STUDY OF CHILDREN EXPOSURE TO PARTICULATE MATTER INDOOR AIR INSCHOOL CLASSROOMS

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SUMMARY

This study is about the evaluation ofchildren exposure to PM_{10} and $PM_{2.5}$to Indoor Air in school classrooms. An identification of PM_{10} and $PM_{2.5}$ concentrations levels, not onlyindoor,but also outdoor were made to understand indoor/outdoor PM relations. A study of its impact in children exposure was made. Indoor and outdoor PM concentrations (PM_{10} e $PM_{2.5}$)were measuredin one school in Barreiro city in Portugal.In this school, indoor classroom activities were registered and related with indoor and outdoor PM sources.A children population that attend the city hospital urgencies was correlated to pollutant concentration levels. Pollutant dispersion simulation wasalso made using ADMS Urban to study the outdoorconcentrations in the city. Also a typical one day short term exposure study to the child population of the school was made, showing that 1,68 higher short term exposure values can be achieved to a child, depending on classroom and home (indoor) concentrations and playground and trajectory (outdoor) concentrations levels differences.

Keywords:*exposure, indoor air quality, outdoor air quality, $PM_{10}$and $PM_{2.5}$concentrations, children health*

1. INTRODUTION

Indoor air pollutionis raising its importance nowadays. It is known thatin urban environmentspeople spend about 90% of their time indoor,being exposed to a cocktail of physical-chemical and microbiological pollutants, most of the time with high levels of pollutant concentrations.Several studies about indoor air quality in schools identify pollutant sources and concentrations, to propose and evaluateways to improve indoor air quality [1][3][4][5][6][7]. Children in scholar age spend one-third of their normal day in school,thereforegood air quality inside the building must be guarantee. Indoor pollution can cause negative effects on health such as headache, dizziness, nauseas, exacerbation of respiratory problems like asthma, wheezing, allergies, and can be a way to disseminate viral diseases and bacterial infections, decreasingconcentrationand learning capacity [4].Cleaning and natural ventilation are not enough to protect school community from the adverse effects of indoor air pollution.It is important to optimise the ventilation system, through mechanical or natural ventilationand with other strategies that induces inlet of outdoor air less contaminated to renovate the indoor air [5]. This study focus only on particle matter, and specifically in $PM_{2.5}$ and PM_{10}effectsand was performed in a school in Barreiro city (Portugal).Barreiro is a typical medium Portuguese city, is almost plane with the highest point at approximately 10 meters above sea level.The actual resident population is approximately 80,000 inhabitants and the major economic activities of the city are metal mechanical and chemical industries. Like other similar cities near the capital (Lisbon) traffic is an important source of pollution.

2. METHODS

The characterization of children exposure to air pollutants was made by measuring outdoor and indoor PM_{10} and $PM_{2.5}$ in one school in Barreiro and following the urgent cases in the city Hospital.The school has an air quality monitoring station inside the school perimeter,permittinga real time comparison between indoor and outdoor PM_{10}. This allowsrelating the influence of outdoor pollution in the indoor. The measurements were made hourly by a Beta Gauge Dust Monitor for two weeks one for PM_{10} and the other for $PM_{2.5}$. The same method is used outdoor and the inlet of PM was about 2m above the ground both indoor and outdoor.

Outdoor measurements were provided by Comissão de Coordenação e Desenvolvimento Regional de Lisboa e Vale do Tejo (CCDR-LVT), who manage the air quality monitoring stations network in Barreiro, as well as meteorological data, which was also provided by Escola Básica do 2º e 3º ciclos D. Luís Mendonça Furtado. The air quality station only measures PM_{10}.

The school has only natural ventilation provided by opening windows. The classroom has standard school furniture and a blackboard.Windows size and directionwas also considered as well asthe floor material and windowsprotection type. This characterization is resumed in table 1.

Table 1. Classroom characterization

Volume (m^3)	180
No. Windows	7
Windows area (m^2)	2/window
Windows direction	NE/SE
Windows protection	Blind
Floor type	Wood
Furniture	Wooden chipboard and metal

The effect of air pollutants in health was studied in the paediatric population, children from 0 to 16 years, who attend the public hospital with respiratory problems. These data is being collected by paediatric doctors from Barreiro city hospital fromOctober 2003 to November 2004and has being confronted with air quality measurements.

To understand the behaviour of air pollutants in the outdoor, a simulation model, ADMS-Urban, was used. This software modelled the dispersion and concentration of air pollutants in the city. These results were important to know the most affected areas in the city in most common meteorological conditions which permits to study the children living environment and choose the problematic areas to develop the study. The model was validated with the air quality measurements from the city network.

To study the exposure of PM_{10} concentrations (outdoors and indoors) in the children population of the school a short term personal exposure study was developed. Short term personal exposure $E(\Delta t)$ in a period of time t can be expressed as:

$$E(\Delta t) = \int_0^t C(t)dt \cong C_i t_i$$

Where C(t) is the pollutant concentration in a particular time t in µg/m^3, C_i is the discrete concentration in cellule i in µg/m^3 and t_i is time of expose in cellule i in seconds. Two children from two different classrooms were selected to compare the short term exposure to PM_{10}.

3. RESULTS

3.1. PM measurements

PM_{10} and $PM_{2.5}$ measurements were made in different periods of time, the relation between these two PM classes was studied.Figure 1 shows the behaviour of indoor PM_{10} and $PM_{2.5}$ in the same period of the day, in the two different weeks of measurements. As we can see PM behaves in the same way, whether are PM_{10} or $PM_{2.5}$, according to the activity developed in the classroom.

In general, both PM concentration start to increase in cleaningactivities at 7a.m., by re-suspension, reaching the highest value during class activities, depending on the class hours, mostly due to PM re-suspension, penetration and some generated inside. The re-suspension is due to children physical activities, while the penetration is caused by open windows and doors and the generated inside results mostly,from the use of chalk to write on the blackboard and the use of pencil and rubber.At night and on weekends PM concentration is lower since the classroom is closed. The small variation illustrated on the graphic can be due to penetration, across chinks, from outdoor.

Since the measurements where made in different periods, not at the same time, some values of $PM_{2.5}$ are higher than PM_{10} for the same period of the day. This period is nearly always from 2 to 6a.m. which shows that $PM_{2.5}$ deposition is slower than PM_{10}, remaining in the air for a longer period of time. This fact does not occur on Sunday where PM_{10} are always higher than $PM_{2.5}$ since there is no activity developed on weekend.

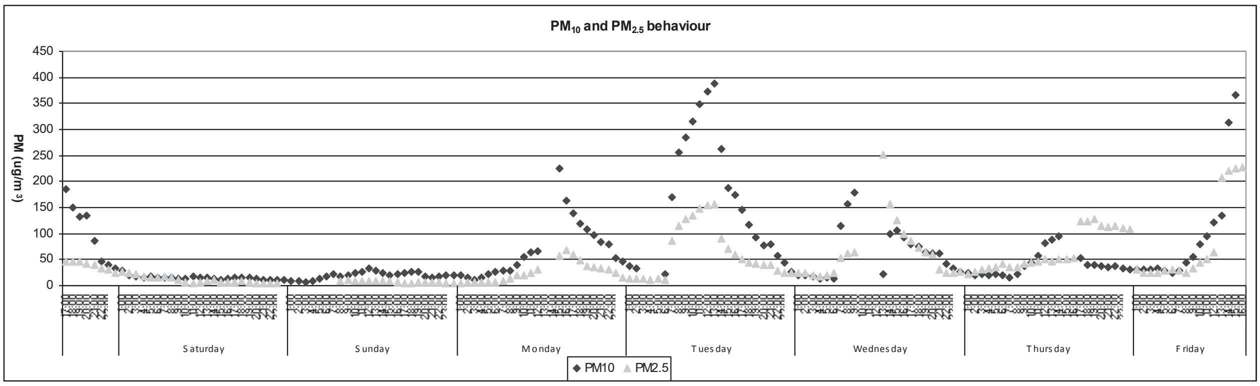

Fig. 1. PM behaviour in the same period of activity days

In order to compare the influence of different PM sources inside the classroom, data was separated in two major different periods, weekdays and weekends. These two periods allow the study of PM behaviour with indoor sources and without them.

To study the impact of outdoor sources in indoor PM behaviour, weekend PM data was studied, since there is no activity in the classroom and penetration is the only source of PM. Figure 2 shows how PM_{10} and $PM_{2.5}$ behaves to Outdoor PM_{10},on weekend. As has been said the indoor PM measurements were made in two different weeks, one for PM_{10} and the other for $PM_{2.5}$. Figure 2 presents the results of indoor and outdoor PM_{10} on a weekend, showed by lines and indoor $PM_{2.5}$ and outdoor PM_{10} on another weekend, showed by points. Indoor $PM_{2.5}$ is compared to outdoor PM_{10}, since $PM_{2.5}$ are not measured outdoor.

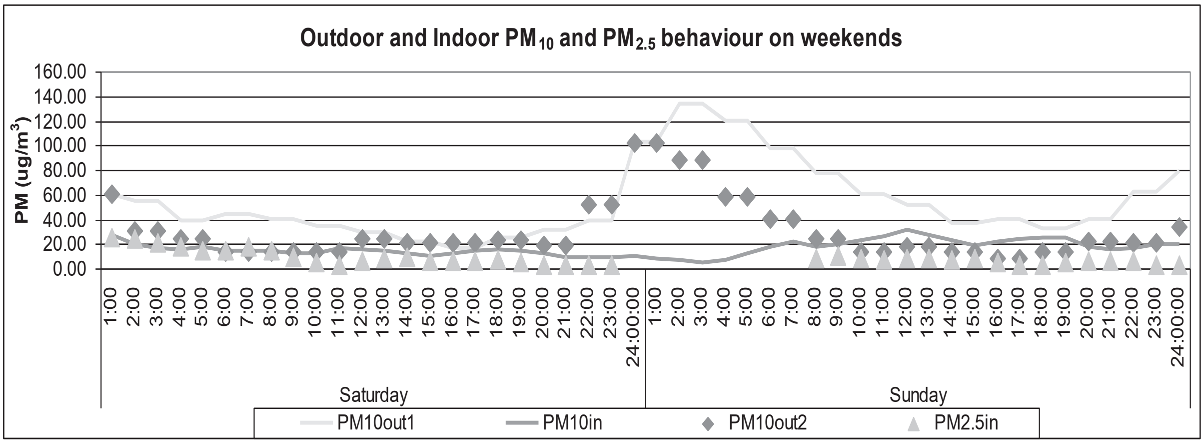

Fig. 2. Influence of Outdoor PM_{10} in Indoor PM_{10} and $PM_{2.5}$behaviour on weekend

The graphic shows that both outdoor and indoor PM behaves more or less in the same way showing the permeability of the building in spite of the closed windows. Taking into account that two different weekends are represented in the graphic, it can be seen the agreement between measures outdoor in both weekends. The highest value is reached around 1a.m., showing a delay in the first weekend. Indoor measurements, both PM_{10} and $PM_{2.5}$ show a slight increase after the outdoor high concentration hour, due to penetration. However the building provides good protection from outdoor sources, since the feedback to the outdoor concentrations increase is very small.Table 2 presents the average ratio between indoor and outdoor PMin three different periods;using all data. There is also a separation by night and day.Considering all data of average ratio, weekdays have higher values even exceeding the unit, showing the importance of indoor sources.Indoor $PM_{2.5}/PM_{10}$have always a great value at night meaning that $PM_{2.5}$ deposition is slower than PM_{10}, as concluded before, while indoor $PM_{2.5}$/outdoor PM_{10} and indoor PM_{10}/outdoor PM_{10} have greater values during day.Indoor PM_{10}/outdoor PM_{10}ratio exceeds the unit when the classroom has interior activity.

Table 2. Ratio between PM indoor and outdoor

		$PM_{2.5}$In/ PM_{10}In	$PM_{2.5}$In/ PM_{10}Out	PM_{10}In/ PM_{10}Out
Total	Total	0.86	0.84	1.29
	Day	0.79	1.25	2.41
	Night	0.94	0.44	0.70
Weekend	Total	0.52	0.46	0.40
	Day	0.44	0.56	0.53
	Night	0.65	0.35	0.27
Weekday	Total	0.99	1.09	1.94
	Day	0.96	1.76	3.04
	Night	1.02	0.49	0.85

.3.2. Health effects on a children population

Air quality and children data were statistically treatedto study the possible relation between pollutants and respiratory problems, in a children population observed in Barreiro city hospital.The most significant correlations were found for CO. Figure 3 shows that the number of children observed in hospital urgencies is higher in winter conditions following the tendency of pollutant concentrations in this period.

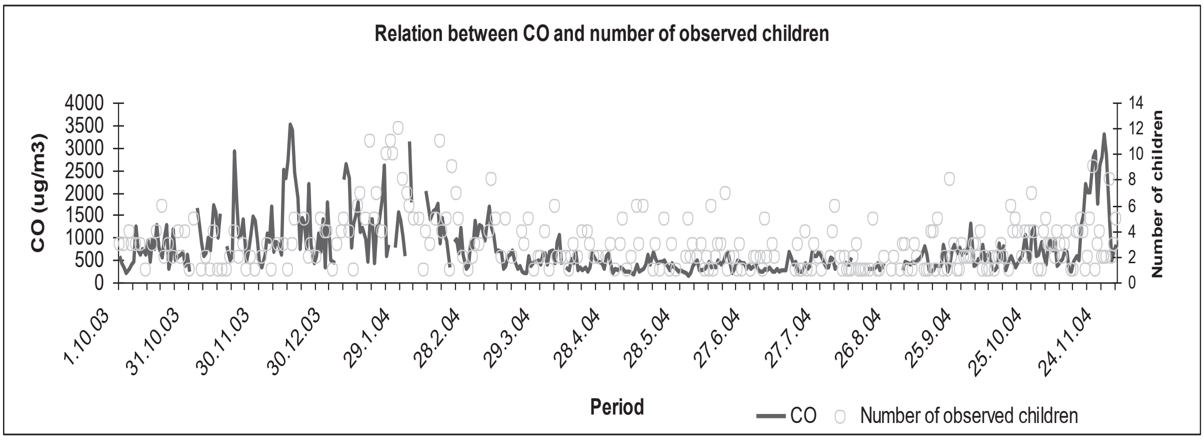

Fig. 3. Relation between CO and number of observed children

In spite of the relation presented in Figure 3, the analyses results of children exposure to urban air quality were inconclusive for other pollutants, like PM. This relation is not easy to predict due to a large number of variables which are being study for further conclusions and due to the reduced size of the sample.

3.3. Simulation work on PM_{10} outdoor concentrations

ADMS-Urban was used to know the outdoor air pollutantsdispersion and concentration in Barreiro city, for most frequent meteorological conditions in winter and summer time. With the simulation results and it´s validation, it’s possible to know the concentrations in the city streets. Figures 4 and 5 representPM_{10} dispersion and concentration in winter meteorological most frequent conditions for traffic and industry, respectively. Figure 6 and 7 show the same results in most frequent summer conditions.

Fig. 4. PM_{10}outdoor concentration from traffic (winter)

Fig 5. PM_{10} outdoor concentration from industry (winter)

In winter conditions, industry show higher concentration, but the dispersion of PM_{10} from traffic affects more the city centre. The higher value from traffic is about 43µg/m^3 near the road wile for industry the value is around 102µg/m^3. However, despite of industry emission concentration is higher, the plume doesn't affect citizens so directly like traffic sources, since this emission is produced near the floor where citizens circulate (Figures 4 and 5).In summer (Figures 6 and 7) and due to wind direction industry affects more the city centre than traffic does. The concentration is higher and the plume goes directly to the city centre. Due to higher wind speed near the surface, traffic emissions dispersion is stronger reducing PM_{10} concentration.

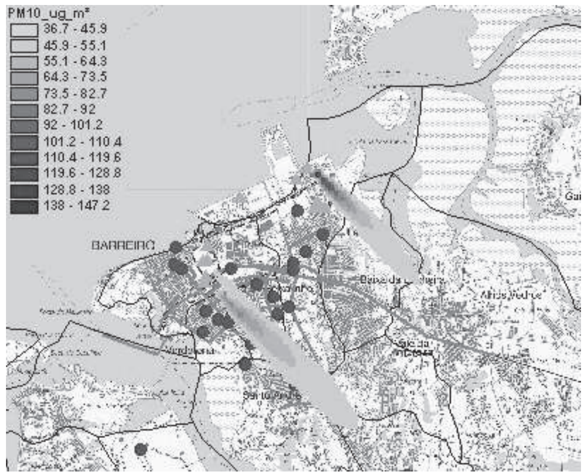

Fig. 6. PM_{10} outdoor concentration from traffic (summer)

Fig 7. PM_{10} outdoor concentration from industry (summer)

Summer most frequent meteorological conditions seem to be the most unfavourable scenario for PM_{10} from industry, reaching concentrations of 102µg/m^3in city centre (Figure7). According to Environmental Institute from Portugal, this value fits on week Air Quality Index.Inthese conditions, city centre is more affected due to the most frequent wind direction, NW. However the wind speed is higher which permit a better dispersion near the surface, so traffic emissions have lowest concentration than in winter.

3.4. Children exposure to PM_{10} concentrations

To study the level of exposure of the school child population to PM concentrations (indoor and outdoor), a typical one day short term exposure study was made. Two different children from two different classes and living in two different locations were identified and one day short term exposure was calculated for each.Indoor (classroom and home) and outdoor (playground and walking trajectories) were identified as well times of exposure in each environment. Results for short term exposure for each child were dimensionless normalised with the basis value. Results are showed in table 3.

Table 3. Short term exposure for two different children

	indoor classroom			Outdoor playground			indoor classroom			Outdoor back home trajectory			indoor home			Outdoor trajectory to school			
	PM10 average concent. (μg/m3)	hour	time (s)	PM10 average concent. (μg/m3)	hour	time (s)	PM10 average concent. (μg/m3)	hour	time (s)	PM10 average concent. (μg/m3)	hour	time (s)	PM10 average concent. (μg/m3)	hour	time (s)	PM10 average concent. (μg/m3)	hour	time (s)	dimension less short term exposure
Child X Class A	23,28	8h-11h	10800	47,5	11h-11h30m	1800	23,28	11h30-13h	5400	45,0	13h-13h30	1800	30,0	13h30-7h30	64800	44,3	7h30m-8h	1800	1,68
Child Y Class B	21,94	8h-11h	10800	29,2	11h-11h30m	1800	21,94	11h30-13h	5400	22,0	13h-13h30	1800	16,0	13h30-7h30	64800	23,7	7h30m-8h	1800	1,00

Results show that the two children studied (child X – class A and child Y – class B) considering one day exposure,child X is exposed to 1.68 times higher values than child Y. This is due not only to the indoor classroom PM10 concentrations but also home indoor values and outdoor (playground and walking trajectories) that are higher for child X.

4. CONCLUSIONS

PM_{10} and $PM_{2.5}$ measurements were made inside a classroom and compared with outdoor PM_{10} concentration, to study the impact of outdoor and indoor sources in a school environment.The two classes of PM studied, behaves identically, increasing in activity hours due to re-suspension, penetration and inside generation.The lower inside concentration is reached on weekends and nights, when the classroom is closed, showing the good protection from outdoor pollution.Some $PM_{2.5}$ values are higher than PM_{10}, especially at night, showing the slower deposition velocity of $PM_{2.5}$, remaining in the air for a longer period.The average ratio between indoor and outdoor PM showed the importance of indoor sources, since in weekdays, especially during day time, had higher values.Indoor $PM_{2.5}$ and PM_{10} ratio was higher during night proving the slower deposition velocity from $PM_{2.5}$. Indoor, Outdoor correlations were superior during day time, especially on weekdays, resulting from penetration due to open windows. The lowest correlations on weekends show that the building is well protectedfrom outdoor pollution.Statistical study of children health and air pollution showed a relation between CO and attended urgent cases in the city hospital. It seems that in winter conditions CO concentration is higher as well as the number of children who received medical treatment. For other pollutants the results were inconclusive.A one day short term personal exposure study was also done, were results show that two children studied and compared, one child were exposed to 1,68 times higher values than other child, due to not only the indoor classroom PM_{10} concentrations but also home indoor values and outdoor (playground and walking trajectories) that are higher for child X.

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