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Would removing indoor air particulates in children's environments reduce rate of absenteeism — A hypothesis

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Abstract

To conduct a controlled trial to test the ability of a newly developed electrostatic air cleaning technology (EAC) to improve Indoor Air Quality (IAQ) as defined by levels of airborne particles and to investigate the potential to reduce non-attendance rates due to illness among children in two Swedish day care centres. The EAC technology was shown to significantly reduce the indoor particulate load for very fine particles caused by outdoor air pollution by 78% and to reduce the number of fine particles produced indoors by 45%. To test the hypothesis, non-attendance was followed in two centres during 3 years. The EAC technology was in operation during year 2. Non-attendance rates among children in the larger day-care centre decreased by 55%, equalling those levels noted in family-based day care. It is speculated that the air cleaning effect may be due to alterations in electrostatic forces operating within the room enabling fine particulate matter to more easily become and stay airborne. The EAC technology is cost-efficient and might be a way forward to improve IAQ. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Indoor air quality; Air pollution; Day care centres; Absenteeism; Children

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1. Introduction

Indoor air quality (IAQ) is a complex function of outdoor air quality, indoor activities past and present, design of ventilation systems, number of air changes per minute, building design/size and emissions from the building materials. Up to now, volatile organic compounds (VOCs) have been associated with the adverse effects noticed in the indoor environment. However, at a recent Nordic Scientific Consensus meeting, Andersson et al. (1996) reviewed 120 publications and established that present data are inconclusive.

Recently, fine particulate matter generated by the combustion process and the diesel engine in particular, has come to the fore as a potential cause of respiratory symptoms among those children and adults suffering from chronic respiratory disorders (Schwartz, 1994) but also as an adjuvant for the development of allergy (Devalia et al., 1994).

In a questionnaire-based study covering 39 Swedish schools, Norbäck and Smedje (1996) reported on a positive relationship between respirable dust and airway infections in adults as well as between viable airborne bacteria and moulds and asthma in children.

Ståhlberg (1980) and Dahl et al. (1991) noted the negative consequences from the indoor environment in the two- to threefold increase in upper respiratory tract infections (URTI) and the use of antibiotics among children attending day-care centres where most of their time is spent indoors. URTI among children causes a socio-economic inconvenience and aggravates asthma (Sporik et al., 1992).

Thus the issue of IAQ is of great importance as more time is spent indoors and data is accumulating to show the consequences of poor IAQ.

Although epidemiological studies are important to identify a potential problem, interventional studies are equally relevant to study the mechanisms behind the problem and to explore potential remedies.

In Sweden increased forced air ventilation rates have been tried over many years as a method to improve indoor air quality, in public and private buildings. In 1994, Sweden set a new standard for IAQ, based on a maximum carbon dioxide concentration of 1000 ppm in an attempt to further control the IAQ issue (NSBOSH, 1993). Surprisingly few data are available to prove how effective the approach has been (Norbäck and Smedje, 1996).

It appears as if the concentration of respirable particles is a significant factor influencing the quality of the indoor environment. Increased forced air ventilation does not necessarily reduce the number of particulates as efficiently as carbon dioxide and VOCs are removed.

Electrostatic mechanisms provide an alternative means to control the movement of fine airborne particles (Jackson, 1975). One way of generating electrostatic fields in a room, is to produce free electrons in the air. Some of these electrons will combine with oxygen and a negatively charged small air ion is produced. There is empirical evidence that such charged air can reduce the growth of microorganisms (Krüger and Reed, 1976). This observation has been further strengthened by the observation that small amounts of hydrogen peroxide are produced with increasing levels of negative air ions (Challenger et al., 1996). Hydrogen peroxide may act to reduce the growth of microorganisms (Hyslop et al., 1995).

Thus, the delivery of free electrons into the indoor air has the potential to enhance the air quality by reducing the number of airborne particles through electrostatic 'filtering' mechanisms and via the hydrogen peroxide mechanism reduce the growth of microorganisms.

2. Hypothesis

Does the production of free electrons into the indoor air have the ability to reduce the number of airborne particles of a defined size in children's day care centres?

Would the potential improvement in IAQ from such a system, reduce the non-attendance rate due to sickness among the children in these day care centres?

To evaluate these hypotheses, electron producing devices [Electrostatic Air Cleaning (EAC) system, Neoventor Medicinsk Innovation AB, Kungälv, Sweden] were installed in two Swedish day care centres. The non-attendance rates among the children were recorded over a 3 year period. The concentration of fine (> 3 μm, < 7 μm) and very fine (> 0.3 μm, < 3 μm) airborne particulate matter was recorded.

3. Methodology

Although the EAC system is not regarded as a medical device, its use in children's day care centres was approved by the Ethics committee, Faculty of Medicine, University of Gothenburg, Sweden. Parents were given written and direct information at meetings.

Two day care centres, A and B, were chosen in collaboration with the municipality of Uddevalla, located on the west coast of Sweden, to be equipped with EAC-systems. Centre A was an older building with a large group of children whereas centre B was located in a modern building with half as many children using the premises on a daily basis. The two buildings had controlled forced air ventilation that fulfilled the standards required of 7 l/s per child (NSBOSH, 1993). No other changes were undertaken in the centres during the 3-year trial. Table 1 provides further details.

The local Social Services office registers and collates figures for non-attendance among preschool children indicating reasons for the absence. The non-attendance rates due to illness used for this research were taken from this database.

Comparisons of non-attendance rates were made over a 3-year period with year 2 being the year of 'EAC'-treatment in centres A and B.

Table 1
Basic data and annual non-attendance rates

Day care centre	A	B
EAC	Yes	Yes
Built, year	1975	1991
Number of children attending	63	30
Range of age of children, years	1–6	1–6
Non-attendance due to sickness, annual rates (%)		
Year 1	8.31	9.20
Year 2, EAC year	3.75**	6.09
Year 3	7.94*	5.92

*$P < 0.05$, paired t-test.
**$P < 0.01$, paired t-test.

4. The EAC-system

The EAC-system delivers a high voltage (7 kV negative polarity), DC current (< 0.5 mA) to a frayed multi carbon fibre thread (the emitter) positioned close to each ceiling-mounted forced air inlet without the generation of ozone. The number of small air ions produced was regularly measured using an atmospheric ion analyser (Medion type 134A). EAC-systems were only installed in rooms used by the children in the day care centres. Throughout the time of the study negative air ion levels of 20 000–40 000/cm^3, at a height of 1 m above the floor were recorded. A standard DC electrical field recorder (ELTEX Q475C) recorded a negatively charged electrostatic field of −30 kVm, at a distance of 30 cm from the emitters. The field strength 1 m from the emitter was −15 kVm which is equivalent to the field strength of a TV set (positive electrostatic field). The walls of the rooms in centre A became slightly negatively charged (1.5–2.0 kVm) compared with a zero or slightly positive charge previously recorded. No alteration of wall charge was noted in centre B.

The EAC systems were in operation throughout the second year from the first week in April of year 2 until the first week in April of year 3. They were then turned off with the equipment left in place throughout the third year.

5. Measurements of airborne particles

A MET-ONE model 227B (Met-One, Oregon, USA) laser beam particle counter was used to record the number of particles per litre of ambient air.

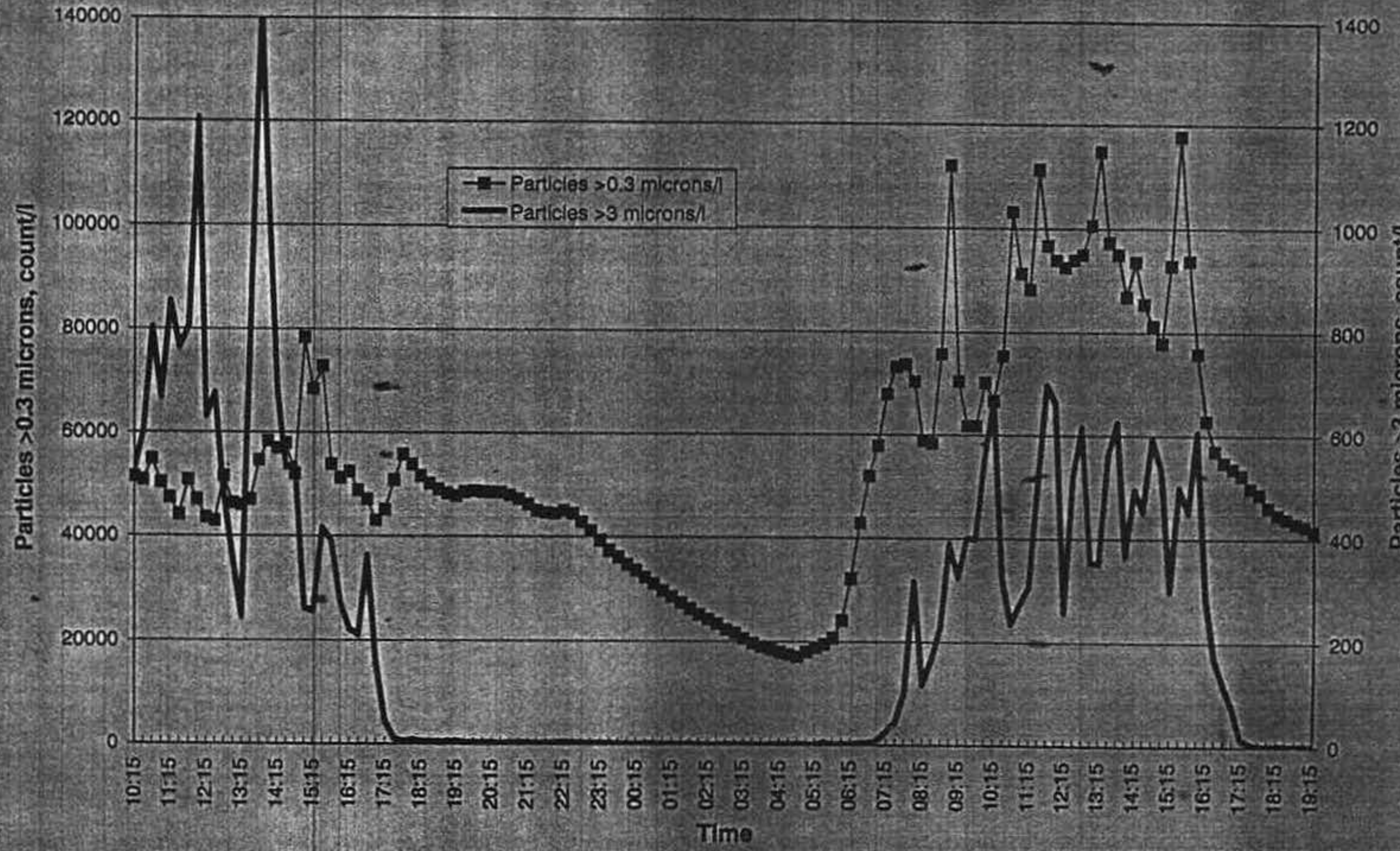

Fig. 1. A representative recording of the number per litre of air borne particles of two sizes, > 0.3 μm and > 3.0 μm, during a 33-h period in a day care centre room. Note how the very fine particles stay air borne throughout the night and markedly increase as the ventilation system is turned on at 06.00 h. The larger size particles increased as the staff and children made use of the room in the morning and fluctuated throughout the day depending on the activity level.

The particle counter was set to measure:

(i) Very fine particles defined as > 0.3 and < 3.0 μm and
(ii) Fine particles, > 3.0 and < 7.0 μm in size

Comparisons were made intermittently between indoor and outdoor particle counts at varying weather conditions. Indoor particle counts were recorded for 24-h periods in centre A only. Measurements were taken during a 30-s period every 5 min. Particle counts were made in one playroom at a height of 1.2 m and at a distance of 3 m away from the forced air inlet.

Fig. 1 gives an example of a 24-h recording of how the number of particles varies depending on the level of activity in the room. This was most pronounced for particles > 3 μm. The number of these particles dropped to zero during the night, increasing again as staff entered the room in the morning. The number of very fine particles also increased in the morning when the ventilation system was switched on, prior to the arrival of the staff.

Thus, the particles measured represented:

(i) Very fine particles, > 0.3 and < 3.0 μm, entering the room from the outside air through the ventilation ducts. The relationship between in- and outdoor concentrations was used to quantify IAQ.
(ii) Fine particles of size > 3.0 and < 7.0 μm generated from activities within the room. The average reading recorded during office hours, 08.00–15.00 h was used to quantify IAQ.

The carbon fibre threads were vacuum-cleaned every third month to ensure their function.

Statistical analysis for absenteeism was performed using two-tailed, paired Student's *t*-test and for particulates, unpaired Student's *t*-test.

6. Results

The outdoor air was always found to have a higher concentration of very fine particles than the indoor air. On average, a 25% reduction of very fine particles was noted under normal conditions as the air passed through the existing ventilation system and settled within the room. This difference was markedly enhanced when the EAC-system was in operation showing, on average a 78% reduction of very fine particles ($n = 17$, $P < 0.001$).

The average daily count of fine particles was recorded on 10 occasions, four without and six with EAC. A significant reduction was noted with the EAC-system as the daily averages decreased from 428 (median, range: 340–649) particles/litre of air to 232 (range: 166–287), $P < 0.01$.

Table 1 gives a comparison of absenteeism during the 3-year period. Centre A had a significant reduction in absenteeism from 8.31 to 3.75% returning to 7.94% during the third year.

Table 1 also give the non-attendance rates for the smaller and more modern day-care centre B. This centre showed a decrease by 33% comparing years 1 and 2. This difference did not reach statistical significance. There were no epidemics noted among the children.

An observation was made regarding a difference in wall dirt deposition as in centre B the walls required repainting, something not required in centre A.

7. Discussion

The aim of the study was to conduct a trial to test the ability of a newly developed electrostatic air cleaning device to improve IAQ as defined by levels of airborne particles and to investigate the potential to reduce non-attendance rates among children in day care centres. Non-attendance rates among children in Swedish day care centres are known to increase almost threefold compared with family-based day care. Primarily due to viral URTI which is related to the number of children (Dahl et al., 1991) and possibly the load of biologically active airborne particles.

Repeated measurements were undertaken in order to demonstrate effects on the number of airborne particulate matter. The non-attendance rate due to illness was provided from the records on absenteeism kept by the Social Services administration. This independent data collection together with the unlikeness that the children per se would alter their behaviour due to some equipment being mounted in the ceiling should reduce the methodological error. Leaving the equipment mounted after it was turned off further reduced this risk. Furthermore, by including data obtained on a yearly basis short-term trends due to seasonal variation in URTI can be excluded and the non-attendance rates noted during years 1 and 3 are in keeping with previously published data (Dahl et al., 1991).

It appears logical to assume that the very fine particles generated outdoors, and reduced by 78%, became trapped as the air entered the room and passed close to the EAC system, the site where the negative electrostatic field was the strongest and the dirt deposition the most marked. The larger size particles generated by the activity within the room became less airborne (45% reduction) either by not leaving their source (humans or horizontal surfaces) so easily due to the alteration of the electrostatic field within the room and/or being captured by the strong electrostatic field operating close to the EAC emitters. It took approximately 2 weeks for the walls in centre A to obtain a slight negative electrostatic charge as compared with the overall positive charge noted initially. Not until this was achieved did the reduction in particles reach its maximum in reducing airborne particulate matter, indicating that a negative electrostatic field effect is important.

IAQ and its impact on the indoor environment is not only a function of the concentration of airborne particles. Equally relevant is the potential biological activity of these particles (Seaton et al., 1995). This bioload concept includes fine respirable particles generated by microorganisms. Our own experimental work on enhanced negative air ionisation has demonstrated the generation of hydrogen peroxide in the range of 0.7–1 μM at 20–50 000 negative air ions/ml of air (Challenger et al., 1996). Hyslop et al. (1995) recently reported on hydrogen peroxide as a potent antibiotic. They showed a bacteriostatic effect at 25 μM without any signs of affecting the growth of human fibroblasts. To what extent a hydrogen peroxide concentration of 1 μM operating over time would affect the growth of microorganisms remains to be tested. However, our own observational data have indicated a marked decrease in airborne moulds in rooms after 2–5 months of EAC treatment.

To our knowledge no previous attempt has been made to study interventional procedures and their capacity to improve indoor air quality, relating the effects to the non-attendance rate among children. In the current study a substantial reduction of indoor air particles was shown to be possible by altering the electrostatic fields within the rooms. The impact of this on non-attendance rates among children in the larger day-care centre was most striking with a 55% decrease and non-attendance rates equalling those noted in family-based day care (Dahl et al., 1991). The lack of a significant reduction in nursery B may be due to a smaller number of children, 30 vs. 63, and thereby the effect of independent factors, such as a change in age distribution, would increase.

Obviously, the possibility also exists of other mechanisms affecting the outcome, such as different building materials, wooden boards vs. plaster of paris boards, age of the buildings and their previous history. Assuming the reason behind a reduction in infection rates is dependent on the ability of particulate matter to leave a surface, centre A showed evidence of a change in indoor structural surface electrical charge, not seen in centre B. Perhaps such an effect also did apply to the surface of children making an alteration in the predominant positive charge more likely and thereby reducing the repellent electrical forces that would otherwise keep the human-generated particles airborne.

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