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INDOOR AIR POLLUTION STUDY IN SIX DAY-CARE CENTERS LOCATED IN METROPOLITAN MONTREAL

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Studies on indoor air quality (IAQ) in day-care centers (DCCs) are rather limited as for the measurements of different pollutants and the studies samples. The purpose of this study in six naturally ventilated DCCs was to describe the effect of window opening habits on the concentrations of selected pollutants and to correlate them with occupancy, illness rates and some organisational characteristics of DCCs. Indoor environmental measurements demonstrate the influence of occupants' behaviour on the quality of indoor air. The variation in caretakers' window opening patterns combined with a high rate of occupancy, a high risk of infectious diseases, and difference in the volume of air per child are the main elements that contribute to the increase of indoor pollutants.

INTRODUCTION

Many studies have showed that children in DCCs play an important role in the propagation of infectious diseases (1,2,3,4). Diseases that spread through the intestinal track, respiratory system or by direct contact (touching) are numerous and frequent in this milieu (5). However, relatively little has been written concerning IAQ in DCCs. Table I summarize these IAQ studies. In many of these studies the source of data was not mentionned or it come from small sample of children or DCCs. By measuring indoor air conditions (carbon dioxide, temperature, relative humidity, total dust, bacteria, fungi and noise levels) the aim of the present study was to caracterize their concentrations, to identify the indoor environment parameters that accentuate or facilitate the dissemination of infectious diseases among children and personnel and to establish a correlation between pollutants concentration, occupancy, ventilation habits and incidence of infectious diseases.

MATERIALS & METHODS

Six DCCs for children (6 months to 6 years of age) were included in this cross-sectional preliminary study. The study sample was selected according to respiratory illness rates expressed in number of cases per 100 child-month (two DCCs with >20, two with 10-19.9 and two with <10). A questionnaire was developped and all data and measurements were collected during a full day period (07:00 to 18:00) in March and April 1989. Except for the total dust and noise levels, the measurements were taken inside and outside of the DCCs.

Carbon dioxide concentration was monitored with an infrared spectrophotometer (ADC-CO_2), while temperature and humidity were measured with a psychrometer (Cole-Parmer). Total dust was collected using a 37 mm polyvinyl chloride filter and a pump (GILIAN or MSA-G) calibrated at 2 l/min. during an 8-hour period. Noise was monitored with personal dosimeters (Dupont MK-1 and BRUEL & KJAER 4431). The recording time varied from 45 to 360 minutes. For the collection of airborne fungal and bacterial particles, the Andersen N_6 sampling device was used at 28 l/min. Two samples were taken in parallel during a 2-minute period. The culture media used were SABOURAUD dextrose agar for the fungi and trypticase soy agar for the bacteria, respectively. The incubation period was 4 to 7 days at 21°C.

Data analysis was performed using the Statistical Package for Social Sciences (SPSSS-PC+). The sample size of our study was too small to statistically test the independance of the variables (indoor air quality parameters vs incidence of infectious diseases). We analyzed the data in a descriptive rather than an analytical manner. Following a dychotomisation of the DCCs, the student T test was used to compare the mean values of environmental parameters between two different strata of DCCs (<20 and $\geqslant 20$ m^3/person).

RESULTS & DISCUSSION

The characteristics of the six DCCs buildings, IAQ elements, pollutants concentration and the outside environmental parameters are presented in table 2. Two DCCs (G_1,G_6) with a quite similar number of children showed a huge difference in their volume (a ratio of almost 5/1).

Temperature recordings in the room showed variations within 3 to 6.5°C. By contrast, the relative humidity increased in relation to the occupancy and it was controlled by window opening. The maximums recorded were 68% and 63% (G_2,G_3) due to the fact that the windows were kept closed all day. Similarly, the carbon dioxide concentration directly reflected the occupancy in the room and reached a maximum of 1900 and 2690 ppm (G_2,G_3).

The variation of the total dust concentration was quite large (ratio of 1/5 between G_1 and G_6). However, as the children's age also vary (much older in G_6) the dust concentration was probably related to the type of activities during the day and to a higher mobility of the older children. The floors of the six DCCs are covered with linoleum and the cleaning procedure (technique, products and frequency) was similar.

The noise level was directly related to the ratio children/caretaker, the type of activity, the dimension and architectural characteristics of the rooms.

The concentration of microorganisms presented in table 2 represents the mean values of all species identified. Details concerning their types and concentrations are illustrated in table 3. For the bacteria, Staphylococcus was found most frequently in the indoor environment. The outdoor concentrations were lower specially at G_1 and G_4 (2 and 10 fold less). The highest measured concentrations of bacteria were founded in gathering-rooms followed by the kitchens and the children's rooms (42 months old and over).

Regarding fungal spores, the species most frequently founded were Aspergillus, Cladosporium and Penicillium. The indoor concentrations in the gathering-rooms and in the kitchens are higher than outside. Two DCCs (G_2 and G_5) seem to have a contamination problem since the total fungi concentrations measured were respectively 2797 and 1652 (CFU/m^3) in the gathering-rooms; 1952 and 1259 (CFU/m^3) in the kitchens. Nevertheless the outside concentrations were 64 and 232 (CFU/m^3).

DCCs with less than 20 m^3/person were associated with higher values of CO_2 relative humidity, temperature, diarrhea rate and child/caretaker ratio ($p < 0,001$). Respiratory illness rates were similar, problably due to the higher contagiousness of colds which seem to be more associated with direct contacts or with immediate exposition to the droplets emitted by infected persons.

CONCLUSIONS & RECOMMENDATIONS

The effect of window-opening patterns on the indoor concentration of pollutants has been showed in this study. Unacceptable high levels of carbon dioxide and relative humidity did occur in two DCCs where the windows were kept closed. The number of air changes per hour is very low, then the fine particles and droplets stay in suspension for long periods and can be inhaled by children and caretakers.

Published studies that correlate the indoor air quality parameters and infectious diseases among children and personnel of DCCs are non-existent. Infectious diseases in DCCs cannot be explained by the effect of one factor. Multicausality is probably the rule.

To improve the IAQ in DCCs changes in ventilation habits, cleaning and maintenance activities have been strongly recommended. In order to establish environmental standards for DCCs, a larger survey involving a representative sample from the province of Quebec is in preparation.

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TABLE 1. INDOOR AIR QUALITY STUDIES IN DAY-CARE CENTERS *

	AUTHOR	YEAR PUB.	COUNTRY	DCCS NO/ POP.	PARAMETERS EVALUATED
6)	DIONNE, J.C.	1989	CANADA	6/270	Bacteria, CO_2, dust, fungi, humidity, noise, temperature
7)	SAGUNSKI, H.	1989	WEST GERMANY	12/?	Dioxins, furans
8)	PAPKE, O.	1989	WEST GERMANY	1/?	Dioxins, furans
9)	VIKSTRÖM, P.	1988	SWEDEN	1/?	CO_2, temperature, ventilation
10)	ANDERSSON, J.	1988	SWEDEN	1/30	Formaldehyde, noise, radon, temperature, ventilation
11)	NEVALAINEN, A.	1987	FINLAND	11/?	Bacteria, fungi, humidity, temperature, ventilation
12)	JORGENSEN-BIRCH, L.	1986	DENMARK	?/?	Mineral fibers
13)	KAHR, O.	1986	DENMARK	?/?	Mineral fibers
14)	JOUAN, M.	1983	FRANCE	2/?	Aldehydes, CO, NOx, smoke, SO_2
15)	LUNDQUIST, G.	1982	DENMARK	1/32	CO_2, humidity, temperature, ventilation
16)	LANNEFORS, H.	1981	SWEDEN	1/?	Bromine, lead
17)	SALE, C.	1972	UNITED-STATES	3/515	Bacteria, temperature, ventilation

* Studies in kindergartens and preschool are excluded.

PUB : PUBLICATION

NO : NUMBER

POP : POPULATION OF CHILDREN

TABLE 2. CHARACTERISTICS AND PARAMETERS EVALUATED AMONG THE PARTICIPANTS DAY-CARE CENTERS DURING THE STUDY PERIOD (MARCH TO APRIL 1989). MONTREAL, (QUEBEC), CANADA.

CHARACTERISTICS AND PARAMETERS	DAY-CARE IDENTIFICATION					
	G1	G2	G3	G4	G5	G6
. BUILDING						
age (years)	40	5	40	40	20-40	40
type	School	Nursery	School	School	School	House
surface (m^2)	1136	349	214	664	241	318
volume (m^3)	3731	803	783	2632	868	823
. POPULATION						
number of children	56	30	38	70	25	51
number of adults	10	10	7	10	7	5
. IAQ ELEMENTS (MIN-MAX)						
temperature (°C dry)	21.0-27.5	20.0-24.5	21.0-24.5	20.0-25.0	22.0-24.5	19.5-23.5
relative humidity (%)	21-29	38-68	44-63	21-34	32-50	40-49
carbon dioxide (PPM)	400-750	400-1900	400-2690	360-860	405-1260	380-1450
. POLLUTANTS						
dust (ug/m^3) *	42	150	150	83	150	183
noise (dBA min-max)	80-87	80-84	80-89	80-89	80-82	80-92
bacteria (CFU) *	236	1051	592	618	455	438
fungi (CFU) *	120	1830	64	137	1012	70
. EXTERIOR ENVIRONMENT *						
temperature (°C dry)	7.0	10.7	17.0	4.3	9.1	13.8
relative humidity (%)	52	66	72	41	70	59
carbon dioxide (PPM)	407	370	350	370	376	376
wind speed (km/hour)	9	24	17	22	10	11
bacteria (CFU)	233	83	749	1656	822	558
fungi (CFU)	45	64	87	61	232	108

* means values

TABLE 3. INDOOR CONCENTRATION OF BACTERIA AND FUNGI AMONG THE PARTICIPANTS DAY-CARE CENTERS DURING THE STUDY PERIOD (MARCH TO APRIL 1989). MONTREAL, (QUEBEC), CANADA.

TYPE OF MICROORGANISM	CONCENTRATION OF MICROORGANISMS * BY DAY-CARE (CFU/m^3)					
	G1	G2	G3	G4	G5	G6
. Bacteria						
Staphilococcus	116	448	228	210	110	150
Bacillus	36	195	38	9	3	5
Pseudomonas	60	62	67	189	62	81
Enterobacter	21	102	86	75	51	8
Pasteurella	3	0	0	0	0	0
Micrococcus	0	0	90	34	119	169
Unidentified	0	244	83	101	110	25
. Fungi						
Alternaria	0	0	0	3	0	11
Aspergillus	0	0	13	12	0	5
Cladosporium	0	0	16	35	92	20
Mycelia	0	0	0	6	0	6
Penecillium	99	1830	32	75	914	11
Others	21	0	3	6	6	17

* means values