Reprinted from

International Journal of Health Research

Peer-reviewed Online Journal

http://www.ijhr.org

Abstracting/Indexing
Embase, Index Corpenicus, Chemical Abstracts, Socolar, EBSCO, African Journal Online, African Index Medicus, Open-J-Gate, Directory of Open Access Journals (DOAJ)

PORACOM
Academic Publishers

International Journal of Health Research

The *International Journal of Health Research* is an online international journal allowing free unlimited access to abstract and full-text of published articles. The journal is devoted to the promotion of health sciences and related disciplines (including medicine, pharmacy, nursing, biotechnology, cell and molecular biology, and related engineering fields). It seeks particularly (but not exclusively) to encourage multidisciplinary research and collaboration among scientists, the industry and the healthcare professionals. It will also provide an international forum for the communication and evaluation of data, methods and findings in health sciences and related disciplines. The journal welcomes original research papers, reviews and case reports on current topics of special interest and relevance. All manuscripts will be subject to rapid peer review. Those of high quality (not previously published and not under consideration for publication) will be published without delay. The maximum length of manuscripts should normally be 10,000 words (20 single-spaced typewritten pages) for review, 6,000 words for research articles, 3,000 for technical notes, case reports, commentaries and short communications.

Submission of Manuscript: The *International Journal of Health Research* uses a journal management software to allow authors track the changes to their submission. All manuscripts must be in MS Word and in English and should be submitted online at http://www.ijhr.org. Authors who do not want to submit online or cannot submit online should send their manuscript by e-mail attachment (in single file) to the editorial office below. Submission of a manuscript is an indication that the content has not been published or under consideration for publication elsewhere. Authors may submit the names of expert reviewers or those they do not want to review their papers.

Enquiries:

The Editorial Office
International Journal of Health Research
Dean's Office, College of Medicine
Madonna University, Elele Campus, Rivers State
E-mail: editor_ijhr@yahoo.com or editor@ijhr.org

PORACOM
Academic Publishers

International Journal of Health Research, March 2010; 3(1): 37-44

Available at http://www.ijhr.org

Original Research Article

Open Access
Online Journal

Health Consequences of Using Liquefied Petroleum Gas (LPG) as an Alternative Car Fuel in Gaza Governorates

Abstract

Purpose: To investigate the attitude and perceived health status of car drivers in relation to the use of liquefied petroleum gas (LPG) as car fuel.
Methods: Close-ended questionnaire was administered to 230 drivers and volatile organic compounds (VOC) levels emission were determined for each of the cars driven by the drivers.
Results: Although none of the cars was authorized to work on LPG, 42.6% of car engines were powered with LPG. The lowest health complains were reported by drivers using LPG. Public health and environmental impact of LPG were not among the concerns of the majority of drivers. The mean health complains percentage score (MHCPS) significantly favours LPG as better fuel for driver health. All categories of cars showed more or less degree of VOC emissions, the lowest VOC was recorded in diesel-based engines. Significant correlation was found between MHCPS and VOC.
Conclusions: A high proportion of drivers use LPG in their cars even though public health and environmental soundness of LPG were not among the concerns of the majority of drivers. It is recommended that a public enlightenment program should be organised to address the problem properly.

Keywords: Fuel; Liquefied petroleum gas; Attitude; Health complains; Volatile organic compounds

Mahmoud Sirdah[1]*

Mohammed A Rahma[2]

[1]Faculty of Science, Biology Department, Al Azhar University, P O Box 1277, Gaza, Palestine
[2]Directorate of Primary Health Care, Palestinian Ministry of Health, Palestine

***For correspondence:**

Tel: +97059 94 811 94

Email: msirdah@hotmail.com
sirdah@alazhar.edu.ps

This article is available in Embase, Index Corpenicus, Chemical Abstracts, Socolar, EBSCO, African Journal Online, African Index Medicus, Open-J-Gate, Directory of Open Access Journals (DOAJ) databases

Introduction

Car emissions continue to attract the attention of public health specialists, and environmentalists because of their adverse effects on global climate and the high ozone forming potential of many organic compounds found in car emissions which adversely effect human health and other living organisms and ecosystems. The increasing awareness about the consequences of fuel combustion on the local and global environmental issues together with the continued and sharp increases in prices of petroleum products has enhanced and promoted the use of alternative fuel types which include liquefied petroleum gas (LPG). Many descriptive and comparative studies about of the emissions from LPG-powered vehicles have been carried out and reported in recent literature. Now it is generally accepted that the emissions from LPG-powered vehicle are less

than those from the gasoline or diesel fuelled equivalents [1,2].

The Gaza Strip (31° 25' N, 34° 20' E) of Palestine, is a narrow piece (365 km^2) of land along the Mediterranean coast, just 40 km long and 10 km wide. It is divided into five governorates: the North, Gaza, Mid Zone, Khan Younis, and Rafah governorate and has an estimated population of about 1.48 million according to July 2007 report [3]. The peoples of the Gaza Strip are sufferings from worsened economic situation due to constrains and border closures affecting all the living conditions of the people in the Gaza Strip. Border closure prevents flow of goods and supplies allowed to entered to the Gaza Strip which include petroleum products and their derivatives (e.g. gasoline, diesel, and LPG). In addition to their shortage and scarcity, the imported car fuels (gasoline and diesel) are very expensive compared to the prices of these products in neighbouring countries like Egypt and Jordan. Accordingly, a considerable number of car drivers in the Gaza Strip switched their vehicle engine to LPG instead of gasoline or diesel.

Of the about 58,700 officially authorized vehicles in the Gaza Strip (based on the records of the Palestinian Ministry of Transportation (MOT)), none is allowed to run on LPG but on diesel or gasoline [4]. Therefore, we designed the present study in order to identify the attitude and perceived health consequences of LPG as a alternative fuel in the Gaza governorates.

Methods

This cross sectional study was carried out in the five governorates of the Gaza Strip between May 2008 and August 2008. The sample size of the present study was calculated with 10% precision, and at least 100 drivers must be included [5]. For no-responsive expectations, and to avoid low number of cases and hence low frequencies, our provisional sample size was increased to 255.

We than prepared a pre-tested questionnaire using close-ended questions. The questionnaire which was designed to include technical and descriptive information about the cars, health characteristics and complains (6 major complains) of the drivers, as well as knowledge and attitude of the drivers towards LPG. The questionnaire was distributed thorough meeting interviews at traffic stations and locations where the drivers grouped (like gas supply stations) at the five governorates. The purpose and objectives of the study were explained and after free acceptance, subjects were asked to fill the proper questionnaire. The average time for filling the questionnaire was about 10 min.

The levels of volatile organic compounds (VOC) were measured using the C-21 gas sensor (ECO Sensors, Inc., USA) in order to relatively quantify the amount of leakage of VOC inside car space. The screen of the apparatus displays the following results: < 20 ppm, 40 ppm, 50 ppm, 100 ppm, and 140 ppm which respectively correspond to normal/accepted, caution/moderate, danger/high, very high, and the highest level of VOC.

Data analysis

The data were tabulated, encoded and statistically analyzed using the Statistical Package for the Social Sciences (SPSS) version 13. Statistical tests were carried out using chi square test, Z-test, spearman rank correlation coefficient (r_s) and Kruskal–Wallis test as appropriate. At 95% confidence interval p values less than 0.05 were considered to be significant [6].

Results

Appreciatively, 230 of the 255 drivers filled the questionnaire which indicated a total response rate of 90.2 %. The percentages of car drivers who used LPG was 42.6% (n=98), while those who using diesel or gasoline was 57.4 % (n=132). The cars production year varied from 1970 to 2004, while the mean car age was 20.41±6.72 yr. Majority of the cars (63.9%, n=147) were produced between 1980 and 1989. Valid license and valid insurance was reported for 78.7% (N=181) and 50.0% (n=115) of the cars, respectively while 50.0% of them were both

licensed and insured. According to official license of the cars, none of the car engine was authorized to work on LPG, while 63.0% (n=145) were authorized as gasoline engine and 37.0% (N=85) as diesel engine. Contrary, 42.6% (n=98) of the car engines were driven on LPG, 48.7% (n=112) on diesel, and only 8.7% (n=20) on gasoline.

Knowledge of drivers towards LPG

The answers to the items related to the knowledge of the drivers are given in Table 1. All the responding drivers had good knowledge about the use of LPG as car fuel, and majority of them (61.4% of those using diesel/gasoline engines and 74.5% of those using LPG) have knowledge about the method for LPG switching. The major knowledge source of information for 43.9 % of diesel/gasoline and 79.0 % of LPG drivers was car repairing technicians. The majority of the drivers (79.5% of diesel/gasoline and 71.4% of LPG) attributed LPG switching to economical impacts of LPG compared to diesel or gasoline. Unfortunately, low percentages of drivers (8.3 % of those using diesel/gasoline and 35.7% of those using LPG) showed correct knowledge about the healthy and environmentally advantages of LPG. Regarding the security and public safety of LPG switching under the current way and conditions, the majority of the drivers (93.9 % of those using diesel/gasoline and 75.5 % of those using LPG) expressed their anxiety and worries about public safety.

The drivers using diesel/gasoline and those using LPG (83.3% and 78.6%, respectively) had good knowledge about the increased injuries and impairments of LPG engine. They (84.8% and 76.5%, respectively) also had negative change of LPG engine mechanical power compared to diesel or gasoline engines. With respect to economical benefits, 50% of drivers using diesel/gasoline estimated a reduction of 20-40% in fuel costs when switching to LPG, while 49.0% of those using LPG estimated a reduction of about 40-60 % of fuel costs. However, majority of the drivers (>72.0%) generally considered diesel and gasoline to be the best fuel for their cars in terms of economy, availability and handling.

Attitude of drivers

Table 2 illustrated the responses of the drivers for the items related to attitudes. LPG drivers significantly (66.3%, p=0.001) supported the introduction of LPG as car fuel, and they greatly preferred (75.5%, p<0.001) it to be introduced under legal and official conditions. Unfortunately the diesel/gasoline drivers did not favour (81.1%, p<0.001) LPG introduction even under legal and official conditions (65.9%, p<0.001). When the drivers were asked about the preferable fuel under comparable economical benefits and availability, the majority (82.7%, p<0.001) of LPG drivers preferred the LPG. However, 53.8 % of diesel/gasoline drivers significantly (p<0.001) preferred diesel, 42.4% preferred gasoline, and only 3.8% preferred LPG. The majority of diesel/gasoline drivers (83.3%, p<0.001) and LPG driver (71.4 %, p<0.001) supported the economical point of view for advertising and recommending LPG, while only 5.7% of the overall drivers could recommend it due to environmental and health considerations.

Specific practices of the LPG drivers

Table 3 showed the specific practices of the LPG drivers. The higher and significant percentage (69.4%) of them had switched their car engines to LPG for 6-12 months earlier. A significant percentage (52.0%, p<0.001) of the drivers using LPG utilize weekly 4 or more LPG cylinders of 12 kg. Fortunately, the majority of LPG drivers did not report unpleasant odour or unburned gas inside or outside cars, or gas odour on clothes. The vast majority of them (about 93%) did not report fire or explosive accident while powering engines with LPG. Luckily, the majority (82.7%) of drivers using LPG did not report criticism upon using LPG as car fuel, which gave an early prediction of the acceptability of LPG by the public.

Health status drivers and VOC measurements:

Table 4 showed that majority (70.4%) of drivers using LPG significantly (p<0.001) expressed no

negative changes on their health status after switching to LPG, while more than half (59.1%) of diesel/gasoline drivers significantly (p=0.037) reported a negative change in health status due to driving. A significantly (p<0.001) higher parentage of diesel/gasoline car drivers (53.0%) reported headache compared to only 21.4% of those using LPG. The same higher significant percentages are found among diesel/gasoline drivers when compared to drivers using LPG for complains related to blurred vision and nausea.

Table 1: knowledge of drivers toward the use of LPG as car fuel

Item / Question	D/G N=132			LPG N=98		
	N	%	P value	N	%	P value
Knowing that LPG used as car fuel	132	100		98	100	
Knowledge about how LPG is used as cars fuel	81	61.4	0.009	73	74.5	<0.001
Source of knowledge:						
Car technicians	58	43.9		48	49.0	
media	12	9.1	<0.001	16	16.3	<0.001
Others	5	3.8		6	6.1	
Formal organizations	6	4.5		3	3.1	
LPG is authorized as car fuel	26	19.7	<0.001	27	27.6	<0.001
The Reason behind using LPG as car fuel:						
Economical	105	79.5		70	71.4	
Obligatory	19	14.4	<0.001	26	26.5	<0.001
Environmental	3	2.3		2	2.0	
Health	5	3.8		0	0.0	
Switching to LPG is performed by authorized	16	12.1	<0.001	14	14.3	<0.001
LPG is healthy and environmentally sounded fuel	11	8.3	<0.001	35	35.7	0.005
In the current way, LPG is secure for public safety	8	6.1	<0.001	24	24.5	<0.001
Using LPG will affect motor injury (impairments):						
Increased	110	83.3	<0.001	77	78.6	<0.001
Decreased	22	16.7		21	21.4	
Reduction in fuel cost when using LPG:						
< 20 %	21	15.9		12	12.2	
20-40 %	66	50.0	<0.001	26	26.5	0.00
40-60 %	31	23.5		48	49.0	
> 60 %	14	10.6		12	12.2	
Expected change in motor power with LPG:						
Positive	9	6.8		18	18.4	
Negative	112	84.8	<0.001	75	76.5	<0.001
No change	11	8.4		5	5.1	
For same amount of money, car moves more km with:						
LPG	31	23.5		54	55.1	
Diesel	61	46.2	0.005	12	12.2	<0.001
Gasoline	40	30.3		32	32.7	
Best fuel for cars is:						
Diesel	95	72.0		6	6.1	
Gasoline	32	24.2	<0.001	72	73.5	<0.001
LPG	5	3.8		20	20.4	

Table 2: Attitude of drivers toward the use of LPG as car fuel

Items	Diesel/gasoline car drivers N= 132			LPG car drivers N= 98		
	N	%	P value	N	%	P value
Support using LPG as car fuel	25	18.9	<0.001	65	66.3	0.001
LPG is the best fuel for the car engine	18	13.6	<0.001	68	69.4	<0.001
Agree to use LPG in the present conditions	37	28.0	<0.001	55	56.1	0.225
Agree to use LPG under legal and official conditions	45	34.1	<0.001	74	75.5	<0.001
At equal economical benefits, the preferred fuel:	56	42.4		81	82.7	
Gasoline	71	53.8	<0.001	5	5.1	<0.001
Diesel	5	3.8		12	12.2	
LPG						
LPG could be recommended	110	83.3		70	71.4	
Economically	3	2.3	<0.001	2	2.0	<0.001
Environmentally	6	4.6		2	2.0	
Healthily	13	9.8		24	24.6	

Table 3: Specific practices of drivers using LPG

Item	Number	%	p-value
Using LPG since			
< 6 months	17	17.4	
6-12 months	51	52.0	<0.001
13-24 months	30	30.6	
Average weekly consumption of LPG cylinders (12 kg)			
≤1	33	33.7	
2-3	13	13.3	0.001
4-5	15	15.3	
> 5	37	36.7	
Unpleasant odour smelling (inside car) during driving			
Yes	40	40.8	0.069
No	58	59.2	
Unburned gas odour smelling from exhaust			
Yes	41	41.8	0.106
No	57	58.2	
Fire or explosive accident while using LPG			
Yes	7	7.1	<0.001
No	98	92.9	
Criticism arise by passengers for using LPG			
Yes	36	36.7	0.011
No	62	63.3	
Gas odour on clothes when return home			
Yes	17	17.3	<0.001
No	81	82.7	

However, with health complains about dyspnoea and depression, the differences were not significant ($p > 0.05$).

The mean health complain score percentage (MHCSP) significantly favoured LPG as better fuel on driver health ($p<0.001$). Drivers using LPG showed the lowest MHCSP followed by diesel users, while gasoline users had the highest MHCSP. Additionally, a significant ($p<0.001$) differences were reported between MHCSP and the measured VOC. The health status of the drivers were not associated with age, education level and driving experience. For drivers using

Table 4: Health status drivers and VOC measurements

Item / Question	D/G drivers N= 132			LPG drivers N= 98		
	N	%	P value	N	%	P value
Health status changed negatively	78	59.1	0.037	29	29.6	<0.001
Headache while driving car	70	53	0.49	21	21.4	<0.001
Blurred vision while driving car	50	37.9	0.005	12	12.2	<0.001
Nausea while driving car	37	28	<0.001	13	13.3	<0.001
Dyspnoea while driving car	42	31.8	<0.001	25	25.5	<0.001
Depression and/or hopelessness while driving	54	40.9	0.037	33	33.7	0.001
Health complain score (zero to 100):						
No complains	38	28.8		54	55.1	
20	26	19.7		16	16.3	
40	23	17.4	0.002	9	9.2	<0.001
60	14	10.6		8	8.2	
80	16	12.1		9	9.2	
100	15	11.4		2	2.0	
Voc (ppm):						
0	7	5.3		1	1.0	
< 20	70	53.0		48	49.0	
< 40	53	40.2	<0.001	43	43.9	<0.001
< 50	2	1.5		6	6.1	

LPG, the Spearman rank correlation coefficient, r_s, indicated poor correlation between MHCSP and the measured VOC ($\boldsymbol{r_s}$ =0.42, p< 0.001) and age of the car (r_s=0.23, p=0.022) but no significant correlations between MHCSP and driver experience (r_s = - 0.04, p = 0.70), driver age (r_s=0.09, p = 0.35), and years of education (r_s=0.06, p = 0.59).

All categories of cars showed some degree of VOC. While about half of the cars running on diesel/gasoline and LPG had < 20 ppm of VOC, 6.1% of cars running on LPG and 1.5 % of cars running on diesel/gasoline had < 50 ppm of VOC. The lowest amount of VOC was recorded in diesel-based engines, followed by LPG-based, while gasoline-based engines showed the highest VOC score. Fortunately, higher concentrations of VOC (> 50 ppm) were not reported in any of the cars.

Discussion

The present study has evaluated the knowledge, attitude, and practices of car drivers toward the use of LPG as an alternative fuel. The proposal for adopting and authorizing LPG as a vehicles fuel in Palestine was discussed and approved by the Palestinian Cabinet in 2006. However, as at the time of this study, there has not been any official decision approved method for switching cars to LPG [7].

Apart from its health, and environmental problem, the vast majority of the drivers attributed the LPG switching to the economical impact of the LPG compared to diesel or gasoline [1,2]. The impacts of LPG switching on travel security and public safety were reported by the vast majority of the drivers who expressed their anxious and worries about accidents and explosions from LPG-fuelled cars. Concomitantly, it is worthwhile to mention that a considerable number of explosive and inhalation accidents from LPG leakage were reported worldwide and attributed to haphazard and unawareness practices in utilizing LPG [8,9]. Therefore, to secure public safety from a relatively preventable explosions and fires, specific standards and constrains must be adopted when LPG switching is approved in Gaza governorates.

Concomitant to what have been mentioned in present study about increased impairments and the negative change in mechanical power of

LPG-powdered engine, the reports and studies in this regard refer the increased injuries and impairments of the LPG engine to the non-lubricating nature of LPG fuel as compared to gasoline or diesel. Absence or reduced valve lubrication results in valve damage and therefore increase injuries and reduce the life of engine. This issue is not applicable for the cars that originally built-in to work on LPG. However, for switched cars, which is also known as hybrid fuel or dual fuel cars, this lubrication problem could be solved properly by using special valve for gas-fuelled engines or by powering the engine regularly with gasoline or diesel [10,11]. Moreover, reports also mentioned a power loss of about 4-20% among engines that have been converted to burn LPG. However, solutions for the reduced power of LPG engines could be overcame by using superchargers or turbochargers to increase the volume of air that's burned with LPG in the engine's combustion chambers[12,13]. The knowledge of the drivers toward the reduction in fuel cost when conversion to LPG was satisfactory and comparable with the results of the studies published in this regard [2,14,15].

The relatively good health of the LPG drivers that mentioned in the present work is concomitant with the published reports about the safety of LPG on driver health which mainly due to the less emissions produced by burning of LPG compared to gasoline and diesel [18-20]. In our study we also reported a significant correlation between the health status of the drivers and the measured VOC**.** Different studies and reports mentioned the impact of vehicle emissions (VOC, carbon dioxide, carbon monoxide, nitrogen oxide particulate matter) on the health and environmental issues of people in different countries. These studies illustrated that LPG vehicles produces at least 20% less CO_2, 60% less CO, and 20% less NO than gasoline or diesel [18-20]. In our study the statistical analysis revealed lowest VOC emissions to diesel cars followed by LPG and the higher emissions to gasoline cars. The relatively higher emissions of LPG cars than diesel cars could be attributed to random and unauthorized and unchecked conversion pipes and system. This explanation is also supported by the insignificant correlation between the amount of VOC and LPG car age, while VOC amount was significantly correlated with the ages of cars using diesel/gasoline. Performing conversions under the full supervision and authority of ministry of transportation and by authorized motor technicians is expected to reduces the emissions from LPG cars and hence protect and keep the advantages of LPG on public health and environment valid.

Conclusion

This study has revealed the illegal use of LPG in cars with obvious health consequences. The need to carry out enlightenment program to educate drivers on the advantages/disadvantages of using LPG is vital for people living in Gaza strip.

Acknowledgments

We thank Dr Ahmed Joudeh, the Director of Occupational Health at the Palestinian Ministry of Health, who provided the authors with the C-21 gas sensor (ECO Sensors, Inc., USA) for VOC measurements.

References

1 Chih-Chung C, Jiunn-Guang L, Jia-Lin W. Assessment of reducing ozone forming potential for vehicles using liquefied petroleum gas as an alternative fuel. Atmos Environ. 2001; 35: 6201–11.

2 Di Pascoli S, Femia A, Luzzati T. Natural Gas, Cars and the Environment: A Relatively Clean and Cheap Fuel Looking for Users. Ecol Econ. 2001; 38: 179–89.

3 The Palestinian Central Bureau of Statistics. The Population, Housing and Establishment Census, 2007. RAMALLAH. Palestine: The Palestinian National Authority.

4 Palestinian Ministry of Transportation. Annual Report/2007. Palestinian National Authority, Gaza, Palestine.

5 Israel G. Determining sample size. Program Evaluation and Organizational Development, IFAS, University of Florida. PEOD 2003; 6:1-5.

6 Daniel W. Biostatistics: a foundation for analysis in the health sciences. 5th ed. New York, USA: John Wiley and Sons, 1991, pp 576-624.

7 Palestinian Cabinet resolutions. Use of LPG as an alternative vehicle fuel in Palestine. 2006. resolution number PC/9/16/10/2006. Palestinian National Authority, Gaza, Palestine.

8 Sugie, H., Sasaki, C., Hashimoto, C.,Takeshita, H., Nagai, T., Nakamura, S., Furukawa, M., Nishikawa, T., Kurihara, K. Three cases of sudden death due to butane or propane gas inhalation: analysis of tissues for gas components. Forensic Sci Int. 2004; 143: 211-4.

9 Astbury GR, A review of the properties and hazards of some alternative fuels. Process Saf Environ Prot 2008; doi:10.1016/j.psep.2008.05.001.

10 Katsuaki S, Teruaki M, Yasuhiro Y, Teruo T. Development of Valve Seat Material for Gas Fueled Engine. Honda R&D Tech Rev. 1999; 11: 149-56.

11 Kimihiko A, Akira M, Akio Y. Development of Hardfaced Valve and Sintered Valve Seat for Gas Fueled Engines. Proc JSAE Annu. Congr. 2000; 56: 1-4.

12 Naoya H, Masakazu S, Akinori M, Akira N, Kunihiko H. Development of Fuel Injection Type Lean Burn LPG Engine for Medium-Duty Trucks. Proc JSAE Annu Congrs. 1999; 73: 1-4.

13 Leea K, Ryub J. An experimental study of the flame propagation and combustion characteristics of LPG fuel. Fuel. 2005; 84: 1116-27.

14 Armstrong R. (1980): "The Role of L.P.G. in Fuel Conservation". technical report produced by Institution of Engineers, Australia, Engineering Conference, no. 80/2. 63-67.

15 Karamangil I. Development of the auto gas and LPG-powered vehicle sector in Turkey: A statistical case study of the sector for Bursa. Energ Policy. 2007; 35: 640-9.

16 Johnson E. LPG: A secure, cleaner transport fuel? A policy recommendation for Europe. Energ Policy. 2003; 31: 1573-7.

17 Ning Z, Chan T. On-road remote sensing of liquefied petroleum gas (LPG) vehicle emissions measurement and emission factors estimation. Atmos Environ. 2007; 41: 9099–110.

18 Gasca J, Ortiz E, Castillo H, et al. The impact of liquefied petroleum gas usage on air quality in Mexico City. Atmos Environ. 2004; 38: 3517–27.

19 Ristovski ZD, Jayaratne ER, Morawska L, Ayoko GA, Lim M. Particle and carbon dioxide emissions from passenger vehicles operating on unleaded petrol and LPG fuel. Sci Total Environ. 2005; 345: 93–8.

20 Lim M, Ayoko G, Morowska L, Ristovski Z, Jayaratne R., Kokot S. A Comparative Study of the elemental composition of the exhaust emissions of cars powered by Liquefied Petroleum Gas and Unleaded Petrol. Atmos Environ. 2006; 40: 3111-22.