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Workplace personal exposure to respirable PM fraction: a study in sixteen indoor environments

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ABSTRACT

The present paper focuses on respirable particulate matter (RPM) measurements conducted at the breathing zone of adult volunteers in sixteen different working environments: two offices, a house, a chemical laboratory, a non–smoking shop, a pharmacy store, a car garage, a hairdresser's store, a photocopy store, a taxi, a gym, a mall, a restaurant, a bar, a kiosk and a school. The sixteen different cases were categorized according to the location, the type of the activities taking place indoors, the number of occupants, the proximity to heavy traffic roads, the ventilation pattern etc. According to the results, the maximum particle concentration (in average 285 µg m^{-3}) was recorded at the hairdresser store while the minimum concentration was measured in the cases of the housewife and the employee in the non–smoking shop (in average 30 µg m^{-3}). The results indicated smoking as a factor which strongly influences the exposure levels of both smokers and passive smokers. Furthermore, it was found that the building ventilation pattern comprises an important factor influencing the exposure levels especially in cases of buildings with great number of visitors (resuspension) and smoking.

Keywords: *Exposure, respirable particles, working places, ventilation rate*

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1. Introduction

The term of respirable particulate matter (RPM) refers to the suspended particle fraction with aerodynamic diameter smaller than 4 micrometers (OSHA–Occupational Safety and Health Administration). Personal exposure is the concentration measured near the breathing zone, integrated over a specified time period and varies as a person moves from one microenvironment to another. Although indoor air constitutes only a small fraction of the planet's atmosphere, it occupies the majority of the respirable human air fraction, as people spend almost 90% of their time in indoor environments. It is noteworthy that for many individuals, average exposures to particulate matter (PM) show higher correlation with indoor than ambient PM concentrations (Chow et al., 2002). Furthermore, studies have proved that most chemical substances, to which people are exposed every day (such as particulate matter), constitute an additional risk factor in the development of several pathologies (Guo et al., 2003; Sundell, 2004; Pilou et al., 2010; Moghaddasi et al., 2014). For instance, exposure to particles originated from indoor combustion sources as tobacco smoke (Hackshaw et al., 1997) has been associated to increased mortality and morbidity from lung cancer and other diseases. Several studies have reported significant health risks associated with exposure to particulate matter (Pope et al., 2002; Pope and Dockery, 2006; Ashok et al., 2014). During the last decades, research works have studied the relationship between indoor and outdoor concentrations of different air pollutants, in various microenvironments (Chaloulakou et al., 2003; Long and Sarnat, 2004; Lai et al., 2006; Sarnat et al., 2006; Jones et al., 2007; Halios et al., 2009; Siddiqui et al., 2011; Buonanno et al., 2014). Indicatively, EXPOLIS project aimed at studying adult exposure to $PM_{2.5}$ in the city of Helsinki, concluding that active smokers were exposed to almost double levels than those of passive smokers exposed to environmental tobacco smoke (ETS) and three times those of participants not exposed to tobacco smoke (Koistinen et al., 2001). In another study, measurements of commuter and driver exposure to aerosol particles were conducted in buses and trams in Helsinki (Asmi, 2009). Berghmans et al. (2009) have studied and estimated the exposure of a cyclist to particles of various size fractions including ultrafine particles (UFP) in the town of Mol, Belgium. The major sources of UFP and PM_{10} were identified as vehicular emission and construction activities, respectively. Indoor and outdoor ultrafine particles (UFPs) concentration levels were examined in the area of Athens during the cold period of 2003 and 2004 by Diapouli et al. (2007) who indicated outdoor environment, smoking, cleaning activities and the large amount of people in a small place as the main sources of UFPs.

The present study focuses on the comparison of respirable particle levels measured in sixteen different workplaces in a big European city, Athens. Parameters as the buildings location, the type of the activities taking place indoors, the number of

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occupants, the proximity to heavy traffic roads, and the ventilation rate were examined.

2. Materials and Methods

Two TSI Sidepak Sampling Pumps (SP530) were used for the purpose of this study (Figure 1). Each sampler (flow rate 0.002 $m^3\ min^{-1}$) was placed at the breathing zone of the volunteers, who carried it during the working hours (approximately 8 hr). Three samples were obtained from each volunteer (sampling during three consequent working days). Particles were collected on quartz filters and mass concentration determination was done using the gravimetric method (Saraga et al., 2010). In most of the cases, measurements were conducted simultaneously for two volunteers who –although being in the same indoor environment– presented a different characteristic: i.e. smoker and non smoker, stable and in motion, close to or away from a window etc. Detailed information about the activities conducted during the sampling period was reported by the volunteers in a questionnaire. Furthermore, average air temperature and relative humidity during the sampling periods were recorded. Finally, the air exchange rates (AERs) were measured by the concentration–decay method using metabolic CO_2 as the tracer gas (Aizlewood and Dimitroulopoulou, 2006; Asadi et al., 2011) for the examined environments (except for the cases of complex or multi–zone environments: school, mall, chemical laboratory, taxi).

Figure 1. *TSI Sidepak sampling pump (SP530).*

Table 1 summarizes the characteristics of the sixteen work-places selected for the purpose of the measurements while Figure 2 presents the location of the buildings (the case of the taxi is not included).

3. Results and Discussion

3.1. Respirable particulate matter levels

As mentioned, in each case, measurements were conducted simultaneously for two volunteers. In cases that sampling took place under the same conditions (i.e. both volunteers were non smokers or remained stable etc.), the results from the two samplers showed strong correlation (Pearson r=0.901, p<0.001). In cases that one of the volunteers was exposed to a strong source (smoking, spraying etc.), no correlation was observed (r=0.41, p<0.05). The maximum concentration was noticed for the hairdresser (286 $\mu g\ m^{-3}$) who –during sampling– had been exposed to two significant aerosol sources: sprays and hairdryer emissions (van der Wal et al., 1997). In terms of health, the magnitude of this concentration for human exposure is high. Indeed, in a retrospect-tive study, a higher asthma incidence has been observed for the hairdressers (3.9 per 1 000 persons) compared to the referents–women randomly selected from the general population (Albin et al., 2002). It has to be noted that the national legislation (based on the EU Directive 88/642/EEC) for an 8–hour exposure to respirable particulate matter in workplaces includes the limit value of 5 $mg\ m^{-3}$ (EC, 1998). In terms of this, RPM levels measured in this study were lower than the established limit value. The minimum concentration was measured for the housewife (27 $\mu g\ m^{-3}$) and the employee in the optics shop (31 $\mu g\ m^{-3}$).

Figures 3a–3e present comparative results for five categories: cases that measurements were conducted in places located in urban areas, those that measurements were conducted in places located in suburban areas, places with intense resuspension due to great number of visitors, places characterized as office environ-ments and cases where smoking activity occurred.

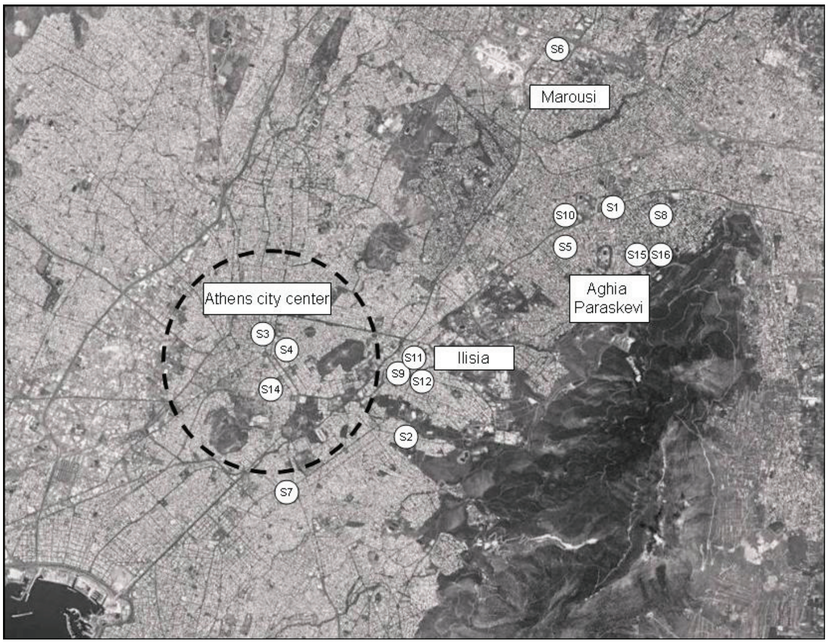

Figure 2. *Location of the sampling sites: S1=kiosk, S2=school, S3=bar, S4=restaurant, S5=house, S6=mall, S7=car garage, S8=gym, S9=pharmacy store, S10=optical store, S11=photocopy center, S12=hairdresser's, S14=office (urban area), S15=office (suburban area), S16=chemical laboratory. The case of the taxi is not included.*

Table 1. *Characteristics of the sixteen workplaces selected for the purpose of the measurements*

	Chemical Laboratory	Office (Suburban Area)	Office (Urban Area)	Taxi	Hairdresser's	Photocopy Center	Optical Store	Pharmacy Store
Location	Ag. Paraskevi (suburban)	Ag. Paraskevi (suburban)	Center of Athens (urban)	Not stable	Ilisia (suburban)	Ilisia (suburban)	Ag. Paraskevi (suburban)	Ilisia (suburban)
Floor	Ground	Ground	1st	Road	Ground	Ground	Ground	Ground
Number of Occupants	5 employees (2 volunteers)	2 employees (volunteers) and apr.10 visitors	2 employees (volunteers) and appr. 10 visitors	Driver (volunteer) and 15 passengers	2 employees (volunteers) and 8 customers	2 employees (volunteers) and appr. 20 customers	2 employees (volunteers) and >3 customers	2 employees (volunteers) and appr. 20 customers
Volunteers Movement	Continuous	Steady	Steady	Steady	Continuous	Continuous	Continuous	Continuous
Smokers in the Building	0	One of the volunteers	0	1 (Driver)	0	0	0	One of the volunteers
HVAC	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Ventilation	Physical	Physical	Physical	Physical and mech.	Physical	Physical	Physical	Physical
Outdoor Environment	Trees, parking area	Trees, parking area	Roads, densely–populated area	High traffic roads	Roads, densely–populated area	Roads, densely–populated area	Roads, blocks of flats	Roads, densely populated area
Distance From Closest Road	High traffic road, 500 m	Peripheral highway, 100m	High traffic road (Stadiou) 10 m	On the road	High traffic road, 2 m	High traffic road, 2 m	High traffic Mesogeion avenue (30 m)	High traffic road, 2 m
Potential PM Indoor Sources	Resuspension	Photocopy machines, printers, PC, resuspension, smoking	Photocopy machines, printers, resuspension	Smoking	Sprays, hair dryers, resuspension	Photocopy machines , PC, resuspension	Cleaning activities, resuspension	Dust resuspension, smoking
Average Temperature Indoors	27 °C	31 °C	24 °C	31.5 °C	28 °C	28 °C	30 °C	27 °C
Average Relative Humidity Indoors	32%	46%	33%	70%	35%	40%	41%	39%

	Gym	Garage	Mall	House	Restaurant	Bar	School	Kiosk
Location	Ag. Paraskevi (suburban)	Neos Kosmos (urban)	Marousi (suburban)	Ag. Paraskevi (suburban)	Exarchia (urban)	Exarchia (urban)	Kesariani (suburban)	Ag. Paraskevi (suburban)
Floor	1st	Ground	Ground/1st/ 2nd/3rd	3rd	Ground	Ground	1st and 2nd	Ground
Number of Occupants	2 employees (volunteers) and >30 customers	2 employees (volunteers) and appr. 10 customers	2 volunteers, crowded	3 occupants (2 volunteers)	2 volunteers and >30 customers	2 volunteers and >30 customers	2 volunteers , >200 kids (hole building)	1 volunteer
Volunteers Movement	Continuous	Continuous	Continuous	Continuous	Steady	Steady	Continuous	Steady
Smokers in the Building	0	2 (Volunteers)	0	0	0	The majority of the customers	One of the volunteers	1
HVAC	Yes	No	No	Yes	Yes	No	No	No
Ventilation	Physical	Physical	Physical and mechanical	Physical	Physical	Physical	Physical	Physical
Outdoor Environment	Trees, blocks of flats	Roads, densely–populated area	Large open area, peripheral highway	Trees, blocks of flats	Roads, densely–populated area	Roads, densely–populated area	Roads, densely–populated area	Roads, densely–populated area
Distance From Closest Road	High traffic road, 10 m	Low traffic road, 5 m	Peripheral highway, 100 m	Low traffic road (5 m), Mesogion avenue, 200 m	Low traffic road, 5 m	Low traffic road, 5 m	Low traffic road, 5 m	High traffic Mesogeion avenue (2 m)
Potential PM Indoor Sources	Resuspension	Garage machines, resuspension, sprays	Resuspension	Cleaning activities, cooking	Cooking, dust resuspension	Smoking, resuspension	Resuspension (smoking for the smoker volunteer)	Smoking, resuspension
Average Temperature Indoors	30 °C	20 °C	26 °C	26 °C	22 °C	25 °C	20 °C	29 °C
Average Relative Humidity Indoors	33%	35%	39%	39%	45%	45%	45%	55%

Concerning cases in urban areas (Figure 3a), the maximum concentration was noticed for the hairdresser and the volunteers in the bar and the pharmacy store. The common characteristic in all cases was the presence of a strong indoor source: spraying and hairdryer use for the hairdresser and smoking for the other two volunteers. On the other hand, in the absence of significant indoor sources, the role of air exchange is expected to be two–fold: in cases where the outdoor atmosphere is quite aggravated (eg. office at the center of the city) RPM levels for the volunteer sitting next to the window were elevated compared to those for the other volunteer (Figure 3a). In opposition, at the photocopy store and the restaurant, RPM levels were lower for the volunteer sitting next to a window or a door, implying the pollutants dispersion by the incoming air. In cases of suburban background (Figure 3b), the factors that contribute to particle levels are the same with those in cases of urban areas: a strong indoor source (e.g. smoking) and the influence from the outdoor environment. Nevertheless, on average, RPM levels in places in suburban areas are 26% lower than those in places situated in urban areas. A similar result was found by (Koistinen et al., 2001) where concentration levels for volunteers living in Helsinki suburban areas were lower by 28% than those living at the center of the city. Places visited by a great number of people (>30) during the day present a special interest, as resuspension is expected to be a significant source (Luoma and Batterman, 2001). The maximum concentration in this category was noticed in the bar (Figure 3c), due to intense smoking activity and especially for the volunteer sitting not close to the window (possible pollutants accumulation at the interior). On the contrary, the concentration for the volunteer who was close to the gym's window was twice than for the other volunteer. The lowest levels in this category were noticed for the volunteers who were walking in the mall and the non–smoker volunteer at the school. Comparing RPM levels in office environments (Figure 3d), the smoker's and passive smoker's levels (in the suburban office) presented the highest values while concentration levels for laboratory employees were significantly lower. Finally, the cases where the volunteer or other people smoked during sampling are collected in Figure 3e. It is a fact that measured RPM level for each volunteer is expected to depend on several additional (to the other cases) factors: passive or not smoking, smoking frequency, kind of cigarette etc. For instance, while both volunteers remained in the smoking–permitted bar, a remarkable difference of 95% is observed between them, possibly because of the poor air renewal in the interior of the room. On the contrary, particle levels for the two smoker volunteers in the car garage were similar because of their continuous movement to all over the indoor area. High concentrations were observed for the smoker employees at the office, the pharmacy store and the kiosk. The kiosk is characterized by its small volume and smoking can lead to an aggravated indoor air quality due to poor pollutant dispersion. Furthermore, it is situated close to a high traffic avenue (ground level), thus vehicle emissions contribution is expected to be significant.

It is obvious that there is a number of factors contributing to respirable particle levels as the building's location, the background area, the floor, the existence of strong indoor sources and anthropogenic activities, the volume and design of the room, the ventilation pattern, the volunteers' movement etc. As concentration levels presented significant variation (SD=57%) among the different cases, a statistical analysis examining the differences between the groups of cases was conducted through SPSS one–way ANOVA test (Table 2). The factors of the location (urban/suburban), the presence of smoking, the intense resuspension, the volume of the room or building and the range of air exchange rate were examined. No statistically significant differences were observed among groups except for the case of smokers/non smokers, implying smoking as a factor strongly influencing the levels of personal exposure to RPM. The statistically significant difference between cases with presence and absence of smoking was confirmed by the student's test (t=2.682, p=0.012).

3.2. The role of the air exchange rate

Room's air renewal plays a crucial, two–fold role in pollutant levels, as incoming air from an aggravated outdoor atmosphere can increase indoor levels (i.e. the case of the office in the city center) or lead to pollutants dispersion and concentration's decrease (i.e. the case of photocopy store, gym, bar, car garage). In the present study, the air exchange rate was measured for all the examined environments except for the cases of the taxi and the school, the mall and the chemical laboratory (multi–zone environments). The measured air exchange rates are presented in Figure 4. As shown, the lowest values were noticed for the pharmacy store and the hairdressers', which in combination with the presence of strong indoor sources (spraying and smoking respectively), lead to high levels of respirable particles. The highest values were noticed for the car garage and the kiosk which presented the common characteristic of a large opening (door and window respectively) relatively to the total buildings' volume. However, in the two last cases, frequent air renewal played an opposite role: at the kiosk, the indoor atmosphere was strongly influenced from both smoking activity and vehicle emissions, thus high air exchange rate did not lead to particle levels decrease. On the other hand, at the car garage, high air exchange rate seems to contribute positively to particle levels decrease, although the sources of smoking and resuspension existed.

Table 2. *ANOVA test results*

	Group of Cases	N (cases)	Mean (μg m^{-3})	St. Dev. (μg m^{-3})	*p*–value
Location [b]	Urban	51	144.4	80.84	0.143
	Suburban	45	102.5	75.99	
Smoking	Smoking	30	176.2	77.02	0.012 [a]
	Non smoking	66	101.4	71.53	
Resuspension [b]	>50 visitors (intense resuspension)	54	131.8	82.39	0.580
	<50 visitors	42	115.6	79.39	
Room/building volume	<150 m^3	48	146.5	87.39	0.127
	>150 m^4	48	103	68.19	
Air exchange rate [b]	<1 h^{-1}	33	143.9	103.2	0.821
	1–5 h^{-1}	18	120.5	86.01	
	>5 h^{-1}	21	150.5	65.73	

[a] *level of significance p<0.05*
[b] *The case of the taxi was excluded for the cases of location, resuspension and air exchange rate*

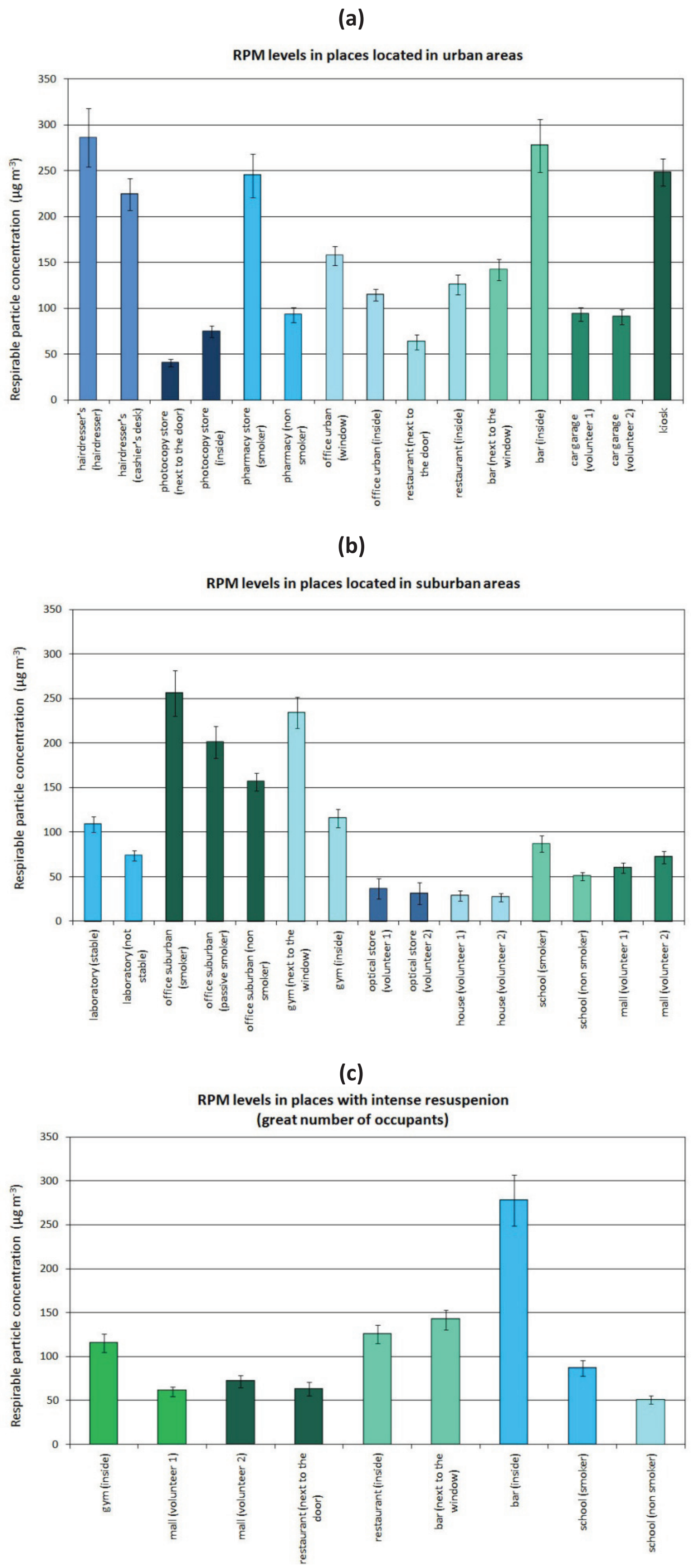

Figure 3. *RPM levels (μg m*$^{-3}$*) in places located in urban areas* ***(a)****, RPM levels (μg m*$^{-3}$*) in places located in suburban areas* ***(b)****, RPM levels (μg m*$^{-3}$*) in places with intense resuspension (great number of occupants)* ***(c)****.*

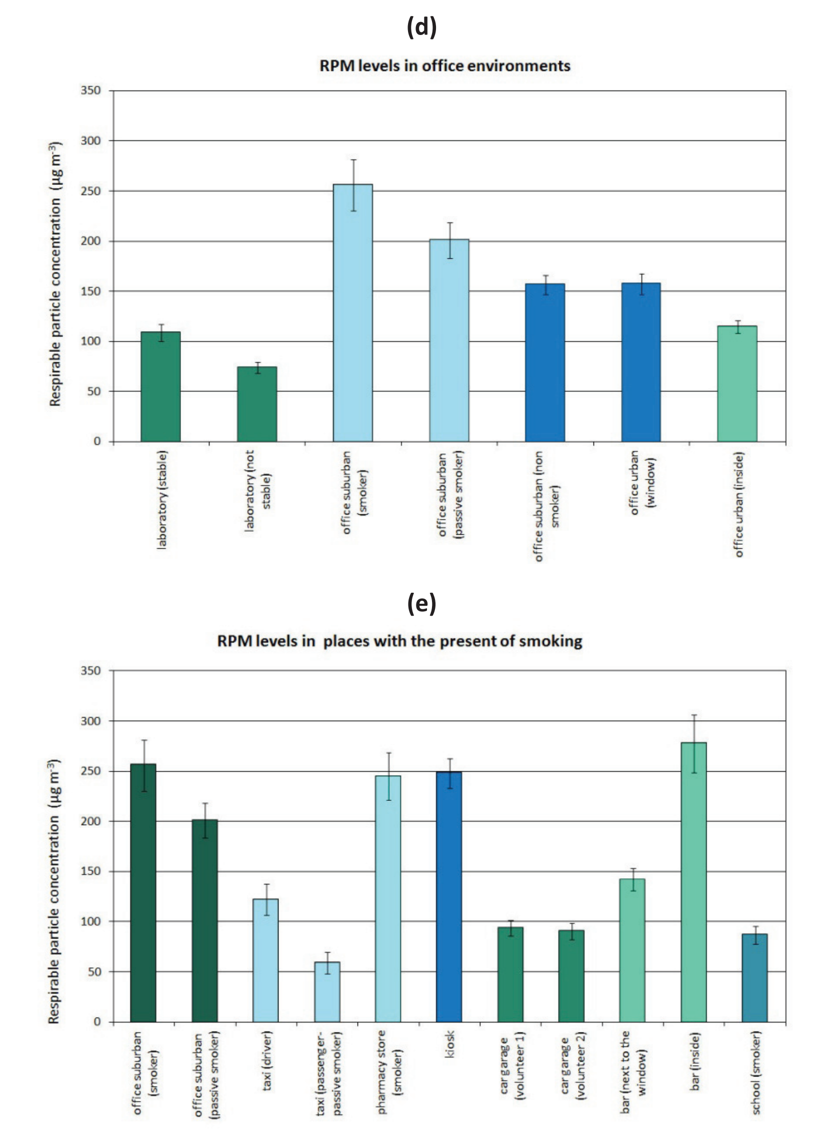

Figure 3. *Continued. RPM levels (μg m^{-3}) in office environments* ***(d)****, RPM levels (μg m^{-3}) in places with the presence of smoking* ***(e)****.*

No correlation was found (Pearson r=0.31, p<0.05) between air exchange rate and average RPM levels for the cases of Figure 4 due to this complex combination of the ventilation pattern, indoor and outdoor sources. This is also verified by the fact that although no statistically significant difference was observed through ANOVA test when three groups of cases of different ventilation rate (<1 h^{-1}, 1–5 h^{-1}, >5 h^{-1}) were compared (Table 2). On the contrary, when cases that smoking took place are excluded, a strong correlation is observed between particle concentration and air exchange rate (Pearson r>0.9, p<0.05). Finally, a multivariate analysis of variance (MANOVA) analysis was also performed for identifying the effects of air exchange rate on RPM concentrations among the groups. A statistically significant difference was observed in two cases: between places with/without intense resuspension (p<0.001) and between smoking/non smoking groups (p=0.014), implying an important influence of ventilation in these cases.

4. Conclusions

The present study aimed at a qualitative comparison of the respirable particles (RPM) levels in sixteen different indoor workplaces. RPM levels presented strong variation among the different cases, as several factors contribute: the building's location, the background area, the floor, the proximity to a heavy traffic road, the presence of strong indoor sources and anthropogenic activities, the ventilation pattern, the volunteers' movement etc.

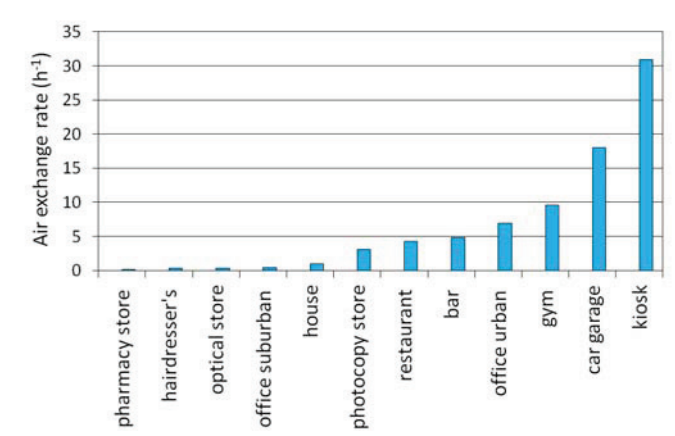

Figure 4. *Air exchange rates (h^{-1}).*

In cases of relatively low RPM levels and absence of strong indoor sources (such as smoking, spray use etc.), it seems that it is the outdoor environment that mainly contributes to particle levels, especially when the air renewal is frequent. Furthermore, the results indicated smoking as a factor which strongly influences the exposure levels of both smokers and passive smokers. Finally, it was found that the building ventilation pattern comprises an important factor influencing the exposure levels especially in cases of buildings with great number of visitors (resuspension) and smoking.

To conclude, as human exposure to particles is quite complex, a further study of the chemical components of particles can lead to source identification in a variety of workplaces. The connection of results with human health effects would support epidemiological studies, aiming at improving the quality of life.

References

Aizlewood, C., Dimitroulopoulou, C., 2006. The HOPE Project: The UK experience. *Indoor and Built Environment* 15, 393–409.

Albin, M., Rylander, L., Mikoczy, Z., Lillienberg, L., Hoglund, A.D., Brisman, J., Toren, K., Meding, B., Diab, K.K., Nielsen, J., 2002. Incidence of asthma in female Swedish hairdressers. *Occupational and Environmental Medicine* 59, 119–123.

Asadi, E., Costa, J.J., da Silva, M.G., 2011. Indoor air quality audit implementation in a hotel building in Portugal. *Building and Environment* 46, 1617–1623.

Ashok, V., Gupta, T., Dubey, S., Jat, R., 2014. Personal exposure measurement of students to various microenvironments inside and outside the college campus. *Environmental Monitoring and Assessment* 186, 735–750.

Asmi, E., Antola, M., Yli–Tuomi, T., Jantunen, M., Aarnio, P., Makela, T., Hillamo, R., Hameri, K., 2009. Driver and passenger exposure to aerosol particles in buses and trams in Helsinki, Finland. *Science of the Total Environment* 407, 2860–2867.

Berghmans, P., Bleux, N., Panis, L.I., Mishra, V.K., Torfs, R., Van Poppel, M., 2009. Exposure assessment of a cyclist to PM_{10} and ultrafine particles. *Science of the Total Environment* 407, 1286–1298.

Buonanno, G., Stabile, L., Morawska, L., 2014. Personal exposure to ultrafine particles: The influence of time–activity patterns. *Science of the Total Environment* 468, 903–907.

Chaloulakou, A., Mavroidis, I., Duci, A., 2003. Indoor and outdoor carbon monoxide concentration relationships at different microenvironments in the Athens area. *Chemosphere* 52, 1007–1019.

Chow, J.C., Engelbrecht, J.P., Freeman, N.C.G., Hashim, J.H., Jantunen, M., Michaud, J.P., de Tejada, S.S., Watson, J.G., Wei, F.S., Wilson, W.E., Yasuno, M., Zhu, T., 2002. Chapter one: Exposure measurements. *Chemosphere* 49, 873–901.

Diapouli, E., Chaloulakou, A., Spyrellis, N., 2007. Levels of ultrafine particles in different microenvironments – implications to children exposure. *Science of the Total Environment* 388, 128–136.

EC (European Communities), 1998. Directive 88/642/EEC Amending Directive 80/1107/EEC on the Protection of Workers from the Risks Related to Exposure to Chemical, Physical and Biological Agents at Work.

Guo, H., Lee, S.C., Li, W.M., Cao, J.J., 2003. Source characterization of BTEX in indoor microenvironments in Hong Kong. *Atmospheric Environment* 37, 73–82.

Hackshaw, A.K., Law, M.R., Wald, N.J., 1997. The accumulated evidence on lung cancer and environmental tobacco smoke. *British Medical Journal* 315, 980–988.

Halios, C.C., Helmis, C.G., Eleftheriadis, K., Flocas, H.A., Assimakopoulos, V.D., 2009. A comparative study of the main mechanisms controlling indoor air pollution in residential flats. *Water Air and Soil Pollution* 204, 333–350.

Jones, J., Stick, S., Dingle, P., Franklin, P., 2007. Spatial variability of particulates in homes: Implications for infant exposure. *Science of the Total Environment* 376, 317–323.

Koistinen, K.J., Hanninen, O., Rotko, T., Edwards, R.D., Moschandreas, D., Jantunen, M.J., 2001. Behavioral and environmental determinants of personal exposures to $PM_{2.5}$ in *EXPOLIS* – Helsinki, Finland. *Atmospheric Environment* 35, 2473–2481.

Lai, H.K., Bayer–Oglesby, L., Colvile, R., Gotschi, T., Jantunen, M.J., Kunzli, N., Kulinskaya, E., Schweizer, C., Nieuwenhuijsen, M.J., 2006. Determinants of indoor air concentrations of $PM_{2.5}$, black smoke and NO_2 in six European cities (EXPOLIS study). *Atmospheric Environment* 40, 1299–1313.

Long, C.M., Sarnat, J.A., 2004. Indoor–outdoor relationships and infiltration behavior of elemental components of outdoor $PM_{2.5}$ for Boston–area homes. *Aerosol Science and Technology* 38, 91–104.

Luoma, M., Batterman, S.A., 2001. Characterization of particulate emissions from occupant activities in offices. *Indoor Air–International Journal of Indoor Air Quality and Climate* 11, 35–48.

Moghaddasi, Y., Mirmohammadi, S., Ahmad, A., Nejad, S.E., Yazdani, J., 2014. Health–risk assessment of workers exposed to flour dust: A cross–sectional study of random samples of bakeries workers. *Atmospheric Pollution Research* 5, 113–118.

Pilou, M., Saraga, D., Tsangaris, S., Vasilakos, S., Housiadas, C., 2010. Particle deposition in the lung during domestic activities. *International Aerosol Conference,* August 29 – September 3, 2010, Helsinki, Finland.

Pope, C.A., Dockery, D.W., 2006. Health effects of fine particulate air pollution: Lines that connect. *Journal of the Air & Waste Management Association* 54, 709–742.

Pope, C.A., Burnett, R.T., Thun, M.J., Calle, E.E., Krewski, D., Ito, K., Thurston, G.D., 2002. Lung cancer, cardiopulmonary mortality, and long–term exposure to fine particulate air pollution. *JAMA–Journal of the American Medical Association* 287, 1132–1141.

Saraga, D.E., Maggos, T., Helmis, C.G., Michopoulos, J., Bartzis, J.G., Vasilakos, C., 2010. PM_1 and $PM_{2.5}$ ionic composition and VOCs measurements in two typical apartments in Athens, Greece: Investigation of smoking contribution to indoor air concentrations. *Environmental Monitoring and Assessment* 167, 321–331.

Sarnat, S.E., Coull, B.A., Ruiz, P.A., Koutrakis, P., Suh, H.H., 2006. The influences of ambient particle composition and size on particle infiltration in Los Angeles, CA, residences. *Journal of the Air & Waste Management Association* 56, 186–196.

Siddiqui, H., Ashquin, M., Prasad, R., Arif, J.M., Patil, T.N., Ahmad, I., 2011. Industrial hygiene and toxicity studies in unorganized bone–based industrial units. *Environmental Monitoring and Assessment* 176, 213–223.

Sundell, J., 2004. On the history of indoor air quality and health. *Indoor Air* 14, 51–58.

van der Wal, J.F., Hoogeveen, A.W., Moons, A.M.M., Wouda, P., 1997. Investigation on the exposure of hairdressers to chemical agents. *Environment International* 23, 433–439.