Microchemical Journal 139 (2018) 69–73

Contents lists available at ScienceDirect

Microchemical Journal

journal homepage: www.elsevier.com/locate/microc

Preliminary results on the influence of car characteristics on their gases emissions using gas sensors

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ARTICLE INFO

Article history:
Received 10 January 2018
Accepted 19 February 2018
Available online 21 February 2018

Keywords:
Gas sensors
Car exhaust
Human breath

ABSTRACT

A method, based on the use of monitoring portable sensors, has been successfully employed for the determination of the composition of car exhausts from 11 diesel and 5 gasoline cars. These emissions include nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO_2) and volatile organic compounds (VOCs). The measures were taken in different places where each car was parked. In this study it has been tried to correlate the emitted gases with some of the car characteristics, such as the power (varied from 68 to 143 HP), the number of kilometers traveled and the age of the car (between 2 and 19 years). Results found show a significant variation of the emission values, which range between 490 and 3350 ppm for CO_2, from 0.1 to 40.3 ppm for CO and between 0.13 and 32.25 mg/m^3 for VOCs. In the case of NO_2 emissions, the highest measured level was 4.66 mg/m^3. Moreover, measurements of human breath, before starting up and turning off the car, were used to evaluate the impact of vehicle emissions on the human health. It was found exposition levels which indeed the effects of exhausts on the quality of operator air lungs.

1. Introduction

Transport is a vital part of modern life and there is something like a half billion cars in the roads today, one for every two people in rich countries, and them moves everyday [1]. Unfortunately, in its displacement, cars emit high quantities of pollutant gases such as carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x) and volatile organic compounds (VOCs) [2]. These gases, mixed together and energized by the sunlight, will produce a fog of pollution called smog; which is an important global source of air pollution in urban areas that has increased the so-called greenhouse gas emissions.

Currently, before than a passenger car can be type approved for sale in the European Union, they must meet certain standard for exhaust emissions air quality and thus must following the Euro6 norms [3], limits which are 500 mg/km for CO and 60 mg/km NOx. However, they are working in a new Euro7 [4] will put limits for CO_2 emission not more than 5000 ppm and also for the VOCs.

To characterize car emissions, some studies, including laboratory testing for regulating purposes, enhanced laboratory testing [5], on road testing [6], remotes sensing [7], simulation [8] and data analysis [9] have been made.

Generally, car and engine emissions control are performed with an engine and chassis dynamometer at controlled conditions [10] but do not represent the real-world emissions. Besides, other instruments, such a mobile sampling system which included a flexible tube connecting the exhaust coupler and a compartment containing a fuel gas analyzer [11], or a calibrated instrument installed in the road which detect every car emissions and connected to one computer to save the values were also used with the same purpose [12].

In the present study, portable gas sensors, previously used to measure the indoor quality of air [13] were employed to evaluate the CO, CO_2, NOx and VOCs emission from diesel and gasoline cars. The study has involved the evaluation of the relation between emissions and different car data as their power, age and number of kilometer traveled.

2. Experimental procedure

2.1. Instrumentation

To determine the quality of car exhaust and the presence of pollutants in the breath of operator, several air monitoring devices were used, which include: i) a Photocheck Tiger from Ion Science (Laubach, Germany) to determinate VOCs based on the use of photo-ionization detector ii) An airflow multi-function anemometer TA645-P from TSI (Shoreview, MN, USA). This device was equipped with infrared spectroscopy technology to do the measurements of CO and CO_2, and a telescoping, thermos-anemometer probe to measure temperature and relative humidity. iii) Aeroqual series 500 (New Zealand) to determinate the NO_2 concentration. All devices were previously calibrated and

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https://doi.org/10.1016/j.microc.2018.02.022
0026-265X/

Table 1
Details of air monitoring devices employed in this study.

Device	Sensor	Concentration range ppm	Resolution ppm	Measurement program
Airflow multi-function anemometer TA465-P	IR	0 to 500 (CO)	0.1	1 value each 10 s
Airflow multi-function anemometer TA465-P	IR	0 to 5000 (CO_2)	1	1 value each 10 s
PhoCheck Tiger	Photoionisator	0.001 to 10,000 (VOCs)	0.001	1 value each 5 s
Aeroqual series 500	Gas sensitive electrochemical	0–1 (NO_2)	0.001	1 value each 5 s

employed after stabilization. Table 1 provides details about the measurement concentration ranges and resolution of the devices employed in this study.

2.2. Assay conditions

Cars are usually classified according to engine fuel types as gasoline and diesel powered. Since in Spain the number of diesel cars is greater than that of gasoline, the study has been carried out on 11 diesel cars and 5 gasoline cars from different brands and models. In addition to fuel type, power, age of car and the number of kilometer traveled could also significantly influence on car emissions.

The measurements were recorded in different places, where each car was parked. The measurements of the car gas exhaust were taken during 5 ± 2 min when the engine was running. All the tests were made at 30 ± 2 cm from the car exhaust.

The measurements of human breath were taken before starting up and after turning off the car at 20 ± 2 cm from airway by using the monitoring devices and these data were employed as a test of the impact on human lungs of the cars emissions.

3. Results and discussion

In order to evaluate their impact on the quality of air, the gas emissions of CO_2, CO, NO_2 and VOCs in 11 diesel cars and 5 gasoline cars were determined. The concentration of exhaust gases has been related to parameters such as the power, age and number of kilometers of each car. Moreover, the cars have been separated according to the type of fuel used in the engine.

3.1. Diesel cars

Table 2 shows the emissions measured for the diesel cars and the characteristics of power engines, age and number of kilometers traveled. For each parameter measured, the minimum, maximum and average values obtained during sensor operation time were included, and, as can be seen, the emission values changes as a function of the characteristics of each vehicle.

3.1.1. Influence of age and number of kilometer traveled

Table 2 shows that the age of cars varied between 5 and 19 years old. As compared with the kilometers traveled there was not found a direct relationship between the car age and the number of kilometers, varying the values found between 19,439 km (5 years) and 279,933 km (10 years).

In view of the concentrations of the different gases, and in general terms, no correlation with the kilometers traveled or with car age was found. Comparing the emissions of CO_2 for vehicles with the same number of kilometers, as cars 8 and 5 or cars 10 and 9, it can be see a big difference on emitted values. In all diesel cars measured, the highest CO_2 emission was obtained for car 8 and the lowest emission was achieved in car number 5, despite of the fact that it was the oldest one (19 years). On the other hand, when comparing cars 10 and 9, with similar powers, the CO_2 content in the exhausted gases was three times higher in car 9 with respect to car 10. A possible explanation for this behavior could be found due to the number of kilometers per year; for car 8, 18,525 km/year, being the double than for car 5, 9526 km/year, but that correlation with the rest of the studied cars was not found. Moreover, on comparing the four cars with 10 years old, and with big differences in the number of traveled kilometers, from 86,788 to 279,933 km, it was found that the highest CO_2 value was obtained for the car that traveled 185,249 km, and the other three cars exhaust CO_2 values were near 600 ppm.

As can be seen in the Table 2, the intermediate power car 8 provided the highest values for CO_2 and NO_2 emissions, and it was between the firsts for the rest of parameters determined, as CO and VOCs. Regarding VOCs emitted values, it could be thought that this parameter should be in direct relation to the power of the car. This is the case with car 11 (143 HP) with a VOCs value of 32.2 mg/m^3. However, one of the lowest power car (82 HP) provided the second highest value for VOCs with a 15.1 mg/m^3 concentration. The CO emissions were higher for the car 6, 10 years old and with 90,753 km traveled, than for car 1, 5 years aged and traveled 19,439 km, which could be related to the power and car technology. However, and interestingly, the two oldest cars with 17 and 19 years old do not provided the highest values for CO emissions.

Fig. 1 shows, as an example, the NO_2 emissions from cars 1 and 8. The emissions from car 1 were significantly lower than those from car

Table 2
Characteristics and gas emissions of diesel cars evaluated through this study.

Car	Power (horse)	Age	Number of kilometer	CO_2 (ppm)			CO (ppm)			NO_2 (mg/m^3)			VOCs (mg/m^3)		
				Min	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max
1	75	5	19,439	279	1280	4562	0.1	0.3	0.5	0.042	0.105	0.236	1.314	6.853	16.780
2	82	17	120,000	474	1193	3778	0.1	1.2	2.6	0.000	0.188	1.087	1.623	15.143	38.000
3	88	10	279,933	285	537	1263	0.0	0.1	13.2	0.092	2.362	7.260	1.056	2.059	3.792
4	100	9	157,294	446	671	1342	0.0	0.8	3.0	0.122	0.130	0.147	0.122	0.130	0.147
5	100	19	181,000	220	494	900	0.0	3.3	20.0	0.099	0.235	0.687	1.084	3.237	15.460
6	105	10	90,753	479	751	4037	0.0	40.3	152.8	0.000	0.076	0.104	1.972	4.954	41.540
7	110	8	36,500	223	495	739	0.5	1.9	3.2	0.040	1.430	5.652	1.695	2.419	6.228
8	112	10	185,249	561	2459	5119	0.5	16.8	65.9	0.010	4.658	7.264	1.501	5.038	11.990
9	126	9	88,134	446	1598	3828	0.0	6.6	19.7	0.122	0.147	0.223	1.027	1.076	1.149
10	136	10	86,788	474	606	1001	0.1	0.5	1.2	0.064	0.319	1.087	1.300	3.350	8.943
11	143	9	172,060	266	895	3387	0.0	6.0	39.1	0.129	0.473	1.188	1.723	32.247	62.770