Energy efficient air purification indoors

Introduction

Indoor air quality (IAQ) is an important aspect of life as we spend 90% of our time indoors. Hitherto, forced ventilation has been the norm at the cost of energy and dry air affecting us all. For further information, see the enclosed publications[1],[2]. As stated by the Editor of the journal Indoor Air "indoor air science needs to broaden its scope, involving cross-disciplinary and applied research"[3] of which our work with electrostatic air purification may serve as an illustration.

The concentration of air borne particles indoors is the best measure of the quality of the indoor air. The reason is most of the particles due to their size and compositions are biologically active and therefore constitute a bioload. This bioload is generated by different classes of particles as summarized in Table 1.

The ultra-fine particles

Of special concern are the finest, nano-size particles, often generated outdoors. A measure of these is the PM2.5 index used as a measure of the ambient air quality and risk factor. Today, we know that 90% of citizens in major European cities from 41 countries are exposed to levels exceeding the WHO safety limit of 10µg/m^3. As a consequence there are 467 000 premature deaths due to stroke, heart infarcts and cancer (www.eea.europa.eu/publications/air-quality-in-europe-2016). Increasing epidemiological evidence suggests that exposure to air pollutants plays a major role in the development and/or acceleration of Alzheimer's disease. Urban polluted environments and occupational exposures with ubiquitous distribution of high concentrations of ultrafine particulate matter are of great concern for the central nervous system due to their ease to go through biological barriers, causing an uncontrolled inflammatory response.

Our children

Recently, UNICEF (https://www.unicef.org/environment/files/Danger_in_the_Air.pdf) declared these nano-sized particles to be a major risk in the development of the brain. Air pollution is also linked with asthma, bronchitis and other respiratory infections and diseases, which can be debilitating, force children to miss school, and even cause long-lasting damage to their health and wellbeing.

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[1] Gustafsson, P., Abbas, M., Alm, M., Andersson, J. E., Bengtsson, M., Blad, S., ... & Rosén, K. G. (2017). Dålig inomhusluft kan ligga bakom hög sjukfrånvaro i förskolan. *Lakartidningen*, *114*.

[2] Gustafsson, P., Alm, M., Andersson, J. E., Dahl, Å. Wetterlund H. & Rosén, K. G. (2018). Luften inne på sjukhusen är en viktig faktor. Dagens Medicin nr 22, 2018-05-23.

[3] Corsi RL. Connect or stagnate: the future of indoor air sciences. Indoor air. 2015; 25: 231-234.

These effects are well established. But a growing body of scientific research points to a potential new risk that air pollution poses to children's lives and futures: its impact on their developing brains. This should concern us all. Few things are as important to a child's future as the first 1,000 days of life, when the brain undergoes the most critical and rapid growth. Every neural connection made during this critical window of brain development in early childhood forms the foundation for future neural connections, and ultimately influences the likelihood of healthy development of a child's brain. This, in turn, is crucial to children's ability to learn and later, to earn a living and fulfil their potential as adults.
Furthermore, young children's immune systems are still developing, and their lungs are still growing. With every breath, children take in more air per unit of body weight than adults. By extension, when air is toxic, they take in more toxic air per unit of body weight than adults. Unfortunately, staying indoors does not provide protection. In fact, the situation may become even worse as the ultra-fine particles enter easily and are added to by the air pollutants generated by the indoor activity.

What to do.

The only air we can control is the indoor air or the air in the car we drive. The problem is that staying indoors is not enough as the indoor air may become even more risky and fine and ultra-fine particles will enter indoors as well. Therefor some sort of air purification is required unless we do what people did 100 years ago - choose to spend time in the mountains or by the sea-side just to recover from air pollution.

An alternative is to install air filtration units at home but these are complex to operate, expensive to run and require regular maintenance. However, Danish researchers has shown that when this high-tech technology was used in homes of 60+ year old healthy people living in Copenhagen, their ability to regulate the blood flow improved already after 48 hours and this improvement was related to a reduction in the ultra-fine particles. Now we know what to target therefore there is an opportunity to develop new and more environmental friendly technology. Could a controlled electrostatic field operating in the room become an alternative?

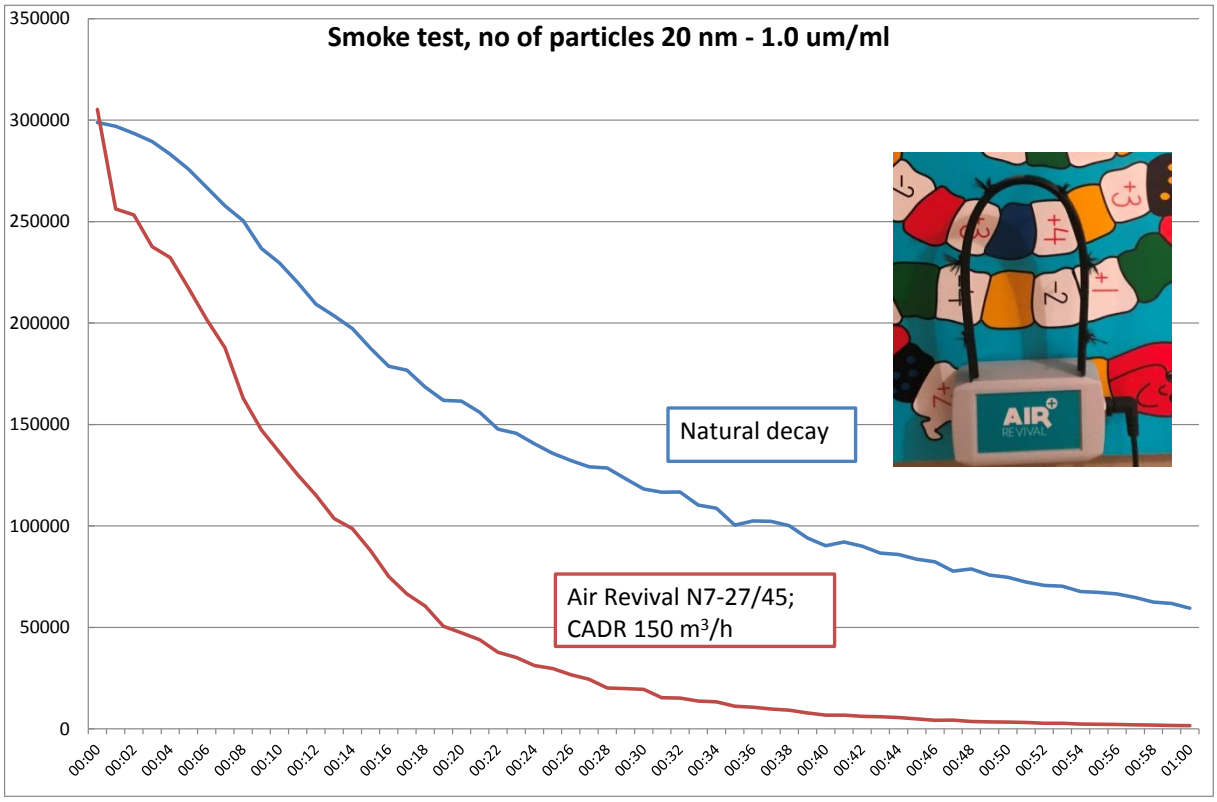
The AirRevival technology

This was the question scientists and clinicians working at the University of Plymouth, UK headed by Prof. Karl Rosén asked themselves some 25 years ago. After a combination of basic and applied research studying what happened to the chemistry of the air when electrons were released to generate a negatively charged electrostatic field and tests in schools and offices in the UK and Sweden, the basis was laid for the development of the AirRevival technology by a Swedish company, Neoventor Medicinsk Innovation AB working in close collaboration with the researchers.

Electrons may be used for many different purposes. In the body, the role of oxygen is to capture electrons released when energy is generated. In the air, the same happens in the air and a small amount of hydrogen peroxide (H_2O_2) is generated when vapor is added. We produce ourselves H_2O_2 when the immune system has to fight against microorganisms and it could be demonstrated that the AirRevival technology could reduce the bioload of the air by "starving" molds indoors and most likely

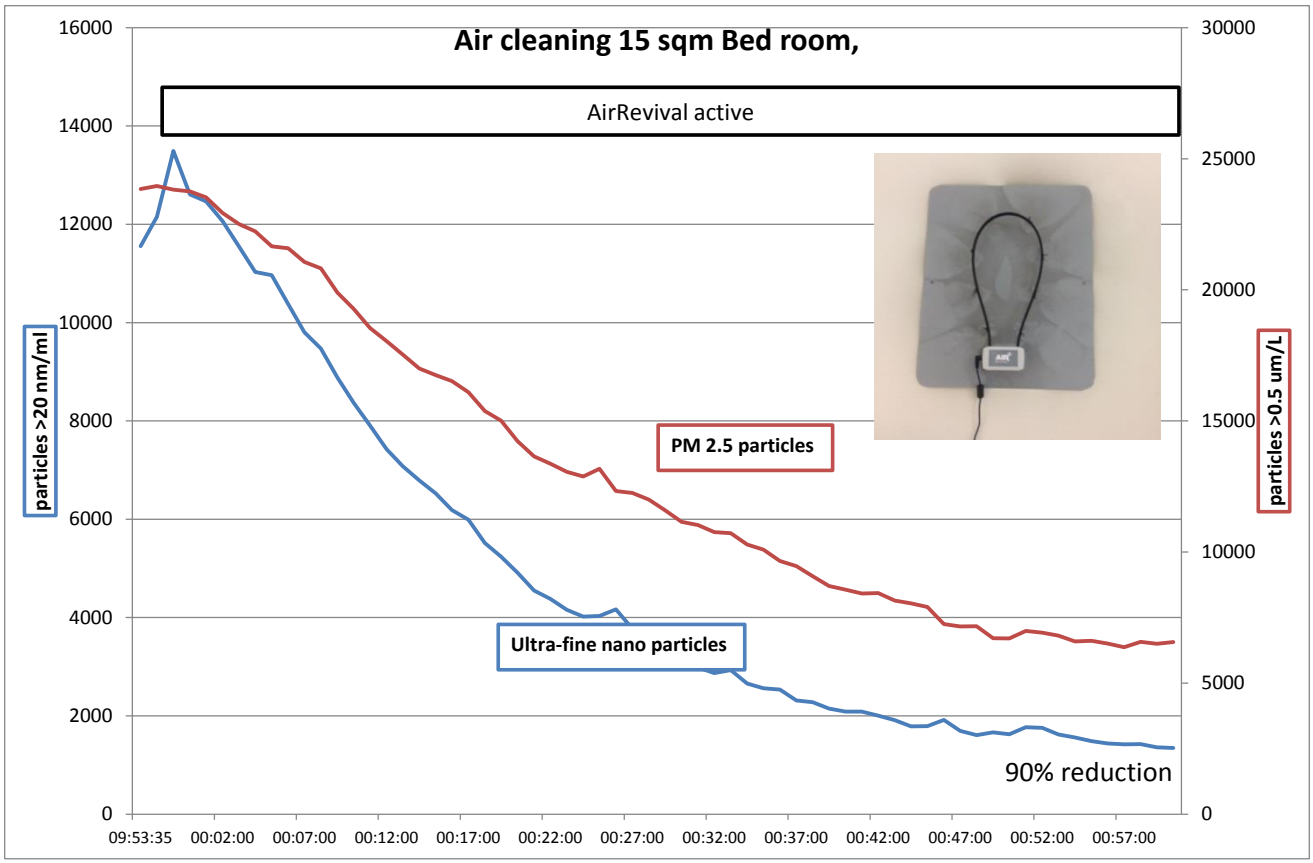
kill viruses[4]. Already in the first study in Swedish preschools published in 1999 a more than 60% reduction in particles could be demonstrated by the electrostatic air cleaning (EAC) technology and most importantly, the non-attendance rate was reduced by 55% i.e. the children had less viral infections[5]. Not only was it possible to purify the air from particles generated by the traffic as well as those generated by the activity of the children but is was also possible to reduce the bioload indoors and have healthier children. However, further work on design and documentation on efficacy was required.

This has now been completed in that independent tests has documented the ability of one AirRevival unit applied to a window to produce 96.6 m^3 of air free from the most hazardous 100 nm size particles per hour when the air is circulating. When it comes to the nano-size particles, the Clean Air Delivery Rate (CADR) is even higher as illustrated by Figure 1 and 2 using the smallest AirRevival unit in a situation with no air circulating.



[4] Hagbom, M., Nordgren, J., Nybom, R., Hedlund, K. O., Wigzell, H., & Svensson, L. (2015). Ionizing air affects influenza virus infectivity and prevents airborne-transmission. *Scientific reports*, *5*, 11431.

[5] Rosén KG, Richardson G. Would removing indoor air particles in children's environment reduce rate of absenteeism - a hypothesis. Sci Total Environ. 1999;234:87-93.



The energy requirement I only 0.6W per unit and the only maintenance required is to wipe the black sooth from the easy to clean surface (window glass or board connected to ground) on where it sits. Furthermore, the use of carbon fibers as electron emitters has prevented the generation of ozone, a problem related to the old ionizer technology. There are many other features that make an AirRevival unit, the most important are its unique air cleaning capacity in relation to ultra-fine particles.

The most important outcome of the work done so far has been the ability of the modern AirRevival technology to achieve the same outcome as previously noted in pre-schools. Recently we could demonstrate a reduction in days being sick from 12 to 5 days per year provided the humidity of the indoor air is >30 – 35% relative humidity.

One could argue; “Clean air should be the expectation of all, not the luxury of some”. It seems as if electrostatic air purification and the AirRevival technology provide such an opportunity.

Fig. 3. An AirRevival N7-70/90 unit placed in a preschool window. Note the accumulation of particles on the glass behind the emitter arch.

Prof Karl G Rosén, MD, PhD, Neoventor AB 2018©

Reduction in sick leave due to upper respiratory infections among pre-school children

Background

The concentration of airborne particles in the indoor air (bioload) is the best measure we have in terms of air quality. The particle content is affected partly by the pollutants that take place outdoors and by the activity that occurs in the room. With this basis, the objective of using an air-cleansing technology developed to handle particles and does not constitute a burden on the environment, require large investments and operating costs. It is also important to be able to document the quality of the air both before and after the inserted action.

It is well known that exposure to air pollution from the outdoor air can lead to asthma symptoms[i,ii] while the quality of indoor air is at least as important as children spend 90% of their time indoors[iii]. An important factor in this context is the risk of being exposed to viral infections[iv] and being exposed to mold[v]. There is a need to develop and use new technology focused on cost-effectively reducing the amount of biologically active particles in indoor air and thus increasing the quality of life for sensitive individuals.

Very small airborne particles are controlled by electrostatic fields. Electronic air cleaning (EAC) provides a means to enrich the air with electrons. Some of these electrons will be captured by oxygen molecules in the air. These then take up an electron and thus increase the oxidative ability of the air. With adequate air moisture (relative water content >40%) low concentrations of hydrogen peroxide (H_2O_2)[vi,vii] are formed.

Own studies in the preschool setting has shown that EAC technology not only removed fine particles and mold spores out of the air, but also made children healthier with fewer respiratory infections[viii]. The concentration of fine particles decreased by 80% and attendance among children (<6 years of age) increased by 55% which led to 190 fewer sick days among the 60 preschoolers compared to control day care centers.

Mechanism of reduced bioload – data from the pre-school LärKan

The preschool LärKan is a newly built preschool that was started in autumn 2017 located in a suburban area in South west Sweden. During Nov/Dec 2017 a test of air cleaning capacity was performed. AirRevival installation was completed by the end of 2018.

A first step in the Project Improved Indoor Environment was to measure the airborne particles content. This was done partly under basic conditions (6 days of the week), partly after AirRevival units had been installed in two playrooms (4 days). Table 1 shows the average number of particles during the daytime 08 - 17, Particulate matter >0.5 um comes mainly from combustion (e.g. diesel exhaust), while particles >2.5 um are created by the activity in the room. Baseline data shows an acceptable air quality that then further improved when normal ventilation was supplemented with EAC.

Table 1

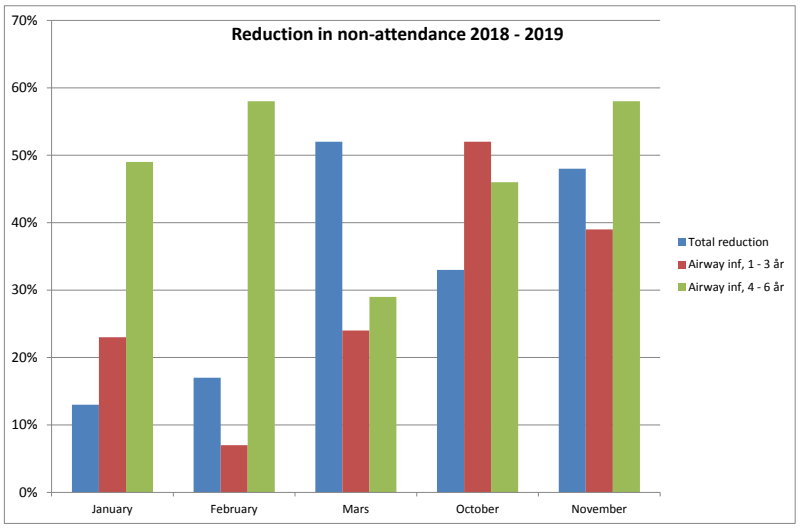
Playroom Particle size	Playroom 1 >0.5 um	Playroom 1 >2.5um	Playroom 2 >0.5 um	Playroom 2 >2.5um
Number of particles without AirRevival	811	251	833	271
Number of particles with AirRevival	455	64	661	136
Reduction	44%	74%	21%	50%

The question then arises to what extent EAC had any impact on sick leave?

Table 2 provides averages for total absence, caused by airway infections (AI) and gastroenteritis (Gastro) on Fsk LärKan in 2018 – 2019 in relation to children's age. Data obtained from the regional Infection control Center (M. Bengtsson).

	Total	AI 1-3 years	AI 4 - 6 years	Gastro
2018	14,40%	10,1%	9%	3,1%
2019	9,20%	7,18%	4,6%	2%

The percentage difference between the two years is shown in Fig 3.

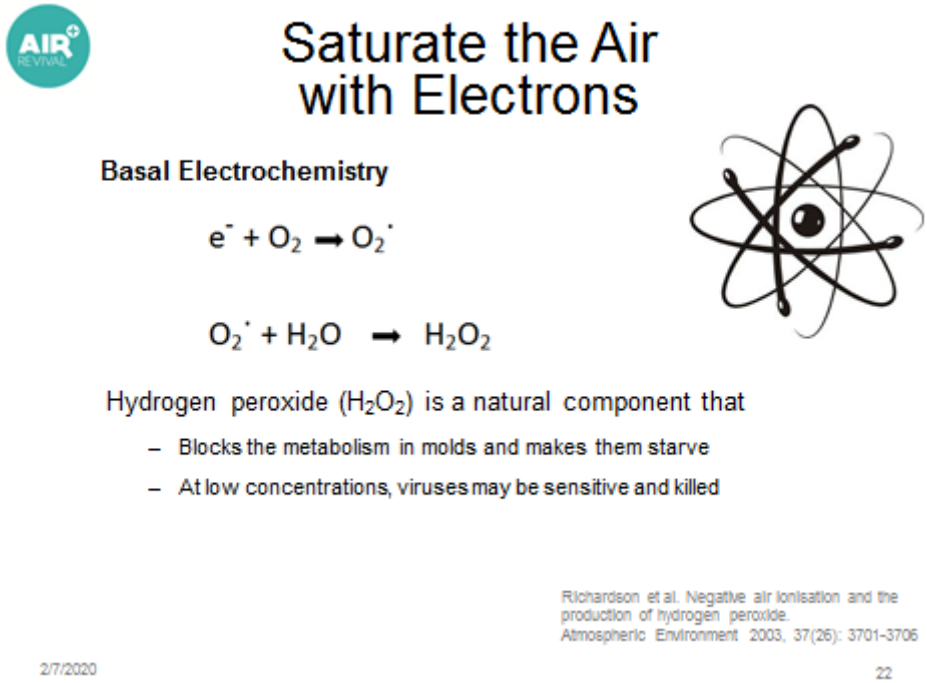


When comparing data from Fsk LärKan to the corresponding non-attendance rates due to airway infections from the nearby City of Gothenburg data show that the most pronounced improvement occurred during the spring month of March and the autumn months of October/November when the humidity of the air was higher the during the cold winter months.

Comment

Total sick leave and those related to airway infections were clearly lower in the months (March, October, November) when the weather was mild and rainy, i.e. there was a higher humidity. This observation also existed when compared to sick leave in Gothenburg city preschools. In connection with AirRevival, electrons that are partly bound by oxygen molecules are released in the air. These charged oxygen molecules can then join the water vapor of the air and form hydrogen peroxide with

known virus-killing effect[8]. This effect is most likely when viruses are airborne as would be tha case with airway infections.



In a recent study in guinea pigs at Linköping University with the support of the Swedish Research Council, Marie Hagbom and co-workers showed that ionization of the air with 100% efficiency prevented transmission of influenza viruses between guinea pigs. The method also effectively captured airborne calicivirus and rotavirus[ix]. According to our findings, one reason for this observation may be that the liberated electrons are captured by the oxygen molecules in the air, which together with the water vapor generate hydrogen peroxide. H_2O_2 is a superoxide that our body itself utilizes in its infectious defense against bacteria and viruses.

Dry air has known effects in terms of increased viral survival and poorer barrier protection of mucous membranes. Consequently, increased humidity can have positive effects on the spread of infection. Here, however, there should be the same conditions because all the participating preschools are located in a rainy part of the Swedish west coast.

References

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