INDOOR ENVIRONMENT IN SCHOOLS - PUPILS HEALTH AND PERFORMANCE IN REGARD TO CO_2 CONCENTRATIONS.

A. N. Myhrvold, E. Olsen and Ø. Lauridsen
RF - Rogaland Research, Stavanger, Norway

ABSTRACT

The results in this paper represent a small part of a 3 year ongoing research project, "Indoor Environment in Schools". The project has been an effect study of rehabilitation in schools with poor indoor air quality. This project is a co-operation between the counties of Oppland and Vest Agder, the municipality of Hå in Rogaland and RF-Rogaland Research.
The aim of the project has been to investigate the indoor environment in regard to the pupils' health, social environment and level of performance. The project has included field investigations of indoor air quality, pupils' health and social climate in addition to a reaction time test, called SPES.

The results show both correlations between pupils' health and the CO_2 concentrations in the class rooms, and between the pupils' performance and the CO_2 concentrations.

INTRODUCTION

The authorities in Vest-Agder, Oppland and Hå had to renovate some of their schools, and they were generally concerned about the increase in asthma and allergy among children. They were aware of the Norwegian Action Plan for the reduction of allergy and hypersensitivity in Norway (1). The builders wanted to renovate the schools "right" the first time, they searched for competence, and the project "Indoor Environment in Schools" started in the autumn 1993. The project will be finished during the autumn 1996. Since a high proportion of the Norwegian schools does not have an acceptable indoor environment, the builders wanted to "share" the knowledge with other builders. A manual describing the renovating of schools is currently being made in this regard.
The main hypothesis in the project "Indoor Environment in Schools" is: *a good indoor environment in schools would promote the pupils' health, well being and performance.* In schools with not acceptable indoor environment this is possible to gain through renovation and maintenance of the schools. The project includes a total of 35 classrooms and about 800 pupils from 8 different schools. The basic design of this project is a pre-test/post-test i.e. before and after rehabilitation of school buildings.
The physical measurements included the air change, ventilation measurements, air content of CO_2 and VOC. The equipment used were Bruel & Kjær (Tracer gas monitoring). In addition air temperature, humidity, radiant temperature asymmetry and air velocity values were measured, and PPD (percentage persons dissatisfied) values were calculated. The equipment used for these measurements were Hydra Fluke Data Logger and Bruel & Kjær (1213). The pupils were asked to fulfill a questionnaire survey; a modified Ørebro questionnaire and also a questionnaire for social climate in the class. In addition to this the pupils performed a concentration test SPES; Swedish Performance Evaluation System (2).

RF – Rogaland Research
P.O. Box 8046, N-4068 STAVANGER, Norway
Phone: (+47) 51 87 50 00,
Telefax: (+47) 51 87 52 00.
HTTP://www.rf.no

The physical measurements (except CO_2) and the results of the questionnaires concerning health and social climate will not be presented in this paper. We will not at this early stage in the data processing discuss the overall effect of the rehabilitation's. This paper will focus on relations between health and CO_2 concentrations, and between the results of the SPES performance test and CO_2.

METHODS

The data presented here includes field survey from 22 classrooms and about 550 pupils, from 5 schools. The administration of research and control conditions follow Solomon's four-group design (3) as shown in Table 1. The field surveys were performed in February-March 1994 and repeated in February-March 1995.

Table 1 The Solomon's four group design used in this project.

	Pre test	Rehabilitation	Post test
Experiment class 1	x	r	x
Control class 1	x	-	x
Experiment class 2	-	r	x
Control class 2	-	-	x

x = performed tests, r = conducted rehabilitation's, - = not performed tests/rehabilitation's

CO_2 measurements

Concentrations of CO_2 were measured approximately every 10 minute during the school day by using Bruel & Kjær Multi-gas monitoring type 1302. The CO_2 concentrations are presented as mean values.

SPES

The SPES test was conducted by each pupil on a computer during a normal class situation. Four to eight pupils conducted the test at the same time. The approximate testing time was 30 minutes. The test system included three performance tests and self report of acute symptoms:
The concentration tests were "Simple reaction time", "Choice reaction time" and "Colour word vigilance". The "Simple reaction time" test is a sustained attention task measuring response speed to an easily discriminated visual signal. The "Choice reaction time" test is a four-choice reaction time task. The stimuli consist of crosses displayed one at a time on the screen, one of the arms of the cross is shorter and the task is to indicate which one it is. The "Colour word vigilance" test is a choice reaction time task in which response selection is based on a more complex signal. The Norwegian words for "red", "yellow", "blue" and "white" is presented on the screen, the text will be written in any one of the colors, and the task is to respond only when congruency between the meaning of the word and the color of the text.
The self report contains questionnaire about 17 acute symptoms, and the pupils did rate the present intensity of each symptom in a five point scale.

Statistical methods

The data analyses were performed with SPSS 6.1 for Windows. Principal factor analysis with varimax rotation and reliability tests of the scales was done on the data sets. Relations between different exposure variables were analysed by partial correlation coefficient analysis.

RESULTS

CO_2 concentrations

The mean CO_2 concentration at the schools at daytime ranged from 601 to 3827 ppm. The CO_2 values have been grouped into 3 groups and the percentage of pupils located in each group are given in parenthesis: 0 to 999 PPM (48,9 %), 1000 to 1499 ppm (24,9 %) and 1500 to 4000 ppm (26,4 %).

Health symptoms and performance levels

Based on the self report questionnaire regarding 17 acute symptoms, 12 symptoms were selected based on principal factor analysis with varimax rotation and listwise deletion of missing cases. From the 12 symptoms two factors were extracted. Finally scores from two unidimensional factor analyses were saved and the scores were used for further analysis, as:

Health index 1:	headache, dizziness, heavy headed, tiredness, difficulties concentrating, unpleasant odour
Health index 2:	throat irritation, nose irritation, runny nose, fit of coughing, short-winded, runny eyes ("irritations of upper air way")

Performance index 1 was created from factor analysis and contains reaction times from "Simple reaction time" test, "Colour Word Vigilance" test and from the "Choice reaction time" test. This factor is unidimensional.

The results from the three unidimensional factor analyses are shown in Table 2 together with the results from the reliability tests.

Table 2 Factor analyses and reliability tests.

Scale label	Eigen value	Explained pct of Variance	No. of items	No. of cases	Std. Cronbachs alpha
Health 1	2,97	49,5	6	549	0,7938
Health 2	2,87	47,9	6	549	0,7782
Performance	1,89	63,0	3	548	0,7059

The magnitude of Cronbach`s alpha in the reliability tests indicates good reliability of the scales. Every item contributed positively to Cronbach`s alpha.

The pupils` age is of significant importance both with respect to their performance capacity and response on health questions. Growing age means better performance and more and stronger health symptoms. The total test group included youth from about 11 to 20 years old, and our analyses show that the low ages influence the results. Pupils under 15 years of age did not perform the tests as well as the older pupils, irrespective of indoor air climate. The results in this paper do not include pupils under 15 years of age.

The correlation between CO_2 concentrations in the class rooms and the pupils' health symptoms and performance index is shown in Table 3. The correlation coefficients are controlled for age. Table 3 shows significant correlation between the indexes and the CO_2

concentration. The correlation is strongest with health index 1, and the weakest correlation is between CO_2 and health index 2.

Table 3 Partial correlation coefficients controlled for the pupils' age.

Scale label	Performance	Health 1	Health 2	CO_2
Performance	1,0000 P= ,	,1976 P= ,000	,1136 P= ,008	,1111 P= ,009
Health 1	,1976 P= ,000	1,0000 P= ,	,4904 P= ,000	,2190 P= ,000
Health 2	,1136 P= ,008	,4904 P= ,000	1,0000 P= ,	,0963 P= ,024
CO_2	,1111 P= ,009	,2190 P= ,000	,0963 P= ,024	1,0000 P= ,

(Coefficient / 2-tailed Significance)

The correlation between CO_2 concentrations in the class rooms and the health index 1 is shown in Figure 1. The grade and the number of symptoms increase significantly (one way ANOVA) with the increase in the CO_2 concentration. The pupils in the environment with CO_2 concentrations above 1500 ppm have significantly higher grade of these symptoms, than pupils in environment with CO_2 levels under 1500 ppm.

The health symptoms characterized as "irritations of upper air way" symptoms (health index 2) do increase with higher CO_2 concentrations in nearly the same way, but weaker, as for health index 1.

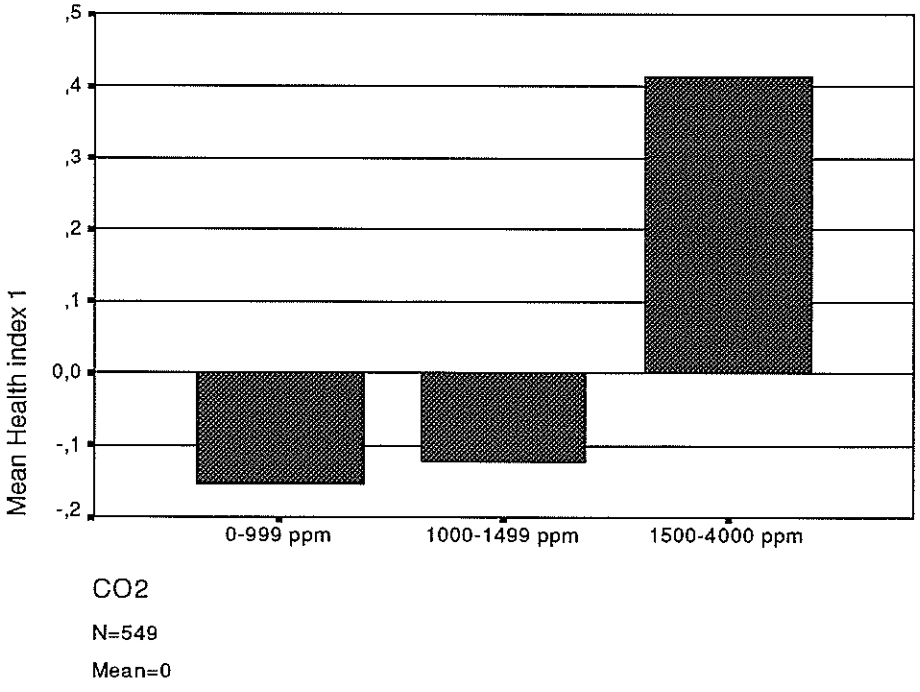

Figure 1. Health index 1 and CO_2 concentration (ppm). Positive scores at the y-axe correspond with high grade and number of symptoms.

The performance index in regard to CO_2 concentrations shows poor performance in environments with high CO_2 concentrations (Figure 2). The correlation of CO_2 and performance is significant as shown in Table 3, but there is no significance directly between the three groups of CO_2 in Figure 2. This figure illustrates the results.

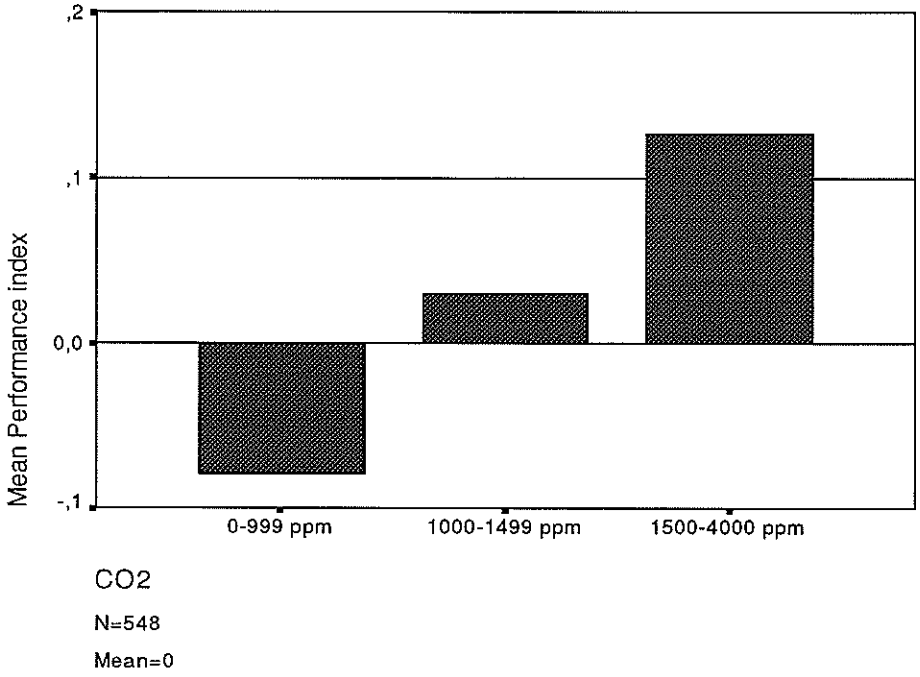

Figure 2. Performance index and CO_2 concentration (ppm). Postive scores at the y-axe correspond with poor performance, and negative score with good performance.

DISCUSSION

The content of CO_2 in the indoor air is only an indicator for the air quality. CO_2 concentrations do depend on both the number of persons in the room and of the air change. Schools have usually a high number of persons per square meter. Nielsen (4) showed that the levels of CO_2 have large fluctuations during a school day, and that single measurements are unreliable. The CO_2 concentrations found in the schools in this project have very much the same variations that Nielsen found.

The SPES test has been used for studying the effects on the central nervous system from low dose exposure to chemicals found in industrial work environments. The thermal effects on human performance has been showed before (5, 6). The SPES performance test has as fare as we know not earlier been used in studying the effect of poor indoor air quality and the level of performance among pupils in schools. We found significant differences between performance of pupils in environments with respectively high and low CO_2 concentrations. We found however an age-factor, which has nothing to do with the indoor air quality. This indicates that a certain degree of awareness is necessary during the treatment of data.
Our findings are interesting in regard to further use of these kind of methods for measuring performance.

The main task of the research project "Indoor Environment in Schools" is not to find the correlations between indoor air and health, since this has been found several times before. The main task is to follow the changes in pupils' health and performance due to renovation. This paper does not present any results due to renovations, but our general findings at the present time do emphasize the reliability of our data.

ACKNOWLEDGEMENTS

This work was supported by the National research council of Norway, the National Health Inspection and the municipality of Hå, Vest Agder county and Oppland county. A special thanks to Olav Lindal, Roy Hoel and Håkon Kleiven.
The authors would like to thank Inger-Lisa Andersen and Åshild Finnestad for their technical assistance. We will also thank the reference group of the project: Kjell Aas, Anker Nielsen, Gaute Flatheim, Finn Levy, Knut Inge Fostervold and Jan Fredrik Kvendbø.

REFERENCES

1. Aas K. Handlingsplan for barn og unge med allergi/overfølsomhet, astma og andre kroniske lungesykdommer. *Helsedirektoratets utredningsserie, 2:91. Oslo 1991.*

2. Gamberale, F., Iregren A., and Kjellberg A. SPES: The computerized Swedish Performance Evaluation System. *Arbete och Helse, 1989:6.*

3. Campbell D. T. and Stanley J. C. Experimental and quasi-experimental designs for research. *Hougton Mifflin Company Boston, 1963.*

4. Nielsen, A. (1994) Measurements of Indoor Climate in School Class Rooms and Improvement Methods, *the Proceedings of the 3rd International Conference on Healthy Buildings -94.*

5. Wyon D. P. Assessing productivity decrements in heat and cold: on-site simulation of industrial work in a mobile chamber. *In: Magnum BW, Hill JE, ed., Thermal analysis-human comfort-indoor environments. Special Publication 491, Washington DC, USA 1977.*

6. Wyon D. P. Healthy Buildings and their impact on Productivity, *the proceedings of the 6th International Conference on Indoor Air and Climate, Helsinki, Finland 1993.*