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Aggravation of Silent killer; Air pollution in the City of Colombo

L. Manawadu[*], Manjula Ranagalage[**]

[*] Professor of Geography, University of Colombo, Sri Lanka
[**] Lecturer, Department of Social Sciences, Rajarata University of Sri Lanka, Sri Lanka

Abstract- Air pollution has been identified as one of the silent killers in the present world as pollutants are taking lives of people without making any noise. Unlike other disasters, air pollution destroys human life gradually. People can see and people can predict when disasters occur. However, people cannot understand or cannot see when air pollution is taking place until people are seriously affected.

The road transport and traffic significantly contribute to degrade the quality of air in any region of the world. This study attempts to examine the spatial pattern of Sulfur dioxide and Nitrogen dioxide in the city of Colombo using the data collected by the National Building Research Organization (NBRO), Sri Lanka from January, 2003 to December, 2005. Some socio-economic data which are used as explanatory variables for the spatial pattern of air pollutants were collected from different government organizations.

GIS techniques such as spatial interpolation, spatial query and Geostatistical techniques were adopted to achieve the desired objectives. The main objective of this study is to understand the air pollution dynamics and explore the reasons for aggravating air pollutants in the city in recent past.

It has been identified that there is a very significant periodic changes of contamination of pollutants with the rainy seasons. However, human factors of the city contribute more than the physical factors in degradation of the air quality.

By using grid based regression analysis, traffic density was identified as the most significant explanatory variable among the selected socio-economic variables. Characteristics of traffic fleets are found to be highly responsible for the degradation of air quality in the city of Colombo.

Index Terms- Air pollution, Car journey travel time, Silent Killer, Sulfur dioxide

I. Introduction

The average contamination of Nitrogen dioxide (NO_2) and Sulfur dioxide (SO_2) in the city of Colombo shows fairly significant statistics when compared with the national air quality standards of the country (Table 01). However, someone can argue that the air quality of the city is not healthy or there is a high tendency to decrease the quality of air when look at the individual observations and occurrences of exceedances (Table 02). Both parameters, SO_2 and NO_2 indicate a high tendency to be increased during the period

Table 01: Average Contamination of Pollutants and National Control levels

Period	Average Contamination of Sulphur dioxide (µg/m^3)	Average Contamination of Nitrogen dioxide (µg/m^3)
Entire Period (2003 – 2005)	34.03	32.43
National Control Levels	80 (24 hr)*	100 (24 hr)*

* See appendix 01

from 2003 to 2005 where data have been collected by the National Building Research Organization (Figure 01 and 02).

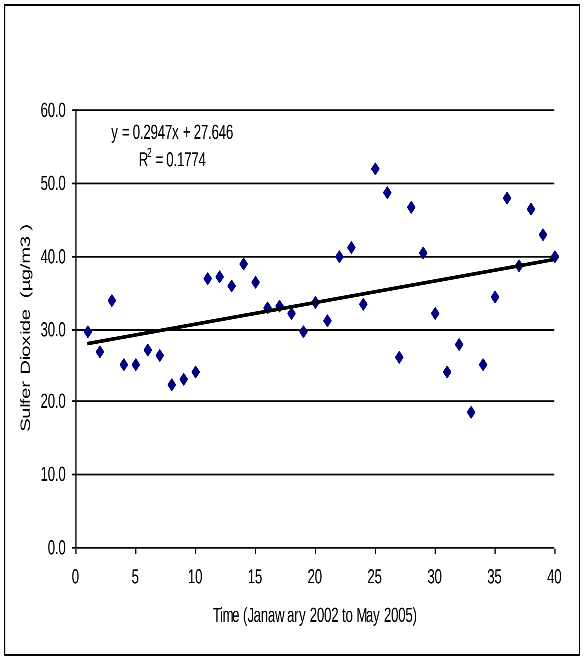


Figure 1: Trend line for Sulfur dioxide

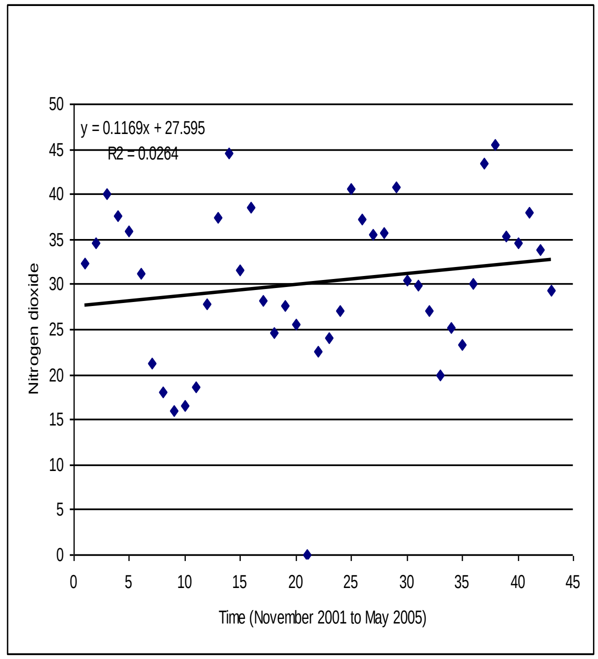


Figure 2: Trend line for Nitrogen dioxide

Many recent studies have indicated some negative impacts of air quality of the city. The Central Environment Authority indicated in their official website that there is a hazardous situation of some air quality parameters such as Sulfur dioxide, Nitrogen dioxide and Particulate matter except Carbon Monoxide in year 2005.

Except Carbon monoxide, the status of other three parameters is not favorable. Sulfur dioxide is identified as seriously unhealthy by the Central Environment Authority whilst Nitrogen dioxide and Particulate material are identified as moderately unhealthy.

Another example can be extracted from the joint report (Sustainable Transport Options for Sri Lanka, 2003) produced by Energy Sector Management Assistance Programme of UNDP and Word Bank. The report has highlighted the degrading quality of the air of the city. This report highlighted the number of exceedances from the National standard of SO_2 from 1996 to 2000. In 1996, there were only 5 exceedances and in 2000 it has increased up to 82 (Table 01). All exceedances have happened in early and the latter parts of the year. Therefore, it can be noted that there is a seasonal variation of exceedances and it is more critical in the period from November to February where the north-east monsoons are active.

Table 02: Number of exceedances of national standard of SO_2 (1996 to 2000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1996												05	05
1997				03	02								05
1998			02								03	02	07
1999	03										01	01	05
2000	04	05	05	01						02	25	40	82

Source: Sustainable Transport Options for Sri Lanka UNDP/Word Bank – 2003

The highest contamination of Sulphur dioxide and Nitrogen dioxide are reported at the Fort and Maradana railway stations respectively which are very close to the Central Business District of the city**.** Also these two observatories indicated very high deviations from the average contamination of air pollutants in the city. Therefore Maradana and Fort observations can be considered as highly significant outliers and the nodal points among the observations. Between these two outliers, the most noteworthy point is that Sulphur dioxide concentration is much higher than that of the average contamination of the Nitrogen dioxide at Fort railway station, amounting to 4.15µg/m^3 of variation (Table 03).

Table 03: Average contamination of NO_2 and SO_2 and differences by observation points

Observation Point	Average NO_2 for whole period ($\mu g/m^3$) (1)	Average SO_2 for whole period ($\mu g/m^3$) (2)	Difference (2) – (1)
Railway Station, Fort	50.93	55.08	4.15
Kirulapona - II	30.67	33.39	2.72
Thimbirigasya	33.90	36.46	2.56
Kirulapona - I	24.51	26.91	2.40
Met Department	27.45	29.79	2.33
Elli House	24.50	26.76	2.26
Kotte	20.60	22.59	1.99
Police, Borella	36.00	37.49	1.49
CEA	22.90	24.28	1.38
Gangaramaya Temple	29.10	30.31	1.21
Railway Station, Maradana	52.02	53.01	0.99
Temple, Borella	30.97	31.38	0.42
Jethawana Temple	34.99	35.35	0.36
Kelaniya	31.82	31.80	-0.02
CMC	36.05	35.85	-0.20

Source: Prepared the by author, based on the data from the NBRO - 2009

Kirulapone II, Borella Temple, Borella Police station, Thimbirigasyaya, Jethawana temple and the Colombo Municipal Council observatories depict a moderate contamination of both pollutant types, whereas observatories such as Kotte, Central Environmental Authority, Elli House, Kirulapone I, location of the Department of Meteorology and the Gangarama temple exhibit a comparatively lower contamination of Sulphur dioxide and the Nitrogen dioxide. Therefore, five distinct areas can be identified as (i) very high contamination, (ii) high contamination, (iii) moderate contamination, (iv) low contamination and (iv) very low contamination in terms of the spatial concentration of both pollutant types . The very high and high concentrated areas of both pollutants are located in the central part of the city and low concentrated areas are located in the southern and the northern parts of the city. Very low concentrated areas such as Elli house, Kirula and the location of the Meteorology department are scattered. The five regions that have been identified show a marked difference from the average concentration of air pollutants.

II. Objectives

The primary objective of this study is to assess the spatial and temporal patterns of the air quality of the city of Colombo and to examine the socio-economic and physical factors influencing the degradation of air quality and their significance in the city of Colombo.

The specific objectives are:

1 Examine the spatial and temporal patterns of air quality of the city of Colombo
2 Examine the socio-economic and physical factors that influence degradation of air quality in the city of Colombo.

III. Methodology

As this analysis was prepared on the basis of literature available in different sources; facts and information produced by different research, this study can be considered as an investigation with secondary sources on Air quality of the city of Colombo. Therefore data has collected from different government organizations, libraries and relevent publications.

IV. Results and Findings

Air pollutants come from a wide variety of sources, both mobile and stationary. Broadly those sources can be divided into two main categories: natural and man-made. On the other hand, the factors affecting the air quality in any region can be divided into two categories: contributing factors (air pollution sources); and negative factors (sinks). When considering atmospheric pollutants, it is important to identify the sources and sinks within the atmosphere. A source is a point or place from where the pollutants are released or emitted. An atmospheric sink is a place or location where the pollutants are removed from the atmosphere, either by chemical reaction or absorption into other parts of the climate system. Therefore, the factors affecting the air quality can be divided into several categories:

4.1 Socio-economic factors and air pollutants in the city of Colombo

Since the Industrial Revolution, atmospheric concentrations of many greenhouse gases have been increasing, primarily due to human activities. During the last fifty years, there has been an additional input to the atmosphere of halocarbons such as CFCs, as well as depleting Ozone, also act as greenhouse gases. With more greenhouse gases in the atmosphere, the natural greenhouse effect is being enhanced artificially, and this could bring about global warming.

In this section, some of the selected man-made factors have been examined against the air quality of the city. The selected man made factors are: population density (population distribution), population density in underserved settlements, housing density, housing condition, building density, traffic density and land use and land cover. Statistical relationships between these parameters and air pollutants have been examined using different techniques available in Geographical Information Systems (GIS). Among the socio-economic parameters selected, traffic density can be considered as the highly contributing factor for degrading the air quality of the city (Table 04).

Table 04: Correlation coefficients between air pollutants and socio-economic parameters.

Socio-economic parameter	Sulfur dioxide	Nitrogen dioxide
Population density	0.2422	0.2810
Population density (Undeserved settlements)	0.1413	0.1416
Housing Density	0.1213	0.1222
Housing Density (Undeserved settlements)	0.1657	0.1534
Housing condition	0.0348	0.0247
Building density	0.1592	0.1865
Traffic density	0.5218	0.5220

4.2 Traffic density and Air pollution

Many documents and research papers indicate that traffic density degrades the quality of air in the city of Colombo. The "Male Declaration" has given concrete evidence that the transport sector is the most important factor that emits Sulfur dioxide rather than the industrial activities, domestic activities, power plants or any other fuel related activities in the city of Colombo (Table 05).

Table 05: SO_2 emissions inventory share, (Colombo) 1990 – 1997

Year	Industry	Domestic	Transport	Power	Fuel	SO_2 emissions
1990	9.92	16.89	32.53	34.40	6.26	26,118
1991	9.20	17.21	35.16	32.90	5.54	27,311
1992	8.05	18.71	36.80	32.05	4.38	28,029
1993	9.40	15.86	37.72	31.12	5.90	28,875
1994	9.84	15.58	38.48	30.06	6.05	29,892
1995	8.70	13.92	37.79	34.38	5.21	32,738
1996	8.47	12.03	42.90	31.31	5.29	35,944
1997	7.37	11.45	47.27	29.51	4.40	38,135

Source: Male Declaration, 2000

The emission inventory of the country shows that transport sector has been consistently increasing from 1990 to 1997 whilst all other sectors show decreasing trend during this period. SO_2 emissions have also increased by 50% from 1990 to 1997.
Thus, traffic density shows a very significant positive correlation with air pollutants unlike other socio-economic parameters considered in this study. This significant relationship between air pollutants and traffic density can be seen clearly in all four rainy seasons (Table 06).

Table 06: Relationship between traffic density and Air pollutants by different rainy seasons

Rainy season	Nitrogen dioxide (r)	Sulfur dioxide (r)
1st Inter Monsoon	0.5133	0.5032
South west Monsoon	0.4790	0.5244
2nd Inter Monsoon	0.5163	0.5031
North East Monsoon	0.4820	0.5052
Whole year	0.5220	0.5217

4.3 Identification of explanatory variables related to air pollution caused by traffic

Several causes have been identified to show the significant relationship between traffic density and air pollution in the city of Colombo. Basically, these causes can be classified into seven main streams as follows;

1. Increasing trend of vehicle fleet
2. Composition of vehicle population (Two stroke, Diesel, Petrol ratio)
3. Fuel consumption
4. Fuel quality of the country
5. Government policies
6. Vehicle inspection system
7. Traffic congestion
8. Road development pattern of the country

4.3.1 Augmentation of vehicle population in Sri Lanka

Number of vehicles operating in the city area has increased rapidly during the post economic liberalization period which commenced in 1977. This increment can be examined in three different ways;

1. Increasing trend of number of vehicles enter / operate in the city
2. Number of vehicles registered in Sri Lanka
3. Changing pattern of car journey speed

4.3.1.1 Increasing trend of number of vehicles enter the city

According o the statistics published by the Road Development Authority (RDA) in year 2000, almost 400,000 vehicles entered the city from main entry points in an average week day (Table 07).

Table 07: Number of vehicles entered the city of Colombo (in a week day)

Entry Points	1985	1995	2000
Negambo road	36,549	54,833	71,270
Kandy road	35,175	52,762	68,591
Kota road	19,391	29,086	37,812
Avissawella road	9,258	13,887	18,053
Kolonnawa road	10,811	16,216	21,081
Nawala road	12,949	19,423	25,250
High level road	25,541	36,811	47,854
Dutugemunu road	11,750	17,625	22,912
Galle road	42,183	63,199	82,159
Total	203,607	303,842	394,982

Source: Road Development Authority, 2003

The number of vehicles that enter the city has increased almost two times from 1985 to 2000. This two fold increase of the number of vehicles, is a general trend at all entry points of the city. However the entry points of from Galle road, Negambo road and Kandy road show that a significantly high number of vehicles have entered the city during week days.

In year 2000, approximately 400,000 vehicles entered the city in a week day. In addition to this it can be assumed that additional100,000 vehicles are positioned within the city limits. Therefore it can be estimated that the total vehicle fleet operating within the city area is almost 500,000 in a week day. This is approximately 1/6 of the total active vehicle fleet in the country (In year 2000, total active vehicle fleet in the country is 3 million).

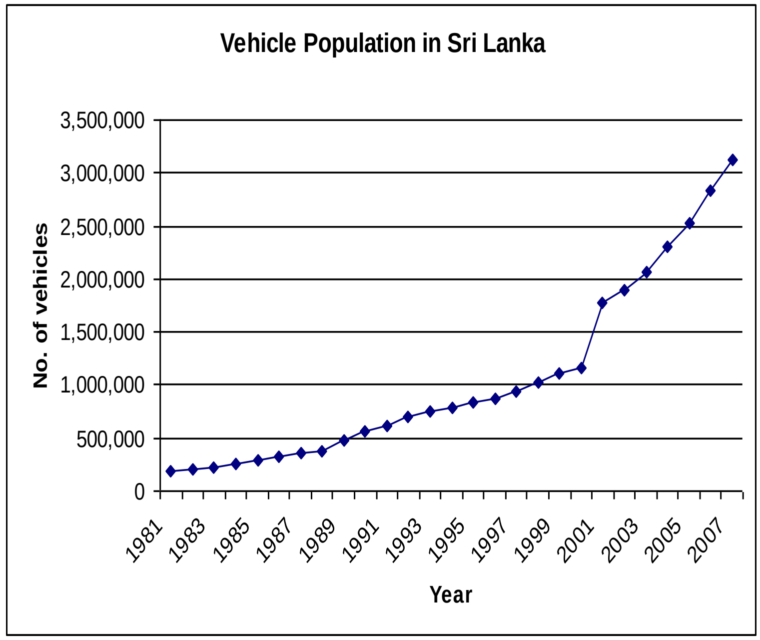
Another estimation describes the number of vehicles entered to the city as follows.

"Commuting population uses various forms of transportation to enter the city. According to the estimates, approximately 27,215 buses, operated both by private and public sectors, transport 958,000 passengers daily to the city. Another 560,132 use about 243,459 private vehicles. The number of commuters who use the railway is estimated to be around 165,000. Both the number of vehicles and the commuters entering the city are increasing year by year. At the same time the residential population and the ownership of vehicles within the city limits will also experience an unprecedented growth. Vehicles that enter the City from 9 entry points on working days have been estimated to be around 275,000, and this is in addition to the contribution to the traffic floor by the use of vehicles of the residents in the city".

4.3.1.2 Increasing trend of number of vehicles registered in Sri Lanka

The registered number of motor vehicle has been increasing at around 6 per cent annually during the last two decades in Sri Lanka and over 60 per cent of all motor vehicles are registered in the Colombo Metropolitan Region (CMR).

Figure 01: Vehicle population in Sri Lanka



The vehicle population in Sri Lanka has significantly increased during the post-liberalization period which commenced in 1977. Especially after the year 2001, registered number of vehicles has increased sharply. In 1981, there were only 250,000 vehicles in Sri Lanka and at the end of 2007, this number has increased over than 3 million (Figure 01). In some years the number of vehicles has increased by 50 per cent annually (Table 08).

Table 08: Annual increase of vehicle population from 1981 to 2001

Period	Annual increment of vehicle population (%)
1981 - 1982	10.09
1982 - 1983	12.06
1983 – 1984	12.60
1984 - 1985	14.05
1985 – 1986	12.02
1986 – 1987	9.45
1987 – 1988	6.30
1988 – 1989	25.18
1989 – 1990	19.64
1990 - 1991	7.49
1991 – 1992	13.99
1992 – 1993	7.15

1993 – 1994	5.31
1994 – 1995	5.27
1995 – 1996	4.59
1996 – 1997	7.55
1997 – 1998	8.63
1998 – 1999	9.24
1999 – 2000	4.91
2000 – 2001	52.24
2001 – 2002	6.37
2002 – 2003	9.59
2003 – 2004	10.79
2004 - 2005	10.00
2005 - 2006	11.89
2006 - 2007	10.53
Average	11.82

Source: Prepared by the Author, 2008

Annually vehicle population of the country has increased by over 10 per cent from 1981 to 2006. However, there are some extreme cases during 1988 – 1989, 1989 – 1990 and 2000 – 2001. Due to the duty concession given in year 2000, large number of vehicles entered the local market during 2000-2001. Furthermore, this increasing trend of vehicle fleet in Sri Lanka describes by Jayaweera (2000) as follows:

"In 2000, the total active vehicle fleet in Sri Lanka was estimated to be 1.165 million, almost twice its size in 1991. In 2004, this further increased to 1.5 million. It is estimated that 60% of this fleet operate in the Colombo Metropolitan Region (Jayaweera, 2000).

In addition to the number, the average age of the vehicle fleet in Sri Lanka is another important factor pertaining to the air quality of the country. Average age of the active vehicle fleet is 6.2 years, which is relatively higher compared to international standards (Jayaweera, 2000).

4.3.1 3 Changing pattern of car journey speed

The changing pattern of car journey speed is a good indicator of the traffic congestion of any area. Car speed has been reduced drastically in the city of Colombo. The survey carried out by the Transport Studies Planning Center, Ministry of Transport in 2001 shows the decreasing trend of car journey speed of the 7 entry points of the city (Table 09). Galle road and High-level road indicate the highest decreasing trend of car journey speed. In 1997, car journey speed in the Galle road was 28 km per hour and in 2001 it has been reduced up to 8km per hour by 4 times. The situation in the high-level road is worse than the Galle road. In 1997 car journey speed in the high-level road was 32 km per hour and in 2001 it has been reduced up to 6 km per hour.

Table 09: Car journey time survey results (as average speeds, km/hour) Inward direction, morning peak

Road and junction	1997	1999	2001
Colombo-Galle (MalibanJunction to Dickman Road)	28	18	8
Colombo – Ratnapura (Maharagama to Kirulap)	32	16	6
Colombo - Kandy (Kadawatha to Orugodawatte)	23	22	11
Colombo - Puttalam (Mahabage to Kelani Bridge)	18	16	7
Jayawardanapura-Kollupitiya Battaramulla to Senanayake Junction	23	17	9
Colombo-Horana (Papiliyana to Vilasitha Nivasa Junc)	27	17	8
Wellampitiya - Kaduwela (Abatale to Wellampitiya)	28	18	9

Source: Transport Studies Planning Centre, Ministry of Transport, 2001

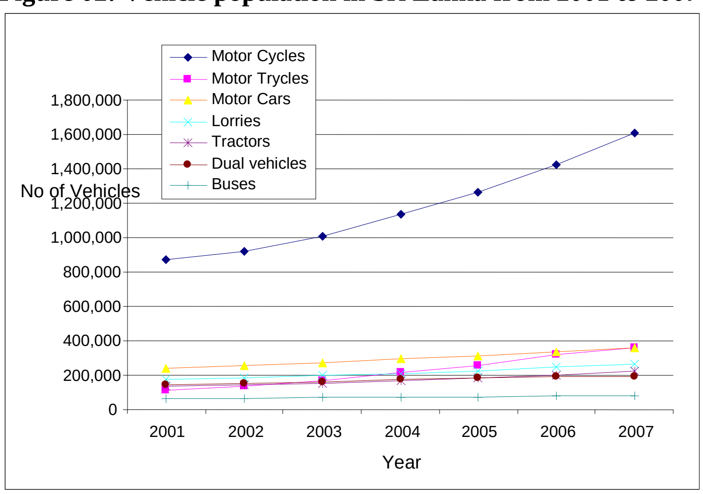
The reduction of car journey speed caused to burn fuel unnecessarily. For an instance, distance from Moratuwa to Colombo is 16 km. Assuming a car needs one liter of fuel to travel to Colombo in 1997, at present 4 liters of fuel are required to travel the same distance from Moratuwa to Colombo with low car journey speed. It appears 3 liters of extra fuel burn by each car approximately running from Moratuwa to Colombo. This simple arithmetic helps to estimate the total wastage of fuel due to the traffic congestion of the city of Colombo.

4.3.2 Composition of vehicle population

In the view of air pollution, the composition of vehicle fleet of the country can be examined in different angles.

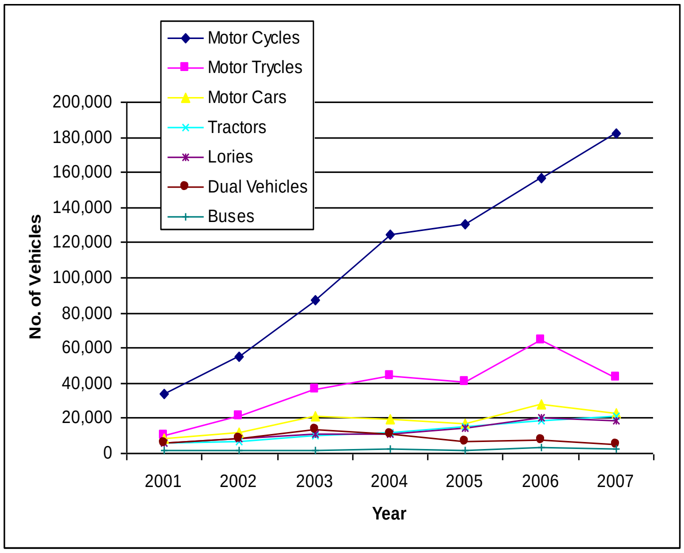
When considered the composition of vehicle population in Sri Lanka, motor cycles are very prominent followed by motor tricycles, motor cars and lorries. The gap between the number of motor cycles and the other vehicles are always high throughout the whole period and tending to increase further more (Figure 02 and 03).

Figure 02: Vehicle population in Sri Lanka from 2001 to 2007



Source: Motor Registrar Department, Sri Lanka, 2008

Figure 03: Vehicle population (New registration from 2001 to 2007)



Source: Motor Registrar Department, Sri Lanka, 2008

This composition of vehicle population is one of the critical factors that cause air pollutants in Sri Lanka. Motor cycles and tricycles belong to the two stroke category. They generate more pollution when compare with four stroke vehicles due to the mechanical structure.

The share of petrol vehicles has remained high compared with diesel vehicles. This is mainly due to the high growth of motorcycle imports during the two decades commencing from 1980. For example, the relative share of motorcycles in the total vehicle number increased from 41 per cent in 1989 to 52 per cent in 1995. In the category of petrol vehicles, the relative share of motorcycles increased from 18 per cent in 1970 to 23 per cent in 1978 and from 61 per cent to 73 per cent in 1989 to 1996. This deserves special attention because of the high emission rates associated with motorcycles. Literature shows that motorcycles contribute 50% more hydrocarbons per kilometer than passenger cars and an almost equal amount of particulate matter as buses and Lorries (Walsh, 1992).

"Combustion cycle for reciprocating Internal Combustion engines may be accomplished in either four strokes or two strokes. Two stroke engines have the advantage of higher power to weight ratio compared to four-stroke engines when both operate at the same speed. However, combustion can be better controlled in a four-stroke engine and excess air is not needed to purge the cylinder. Therefore four-stroke engines tend to be more efficient, and typically emit less pollutants than two-stroke engines (AirMAC, 2004).

4.3.3 Fuel consumption

Annual consumption of vehicle diesel has grown much faster than petrol consumption. The average annual growth of petrol and diesel consumption between 1986 and 1996 is 4.4 per cent and 6.6 per cent respectively. In 1997, the total consumption of leaded and unleaded petrol stood at 200,000 and 25,000 t, respectively, whereas the total diesel consumption was 1,100,000 t. Of this, locally manufactured de-sulphurised diesel accounted for about 500,000 t and direct imports for the remaining 600,000 t.

The diesel to petrol consumption ratio has changed significantly from 1.5 in 1970 to 4.8 in 1996. The rise can be attributed mainly to the high increase in diesel vehicles and high consumption rates of vehicle diesel. The joint effect of these factors has led to grater increase in vehicle emissions from diesel vehicles especially in the city of Colombo.

Diesel engines are substantially more fuel efficient than equivalent petrol engines. However, emission of some pollutants, especially those affecting urban air quality tends to be higher from diesel than petrol vehicles (Faiz, 1996).

Table 10: Percentage distribution of Vehicle types (Excluding Motorcycles) in Sri Lanka (1970 – 2005)

	1970	1978	1989	1996
Petrol	64.5	52.6	45.5	40.2
Diesel	35.5	47.4	54.5	59.8

Source: Chandrasiri, S (2006)

"The per capita petrol consumption has increased from 12.7 liters to 15.9 liters and that of diesel from 28.7 liters to 54.7 liters from 1991 to 2000. This shows that per capita diesel consumption has increased by 91% but per capita petrol consumption has increased only by 25%, indicating a sharp change in fleet mix. The major changes are the rapid increases of three wheelers (as well as two wheelers) and the small diesel vehicles (due to pricing policy of diesel vs petrol and vehicle importation policies). These trends have aggravated the air pollution problems in the urban sector (AirMAC, 2004).

"Regarding the diesel fuel, the situation is remarkably different. The Sri Lankan market is clearly biased towards diesel fuel consumption and the market has more and more evolved in this direction over the last ten years, as shown by the petrol to diesel consumption ratios of table 11.

Table 11: Petrol to diesel ratio

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Ratio	0.35	0.29	0.27	0.26	0.25	0.24	0.21	0.19	0.18	0.17	0.17

Source: AirMAC, 2004

4.3.4 Fuel quality of the country

Fuel quality is one of the most important factors affecting vehicles emission in Colombo. The Ceylon Petroleum Corporation (CPC), the sole supplier of vehicle fuel in Sri Lanka, imports 65 per cent of super diesel and 100 per cent of unleaded petrol. In addition, 35 per cent of normal diesel and 100 per cent of leaded petrol sold in the market are produced by CPC using import crude oil. However, the Sulphur content of the fuel available in Sri Lanka is relatively high when compared with countries in the region (Table 12). The Sulphur contain in the fuel in Sri Lanka is more than twice in the other countries in the region.

Table 12: Sulfur content in Diesel fuel (Percentages by weight)

Country	1998	1999	2000	2001	Future Plans
Brunei	0.25	0.25	0.25	0.25	
Cambodia					
Indonesia	0.5	0.5	0.5		
Laos					
Malaysia	0.5	0.5	0.3		
Myanmar	0.5	0.5	0.5		
Philippines	0.5	0.5	0.5	0.2	
Singapore	0.3	0.05	0.05	0.05	
Thailand	0.25	0.05	0.05	0.07	
Vietnam	0.5	0.5	0.5		
India					
Bangladesh					
China				0.2 – 1.0	0.2 (2002)
Pakistan				1.0	0.5 (2002)
Sri Lanka	1.1	1.1	1.1	1.1	0.5 (2002)

Source: Male Declaration

The import of diesel fuel increased by about 25 per cent over the period 1991-1995 while from 1995 to 1996 the increase has been a phenomenal 60 per cent. This is particularly due to the operation of new diesel power plants. Sri Lankan produced diesel has a higher concentration of Sulphur compared to other countries in the region. Nearly 99 per cent of vehicles use leaded gasoline which has the potential of causing health problems in the city (Male declaration).

4.3 5 Government Policies

The government policies which are favorable to increase the contamination of air pollutants in the city of Colombo can be classified into two main sections namely; Pricing policies and other government policies.

The high growth of diesel-powered vehicles and the high rate of auto-diesel consumption were clearly noticeable throughout the 1990s. This was attributed to the auto-fuel pricing policy (on petrol and diesel) and fiscal policy on vehicle imports. A distinctive feature of auto-fuel (petrol and diesel) pricing in Sri Lanka is the significant price differential between petrol and diesel. In fact, in the 1990s, Sri Lanka was the only country which maintained the highest disparity between petrol and diesel prices. The discriminatory pricing policies adopted by successive governments over the past four decades have been highly favorable towards diesel users. Similarly, the fiscal policy on vehicle imports has also been discriminatory against certain categories of vehicles. Furthermore, the road user charge applicable to different categories of vehicles do not fully capture environment damage cost. These distortions have led to high growth of diesel-powered vehicles which use low quality diesel (i.e., 0.8 per cent of Sulphur). One of the major environmental problems associated with this development is the deterioration of ambient air quality.

Table 13: Retail selling prices in Petroleum products (Price in Rupees per liter)

	1998	1999	2000	2001	2002	2003	2004	2005
Super Petrol	50.00	50.00	50.00	50.00	49.00	53.00	70.00	80.00
Auto Diesel	13.20	13.20	24.50	26.50	30.00	32.00	44.00	50.00
Super Diesel	18.50	18.50	29.80	31.80	35.30	37.30	49.30	55.30
Ratio	3.79	3.70	2.04	1.89	1.63	1.66	1.59	1.60

Source: Annual Report, Ceylon Petroleum Corporation, 2005

Always there is a very high disparity in prices of the main fuel types in Sri Lanka. However there is a positive trend in decreasing the price gap between petrol and diesel which is positively contributed to reduce the air pollution in the country.

Table 14 : Sulfure Emissions kt/y

Year	Diesel Engines Emissions
1990	23.1
1995	31.4
2000	40.6
2005	52.0
2010	63.6
2015	79.3

Source: AirMac, 2004

The emissions of Sulphates are growing proportionately to the growth of the diesel vehicles fleet (AirMac, 2004).

4.3.6. Vehicle inspection system

The National Environmental Act (NEA) of 1980 as amended in 1988 prohibits any discharge of pollutants into the environment. Sections 23J and K prohibit emission of pollutants into the atmosphere. The National Environmental (Protection and quality) Regulations of 1990 prohibits the discharge of wastes into the environment. Discharge standards have been prescribed by the CEA for liquid wastes and the Sri Lanka Standards Institution (SLSI) has prescribed emission standards for Sulphuric acid plants. The CEA in December 1994 gazetted national ambient air quality standards for Sri Lanka. These regulations do not however address vehicular air pollution (Male declaration).

Though the NEA gives the CEA the mandate to regulate and control air pollution, enforcement has been rather slow due to the lack of specific mission standards and reliable data. While the Motor Traffic Act considered visible emission an offence, it is not rigorously enforced (Male declaration).

Diesel consumption has substantially increased in both in absolute and relative terms in the last decade. There are sound technical reasons that justify diesel-powered lorries and buses. The share of diesel cars with respect to the total number of cars has remained constant at roughly 10%. Temporary increases seem to be mainly due to concessionary import licenses. The main source of increase in diesel consumption has been the increases in both the share and the vehicle kilometers traveled (KVT) of vans, pickups and dual-purpose vehicles. The reasons behind this trend seem to be the following:

1. The final price of diesel has never been much more than half the final price of petrel until 2004.
2. A dual-purpose vehicle is a moderately close substitute for a car, depending on the price difference. The price of a diesel dual-purpose vehicle can be lower than the price of a car. The reason for this price difference is threefold;

I. Imported cars cannot be older than three years, whereas imported vans cannot be older than five years. The import price net of taxes is therefore lower for vans, if anything, because they are older. The national base to compute import and excise duties is therefore lower.
II. The excise duty rate is approximately 111% of the import price for diesel cars and 57% for diesel dual-purpose vehicles.
III. The custom duty and the surcharge as percentage of customs duty rates are the same for both vehicle types. The cumulative effort of (II) and (III) results in that the average fuel tax paid on imported diesel cars is 146% of the import price net of taxes whereas the average fuel tax paid on imported diesel dual-purpose vehicles is 92% of the import price net of taxes.

3. The annual license fee is the same for both diesel cars and dual-purpose vehicles.
4. The registration charges are higher for diesel cars than for dual-purpose vehicles.

(AirMac, 2004)

…..and the import regime then favors diesel vans over petrol cars. The problem of pollution is therefore one of vehicle maintenance, possibly of fuel quality and the encouragement offered by the import regime towards older and more polluting vehicles AirMAC, 2004.

4.3.7 Traffic congestion

Traffic congestion is one of the prominent factors which attributed to aggravate the contamination of pollutants in the urban areas. The main reason for heavy traffic congestion of the city of Colombo is, although the traffic on the roads has increased a very high speed, the automobile and railway network dating back to the colonial days has remained almost unchanged except for marginal improvements.

The present transport crisis / impasse / breakdown in the Greater Colombo Area could be quite clearly seen in the traffic congestion along almost of all the major trunk roads leading to Colombo; Galle road congestion starts from Kalutara-Panadura, is intensified after Rathmalana, and leads to vehicles inching their way after Dehiwala. High level road congestion starts from Homagama-Kottawa area, is intensified after Maharagama and leads to vehicles inching their way after Nugegoda. Negombo-Katunayake road congestion starts from Ja-Ela- Kandana area and leads to vehicles inching their way their way after Wattala. Kandy-Colombo road congestion starts from Yakkalamulla – Kadawatha area makes another procession towards Colombo from Kiribathgoda. Hanwella low lying road congestion starts from Habarakada-Athurugiriya area and leads to vehicles inching their way after Malabe-Koswatta.

This traffic congestion starts from 6 a.m. almost on all the roads with fleets of school vehicles and continues until about 10 p.m. with returning evening workers with intermittent brief respites. In a congested hour it takes nearly two hours to reach Colombo from Panadura whereas train takes only 45 minutes.

The current traffic problem in the Colombo Metropolitan Region (CMR) emerged wasting thousands of productive man-hours on roads as well as generating more and more pollutants and burning thousands of barrels of fuel unnecessarily.

This high traffic congestion and generating of high pollutants clearly described the order given by the Supreme Court of Sri Lanka. The attorney General was instructed to prepare a new action plan in consultation with several government organizations to reduce air pollution and traffic congestion from 2010.

4.3.8 Road Development pattern of the city

The city of Colombo attracts about 1.5 Million floating population on any working day and with the addition of the resident population in the city, the total population in the city increases to more than 2 Million during the daytime. It is estimated that about 50% of the commuting population arrives in the city for employment or to engage in commercial activities and or to attend educational institutions. The rest comes to the city for various other purposes.

Traffic problem has been aggravated by the concentration of all forms of economic, commercial and administrative functions in the city. Furthermore, Colombo is the largest city in the country and, therefore, it attracts people because of its commercial and political significance and it offers better facilities in health, education, etc. than any other city in the country. The combination of all these aspects results in a greater attraction of the city for people from the rest of the country thus aggravating the transport problem in the city of Colombo. Transport problem that currently experienced by the city of Colombo is reflected in the increasing traffic congestion. A few years ago, the traffic congestion was largely limited to the CBD, but now it has spread to the entire core area lasting sometimes most of the peak period. The number of vehicles in the city is not the only factor that contributes to congestion. Shortage of parking areas, inadequate facilities for pedestrians, parking of heavy vehicles on busy highways during normal working hours and poor public transport facilities are also equally significant contributors to the congestion problem. As a consequence the average vehicle speed has reduced to around 10 kilometres per hour within most parts of the city during the day.

The main implication of traffic congestion is that it causes higher running costs to the owners of vehicles and results in a considerable loss to the national economy. This problem is likely to exacerbate in the immediate future since the road networks are severely inadequate to meet even the current demand given the projected growth in the demand for transport facilities in the coming decade, upgrading, modernizing and expanding the transport sector must receive urgent priority.

V. Conclusions

Different factors have contributed for the quality of air in the city of Colombo in different ways and in different magnitude. Some of them are physical factors and some of them are man-made factors. Except rainfall other physical factors are not very significant. The contamination of pollutants is not very high within the Southwest Monsoon period and the contamination of pollutants increased drastically in the Municipal area within the Northeast Monsoon period due to different climatic scenarios in different Monsoon periods.

Among the socio-economic factors, traffic density is the most contributing factor for degrading the quality of air in the city of Colombo. Some characteristics related to the vehicle fleet such as, Number of vehicles, Composition of the vehicle fleet and some government policies such as fuel quality of the country, pricing policy and vehicle inspection systems are directly contributed to degrade the quality of air in the city of Colombo.

The decision makers and the policy makers of the country should pay necessary attention to this matter and review the existing government policies related to the air quality and air quality monitoring system and make necessary arrangements to introduce viable government policies which can prevent the air quality of the city.

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Authors

First Author – Prof. L.Manawadu, Ph.D,, Department of Geography, University of Colombo,Colombo, Sri Lanka
SecondAuthor –Manjula Ranagalage, Lecturer, MSc in Geoinformatics, Department of Social Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka,

Correspondence Author – Manjula Ranagalage, manjularanagalage@gmail.com, +94717953995