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NON ATTENDANCE RATES AMONG CHILDREN IN SWEDISH DAY-CARE CENTRES BEFORE, DURING AND AFTER CLEANING THE INDOOR AIR USING AN ELECTROSTATIC AIR CLEANING TECHNOLOGY – A CONTROLLED TRIAL

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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 air borne 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 (>0.3μm) caused by outdoor air pollution by 78% and to reduce the number of particles (>3.0μm) produced indoors by 45%.
Non-attendance was followed for two "treated" centres and two control centres during three years. The EAC technology was in operation during year two. Non-attendance rates among children in the larger day-care centre decreased by 55%, equalling those noted in family based day care.
The EAC technology is cost efficient and might be a way forward to improve IAQ.

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 min., building design/size and emissions from the building materials.

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[1,2] but also as an adjuvant for the development of allergy[3].
In a questionnaire based study covering 39 Swedish schools, Norbäck and Smedje reported on a positive relationship between respirable dust generated indoors and airway infections in adults as well as between viable airborne bacteria and moulds and asthma in children[4].
Upper respiratory tract infections (URTI) are two to three times more common, as is the use of antibiotics, among children attending day-care centres where most of their time is spent indoors[5,6].

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[7]. Surprisingly few data are available to prove how effective the approach has been[4].

Electrostatic mechanisms provide an alternative means to control the movement of fine air borne particles[8]. 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 micro-organisms[9]. This observation has been further strengthened by the observation that small amounts of hydrogen peroxide are produced with increasing levels of negative air ions[10].
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 micro-organisms[11].

HYPOTHESIS:
Does the production of free electrons into the indoor air have the ability to reduce the number of air borne particles of a defined size in a busy children's's day care centre?
Would the potential improvement in IAQ from such a system, reduce the non-attendance rate due to sickness among the children in day care centres?

To evaluate these hypotheses, an electron producing device (Electrostatic Air Cleaning, EAC - system) was constructed and installed in two Swedish day care centres. The non attendance rates among the children were recorded over a three year period. The concentration of fine (> 3μm) and very fine (> 0,3μm) air borne particulate matter was recorded. The number of absent children was compared with day-care centres of similar size and design without the EAC technology.

METHODOLOGY:
Although the EAC system is not regarded as a medical device, it's 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 equipped with EAC-systems. Centre A was built 1975 with a large group of children (63) whereas centre B was located in a modern building, built 1991, with half as many children using the premises on a daily basis. Control centres A_{ref} and B_{ref} were chosen on the basis of size, locality and age. The control centres were both located within less then 1.5 km of the corresponding EAC equipped units and covered the same residential area of the town. All buildings had controlled forced air ventilation that fulfilled the standards required. No other changes were undertaken in the four day-care centres during the 3 year trial.

The local Social Services office register and collate figures for non-attendance among pre-school 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 three year period with year two being the year of 'EAC'-treatment in centres A and B. centre B_{ref} did not start to operate until august 1993, therefore the period included in the three year analysis of centres B and B_{ref} has been restricted to 8 months (1 Aug. 1993 - 13 March 1994).

THE EAC-SYSTEM:
The EAC- system delivers a high voltage (7 kV negative polarity), DC current (< 0,5 mA) to a carbon fibre thread (the emittor) positioned close to each ceiling mounted forced air inlet. 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 per cm^3, at a height of 1m above the floor were recorded. A negatively charged electrostatic field of -30 kVm was recorded by a standard DC electrical field recorder (Eltex Q475C), at a distance of 30 cm from the emitters. The field strength one meter from the emittor was -15 kVm which is equivalent to the field strength of a TV set (positive electrostatic field). The walls of the rooms became slightly negatively charged (1.5 - 2.0 kVm) compared with a zero or slightly positive charge in a standard room.
The EAC systems were in operation throughout the second year from the first week in April 1994 to the first week in April 1995. They were then turned off with the equipment left in place throughout the third year.

MEASUREMENTS OF AIR BORNE PARTICLES:
A MET-ONE model 2110 (Met-One, Oregon, USA) laser beam particle counter was used to record the number of particles per litre of ambient air.
The particle counter was set to measure, particles > 0,3 and >3,0 μm in size. Comparisons were made intermittently between indoor and outdoor particle counts. Indoor particles counts were recorded over 24-hour periods. Measurements were taken during a 30 second period every 5 minutes. Particle counts were made in one playroom at a height of 1.2 m and at a distance of three meters away from the forced air inlet.

Figure 1

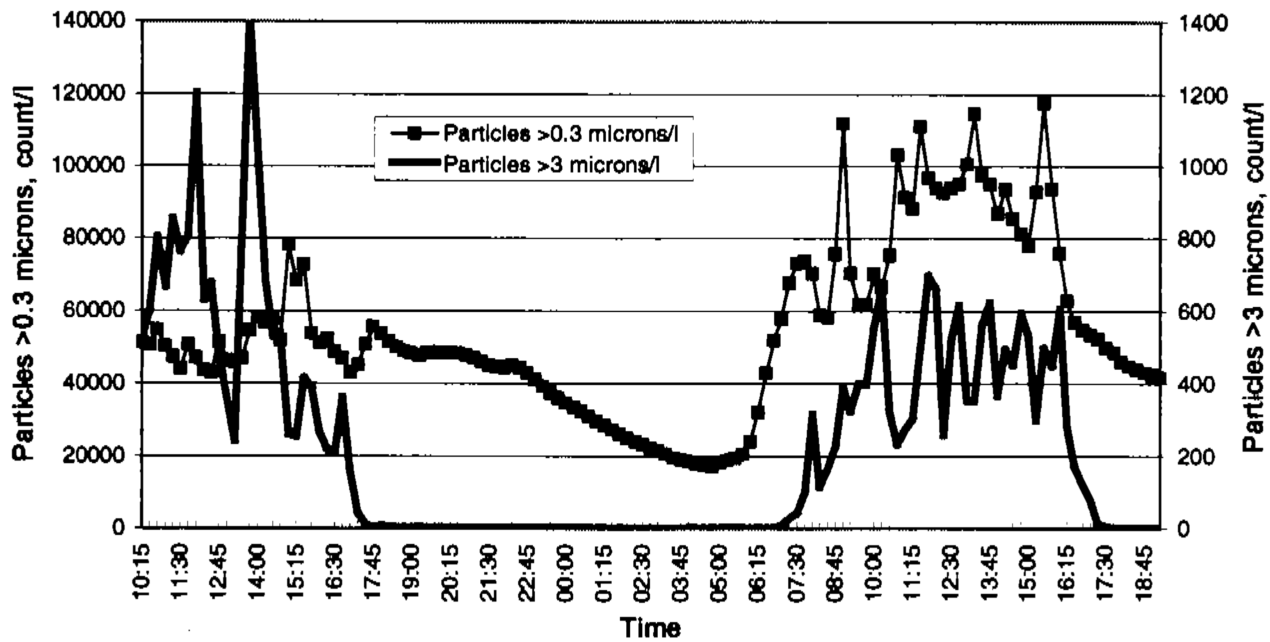


Figure 1 gives an example of a 24-hour recording of how the number of particles varies in a play room, depending on the level of activity in the room. This was most pronounced for particles >3 µm. The number of these particles dropped to zero during the night, increasing again as staff entered the room in the morning. The number of very fine airborne 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:

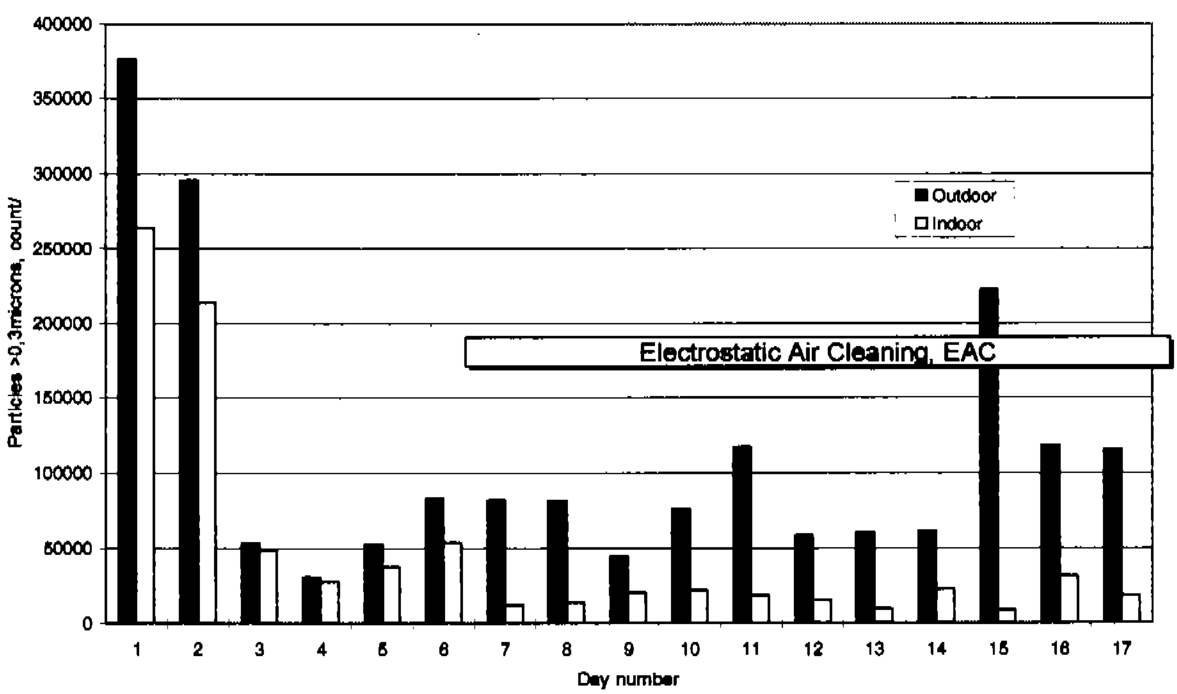
a) Very fine particles, those > 0.3µm, entering the room from the outside air through the ventilation ducts. The relationship between in- and outdoor concentrations was used to quantify IAQ.
b) Particles of a size >3.0µm generated from activities within the room. The average reading recorded during office hours, 08:00 - 15:00 was used to quantify IAQ.

The carbon fibre threads were vacuum-cleaned every third month to ensure their function..
Statistical analysis of the data was performed using two - tailed, paired students T-test.

RESULTS:

The outdoor air was always found to have a higher concentration of particles > 0.3 µm, than the indoor air. This is illustrated in Figure 2 showing parallel in- and outdoor measurements with and without the EAC-system in use. On average, a 25 % reduction of particles > 0.3µm was noted

Figure 2



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 particles > 0.3 µm ($p < 0.001$).

The average daily count of particles >3.0 µm was recorded on ten 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 per litre of air to 232 (range: 166 - 287), p <0.01.

Figure 3

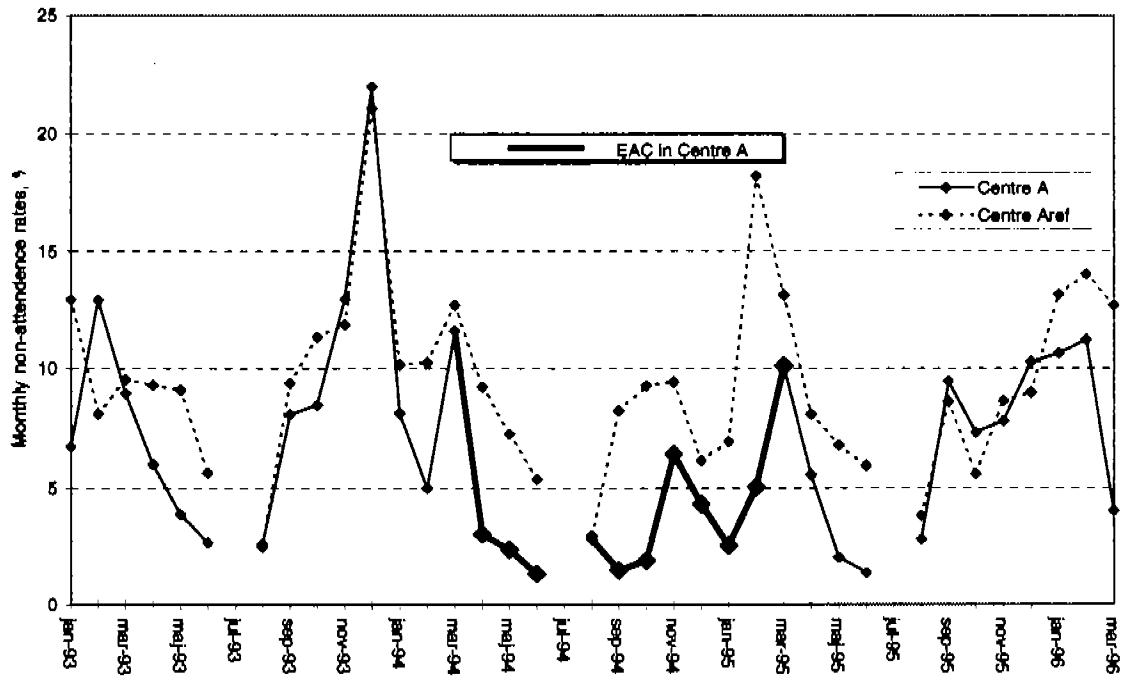


Figure 3 shows the monthly figures for non-attendance rates due to sickness comparing the two larger day care centres A and A_{ref}. The two centres followed a similar pattern during year 1 and 3 whereas during year 2 when the EAC-system was in operation centre A consistently showed lower non attendance figures than centre A_{ref}. (The graphs are disjointed because of summer vacations.)

Table I

Non-attendance due to sickness, annual rates (%)

	Centre A		Centre A_{ref}	Centre B		Centre B_{ref}
1993-94	8.31	**	10.31	9.20	*	5.46
	**					
1994-95, EAC year	**3.75**	***	8.75	**6.09**		6.76
	*					
1995-96	7.94	*	8.76	5.92	**	9.21

* = p<0.05, ** = p<0.01, *** = p<0.001, paired T-test

Table I gives a comparison of absenteeism during the three year period in the four centres. Centre A had a significant reduction in absenteeism from 8.31% to 3.75% returning to 7.94% during the third year. It appeared as if centre A was significantly healthier than centre A_{ref} with 19 and 9% less sick children year 1 and 3, respectively. This difference became highly significant with 57% less sick children in centre A during the EAC year.
Table I also gives the non-attendance rates for the smaller and more modern day-care centres B and B_{ref}. centre B showed a decrease by 33% as compared with an increase in non-attendance by 23% in centre B_{ref} comparing year 1 and 2. These differences did not reach statistical significance. Note the increase in non-attendance in the newly built centre B_{ref} which became significant during the third year ($p<0.05$).

When the EAC system was turned off the staff in centre B complained of the stuffiness of the indoor air and had the ventilation system checked. The system was operating according to specifications. The only side effect noted during the EAC year was an accumulation of dirt around the emitters. This was markedly reduced by placing a metal sheet between the emitting thread and the ceiling. More dirt was noted when cleaning the floors on a daily basis. The parents also noted that the children's socks became more dirty during the EAC year.

DISCUSSION:
The aim of the study was to conduct a controlled trial to test the ability of a newly developed electrostatic air cleaning device to improve IAQ as defined by levels of air borne particles and to investigate the potential to reduce non-attendance rates among children in day care centres. These are known for an almost three-fold increase in non-attendance, primarily due to viral URTI which is related to the number of children[6] and possibly the load of biologically active air borne particles.

In the larger centre repeated measurement were undertaken in order to demonstrate effects on the number of air borne 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. This risk was further reduced by leaving the equipment mounted after it was turned off. Furthermore by including data obtained on a yearly basis short term trends due to seasonal variation in URTI can be excluded.

It was obvious that the EAC - system altered the pattern of dirt deposition with more dirt deposited on the floor and around the emitters. It appears logical to assume that the very fine particles generated outdoors, and reduced by 78%, got trapped as the air entered the room and passed close to the EAC system, the site where the negative electrostatic field was the strongest. 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 two weeks for the walls 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 become maximal, indicating that the negative electrostatic field effect is important.

IAQ and its impact on the indoor environment is not only a function of the concentration of air borne particles. Equally relevant is the potential biological activity of these particles[13]. This bioload concept includes fine respirable particles generated by micro-organisms. Our own experimental work on enhanced negative air ionisation has demonstrated the generation of hydrogen peroxide in the range of 0.7 to 1 μM at 20-50 000 negative air ions per ml of air[10]. Hyslop and collaborators recently reported on hydrogen peroxide as a potent antibiotic[11]. They showed a bacteriostatic effect at 25μM without any signs of affecting the growth of human fibroblasts. To what extent a hydrogen peroxide concentration of 1μM operating over time would affect the growth of micro-organisms remains to be tested. However, own observational data has indicated a marked decrease in air borne moulds in rooms after two to five months of EAC treatment.

To our knowledge no previous attempt has been made to study interventional procedures and their capacity to improve indoor quality, relating the effects on the non attendance rate among children. Hawkins, in a previous controlled trial on negative air ionisation showed positive effects on subjective parameters such as headaches etc[12]. Such observational studies need to be substantiated by more detailed research into possible mechanisms. In the current study a substantial reduction of indoor air particles was achieved by altering of 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[6].

Un-expectantly, centre B_{ref} which was established in a new building in August 1993, showed a significant increase in the non-attendance rate from 5.46 to 9.21% ($p < 0.05$) during the three year period. Perhaps the biological history of a building and its accumulated bioload should also be considered when assessing the state of a building from a health perspective.
Whatever the complexity of factors affecting the indoor environment, it appears as if electrons released into the room thereby generating a weak negative electrostatic field and an increased level of negative air ionisation could significantly enhance IAQ with a potential to reduce URTI among children attending large day care centres.

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