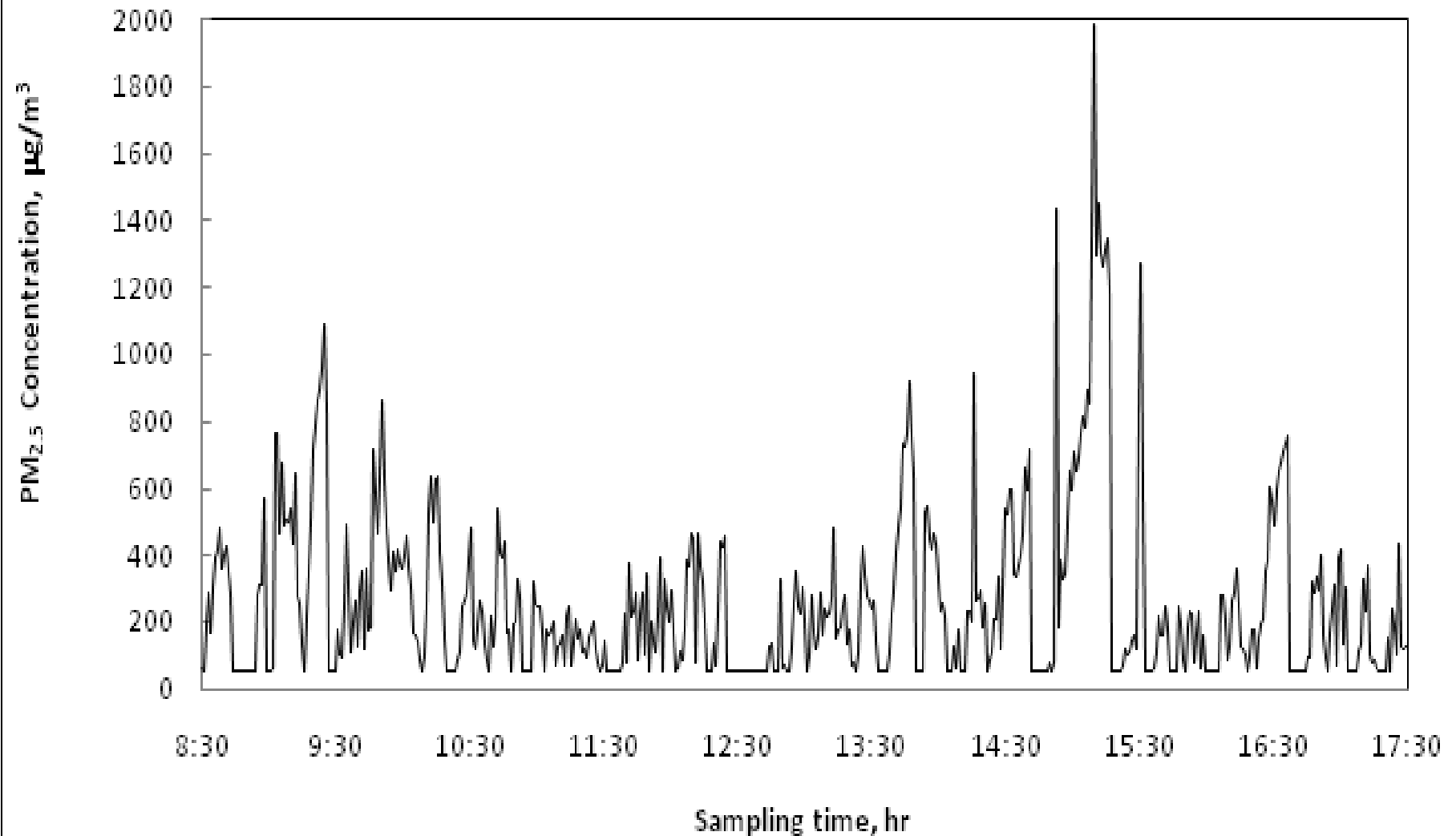
Determination of Air Quality and Impact Evaluation Continued

- **Determination of particulate matter ($PM_{2.5}$) concentration**
 - Concentration levels of $PM_{2.5}$ in the ambient air were measured and determined at all sites
 - Measurement results are presented in a tabular and graphical form
 - Graphical data for some sites

PM_{2.5} concentrations at Teklehaimanot Square during dry season



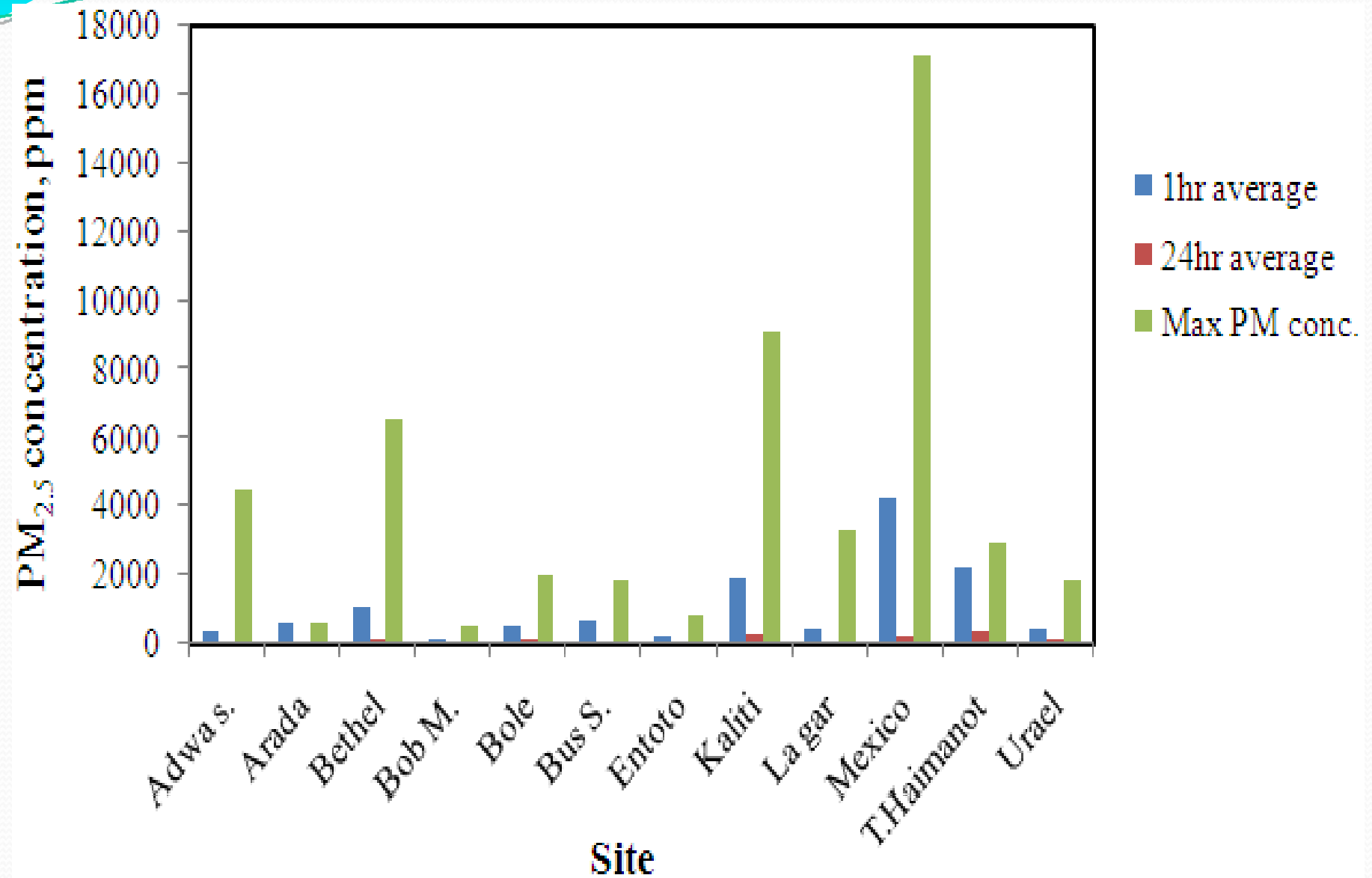
PM_{2.5} concentrations at Bole Bridge during dry season



PM_{2.5} concentration data for different sites during the dry season

Site		PM _{2.5} Concentration, µg/m ³	
Code	Name	24-hour average	Maximum
S1	Aduwa Square (Megenagna)	54.8	4471.9
S2	Arada (Arada building)	30.7	624.0
S3	Betel	135.6	6576.4
S4	Bob Marley Square (Imperial Hotel)	43.6	511.1
S5	Bole Bridge	97.3	1982.6
S6	Bus Station (Addis Ketema)	70.4	1827.5
S7	Entoto (St. Mary Church)	27.2	808.5
S8	Kaliti Road Intersection (Traffic light)	271.4	9082.6
S9	La gare traffic light	83.5	3268.8
S10	Mexico Square	228.6	17169.3
S11	Taklehaimanot Square	342.1	2933.7
S12	Urael Traffic Light	165	1837.5

PM_{2.5} concentration in ambient air, dry season



PM_{2.5} concentration levels at the three sites during the wet season

Site	PM _{2.5} concentration, µg/m ³	
	24-hour average	Maximum
Bus station (Addis Ketema)	34.6	4824.6
Mexico Square	59.3	1529.6
Teklehaimanot Square	60.9	3531.6



PM_{2.5} Impact Evaluation

- PM_{2.5} concentration levels in the ambient air are higher than the WHO guideline limits for all sites.
- PM_{2.5} concentration levels are also higher than the ETHEPA guideline limit values except for Aduwa Square (S1), Arada (S2), Imperial Hotel, (S4) and Entoto sites (S7).
- Impact of particulate matter can be considered significant with a potential to pose considerable negative health effects on the city population.

Determination of Air Quality And Impact Evaluation Continued

- **Determination of NO₂ concentration**
 - Measurement of NO₂ concentration in the ambient air was performed at all selected sites.
 - NO₂ concentration level in the ambient air was not detected/indicated at all measurement sites .
 - NO₂ concentration is below guideline limits.

Determination of Air Quality and Evaluation Continued

- **Determination of SO₂ concentration**
 - Measurement of SO₂ concentration in the ambient air was carried at all selected sites.
 - SO₂ concentration was not detected/indicated by the instrument.
 - SO₂ level in the ambient air is below guideline limit values

Estimated annual emission of pollutants per vehicle category (2010/2011)

Vehicle category		Annual Emission [kg/yr]				
		CO	VOC	NO _x	SO _x	PM ₁₀
Passenger cars	Petrol without catalyst	109,119.792	18,216.829	5,188.337	102.943	20,589
	Petrol with 3-way catalyst	17,572.464	761.473	1,142.210	48.812	9.762
	Diesel- OLD-without PM filter	294.663	153.453	136.312	17.957	17.957
	Diesel- with PM filter	3,324.897	16.578	819.711	147.364	73.682
Light Duty Trucks and Buses	Light Duty-pre Euro	709.004	369.232	327.988	56.956	53.028
	Light Duty-Euro I+II	4,343.400	229.235	1,978.660	313.690	156.845
	Light Duty-Euro III+IV	1,523.880	80.427	694.212	105.825	55.029
Heavy Duty Trucks and Buses	Heavy Duty-pre Euro	292.919	56.265	522.753	23.529	22.847
	Heavy Duty-Euro I+II	2,216.220	425.700	3,872.580	178.020	172.860
	Heavy Duty-Euro III+IV	446.458	95.968	767.740	57.581	24.201
	Bus pre-Euro	348.198	66.286	623.560	25.676	56.330
	Bus Euro I+II	1,476.770	316.630	2,553.060	121.396	167.701
	Bus Euro III+IV	278.210	76.400	480.500	46.609	31.233
Total		141,946.873	20,864.475	19,107.624	1,199.749	862.063

Mitigation Measures

- Develop/ establish national vehicle emission standards
- Introduce more stringent sulfur level requirement in fuels
- Require catalytic converters in all new vehicles
- Set age limits on importation of second hand vehicles
- Limit importation of second hand vehicles to those having catalytic converter installed.



Mitigation Measures

- Retrofit heavy-duty and all other existing diesel vehicles with particulate filters/traps matching the filter requirements, engine technology, and edge of the vehicle.
- Introduce proper vehicle maintenance and stringent inspection.
- Establish air quality monitoring stations.



THANK YOU