# INDOOR AIR QUALITY IN THE CLASSROOMS OF SCHOOLS IN LA CORUÑA

E. Rodríguez[1], J.L. Castellanos[1], A. Baaliña[1], J.A. Santaballa[1], M.Golluboff[2], A. Arce[3], L. García[4]

[1]Escuela S. Marina Civil. Universidad de La Coruña. P° de Ronda, 51, 15011 La Coruña (Spain)
[2]Escuela Téncica S. Arquitectura. Universidad de La Coruña (Spain)
[3]Departamento de Ingeniería Química. Universidad de Santiago (Spain)
[4]Hospital Materno-Infantil "Teresa Herrera", La Coruña (Spain)

## ABSTRACT

The subject of this study was the indoor air quality of schools with natural ventilation in La Coruña (Spain). We took as reference the $CO_2$, $H_2O$ and CO contents of both the indoor and outdoor air. In both cases the monitoring was carried out over a 48 hour period using a photoacoustic infra-red spectroscopy multi-gas monitor. The outdoor air qualitiy was seen to be good. However during daytime occupation of the buildings the quality of the indoor air dropped substantially, caused by a lack of ventilation while the buildings were occupied, which should be remedied by an improvement in ventilation methods during daytime hours.

## INTRODUCTION

Insufficient renewal of air in school classrooms impinges negatively on pupils' educational performance, as well as on the health and welfare of pupils and teachers alike (1).
Studies have been carried out in several countries on indoor air quality in schools and other indoor invironments (2). However, to the best of our knowledge no such studies of similar environments have been carried out in this area.
In this study we examined the indoor air quality in classrooms in several schools in different urban areas of La Coruña. The city is located on the coast of Norh-west Spain. It has a population of 280000, a mild climate and a moderate level of industrial activity. The classrooms chosen for this study had natural ventilation, and normal teaching activity went on while the tests were being carried out. The ages of the pupils were 5,12, 14 and 17 years.
This study came to the conclusion the source of pollution with the greatest influence was the human factor. Among the more significant substances we would note the presence of carbon dioxide, water, carbon monoxide and hydrocarbons (2) (4). However for the purpose of comparing the quality of the indoor and outdoor air only the first three of these substances are recorded.

## METHODS

The area of the different classrooms chosen varied between 55 $m^2$ and 65 $m^2$. Each classroom had one or two external walls which contained manually-operated windows which allowed daytime lighting as well as ventilation. Generally the bottom of the window-frame was at the same height as the studients' work-tables. In all the cases studied here, renewal of air from the outside was carried out through natural ventilation. This was done by opening the manually-operated windows but no other independent entrance or outlet. During the data-collection period in January and February 1996 normal teaching activities took place in classrooms with an average class

occupation of between 30 and 35 people.
Measurements were taken using a photo-acoustic infra-red spectroscopy multi-gas monitor connected to a multi-point sampler controlled by a computer. Changes were recorded every 10 minutes simultaneously indoors and outdoors for a period of 48 hours. In order to test the uniformity of the indoor environment samples were taken at several points in the room.

## RESULTS

Fig. 1 reflects the variation of $CO_2$ in a 5 year-old pupils' classroom, where measurements began on the 17th at 08:00 hours, with a value of 875 mg/m$^3$. With occupation it rose to 2600 mg/m$^3$, at 12:00 hours and it decreased to 1000 mg/m$^3$ at 20:30 hours. Then, during the night it fell to 875 mg/m$^3$ at 07:00 hours of the the 18th. With occupation it reached 2025 mg/m$^3$ at 11:30 hours. Then it fell to 1850 mg/m$^3$ at 14:00 hours. It increased to 1900 mg/m$^3$ at 16:00 hours, falling again to 875 mg/m$^3$ at 22:00 hours and it stayed constant during the night to 08:00 hours of the 19th. With occupation it reached 4600 mg/m$^3$ at 12:45 hours and it dropped to 3000 mg/m$^3$ at 15:30 hours when the measurement ended. Outdoor levels varied between 700 and 800 mg/m$^3$. The indoor temperature oscillated between 15 °C and 22 °C.
Fig. 2 shows the variation of $CO_2$ in a classroom with 12 year-old pupils. Monitoring began on the 22nd at 21:00 hours, with a value of 1000 mg/m$^3$. It remained close to outdoor levels during the night until 08:00 hours of the 23rd. It reached 10200 mg/m$^3$ at 15:00 hours. Then it fell to almost the outdoor value and remained constant during the night. From 08:00 hours of the 24th, it rose to 6900 mg/m$^3$ at 13:00 hours. It dropped to 4200 mg/m$^3$ at 16:00 hours and rose again to 4700 mg/m$^3$ at 17:30 hours. Then it decreased again to the outdoor value. Outdoor levels varied between 850 and 950 mg/m$^3$. The indoor ambient temperature oscillated between 14 °C and 22 °C.
Fig. 3 indicates the variation of $CO_2$ in a classroom with 17 year-old pupils, the tests began on the 22nd at 21:00 hours, with a value of 985 mg/m$^3$. This value continued during the night. On the 23rd, it rose from 08:30 hours to 12:00 hours, at which time it reached 4950 mg/m$^3$. Then it fell to 3500 mg/m$^3$ at 13:30 hours. It reached 6900 mg/m$^3$ at 17:00 hours. Then, it dropped to values of outdoor air during the night. On the 24th at 08:00 hours, it rose from 6250 mg/m$^3$ at 14:00 hours. Then, it fell to outdoor values when the test ended. Outdoor levels oscillated between 850 and 950 mg/m$^3$. The indoor temperature varied between 19 °C and 22 °C.
Fig. 4 shows the variations of $CO_2$ in a classroom of another school with 14year-old pupils, where the test began on the 24th at 22:30 hours with a value of 1100 mg/m$^3$. It descended during the night to 1000 mg/m$^3$. On the 25th, it rose from 08:30 hours, reaching 5200 mg/m$^3$ at 15:00 hours. It fell to 1100 mg/m$^3$ at 21:00 hours and to 1000 mg/m$^3$ during the night. On the 26th it rose after 08:30 hours reaching 3850 mg/m$^3$ at 11:00 hours. It then fell to 3050 mg/m$^3$ at 14:00 hours. It rose to 3800 mg/m$^3$ at 16:00 hours, dropping to 1350 mg/m$^3$ at 18:00 hours when the test ended . Outdoor levels varied between 850 and 950 mg/m$^3$. The indoor temperature oscillated between 19 °C and 22 °C.
Fig. 5 indicates the variations of $H_2O$ in a classroom with 5 year-old pupils, where the test began on the 17th at 08:00 hours with 8840 mg/m$^3$. It rose to 9400 mg/m$^3$ at 13:30 hours and fell again to 8450 mg/m$^3$ at 19:30 hours. However, at night-time and without occupation readings rose to 8700 mg/m$^3$. On the 18th after 08:30 hours it rose to a level of 9300 mg/m$^3$ at 11:30 hours. Then it fell because the classroom was unoccupied. Then it rose to 9000 mg/m$^3$ at 17:30 hours. It fell fell again to 8650 mg/m$^3$ at 20:00 hours. During the night, it rose again as on the previous day to 9050 mg/m$^3$. On the 19th it rose to 10800 mg/m$^3$ at 12:00 hours.It fell to 10000 mg/m$^3$ at 15:30 hours, at which time the test ended. Outdoor levels varied between 6600 and 8000 mg/m$^3$.

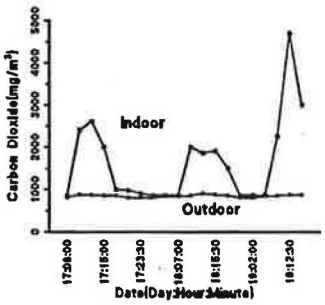


Figure 1. $CO_2$ concentration versus time in 5 years classroom.

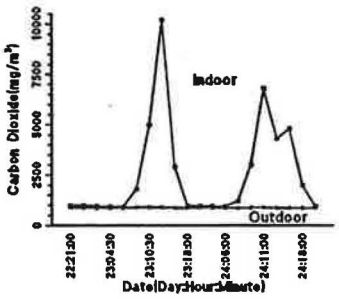


Figure 2. $CO_2$ concentration versus time in 12 years classroom.

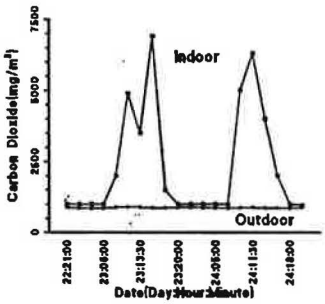


Figure 3. $CO_2$ concentration versus time in 17 years classroom.

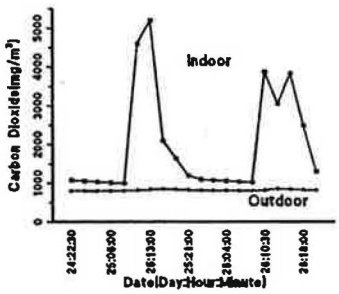


Figure 4. $CO_2$ concentration versus time in 14 years classroom.

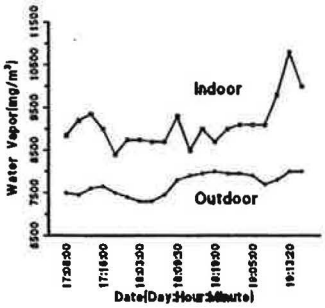


Figure 5. $H_2O$ concentration versus time in 5 years classroom.

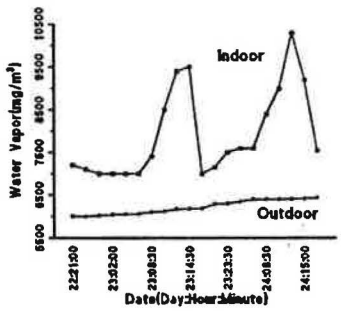


Figure 6. $H_2O$ concentration versus time in 12 years classroom.

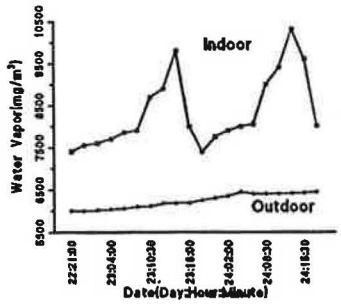


Figure 7. $H_2O$ concentration versus time in 17 years classroom.

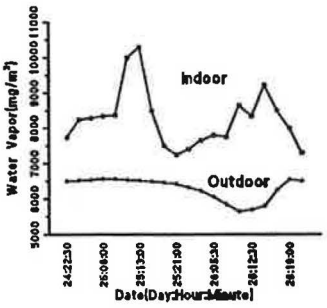


Figure 8. $H_2O$ concentration versus time in 14 years classroom.

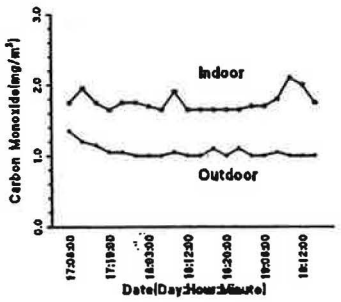


Figure 9. CO concentration versus time in 5 years classroom.

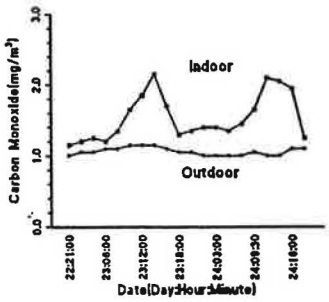


Figure 10. CO concentration versus time in 12 years classroom.

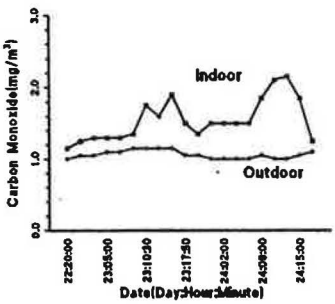


Figure 11. CO concentration versus time in 17 years classroom.

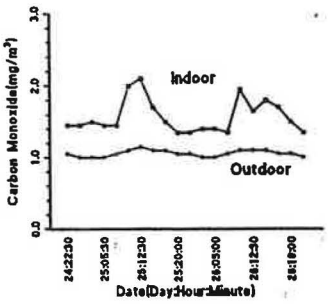


Figure 12. CO concentration versus time in 14 years classroom.

Fig. 6 shows the measurements of $H_2O$ taken in a classroom with 12 year-old pupils, starting on the 22nd at 21:00 hours with 7225 mg/m³. During the night it fell to 7000 mg/m³. On the 23rd, after 08:00 hours it rose to 9580 mg/m³ at 14:30 hours. It fell to 7000 mg/m³ at 17:30 hours. It rose without occupation to 7550 mg/m³ at 07:30 hours of the following day. On the 24th, it rose to 10300 mg/m³, at 13:00 hours. It fell to 7500 mg/m³ at 18:00 hours when the test ended. Outdoor levels varied between 6000 mg/m³ and 6450 mg/m³.

Fig 7 shows the levels of $H_2O$, in a classroom with 17 year-old pupils, beginning on the 22nd at 21:00 hours with 7415 mg/m³. It rose during the night to 7900 mg/m³. On the 23rd, it rose to 9800 mg/m³ at 15:30 hours. Then, it fell to 7350 mg/m³ at 21:00 hours. It rose without occupation to 8000 mg/m³. On the 24th, it rose to 10300 mg/m³ at 13:30 hours. It fell to 7450 mg/m³ at 17:00 hours, at which time the test ended. Outdoor levels varied between 6000 and 6500 mg/m³.

Fig. 8 indicates the variations of $H_2O$, in a classroom with 14 year-old pupils, beginning on the 24th at 22:30 hours, with 7725 mg/m³. It rose during the night to 8400 mg/m³. On the 25th, it rose from 10350 mg/m³ at 14:00 hours, falling to 7250 mg/m³ at 21:00 hours. Then, without occupation it rose from 7650 mg/m³. On the 26th, it rose to 8700 mg/m³ at 11:00 hours, falling to 8300 mg/m³ at 13:30 hours. It rose again to 9200 mg/m³ at 16:30 hours. Then, it dropped to 7400 mg/m³, when the monitoring ended. Outdoor levels varied between 5700 mg/m³ to 6550 mg/m³.

Fig. 9 reflects the variations of CO, in a classroom with 5 year-old pupils, starting on the 17th at 08: 00 hours, with 1.75 mg/m³. During the occupation times they reached 1.95, 1.90 and 2.10 mg/m³, coinciding in time with the maximum level of $CO_2$ in Fig. 1. During the time without occupation there were no variations in the initial value. Outdoor levels oscillated between 1.35 and 1.00 mg/m³.

Fig. 10 corresponds to the monitoring of CO, in a classroom with 12 year-old pupils, which began on the 22nd at 21:00 hours, with 1.15 mg/m³. During occupation levels reached 2.20 and 2.15 mg/m³ at the same time as the $CO_2$ in Fig. 2. During the time without occupation initial values hardly changed. Outdoor levels oscillated between 1.00 and 1.20 mg/m³.

Fig. 11 shows the monitoring of CO, in a classroom with 17 year-old pupils, which began on the 22nd at 20:00 hours, with 1.15 mg/m³. There were registered values of 1.75, 1.85 and 2.15 mg/m³ coinciding with the maximum levels of $CO_2$ recorded in Fig. 3. During the time without occupation there were no variations in the initial value. Outdoor levels varied between 1.00 and 1.20 mg/m³.

Fig. 12 are represents the monitoring of CO, in a classroom with 14 year-old pupils, which began on the 24th at 22:30 hours, with a reading of 1.45 mg/m³, remaining constant during the two nights of evaluation. They reached the maximum of 2.10, 1.95 and 1.80 mg/m³ coinciding with the maximum levels of $CO_2$ recorded in Fig. 4. During the time without occupation initial values hardly changed. Outdoor levels oscillated between 1.00 and 1.20 mg/m³.

## DISCUSSION

Although the $CO_2$ are not considered to have direct harmful effects on human health, a concentration higher than 1600 mg/m³ does indicate a lack of adequate ventilation (5). As can be seen in the Figs. 1 to 4, during periods of occupation the classrooms under study showed a $CO_2$ content above the recommended level. Fig. 1shows clearly that on the third day of monitoring the $CO_2$ content reached six times the level of that in the outdoor air. In Fig. 2 on the first day the level was thirteen times the outdoor figure, while Figs 3 and 4 show respectively values nine and seven times the normal outdoor level, the readings corresponding in both cases to the first day of monitoring.

The recommended upper limit for levels of relative humidity at an indoor temperature of between 20 °C and 21 °C would be 60 %, equivalent to a concentration of $H_2O$ of 10,400 mg/m$^3$.
In general the $H_2O$ content in the outdoor air was always high due to the geographical location. However it also varied according to the direction of the prevailing wind. There being higher contents of $H_2O$ when the wind is from the North-west (the North-west Atlantic) and lower levels when the wind is from the North-east (Continental Europe). As may be seen in Figs 5 to 8 the $H_2O$ content was always above the outdoor level. Morover two facts may be observed. Firstly, the lowest $H_2O$ value recorded at no time reached that of the outdoor air. This is due to the fact that during periods of high concentration, $H_2O$ is adsorbed by material and furniture, followed by a partial drying-out during periods when the concentration is lower.
Secondly, we observed a partial increase in $H_2O$ content due to the drying-out of floor after being washed at the end of the day.
The CO content in these same classrooms is higher than in the outdoor air, as can be seen in Figs 9 to 12, although the rise during the periods of occupation remained well within permitted limits. The general conclusion to be drawn is that the air renewal was inadequate given the number of people present during periods of occupation. We therefore conclude that the system of ventilation should be modified in order to ensure greater indoor air quality.

## ACKNOWLEDGEMENTS

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