MAURITIUS RESEARCH COUNCIL

MONITORING AND CONTROL OF VEHICLE EMISSION EXHAUST IN MAURITIUS

Final Report

Year 2001

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Monitoring and Control of Vehicle Emission Exhaust in Mauritius

Final Report

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Preface

The international community is becoming increasing aware of our common destiny and of the pressing need to protect the Environment. One of the encouraging signs at the wake of this new Millennium is the active interest shown by NGO's around the world to save the planet. Similarly, the fact that developing countries are becoming increasingly involved in addressing the issue of the global environment is equally highly promising. What is required is local action to confirm our global commitment to sustaining the future of our planet by limiting the adverse effects on the environment of scientific/technological developments. It is in this context that the current research work to monitor and control vehicle emissions in Mauritius has all its importance.

Mauritius is about to emerge as a newly-industrialised country with a modern economy based on agriculture, industry and the services sector including tourism. The standard of living of the Mauritian has constantly increased over the past decades – an evolution that is reflected in the increase in mobility of the average citizen. Vehicles on the road have increased both in number and in type – it is vital to consider ways and means to monitor and control vehicle pollution in Mauritius in line with the modernization effort that is taking off. The University of Mauritius is taking such an initiative, with the support of the Mauritius Research Council and other public and private organizations, towards ensuring a better environment for Mauritius. It is expected that fresh avenues will be identified in the light of the current findings in order to provide the Government and other stakeholders with information of fundamental importance in their respective policy decisions and actions.

Acknowledgements

The research team from the Faculty of Engineering is indebted to the Mauritius Research Council (MRC) for its support. The collaboration of the Ministry of Land Transport, the Department of Environment of the Ministry of Environment, the Traffic Branch of the Police Force and Shell Mauritius Ltd should also be put on record. The help and support of the Dean of the Faculty towards the successful conduct of the current research was also invaluable.

1.0 Summary

The present project proposes to assess the extent of atmospheric pollution caused by the exhaust system of mobile internal combustion (IC) engines. The appropriate experimental and analytical investigations were undertaken. A smokemeter was used for assessing pollution from diesel vehicles while for petrol-driven vehicles, use was made of an engine gas analyser.

The relevant parameters monitored were identified as follows:

- for diesel vehicles : Smoke opacity level
- for petrol vehicles : HC and CO emissions.

On-road tests were carried out on samples of the diesel- and petrol-driven vehicle populations, which were worked out using the Stratified Random Sampling Method.

In parallel with the project, a survey was carried out to assess the perception of the general public, drivers and enforcement officers vis-à-vis vehicle pollution.

2.0 Background

Vehicles using petrol and diesel based on conventional crude oil emit a complex mixture of compounds that lead to air pollution. Some of these compounds are toxic and the US Environmental Protection Agency estimate that toxic emissions from cars, buses and trucks account for as much as 50% of all cancers attributed to outdoor sources of toxic air pollutants. Investigations carried out as far back as 1992 (SEMES, 1992) had claimed that inter alia:

(i) the level of CO in the atmosphere exceeded the standards set by the WHO

(ii) the blood level of lead was a serious occupational health hazard and

(iii) the smoke emitted from vehicles was a serious health and safety risk.

The fleet of vehicles in Mauritius has increased threefold over the last ten years to around 255 000 in 1999 (CSO,2001). In 1997, a study commissioned by the Government was carried out by SEMES, a consultancy firm based in Singapore with a view to propose measures to counteract air pollution from vehicle exhausts. However, the measures have hardly been implemented except, with some delay, for the reduction of sulphur level in diesel to 0.5 % and, hopefully, to 0.2 % by the next tender exercise.

SEMES was approached by the Government to look into the whole issue of motor vehicle emissions and to come up with recommendations capable of being effectively implemented. The main objectives of the investigation were the following

1. Review earlier relevant reports submitted
2. Study vehicle emissions, existing legislation, and air quality level
3. Prepare draft legislation for effective implementation

To meet the above objectives, the scope of the investigation covered the following issues:

Formulation of practical vehicle emission control programmes

Recommendation of suitable changes to existing legislation

Development of institutional set-ups and procedural guidelines

Identification of training needs

SEMES made the following recommendations:

- Improvement of automotive fuel quality

- Application of emission standards for newly registered motor vehicles
- Ensuring proper maintenance of vehicles
- Conducting proper enforcement programmes on smoky vehicles
- Establishment of a proper de-registration system for old vehicles
- Provision of training to key personnel
- Effective public awareness.

In 1992, a joint venture team from Norway, namely Kruger Consult ASCOWI Consult, had undertaken a screening study over a two month period on air pollution in Mauritius in order to determine the standard of air quality and the factors responsible for air pollution problems. The findings of the above study were the following;

1. The main pollution problem was the high particulate matter levels associated with diesel driven commercial vehicles.
2. On the most polluted days, CO levels were comparable or even exceeded the limits set by the World Health Organisation on Air Quality Guidelines.
3. Higher blood levels in lead were likely to be found in people most exposed to vehicle exhausts given that petrol driven vehicles in Mauritius use leaded petrol.

Another study had also been commissioned by the Government in 1992 to a consultancy firm in the USA namely, KBM Engineering and Applied Sciences. The report constituted of four major sections as follows:

Vehicle emissions and related air quality
Vehicle emission criteria and standards
Proposed vehicle emission standards and
Measures to check for compliance.

However, the recommendations made were found to be impractical to implement as the socio-economic situation in the country was not taken into account during the study.

While the literature is abundant around the world on the causes and impacts of vehicle pollution, in the case of Mauritius the short history of such studies and the lower magnitude and scope of research undertaken imply that the state of affairs is not too well encompassed. Hence, the current research has its importance even if the focus is on tail-pipe emissions. Moreover, the literature on vehicle pollution elsewhere has shown clearly the danger of leaded petrol and of high-sulphur diesel, the two

common fuel sources in Mauritius. These facts can only re-inforce the relevance of the objectives set in the context of the current work.

3 Objectives

The objectives of the study are as follows:

- To assess the level of pollution related to exhaust emissions (tail-pipe emissions) from diesel and petrol vehicles in Mauritius.
- To conduct a survey on the attitude of the general public, drivers and enforcement officers towards the problem of pollution due to vehicle pollution.
- To recommend measures in the light of the above towards the monitoring and control of pollution due to vehicle emissions.

4. Methodology

Techniques and Technology

The monitoring of air pollution from vehicle exhaust is mainly about measuring and following the trend of emissions from the vehicles. Various techniques are available for the assessment of the level of pollution, namely through the use of smokemeters, dynamometer test benches and the automotive gas analysers. Given that the project involved on-site monitoring, the smokemeter and the automotive gas analyser, which are both portable instruments, were selected. The former was used for determining the opacity level of the exhaust from diesel-driven vehicles while the latter was used to measure the level of CO and HC from the exhaust of petrol-driven vehicles. It should be noted that more sophisticated versions of the above two equipment (including the dynamometer bench) are capable of monitoring each of the constituents forming the exhaust from the vehicles, as summarised in Table 1. However, the cost and capabilities of these equipment are well beyond the scope of the current project.

Table 1 Summary of sources, monitoring techniques and impacts of vehicle exhaust pollution

Vehicle Type	Emissions	Monitoring Technique	Impact of pollutants
Diesel-driven (buses, lorries, 4x4 pick-up, vans etc…)	Smoke, CO, HC, S02, particulates, benzene	Smokemeter Dynamometer test bench	Respiratory disease (CO, HC, SO2, particulates, etc) Cancer (benzene) Physical damage (local pollution)
Petrol-driven (cars, motorcycles)	Lead, CO, HC	Automotive Gas Analyser Dynamometer test bench	Respiratory disease (as above) Brain problems (lead)

The Smokemeter

The smoke sample enters the smokemeter from vehicle exhaust pipe via a probe and flexible pipe assembly. The sample is then routed to the center of a smoke sampling tube where it then flows towards each open end. As the smoke leaves the ends of the tube, it is deflected in order to enter into a sleeve which surrounds the smoke tube, by a flow of low pressure clean air supplied by a blower unit. The light absorption of the smoke sample is measured using a light source which is directed through the heated smoke tube on to a photo-electric cell.

Thus, by measuring the opacity of smoke, it is possible to monitor the degree of pollution due to smoke. The main parts of the smokemeter are shown in Figure 1.

Figure 1- The smoke meter

The Automotive Gas Analyser

The principles of operation of the automotive gas analyser are as follows:-

1. An electro-chemical sensor measures the amount of gas emitted (e.g CO) from the exhaust through a probe.
2. Measurement is carried out during free acceleration testing (snap-acceleration).

The main parts of the automotive gas analyzer are shown in Figure 2. This equipment is practical, reliable and accurate, suitable for the purpose of the tests conducted in the course of the current research (road-tests and garage tests).

Figure 2

On-site testing procedures

The following procedures were adopted for on- site monitoring of the emissions from the vehicle exhaust:

a) A team comprising of three persons was set up. In practice, a member of the enforcement squad from the Police Force (to stop the road vehicle and to monitor road traffic) , a team leader (from the University or from the NTA to coordinate the test) and a third person (the test-person who actually performs the test) made up the team.
b) An appropriate site was identified well in advance for allowing the vehicles to park securely. The site should have a lay-by of 20m or more, be well ventilated and be on flat ground. As far as possible sites with busy traffic, near bus stops, hospitals, schools, bends and crowded areas were avoided.
c) Drivers were requested to park their vehicles on the site and were briefed on the test being conducted.
d) The engine condition was checked to ensure that it was safe to conduct the test on the vehicle
e) The test was conducted by following the procedures for the relevant equipment.
f) The test results were printed out and collected for further analysis.

Relevance of the tests

These tests were exact replica of those carried out for enforcement purposes in many countries. Thus, the results reflect on the overall state of vehicle pollution due to exhaust emissions in Mauritius, if the sample adopted is statiscally significant. Secondly, the conduct of these tests was an opportunity for training the future enforcement squad – at the same time, the University obtained support from the latter both in terms of human resources and logistics. The involvement of the Police Road Safety Unit helped in the smooth conduct of the on-road tests. Thirdly, the series of tests was also an opportunity to identify the most appropriate framework for the implementation of legislation on the monitoring and control of vehicle emissions . As a result of these tests, a series of recommendations can now be made to facilitate the implementation of the proposed legislation. Last but not least, the sensitization and publicity created around the conduct of these tests should not be under-estimated. For each vehicle tested (primarily for the purpose of research), at least one person has

been familiarized with the impact of vehicle emissions and of the measures that can be taken to improve the situation.

The test results should also serve as a basis for recommending the threshold levels for emissions according to future legislation (the pass-limit of opacity or of gas emission). Furthermore, different scenarios can be developed for analysis by considering the current levels of vehicle emissions as a reference. The impact of both policy measures and the implementation of techniques and technologies to abate vehicle emissions can also be judged with reference to the results obtained.

5. Sampling

As at December 1997, there was a total vehicle population of 106 235 in Mauritius (NTA, 1998), including 24 410 diesel-driven vehicles but excluding auto-cycles and motor-cycles. Given that pollution from vehicles is closely associated with the engine capacity and the age amongst other factors, for the purpose of the project the number of vehicles was classified as per the engine capacity (engine rating) and their age groups as shown in Table 2. Buses have been treated separately as they are perceived as major contributors to pollution in Mauritius. It was noted that 90 % of vehicles, which were under the 3000 cc engine rating, were petrol-driven.

Table 2 Population and sample size for diesel driven vehicles (Source, NTA)

Vehicle Engine Rating	Age Group (yrs)	Number	Sample Size
< 3000 cc	< 5	2966	55
	5 to 10	2635	49
	>10	3491	64
3000-6000 cc	< 5	1569	29
	5 to 10	3354	62
	>10	3441	63
6000-10000 cc	< 5	790	15
	5 to 10	1665	31
	>10	1518	28
> 10000 cc	< 5	104	2
	5 to 10	219	4
	>10	299	6
Buses	< 5	606	11
	5 to 10	1317	24
	>10	436	8
TOTAL		**24410**	**450**

In order to compute the sample size for diesel-driven vehicles, only 10 % of the vehicles within the 3000 cc rating, those above 3000 cc and buses were considered to constitute the population.

A simple formula *($n/N = n_i/N_i$)* from the Stratified Random Sampling Method was used to calculate the sample size for each category identified (Table 2). In the formula,

n = population of vehicle for a given category

N = total population of vehicles

n_i = sample size to be determined

N_i = Overall sample size.

A software called STATS (by DECISION ANALYST, INC, Version 1.1 98) was used to estimate the percentage standard error with a given sample size. With a total population of 24 410 and an overall sample size, N_i of 450, the percentage standard error was found to be 4.58 % at a 95 % confidence level. Moreover, the sample size for the different age groups for each category of vehicle was also computed. The calculated sample size for each category of the diesel vehicles is as given in Table 2.

For reasons related to time, costs and practical constraints in undertaking tests for the calculated sample size, the number of vehicles to be tested per age group and per category had to be reduced. Furthermore, to keep the same ratio of the data for the different categories of vehicles, it was necessary to scale down the overall sample size *Ni* to 249. This produced a standard percentage error of 6.2 % at a 95% confidence level for the sample of vehicles tested.

The population of petrol-driven vehicles was also categorised according to age groups and the Stratified Random Sampling Method was used to determine the sample size. In this case the total population of vehicles amounted to 81 825 and the percentage standard error at a 95 % confidence level was estimated to be 11.6 %. The calculated sample size for each category of petrol vehicles is shown in Table 3.

Table 3 Population and Sample size for petrol driven vehicles

Vehicle Engine Rating	Age Group (yrs)	Number	Sample Size
< 3000 cc	< 5	26698	49
	5 to 10	23712	43
	>10	31415	58
TOTAL		**81825**	**150**

6. Analysis of results

Diesel vehicles

With regard to the diesel-driven vehicles, the corrected sample was worked out from the actual number of tests carried out. The test carried out on these vehicles allowed to determine the opacity level of the smoke coming out of the exhaust pipe under idling and under normal accelerating conditions.

Considering all vehicles together, it has been observed that 71% of the diesel driven vehicles emit less than 40% smoke opacity level and 20% exceed the 60% opacity level. More than half of the latter are heavy vehicles aged above 10 years. The test results are illustrated in Figure 3.

Considering individual categories of vehicles, buses (representing only 10% of the total diesel vehicle population), contribute up to only 1% of the population of vehicles emitting more than 60% smoke opacity. However, it has to be noted that the utilisation in terms of the number of hours of service on the roads of buses is at least three times more than that of other categories of vehicles. Thus emissions from buses is a more serious problem than suggested by the results and certainly, it is the most visible pollution to thousands of road users.

It is also to be noted that the results as far as the buses are concerned represent an under-evaluation of the real situation as a result of the method used for conducting the tests. Due to the impracticability of conducting tests on the road with vehicles loaded with passengers, tests were done either at the Examination Centres or bus garages. As the tests were scheduled in collaboration with the bus owners, it was likely that they ensured that the buses were in good condition before presenting them for the tests.

Recently there has been an increase in the number of light diesel- driven vehicles on the road. Today, such vehicles (registered in 1995 or later) amount to 23% of the diesel vehicle population of which 4% have been found to emit more than the 60% smoke opacity level.

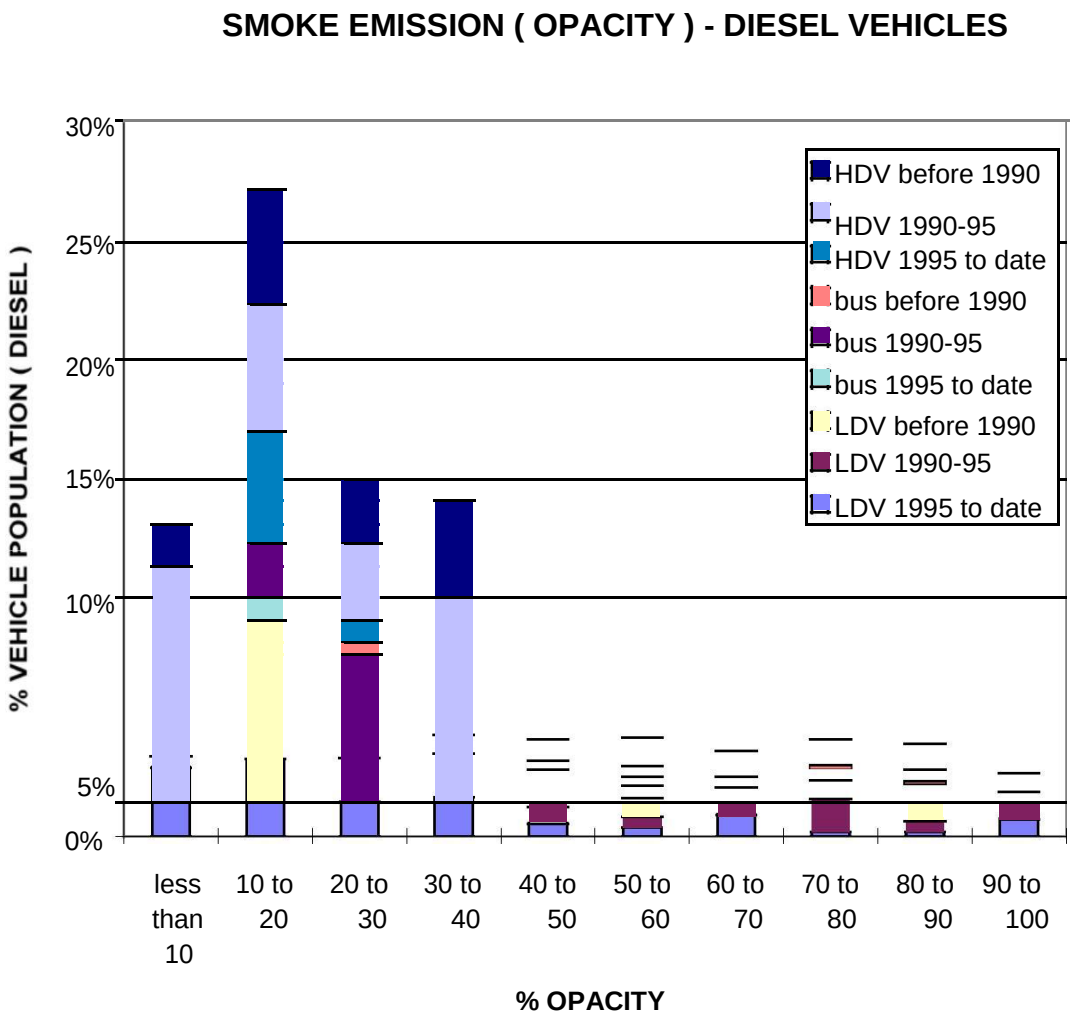

Figure 3. Smoke opacity – diesel vehicles

Currently, 20 % of the diesel vehicle population do not meet the 60 % initial opacity threshold as proposed by SEMES, out of which more than half of the vehicles are above 10 years old. As discussed earlier, this figure is to be interpreted with care

particularly in view of the fact that buses constitute a specific class of vehicles that is relatively small in number (10 % of the diesel vehicle population) but, as pointed out earlier, that remain in operation normally 8 to 12 hours daily. The reduction of smoke emission from buses should be a priority with specific standards and arrangements adopted for its monitoring and control. As the results give no clear indication of the effect of the age factor on the level of emissions for buses, it is proposed that:

1. A uniform emission threshold of 60 % is adopted for all buses.
2. Bus companies are directly involved in the monitoring and control of emissions (individually-own buses will be tested in examination centres).

Within two years, as a reasonable target, there should be less than 5 % of buses exceeding 60 % emissions on the roads (compared to a current corresponding level of more than 10 %). Obviously, a set of supporting measures is vital to ensure the smooth attainment of the set target, as discussed later.

As far as the other categories of diesel vehicles is concerned, it is obvious that delay in the application of the SEMES measures has led to a relative degradation of the situation, particularly with the increase in import of diesel vehicles and of the stagnation of the level of sulphur in diesel at 0.5 % by weight (instead of further reduction in a first instance to 0.3% as recommended by SEMES). **A** comprehensive set of measures, including improvement of diesel quality and standards for new vehicles, is discussed elsewhere. These should allow the setting of a threshold level of 50 % opacity in a first instance, to be reduced to 40 % in two years time. Currently, excluding buses, just above 20 % of the diesel vehicle population emit more than 50 % opacity (one third of which are vehicles more than 10 years old). With the application of the recommended measures, it should be possible to reduce the former figure to a corresponding level of only 10 % of the diesel vehicle population within a couple of years. This is exactly when the threshold as stipulated by law should be reduced to a maximum opacity of 40 %.

Petrol Driven Vehicles

For the petrol-driven vehicles the tests carried out gave the following information:

1. the % amount of CO emitted by the vehicles
2. the amount of HC in parts per million (ppm) emitted by the vehicles

The above tests were carried out under both idling and running conditions. For the latter test, the drivers were requested to *accelerate the vehicle* as if it were running under normal conditions.

Operating under idling condition is a situation commonly met as vehicles travel in cities and towns, particularly during peak hours. Thus the level of HC and CO emissions is of particular interest in the monitoring and control of emissions from the petrol-driven vehicles. The level of HC relates essentially to problems with the carburettor and with the filter cleanliness and the level of CO to incomplete combustion. It has been observed that 12.3% of vehicles had more than 1000 ppm of HC emitted at idling conditions. This percentage decreases to 7.8% under normal running conditions. Basically the results show an improvement under normal running condition compared to the situation under idling conditions as shown in Figure 4 and Figure 5.

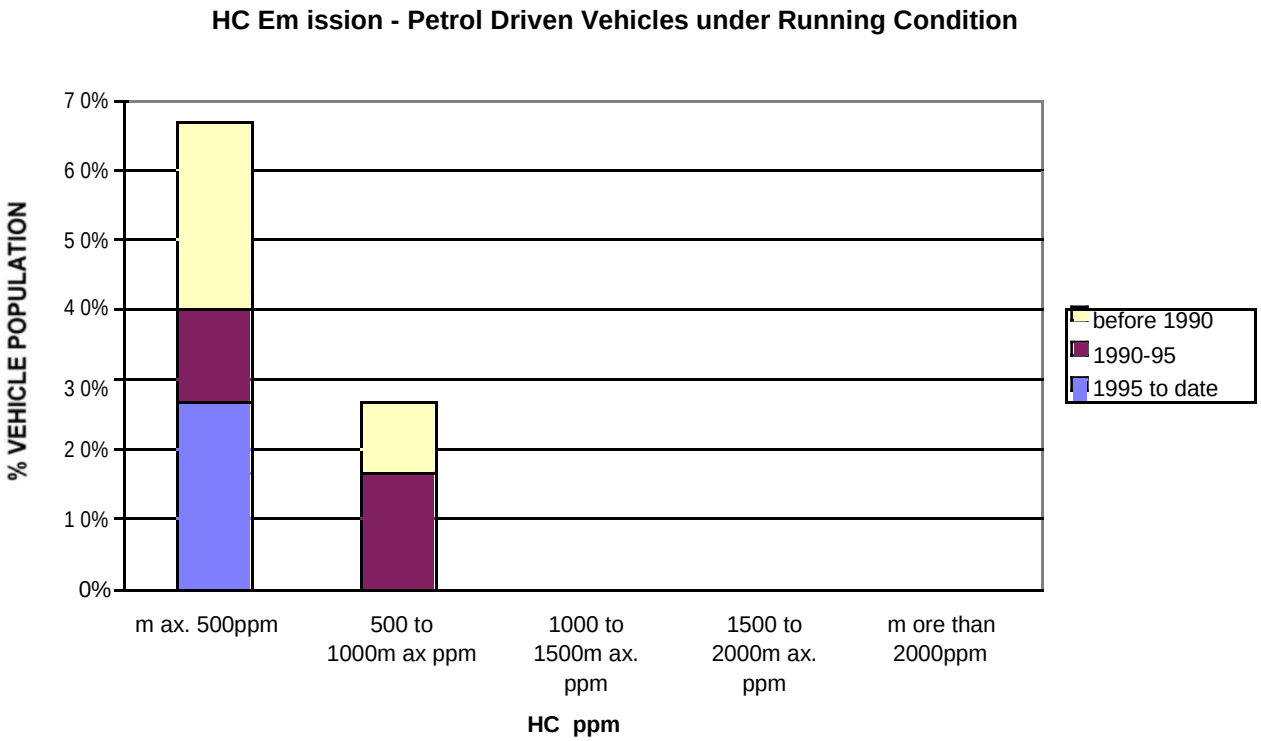

Figure 4. HC emission – Petrol-driven vehicles under running conditions

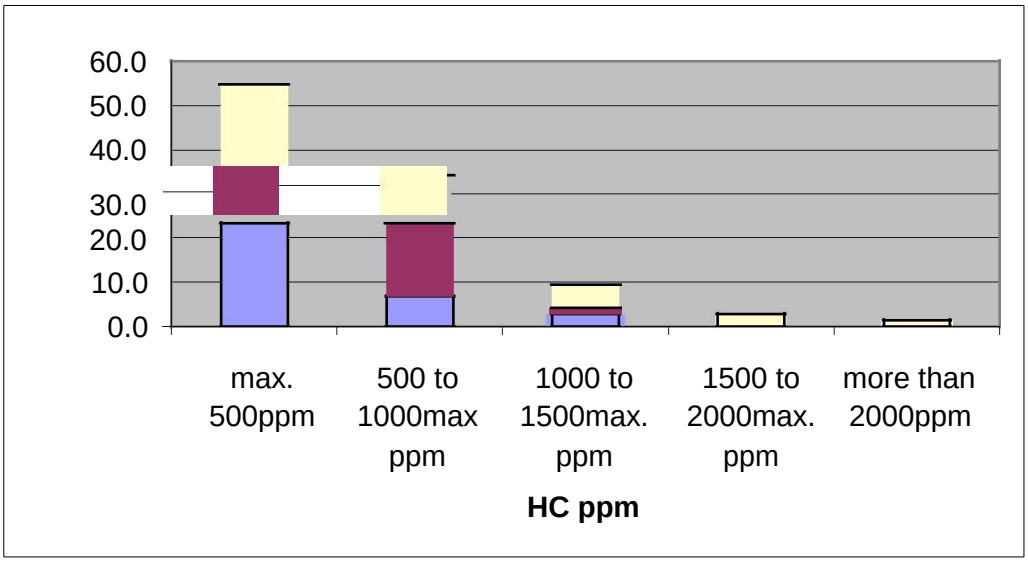

Figure 5. HC emission Petrol-driven vehicles under idling condition

No significant difference was noted between the emission levels under idling and running conditions as far as CO is concerned. Under idling conditions, 64.3% of petrol-driven vehicles emit less than 4.5% CO and 11% emit more than 8% CO as shown in Figures 6 and 7.

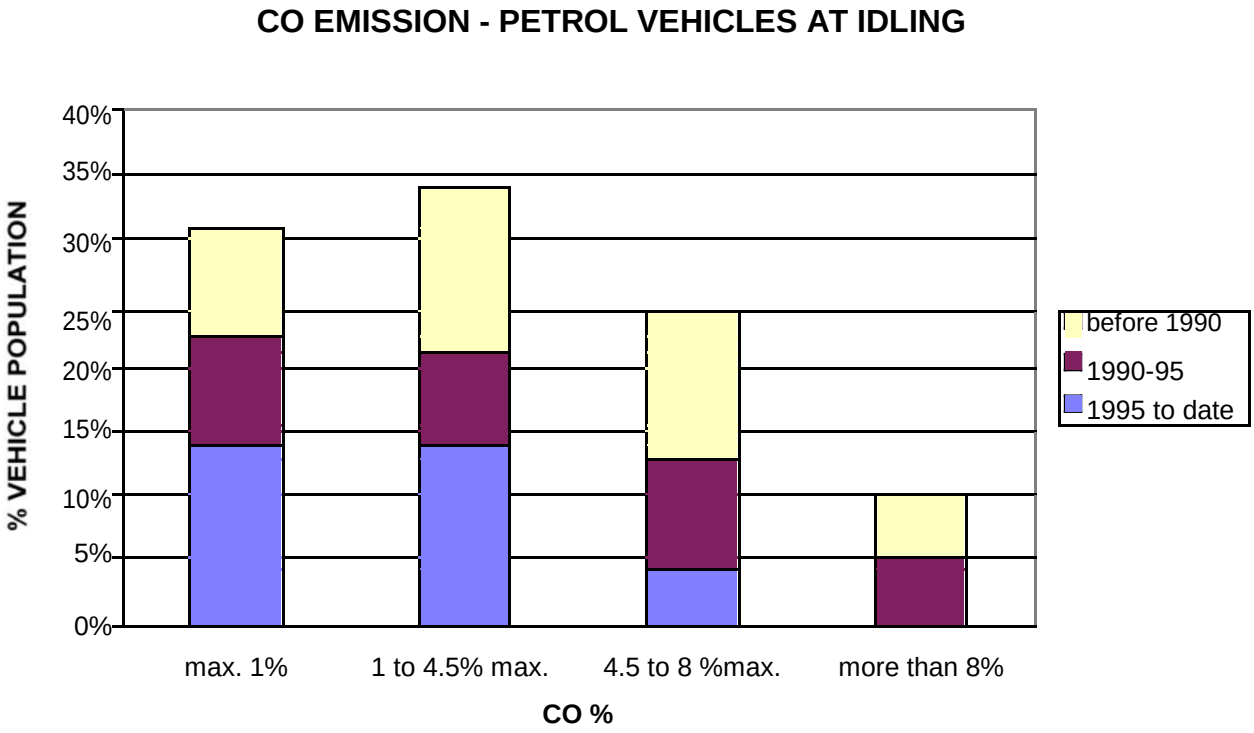

Figure 6. CO emission – Petrol –driven vehicles under idling condition

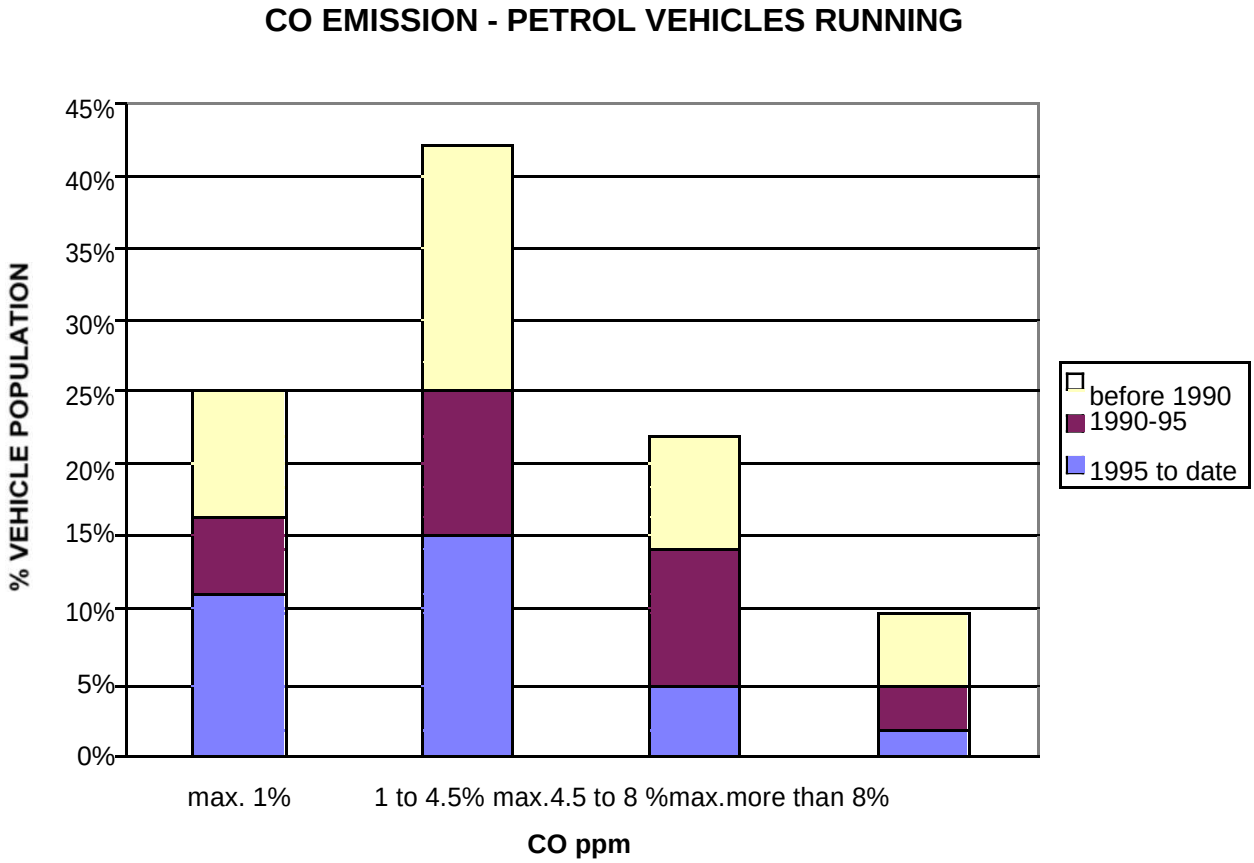

Figure 7. CO emission – petrol-vehicles under running conditions

If the level of HC emissions is not alarming, it is, however, essential to reduce the current number of petrol-driven vehicles on the road emitting more than 4.5 % CO (35 % and 32 % of the petrol-driven vehicle population under idling and normal running conditions respectively). If appropriate strategies and actions are taken, it should be possible to reduce the population of petrol-driven vehicles emitting more than 4.5% CO to less than 10% (the set of recommended measures is discussed elsewhere). This target is highly acceptable for a developing country like Mauritius and should be reached within two years.

The target of reducing within two years to less than 10% the population of petrol driven vehicles emitting less than 4.5% CO, implies that due consideration is to be given to the issue of old vehicles registered before 1990. More than half of the vehicles exceeding 4.5% CO are in fact aged more than 10 years. It is urgent to address the problem caused by these vehicles because together with the hazard of

pollution is associated the issue of waste of energy, and in some cases, safety aspects also.

7. Vehicle Pollution Survey

In parallel with the assessment of the extent of vehicle exhaust pollution, a survey was conducted in collaboration with the Police Road Safety Unit to determine the level of awareness of the general public (road users), drivers and enforcement officers to issues related to vehicle exhaust emissions and pollution control. The questionnaires used for the purpose are given in Appendix D.

As the survey was related to attitude measurement, the Quota Sampling Method was found to be the most appropriate for sample determination. Initially a representative sampling of 3500 interviews for the general public and 1000 for the drivers were decided upon. However, due to time and other constraints, the figures had to be brought down. The response rate obtained for the general public and the drivers' survey is as shown in Table 4.

General Public Survey				Drivers Survey			
Region	Road Users Response			Vehicle Type	Number	Sample size	Response
	Male	Female	Total	Government owned	5094	44	40
Port Louis	61	62	123	Cars	49585	454	122
Pamplemousses	51	51	102	Dual purpose	28944	278	31
Riviere du Rempart	43	43	86	Lorries	9074	81	32
Flacq	54	55	109	Vans	12345	115	99
Grand Port	47	47	94	Buses	2393	21	25
Savanne	29	29	58	Total		993	353
Plaines Wilhems	156	158	314				
Moka	32	33	65				
Black River	23	23	46				
Total	496	501	997				

Table 4 Response rate for general public and drivers' survey

Survey Results (Road Users)

The main findings from the survey for road users are shown in Table 4. It should be mentionned that the road users (general public) have shown keen interest in the survey and it has been observed during the study that a large majority of them (78%) believe that vehicle-related air pollution is a major problem in Mauritius. However, some people (16%) argued that it was normal because of the high traffic density. With regard to the location most affected by vehicle pollution, 43% of the persons surveyed claimed that it was mostly in the city and town centres. Around 20% claimed that it was at the bus stations. Moreover, most of the respondents (94%) held heavy vehicles (buses and lorries) responsible for the pollution. 35% claimed that the pollution could have been controlled through proper maintenance of the vehicles concerned while 16% insisted on the need for serious penalties to polluters of the environment.

GENERAL PUBLIC		
Questions	**Possible answers**	**%**
Respondent's opinion on major causes of vehicle pollution in Mauritius.	**Poor vehicle maintenance**	**35**
	Too many vehicles	**25**
	Old vehicles	**22**
	Poor fuel quality	**18**
	No serious penalties	**16**
	Don't know	**4**
Respondent's opinion on the level of vehicle pollution in Mauritius.	**Very serious**	**43**
	Serious	**35**
	Normal	**16**
	Negligible	**6**
Where do you think you are most exposed to vehicle pollution.	**In towns**	**43**
	At bus stations	**20**
	On bus stops	**7**
	On motorways	**11**
	At home	**1**
	On main roads	**18**
Which type of vehicle which most pollutes the environment.	**Bus**	**50**
	Lorry	**44**
	Car	**4**
	4x4/ Van	**2**
Do you think that petrol contains lead?	**Yes**	**29**
	No	**9**
	Don't know	**63**
Do you think that emissions from diesel engines present any health hazards?	**Yes**	**94**
	No	**2**
	Don't know	**4**
Do you think that emissions from petrol engines present any health hazards?	**Yes**	**71**
	No	**22**
	Don't know	**7**

Table 4 Survey Results (Road Users)

Quite a few respondents (18%) related the cause of pollution to the quality of fuel available in the market. It was clear from the study that the general public was not aware of the health hazards that are associated with the use of leaded petrol. 72% of the respondents were not even aware that petrol contained lead. Most people (94%) associated health hazards to emissions from diesel engines. Also, though 71% claimed that emissions from petrol engines did present health hazards, very few could explain how. Around 29% of respondents either did not know or claimed that petrol engine emissions do not represent any health hazard. The tendency is clearly to judge the pollution by the opacity of smoke emitted.

Survey results (Drivers)

The results of the survey for the drivers are as shown in Table 5. As in the case of the road users, drivers equally showed keen interest in the study and it was observed that they were not conscious of the heath hazards that are associated with pollution caused by vehicles. However, they were eager to take part in programmes to combat the level of emission from their vehicles by taking the appropriate measures.

DRIVERS		
QUESTIONS	POSSIBLE ANSWERS	%
What do drivers think of the level of pollution in Mauritius?	Extremely High	42
	High	36
	Normal	19
	Negligible	3
	No problem	1
Where do drivers find air pollution problems most acute?	In big Agglomeration	50
	On the main roads	18
	On the motorway	14
	Everywhere	18
	Undisturbed	0
What do drivers think are the sources of vehicles air pollution problems?	Bad maintenance	39
	Low grade fuel	31
	Too many vehicles	11
	Old vehicles	12
	Not enough fine	5
	Don't know	2
What are the obstacles for a regular servicing on vehicles?	Cost of servicing	26
	High costs of spares	33
	No time/Vehicles not free	12
	No qualified personnel for servicing	8
	Lack of equipment in workshop	4
	Negligence of owners	5
	No problem	12
Do drivers think that petrol fumes can affect their health?	Think yes	49
	Think no	44
	Don't know	7
Do drivers think that diesel fumes can affect their health?	Think yes	92
	Think no	4
	Don't know	4
Which fuel contains lead according to the driver?	Petrol	38
	Diesel	12
	Neither petrol nor diesel	2
	Don't know	48
Do you think the authorities are doing their best to combat pollution?	Yes	30
	No	59
	Don't know	11
How would drivers react if the authorities decide to put a high fine against the polluters?	Don't know	18
	Opposition to decision	22
	Favourable to decision	60

Table 5 Survey results (Drivers)

About 78% of the drivers claimed that the level of pollution in Mauritius was high while 19% claimed that it was normal. The city and town centres were again identified as the main areas where the problem was most acute. However, 32% of the drivers claimed that the problem was of equal importance on the motorways and mainroads. All the drivers claimed that pollution did cause major disturbance during their journey.

According to 39% of the drivers the major cause of pollution was due to the bad maintenance of the vehicles. 56% claimed that the cost of servicing and spares was the main barrier to proper maintenance A considerable number of respondents (31%) related the vehicle pollution problem to the quality of the fuel available.

With regard to health hazards most of the drivers (92%) considered diesel fumes as being more hazardous to the human health than petrol fumes (49%). Again not many could give details of how the fumes were hazardous. Around 51% of the drivers were of opinion that emissions from petrol driven vehicles did not represent any heath hazard (among which 7% did not know). Surprisingly, 48% of the drivers did not even know which of the fuel types contained lead. Quite a number of drivers (12%) claimed that diesel contained lead. It was clear from the study that the drivers were not aware of the potential risks of pollution from their vehicles to themselves and to the community at large.

It was however interesting to note that almost 59% of the drivers were of opinion that that the authorities were not doing their best to combat pollution and the same number of drivers were favourable to higher fines as a means to control vehicle emission.

Survey Results (Enforcement Officers)

Given that Enforcement Officers from the Mauritius Police Force and the National Transport Authority would be directly involved in the enforcement of legislation related to pollution from vehicle emission, it was decided to include them in the survey in order to gauge their appreciation of the problems related to vehicle pollution. Fifty officers were surveyed and the results are as shown in Table 6.

According to 45% of the enforcement officers, the major cause of vehicle emission pollution in Mauritius was the quality of fuel used by the vehicles and 36% related the problem to the maintenance of the vehicles. Most of them (70%) believed that both the authorities and the drivers/owners should be made responsible for such pollution control. Interestingly, 24% of the enforcement officers blamed the authorities for the pollution problems. Though 70% claimed that there were laws for control of pollution the majority (91%) claimed that there was lack of technical know-how for the application of the laws. While 35% of the officers did attend some seminars on the issue, the majority of them 62% claimed not to have followed any training for the purpose. 84% of the officers claimed that the only way to assess vehicle emission up to now has been through visual inspection. About 13% of the officers have used smokemeters.

Only 21% of the officers were of opinion that the level of penalty imposed will have a positive effect in the reduction of vehicle emission. The majority (76%) believed that the best means of reducing pollution from vehicles was through awareness campaigns. This in fact is similar to the observation made in the survey for drivers and the road users.

ENFORCEMENT OFFICERS		
Questions	Possible answers	%
Respondent's opinion on major causes of vehicle pollution in Mauritius.	The vehicle's condition	36
	The fuel used	45
	The authorities	5
	The drivers/vehicles' owners	7
	Other reasons	7
Who is responsible for our pollution problems?	Drivers/ owners	3
	Authorities	24
	Both of them	70
	None of them	3
Officers who are aware of the existence of a legislation against vehicle pollution and their opinions on the application of such laws	These laws are in force in Mauritius	70
	These laws are not in force in Mauritius	30
What prevents the application of any anti vehicle pollution law?	No problem	0
	Lack of technical know how	91
	Lack of logistics means	9
	Corruption	0
Officers who think that there is a lack of logistics means and also a lack of personnel for vehicle inspections	Enough personnel	91
	Not enough personnel	9
Where do officers get their mechanical background necessary for vehicles inspection?	Seminars/ keep in touch	35
	No training facilities- learn by doing	15
	No training facilities offered at all	47
	Don't know	3
What should be the most important aspect of a anti vehicle pollution legislation?	Wake the awareness of the polluter/driver/owner	76
	Its psychological aspect	3
	The level of the fine	21
Which equipment is used to assess the level of vehicle pollution.	Smoke detector	13
	Gas analyser	3
	No equipment is used, visual inspection	84

Table 6. Survey Results (Enforcement Officers)

Measures recommended

The survey clearly showed that all Mauritians were keen to combat the effect of air pollution from vehicle emission. The main issues to be dealt with are:

1. an awareness campaign on the health hazards that are associated with the use of both diesel and petrol as fuel
2. a review of the quality of fuel imported (unleaded fuel and better quality diesel)
3. a review of the import duties on spare parts (specially those used for regular maintenance, for instance, fuel and oil filters, engine oil)
4. enforcement of legislation for control of pollution from vehicles (in the form of penalties)
5. provision of training to enforcement officers.

8. Conclusions and Recommendations

1. Philosophy

As the Republic of Mauritius steps into the new Millennium, it will have to rise to the challenge of sustainable development. An integral part of the latter paradigm is the need for ensuring that the general air quality is in line with recommended international standards.

Vehicle emissions influence air quality along the road-side in a significant manner. The monitoring and control of vehicle emissions is important for three basic reasons:

- **The health of the population is at risk, particularly in the case of frequent road-users and vulnerable groups such as the elderly, the young children and the sick.**
- **The tourist industry will suffer from a bad image if the problem of vehicle pollution is acute.**
- **Problems ranging from the inefficient use of fuel to road safety are also associated with vehicle emission pollution.**

2. Diesel vehicle pollution

As far back as 1992 in the Kruger report, the black smoke emission from heavy vehicles (buses and trucks) was reckoned as a significant source of pollution. High PM level in the atmosphere as recorded along some busy streets was mainly due to diesel vehicle pollution. Although the level of sulphur in diesel was reduced in 1997 from 1.0 % to 0.5 % by weight, this level is still very high compared to that in countries with the most advanced attitudes towards diesel pollution (0.05 % sulphur for example, in Singapore). The price increment for improving the quality of diesel is affordable, and is certainly much less than the

significant increase of the selling price of diesel that has occurred over the market recently.

Currently, this research has shown that 20 % of the diesel vehicle population emits more than the 60% smoke opacity level. Half of the latter population is made up of vehicles more than 10 years old. It should be possible to reduce the extent of such pollution by introducing, among other measures, the use of diesel with reduced sulphur content (e.g with only 0.2% by weight of sulphur).
The proposed target of reaching within two years not more than 10 % of the diesel vehicle population with 60 % opacity level (or above) is a possible scenario if the complementary measures as discussed further in this section are adopted. Particular emphasis should be laid on the pollution due to buses with the direct involvement of bus companies themselves in the process of monitoring and control of their fleets' emissions.

3. Petrol vehicle pollution

The use of leaded petrol is a real anachronism. The impact of lead on the health of humans is well known and the use of lead, particularly at the high level of 0.5 g/litre as is currently the case in Mauritius, is not acceptable. The reasons put forward namely the unavailability of suppliers, the lack of storage facility, the rise in petrol prices or the case of auto-cycles and motor-cycles that need leaded petrol, are all flimsy if consideration is given to the extreme danger of lead pollution. Strong political will and good administrative follow-up of decisions taken will overcome all the latter problems in a satisfactory manner and smooth the way to a gradual introduction of unleaded petrol. Incentives and complementary measures as discussed further are also needed to allow such a substitution.

Tests carried out in the context of the current research have shown that HC emission at tail-pipe is not a significant issue. However, CO emission in 36 % of petrol vehicles exceed 4.5% level (under idling conditions). The age of the vehicle does not appear to be the overwhelming reason for pollution in the case of petrol vehicles. It should be possible within two years to reduce to not more

than 10 % of the petrol vehicle population, the number of such vehicles emitting more than 4.5 % CO if a package of measures as discussed further in this section is adopted.

4. Emission standards and legislation

The findings of the report submitted by SEMES in July 1997 for on-road vehicles are still valid. Had these been applied as scheduled, the level of pollution would have been much lower than what it is today. In the light of the results of the present study, the following standards are recommended for on-road vehicles:

Buses: 60 % opacity limit

Other diesel-driven vehicles: 50 % opacity limit to be reduced to 40 % within two years.

All new diesel vehicles should comply with established Japanese or EC standards as stated in the SEMES report.

SEMES does not give any specific emission standard for on-road petrol vehicles. In the light of the results of current research, a limit of 4.5 % CO is recommended for both idling and running conditions. New vehicles should comply with established Japanese or EC standards.

The recommendations should not make allowance for the age of the on-road vehicles.

Non-compliance with the standards should be strictly dealt with in the form of deterrent penalties.

6. Framework for enforcement

In order to enhance the coordination of pollution control and monitoring measures in Mauritius, the enforcement responsibility should be attributed to the Department of Environment. However, the close collaboration of the National Transport Authority and of the Police Force will be essential for logistics support.

Enforcement can be effectively carried out only if the Department of Environment is fully equipped. The selection of the specifications of the

equipment should be worked out in collaboration with the Faculty of Engineering of the University of Mauritius.

The training of the enforcement officers is equally essential. In this respect also, the collaboration of the Faculty of Engineering of the University of Mauritius can be solicited, as was successfully carried out in the past.

6. Complementary measures to be adopted.

The following complementary measures are recommended:

- **Removal of import duty on relevant spare-parts for the fuel system of diesel and petrol vehicles.**
- **Incentives for importing vehicles with improved fuel combustion and exhaust management systems.**
- **Adoption of strict specifications to improve the quality of fuel imported (as discussed above).**
- **An action plan for the gradual introduction of unleaded petrol.**
- **Duty exemption on pollution control and monitoring equipment as well as on repair and maintenance equipment.**
- **Special training courses for garage technical personnel.**
- **Incentives to allow the de-registration of old vehicles.**
- **Discount on insurance premium for properly maintained vehicles.**
- **Vehicle examination for road-worthiness should include exhaust emission testing.**

7. Sensitisation.

Last but not least, all of the above recommendations can succeed only under the condition that a sensitization-based strategy is adopted. The three levels of sensitization are as follows:

- **The general public**

- **The stakeholders (including bus companies, fuel distributors, car dealers, maintenance companies,etc)**
- **The authorities**

A participative and consultative role should be granted by the authorities to all stakeholders in the policy-making process. The media should be utilized in educating the public to the pertinent issues related to vehicle emission pollution.

7. Future works.

- **The study should be extended to stationary internal combustion engines such as the thermal power plants.**
- **The impact of other emissions from vehicles should also be investigated.**
- **The correlation between tail-pipe emissions and ambient air quality should be also closely studied in areas at risk.**
- **Modelling of the dispersion of pollution from tail-pipe emissions.**
- **Monitoring of the impact of pollution control measures in the short and long terms.**