Particulate matter exposure in passenger car cabin in Athens, Greece

K. Ntourou[1]*, K-M Fameli[1], I-A Gkountouva[1], Ch. Tsitsis[1], K. Moustris[1] and N. Manousakis[2]

1 Laboratory of Air Pollution, Mechanical Engineering Department, University of West Attica, Campus 2, 250 Thivon and P. Ralli Str., GR-12244 Athens, Greece
2 Laboratory of Electric Power Systems, Measuring Systems, Environment and Reverse Engineering, Department of Electrical and Electronics Engineering, University of West Attica, Campus 2, 250 Thivon and P. Ralli Str., GR-12244 Athens, Greece

ABSTRACT

There is great concern about human exposure to high levels of particulate matter, even for a short period of time, as it is found that it is strongly associated with an increase in respiratory problems, hospital admissions and mortality. In the present study the indoor air quality at a fueled passenger car was examined during the year 2023. Measurements of particulate matter with an aerodynamic diameter of up to 2.5 μm ($PM_{2.5}$) were conducted with the use of low-cost Purple Air Flex monitors having a time step of two (2) minutes. Travelling included routes towards the southern suburbs of Athens and the city center. Parameters such as the route (suburbs or city center) and cooling/heating conditions inside the car were also recorded. The statistical analysis of $PM_{2.5}$ concentrations revealed that higher values were measured when the passenger car was moving to the city center while the air conditioning or heating also affected the measured concentrations. Moreover, it was found that there is a seasonal variation in values and Sahara dust events as well as the fires that took place in the region of Attica during summer worsen the indoor air quality.

Keywords: *$PM_{2.5}$, exposure, in-car, low-cost sensors, Athens, Greece*

METHODOLOGY

The study was carried out between December 2022 and November 2023 in the center and the southern suburbs of Athens. Low cost "Purple Air Flex Air Quality Monitor" sensors were used for data collection. Purple Air sensors measure real-time, (every 2 sec) particle concentrations and are intended for residential, industrial and commercial use. In this study, the measurements taken were for each route. The data used for processing were: measurement date, time, humidity, temperature and $PM_{2.5}$ concentration. During the measurements, the different conditions in the cabin were recorded with the windows open/closed and the heating or air conditioning on. The vehicle used in the study was a catalytic converter equipped Subaru Impreza (1600cc) registered in 2004. It moved mainly in the southern sector of Attica and in the center (1.12.2022-30.11.2023). More specifically, in the areas of Egaleo (University of Western Attica) route A=0, Nea Smyrni, Metaxourgeio and Exarchia route A=1, as shown in Figure 1.

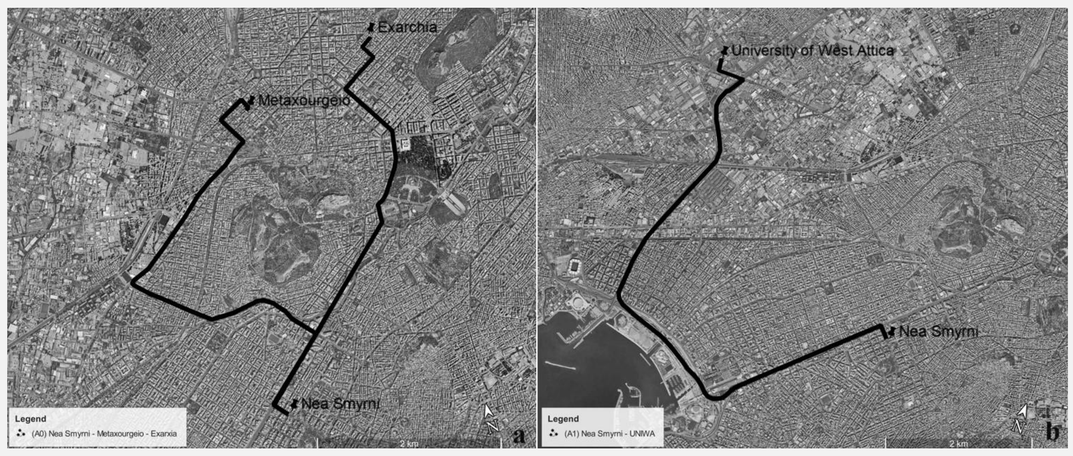

Figure 1. Illustration of study areas (α) Nea Smyrni – Metaxourgeio – Exarxia, route A=0 (b) Nea Smyrni – University of West Attica (UNIWA), route A=1.

INTRODUCTION

The private car is a popular means of transportation in urban areas due to its practicality and convenience. People spend about 45 minutes a day in cars [1]. But what happens to the air they breathe? Vehicle emissions and the intake of pollutants into vehicles can have adverse effects on the health of drivers and passengers [1]. The quality of air inside a vehicle's cabin can be affected by various factors, including ambient air outside the vehicle, self-pollution from the vehicle's exhaust gases, vapors from fuels used, emissions from activities performed inside the vehicle, and the use of air conditioning and heating systems. In the present study the concentration of $PM_{2.5}$ in relation to the thermal comfort of the car cabin on different routes in Athens was investigated.

RESULTS

In the $PM_{2.5}$ variation diagram for the dry season of the year, changes in the variation of $PM_{2.5}$ concentrations (Figure 2) are observed in April, May, July and September. The maximum concentration is recorded in July, when there were fires in semi-urban areas affecting the whole Attica basin. Figure 3 shows the variation of PM2.5 concentrations during the wet season in urban and semi-urban environments as a function of the number of vehicle trips. Maximum concentrations and variations are recorded in December, January and February, suggesting the seasonality of the pollutant during the winter months.

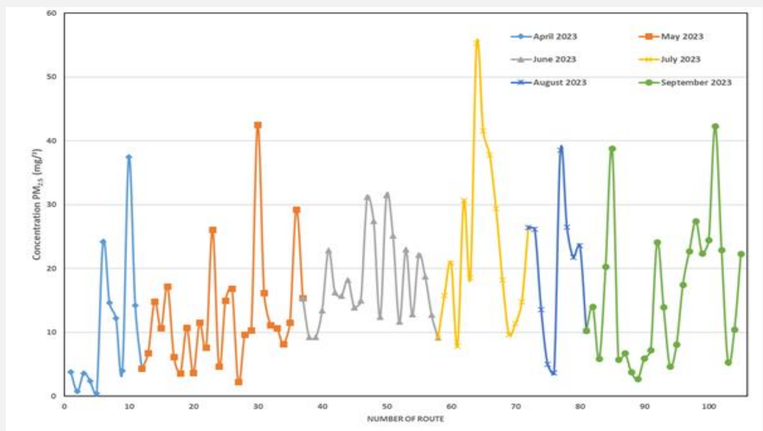

Figure 2. Variation of $PM_{2.5}$ concentration for the Dry Period (2022-2023).

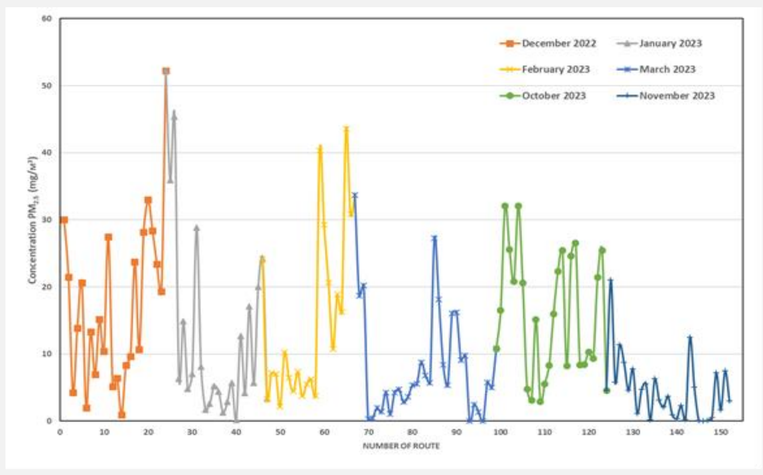

Figure 3. Variation of $PM_{2.5}$ concentration for the Wet Period (2022-2023).

Figure 4 analyses the wet and dry season variables as a function of time zone and route type. The highest mean changes of $PM_{2.5}$ are recorded in the morning time zone, regardless of the route and seasonal variables. It is also evident that journeys within urban centers consistently show the highest mean $PM_{2.5}$ concentrations across all time periods and time zones. This suggests that emission sources are more widespread and persistent in urban centers compared to semi-urban areas.

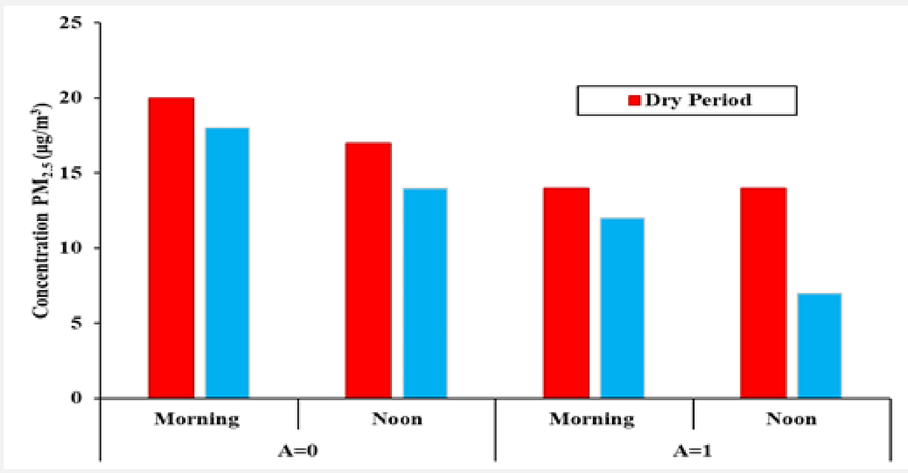

Figure 4. Average concentration of $PM_{2.5}$ by Time zone and type of Route for Dry and Wet Period.(2022-2023).

CONCLUSIONS

This study provides an overview of $PM_{2.5}$ concentrations in the indoor air quality of a passenger car. Measurements were taken in real time while driving to the city center and southern suburbs of Athens during the year 2023. The study showed that $PM_{2.5}$ concentrations inside the vehicle were higher during the dry season, in the morning and when driving to the center of Athens. Concentrations ranged from 18 to 20 μg/m^3, much higher than the WHO guidelines, which set the 24-hour limit for $PM_{2.5}$ at 15 μg/m^3. In addition, the recirculation of particulate matter when heating and air conditioning systems were on, resulted in increased concentrations inside the car. External factors such as fires and African dust affected significantly the measured $PM_{2.5}$ concentrations.

Findings of the present study can improve knowledge about $PM_{2.5}$ concentration inside a car and provide insights of human exposure. Moreover, the need to develop highly efficient cabin air purification systems is highlighted, especially in city centers with poor air pollution.

References

1. Zulauf, N.; Dröge, J.; Klingelhöfer, D.; Braun, M.; Oremek, G.M.; Groneberg, D.A. Indoor Air Pollution in Cars: An Update on Novel Insights. *IJERPH* **2019**, *16*, 2441, doi:10.3390/ijerph16132441.
2. Barnes, N.; Ng, T.; Ma, K.; Lai, K. In-Cabin Air Quality during Driving and Engine Idling in Air-Conditioned Private Vehicles in Hong Kong. *IJERPH* **2018**, *15*, 611, doi:10.3390/ijerph15040611.

Contact e-mail: **kntourou@uniwa.gr**

11th International Conference on Environmental Management, Engineering, Planning and Economics (CEMEPE 2024) & SECOTOX Conference, 16 – 20, 2024, Lefkada Island, Greece