VEHICLE EXHAUST EMISSIONS MEASUREMENTS: EXPLORATORY ANALYSYS OF FIELD OBSERVATIONS AT MOTOR VEHICLE INSPECTION CENTRE, LIKONI ROAD, NAIROBI

A Paper presented to the Eastern Africa Regional Framework Agreement on Air Pollution

by

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PRESENTATION SUMMARY

- Introduction
- Problem statement
- Objectives
- Materials and Methods
- Results
- Vehicle emission reducing strategies
- Conclusions and recommendations

INTRODUCTION

- Air pollution is a serious environmental concerns in urban areas especially in view of its adverse effects on human health, animals and plants (Kojima and Lovei, 2001, Gwilliam *et al*, 2004).
- In developing countries- estimated 0.5 million to 1.0 million people die pre-maturely each year as a result of exposure to urban air pollution (WHO 2002).
- The transport sector is expected to be responsible for about 75% of carbon emission by the year 2020
- Nearly 50% of global CO, HCs and NO_x emissions from fossil fuel combustion come from IC engines.
- The effects of vehicles exhaust emissions is an environmental concern, however, solutions lies in engineering among others.

PROBLEM STATEMENT

- Poor fuel quality & vehicles maintenance culture, high proportion of old vehicles and poor transport policies (Zachariadis *et al*, 2001; Whitelegg and Haq, 2003).
- Due to liberalization of petroleum -adulteration and contamination resulting in poor fuel quality (Kojima and Lovei, 2001; UNEP, 2002).
- No policy in place to govern repair and service industry (Langat *et al*, 2004)
- PM mean values of 239µg/m^3 and 396µg/m^3 for PM_{10} and $PM_{2.5}$ respectively (Van Vliet and Kinney, 2006).
- These concentrations are higher than WHO limits 150µg/m^3 & 65µg/m^3 for PM_{10} and $PM_{2.5}$ respectively (Maina, 2004; Van Vliet and Kinney, 2006).
- High concentration of NOx during peak traffic hours is an indicator that vehicles are the major source of the pollutants.
- However none of these studies linked pollutant levels with vehicle characteristics and engine operating conditions.

PROBLEM STATEMENT (cont.)

- US EPA found -Nairobi vehicles were old with an average age of 6.2 years when imported, had accumulated high mileage of 17,837 km/yr (EPA, 2002).
- Study not exhaustive on how findings would be used to estimate emission levels
- Kenyan's potential to manage air quality has improved with the passage of EMCA (GOK, 1999) and subsequent legal notices.
- No framework in place to support its implementation.
- This research therefore, sought to determine vehicles' exhaust emissions levels and established the major contributing factors based in their category, usage and engine operating parameters and also develop exhaust emission prediction model

RESEARCH OBJECTIVES

Main objective

- To determine vehicles emission levels and sources in Nairobi from measurements of exhaust emissions from vehicles taken for inspection at Motor Vehicle Inspection Centre, Likoni Road, Nairobi, Kenya and to use the results to develop comprehensive vehicle exhaust emissions control measures.

Specific objectives

- To determine the current vehicles' exhaust gases emission levels in Nairobi city.
- To establish the major contributing factors to the current vehicles' exhaust emissions levels in Nairobi city.
- To develop comprehensive integrated vehicles emission reducing strategy to improve ambient air quality in Nairobi city.

RESEARCH JUSTIFICATION

- The harmful effects of conventional pollutants from motor vehicle on human health and ecosystem continue to grow and scientific evidence is required (Gwilliam *et al*, 2004).
- Greenhouse gas emissions from motor vehicles present longer-term problems, potentially with severe health, environmental and economic consequences.
- The transportation sector is responsible for about 26% of global carbon emissions and it is projected to increase to 75% between 1997 and 2020 (U.S.E.P.A., 2002).
- Reducing transport sector emissions will therefore be crucial for stabilizing atmospheric concentrations of pollutants.
- This study therefore contributes towards understanding the enormity of emissions of pollutants substances from vehicles and the various interactions that exist between the various factors that result in this problem.

MATERIALS AND METHODS

Study area each

- Nairobi is the largest town in Kenya and also the county's capital city.
- It covers an area of 684 km^2 and currently has a population of over 2.9 million people with a density of 4230/ km^2 (http://www.nairobicity.org).
- It does not have regular air quality management system yet, and any measurements of air pollution have been done on an ad hoc basis (Maina, 2004).
- Research was conducted at VIC, Likoni Road, Nairobi in conjunction with the Ministry of Transport, Republic of Kenya, Kenya Pipeline Company and Department of Industrial and Energy Engineering, Egerton University.

Sample selection

$$N = \frac{Z^2 PQ}{D^2}$$

$$N = \frac{(1.96)^2 0.5 \times 0.5}{(0.05)^2} = 384$$ each petrol and diesel vehicles

Further thirty nine (39) samples of petrol fuel and thirty (34) samples of diesel fuel from vehicles whose owners accepted to offer the fuel for analysis were collected and tested for quality.

Accumulated Use (km) = 489 (Yrs before Kenya) + 19023 (Yrs in Kenya)-458.3 (Yrs in Kenya) ^2 (US EPA 2002)

DATA COLLECTION

- Vehicle age and mileage

  Parameters collected from the tail pipe based in KS 1515-2000 were
- CO, CO_2, HC, and AFR for different categories of petrol vehicles and opacity for diesel vehicles

Test procedures

- Non-catalyst test
- Catalytic test
- Opacity

Fuel analysis

- FBP in ^{o}C (ASTM D 86), density (ASTM D 1298) in Kg/m^3, colour (visual), Appearance, flash point (ASTM D 93).

Exhaust gases analysis

DATA ANALYSIS

SAS and MS excel

- Chi-square (emission levels and associated factors)
- Logistic regression model (test results & factors)

RESULTS

Demographic characteristics of tested vehicles

Demographic Analysis	Petrol **Diesel**	N=384 **N=384**	**Test results**	
≤ **Vehicle age (Yrs)**	Petrol **Diesel**		Pass=117 (30.5%) **Pass=111 (28.9%)**	Fail=267(69.5%) **Fail=273 (71.1)**
5	Petrol **Diesel**	63 (16.4%) **104 (27.1%)**	41 (65.1%) **71 (68.3%)**	22 (34.9%) **33 (31.7%)**
6 – 10	Petrol **Diesel**	84 (21.9%) **76 (19.8%)**	50 (59.5%) **18 (23.7%)**	34 (40.5%) **58 (76.3%)**
11 – 15 ≤	Petrol **Diesel**	70 (18.2%) **128 (33.3%)**	13 (18.6%) **19 (14.8%)**	57 (81.4%) **109 (85.2%)**
16 – 20	Petrol **Diesel**	115 (29.9%) **43 (11.2%)**	4 (3.5%) **3 (7.0%)**	111 (96.5%) **40 (93.0%)**
21 – 25	Petrol **Diesel**	32(8.3%) **22 (5.7%)**	9 (28.1%) **0 (0%0**	23 (71.9%) **22 (100%)**
>25	Petrol **Diesel**	20 (5.2%) **11 (2.9%)**	0 (0%) **0 (0%)**	20 (100%) **11 (100%)**
Vehicle mileage 000(Km) 50	Petrol **Diesel**	14 (3.6%) **53 (13.8%)**	9 (64.3%) **49 (92.5%)**	5(35.7%) **4 (7.5%)**

RESULTS CONT.

51 - 100	Petrol **Diesel**	59 (15.4%) **58 (15.1%)**	44 (74.6%) **26 (44.8%)**	15 (25.4%) **32 (55.2%)**
101 – 150	Petrol **Diesel**	82 (21.4%) **41(10.6%)**	41 (50.0%) **15 (36.6%)**	41 (50.0%) **26 (63.4%)**
151 – 200	Petrol **Diesel**	37 (9.6%) **39 (10.2%)**	4 (10.8%) **10 (25.6%)**	33 (89.2%) **29 (74.4%)**
201 – 250	Petrol **Diesel**	64 (16.7%) **36 (9.65)**	6 (9.4%) **3 (8.3%)**	58 (90.6 %) **33 (91.7%)**
251 – 300	Petrol **Diesel**	52 (13.5%) **43 (11.2%)**	7 (13.5%) **4 (9.3%)**	45 (86.5%) **21 (90.7%)**
301 - 350	Petrol **Diesel**	17 (4.4%) **40 (10.4%)**	3 (17.6%) **0 (0%0**	14 (82.4%) **40 (100%)**
351 - 400	Petrol **Diesel**	22 (5.7%) **25 (6.5%)**	1 (4.5%) **0 (0%)**	21 (95.5 %) **25 (100%)**
>400	Petrol **Diesel**	37 (9.6% **49 (12.8%)**	2 (0%) **3 (6.1%)**	35 (100%) **46 (93.8%)**
Vehicle category Before 1986 Non cat 1986-2002 Non cat 1986-2002 Cat After 2002 cat	Petrol	33 (8.6%) 193 (50.3%) 125 (32.6%) 33(8.6%)	2 (6.1%) 53 (27.5%) 44 (35.2%) 18 (54.5%)	31(93.9%) 140 (72.5%) 81 (64.8%) 15 (45.4%)
Aspirated Turbo	**Diesel**	**362 (94.3%)** **22 (5.7%)**	**94 (26.0%)** **17 (77.3%)**	**268 (74.0%)** **5 (22.7%)**

RESULTS (CONT.)

Fuel analysis

Fuel	Parameter	STD	Freq	% within limit	% outside limit
Motor spirit premium	Density Kg/m^3 (max)	780	39	100	0.0
	Final boiling point ^{o}C (max)	210	39	35.9	64.1
	Recovery @ 71^{o}C (%)	10	39	100	0.0
	Colour (visual)	Red	39	100	0.0
	Appearance (visual)	FRW&SM	39	51.3	48.7
Automotive Gas Oil	Density Kg/m^3 (max)	870	34	100	0.0
	Final boiling point ^{o}C (max)	400	34	100	0.0
	Flash point 71^{o}C (min)	60	34	100	0.0
	Recovery @ 365 ^{o}C (% v/v) min	90	34	100	0.0
	Colour ASTM (max)	3.5	34	100	0.0
	Appearance	FRW&SM	34	26.5	73.5

RESULTS (CONT.)

Contingency table for CO categories for non-catalytic vehicle

CO limits (% vol.)	Observed	CO categories			Total
		<3.5	3.6 – 4.5	>4.5	
3.5	% within Standard values for various categories	61 (31.6%)	70 (36.3%)	62 (32.1%)	193 (100%)
4.5	% within Standard values for various categories	2 (6.1 %)	0 (0%)	31 (93.9%)	33 (100%)
Total		63	70	93	226

Contingency table for CO categories for catalytic vehicle

CO limits (% vol.)	Observed	CO categories			Total
		<0.25	0.26-0.55	0.56	
.25	% within Standard values for various categories	18 (54.5%)	3 ≥ (9.1%)	12 (36.4%)	193 (100%)
0.5	% within Standard values for various categories	17 (13.6%)	26 (20.8%)	82 65.6%	125 (100%)
Total		35	29	94	158

RESULTS (CONT.)

Contingency table for HC for all categories of vehicles

HC limits (ppm)	**Observed**	**Hydrocarbon category**				
		<200	**201-250**	**251-1≥200**	**1200**	
200	% within Standard values for various categories	24 (70.6%)	7 (20.6%)	3 (8.8%)	0 (0%)	**34 (100%)**
250	% within Standard values for various categories	49 (39.5%	26 (21.0%)	47 (37.9%)	2 (1.6%	**124 (100%)**
1200	% within Standard values for various categories	20 (8.8%)	5 (2.2%)	187 82.7%)	14 (6.2%)	**226 (100%)**
Total		93	38	237	16	**384**

RESULTS (CONT.)

Lambda measurements

Vehicle category	observed	Lambda categories			Total
		≤0.97	0.97-1.03	≥1.03	
Before 1986	% within standards values for various categories	28 (84.8%)	2 (6.1%)	3 (9.1%)	33 (100%)
Non-catalytic between 1986-2002	% within standards values for various categories	117 (13.6%)	34 (20.8%)	44 (65.6%)	193 (100%)
Catalytic between 1986-2002	% within standards values for various categories	70 (56.5%)	38 (30.6%)	17 (12.9%)	125 (100%)
Catalytic after 2002	% within standards values for various categories	13 (39.4%)	19 (57.6%)	1 (3.0%)	33 (100%)
Total		**228**	**91**	**65**	**84**

VEHICLE EMISSION REDUCING STRATEGY FOR NAIROBI CITY

Air quality management governance

1. Existing legislations and regulations for management
2. Roles and responsibilities of stakeholders

(a) The National government

(i) Ministry of Environment and Natural resources

(ii) Ministry of Energy

(iii) Ministry of Trade and Industry

(iv) Ministry of Transport

(v) The Traffic Police

(vi) NEMA

VEHICLE EMISSION REDUCING STRATEGY FOR NAIROBI CITY (cont.)

(b) The private sector

(c) Civil society

(d) Research institutions

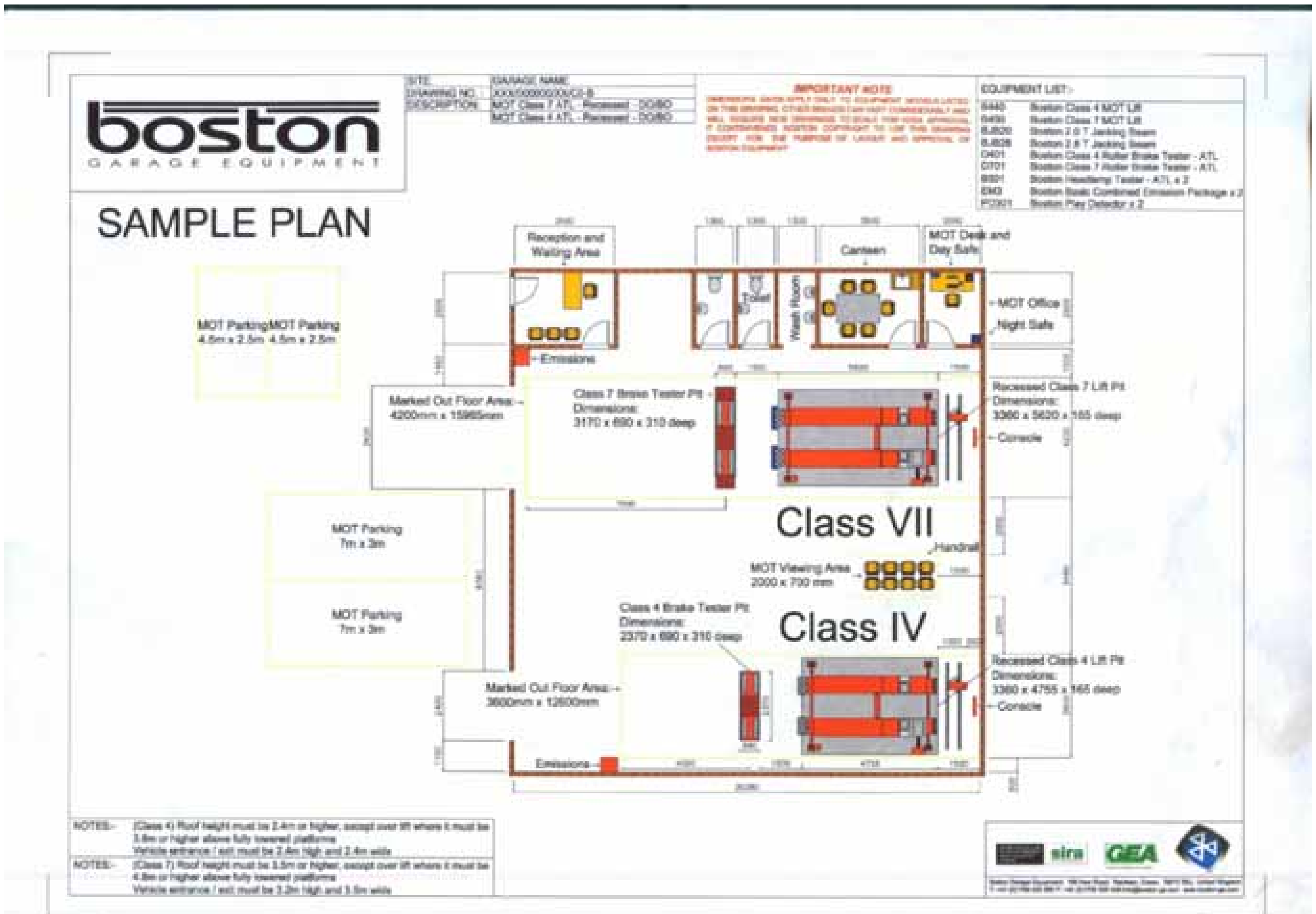
3 Problems and constraints

- (i) Absent of formal coordination
- (ii) Lack of harmonization of the current regulations
- (iii) Lack of human capacity and funding limitations

Current vehicle emission standards

Inspection and Maintenance (I/M)

VEHICLE EMISSION REDUCING STRATEGY FOR NAIROBI CITY (cont.)



Workshop plan showing equipment lay in London city

VEHICLE EMISSION REDUCING STRATEGY FOR NAIROBI CITY (cont.)

Accredited MOT workshop in London city

VEHICLE EMISSION REDUCING STRATEGY FOR NAIROBI CITY (cont.)

Inspection and maintenance of private vehicles

(i) Public and stakeholders’ supervision and regulatory level

(ii) Supervision and service levels (private sector)

(iii) Implementation levels (private sector)

(iv) Inspection of motor cycles and three tricycles (*Tuktuk*)

Time frame for the implementation of I/M

Fuel quality and standards

Vehicle Technology

VEHICLE EMISSION REDUCING STRATEGY FOR NAIROBI CITY (cont.)

Designing Action Plan

- (A) Institutional Approach
  - (i) Multi-sectorial approach
  - (ii) Coordination and cooperation
  - (iii) Capacity building efforts
  - (iv) Public awareness
  - (v) Polluters Pays Principle
  - (vi) Pre-cautionary principle
- (B) Technical Approach
  - (i) Cleaner fuel development
  - (ii) Cleaner vehicle technology
  - (iii) Transportation demand management

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

- The overall emission test results showed that 69.5% and 71.1% of petrol and diesel vehicles failed the emissions test.
- The Chi-square tests for all categories of vehicles showed that there was significant difference between the measure and standard values of CO, lambda and smoke opacity.
- The results from fuel analysis showed that final boiling point for petrol was high an indication of fuel adulteration and may affect exhaust emissions
- The results of this study give a clear indication that the implementation of the developed vehicle emission reducing strategy is not only necessary now but very urgent if any progress is to be made in reducing vehicle emissions in Nairobi city.

CONCLUSIONS AND RECOMMENDATIONS (cont.)

Recommendations

- Raise awareness among policymakers and the general public about urban air pollution levels and damages and specify and promote the roles that transport sector plays.
- Press for sector reform that increases sector efficiency, benefits society at large by providing goods, services at lower cost, and at the same time reduces emissions.
- Raise awareness in business and with consumers about business ‘best practice’ that is also likely to bring about environmental benefits to society.
- Work with, not against, the economic incentives of various transport actors.

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