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Electrostatics in the environment: how they may affect health and productivity

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Abstract. Lifestyles and the built environment have changed considerably during the past century and have greatly influenced the electric field, small air ion and charged submicron aerosol regimes to which individuals are often exposed. In particular the use of electrical items, synthetic materials/finishes and low humidity levels that can lead to the generation of high electrostatic charges, along with inadequate grounding protocols and building techniques which create "Faraday cage"-like conditions, have all greatly altered the electromagnetic nature of the microclimates many people occupy for prolonged periods of time. It is suggested that the type, polarity and strengths of electric fields individuals are exposed to may affect their likelihood of succumbing to ill-health through influencing biological functioning, oxygen-uptake and retention rates of inhaled submicron contaminants to a far greater degree than previously realised. These factors can also influence the degree of local surface contamination and adhesion that occurs. It is further suggested that both health and work productivity can be affected by such factors, and that improved "best practice" electro-hygiene/productivity protocols should be adopted wherever practical.

1. Introduction

Electrical phenomena can act as major transport and removal mechanisms for submicron particles [1]. Over ninety percent of airborne particles indoors may be less than 1 μm in size [2], a size-range occupied by many potential carcinogens and pathogens, the latter including *Adenovirus, Influenza A, B* and *C, Mycobacterium tuberculosis* and *Staphylococcus aureus* (MRSA) [3]. The behaviour of the smaller particles within this range is greatly influenced by their electric charge.

Hypothesis. It is proposed by the present authors that poor electro-hygiene may greatly influence the likelihood of inflammatory effects, infection and contamination occurring (partially through increasing individuals' exposure to nanoparticles and other submicron aerosols), and that the creation of low field microenvironments - particularly those with appropriate small air ion concentrations, vertical electric field protocols, grounding provisions and humidity levels - may dramatically improve biological functioning, indoor air and indoor environmental quality, thereby improving health and productivity. Past research undertaken by different disciplines worldwide has already indicated possible benefits that may be achievable from adopting many of the measures proposed in this paper. As examples of this, the antistatic treatment of rooms has been shown to prevent their occupants suffering incidents of asthma [4], and the utilisation of charged ceilings to create vertical electric fields in hospital wards was found to reduce significantly airborne concentrations of microbes [5]: such treatments should also benefit individuals with chronic obstructive pulmonary disease (COPD).

Similar field regimes have additionally been shown to reduce airborne concentrations of non-biological particulates [6], enhance immune-system functioning, activity levels, oxygen-uptake and aid mental and physical performance [5, 7, 8].

2. Effect of Charge on Particle Deposition

The deposition rates and deposition velocities of nanoparticles and other submicron aerosols can be strongly influenced by charge, with these increasing as localised electric field-strength and/or the charge of the individual aerosol increases. Such factors are seldom taken into account as possible variants in standard pollution / contamination studies, even though the majority of PM_{10} particles encountered indoors can be less than a micron in size [1], and have their deposition strongly influenced by electrical phenomena. It is proposed that this is a serious omission. The creation of very large charges is often noted in hospitals wards [9], particularly when activities such as changing blankets are undertaken and materials at opposite ends of a triboelectric series are brought together [10]. Electrical items such as ungrounded laptop computers, anglepoise lamps and televisions will also increase the localised fields and the deposition of submicron particles, including microbes. It is hypothesised by the present authors that poor electro-hygiene, from a variety of causes, is one of the main reasons behind increased incidences of hospital acquired infections, and that multiple measures, as detailed later in this paper, are required to reduce effectively such problems, as single measures alone may not be adequate. Excess charge can also cause problems in other building types. In office environments, the main reasons for excess charging of individuals can be generation of electrostatic potential when walking across insulative flooring, or the rubbing of shoes and clothing against chairs and surroundings when seated [11]. This can lead to individuals experiencing increased deposition of submicron fine and ultrafine contaminants. Electrical items again may greatly increase local electric field levels and the localised deposition of sub-micron contaminants, including microbes.

2.1. Surface Contamination

Submicron surface contamination can be considerably enhanced by the localised occurrence of high electric fields, with such deposition being harder to remove than that taking place under low field regimes. This is because the increased field strength increases the deposition velocities of charged, charge-neutralised and dielectric submicron aerosols, raising their adhesion both on impact and directly after contact [12]. It is proposed by the present authors that this is a major factor behind the increased incidence of recalcitrant microbial infection in hospital wards and could be easily reduced through enhanced electro-hygiene.

2.2. Skin Contamination

Skin can frequently gain high potential if appropriate electro-hygiene measures are not introduced, thereby enhancing the deposition of high concentrations of oppositely charged aerosols that can contain microbes and other potential contaminants. Triboelectric charging often appears to be the main cause of such deposition, with precipitation increasing as potential is raised [11]; though close proximity to high field-emitters, such as televisions (which are often present in hospital wards in close proximity to patients) have also been shown to raise significantly deposition of submicron aerosols [13]. Increased deposition has additionally been linked with incidences of skin problems and facial rashes, particularly when low levels of humidity are present [11]. High electrostatic fields can significantly increase concentration of contaminants present on skin, skin squamae and other particulate matter.

2.3. Contamination through Inhalation

Between 6,000-50,000 squamae (skin flakes) can be inhaled per litre of air via the nose [14] - with higher concentrations being inhaled through mouth breathing. The present authors suggest that improved electro-hygiene/productivity protocols may greatly reduce the probability of subjects becoming infected through inhaling contaminated squamae – as less contaminants are likely to settle on the skin surfaces to which they originally belonged. Particles may additionally adsorb less toxic substances under such conditions.

It is further suggested that improved electro-hygiene/productivity protocols could significantly reduce the alveolar burden that the body receives from inhaling and retaining submicron particulate matter and its chances of becoming infected from microbes within this size range (both through skin/surface contamination and inhalation). The latter is because the degree of charge that a particle holds can strongly influence the likelihood of it depositing in the respiratory tract. Whilst a relatively high number of charges is needed to increase respiratory deposition of larger particles, simulations have that shown singly charged 0.02 µm particles can deposit five times more readily than uncharged particles, and over three times more readily than charge-neutralised particles [15].

3. Direction of Current Flow

Many indoor environments can inadvertently screen people from beneficial natural electromagnetic phenomena, such as the positive vertical electrical potential gradients of ≥100 V/m that can be created by "fair weather" conditions outdoors, whilst exposing them to distorted current-flow regimes and/or "Faraday cage"-like conditions [16, 17]. It appears that such conditions may have a marked effect on both health and productivity. Individuals can often be exposed to such unnatural field regimes for large proportions of their day.

Past animal research has revealed that exposure to constant vertical DC field protocols can dramatically improve immune-system response compared to Faraday cage and control environments [18]. In that work, the plaque count method was used to determine the degree of immunisation created under different field regimes, with increased rates of immunisation being indicated by increased plaque counts (Table 1).

Table 1. Plaque Counts after 15-day exposure to Various Field Levels

Field strength (V/m)	Constant DC field	Faraday cage
40 V/m	210.2 ± 24.1	111.6 ± 11.0
200 V/m	608.0 ± 55.1	199.2 ± 16.5
1,000 V/m	572.4 ± 112.8	76.0 ± 34.0
5,000 V/m	>3000	125.6 ± 21.5

It is suggested by the present authors that similar improvements in the immune system response of humans may occur through exposure to vertical field regimes in otherwise low field microenvironments, and that introducing such regimes in hospital environments may greatly improve patient recovery. Additionally, it was noted in the past that the presence of constant positive vertical electric fields could have pronounced beneficial effects on the recovery of animals with microbial infections, including bird flu [5]. It is proposed that the validity of such research should be reassessed at the earliest possible opportunity, particularly with regard to investigating the possible effects of such fields on the recovery times of humans. Tests have shown that the direction and degree of current flow that animals are exposed to can also strongly influence their activity levels and oxygen uptake [7]. Human work efficiency and likelihood of producing errors can also be influenced by such factors, with enhanced vertical electric field (and small air ion) protocols being capable of markedly improving performance [8].

4. Incidences of Electro-pollution

Even where beneficial constant vertical electric field regimes can be created indoors, such fields may often be masked by the creation of highly localised incidences of "electro-pollution" caused by fields created by the equipment and finishes present in individual microenvironments (Figure 1), and the materials worn and charges generated by individuals themselves. Measurements taken by the main author [17, 19, 20] indicate that far greater concentrations of charged sub-micron contaminants are often present within areas that exhibit poor electromagnetic hygiene. In the instance shown, the virtual

Lower bound of positive small air ion levels — Electrostatic potentials in kilovolts (kV) [19]

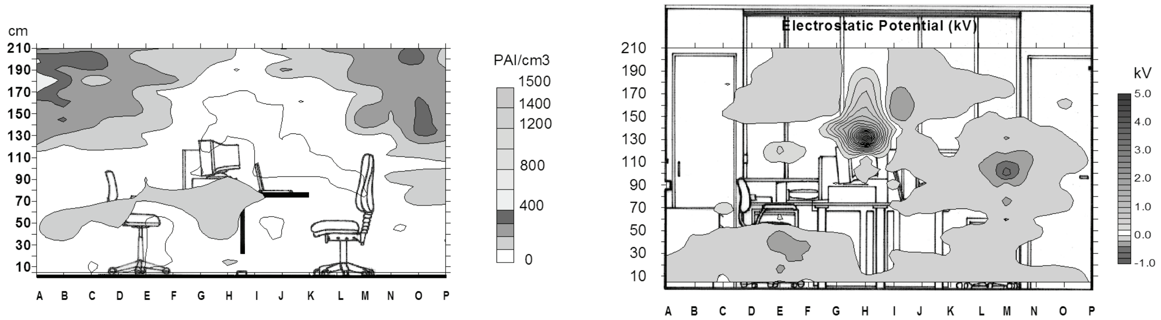

Figure 1. Vertical Section of Non-Ion Enhanced Office Environment

absence of small air ions (of both polarities) occurs in the areas where high electrical fields exist, and is indicative of the presence of high concentrations of large air ions (which normally add little to air's conductivity - except when small air ions are absent) in those areas. The suggested presence of raised concentrations of large air ions (charged ultrafine particles) in such areas indicates that a higher retention of inhaled submicron particles can occur in those places than in lower field microenvironments within such rooms. Increased ingestion of such particles as a result of poor electro-hygiene will reduce biological efficiency and may also exacerbate respiratory complaints. Higher localised deposition of submicron contaminants is also likely to occur onto skin and nearby surfaces under such conditions.

5. Enhanced Electro-Hygiene/Productivity Protocols

Electro-pollution can occur in many everyday situations due to fields emitted by poorly designed electrical items and the contact charging of inappropriately specified finishes and materials. It is suggested that adopting enhanced electro-hygiene/productivity protocols could - at relatively low cost - greatly reduce the chances of individuals succumbing to infections and respiratory infections whilst improving their work efficiency. Such measures could also greatly reduce the likelihood of people suffering from allergies and compromised immune systems due to increased burden from inhaled contaminants. If properly developed, they may also greatly help improve patient turnaround time in hospitals, boost immune system functioning and aid work performance whilst reducing incidence of biological stress.

5.1. Air Ionisation

Small air ions are vital for life [21], are microbiocidal [22] and can help reduce incidents of infection and contamination [23, 25], yet are often present in very low concentrations in many modern environments. The mandatory levels for small air ions *of both polarities* stipulated by the Ministry of Health of the Russian Federation's 'Sanitary and Epidemiologial Norms' Guidelines (SanPiN 2003) for computer workplaces - which are claimed to help improve performance and reduce incidences of fatigue - are shown in Table 2 [24]. Many standard office environments have small air ion levels far below the minimum levels suggested in those standards [17, 19, 20].

Table 2. Mandatory small air ion levels for computer workplaces in the Russian Federation [24].

Concentrations of Small Air Ions /cm^3		Comments – mandatory levels when staying in enclosed space daily.
600 negative	400 positive	Mandatory Minimum allowable concentrations
3000 – 5000 negative	1500 – 3000 positive	Optimal recommended concentrations
50,000 negative	50,000 positive	Mandatory Maximum allowable concentrations

Animal studies have indicated that bipolar air ionisation may significantly improve the body's ability to fight disease. As an example of this, levels similar to those recommended as optimum in the Russian Federation's guidelines [24] were shown to increase markedly the survival time of animals infected with influenza [26], as opposed to controls exposed to low small air ion levels (similar to those found at many computer workstations). It is suggested by the present authors that properly balanced bipolar ionisation may also help reduce the levels of inhaled fine and ultrafine particles retained by the body.

It is proposed that negative ***unipolar*** air ionisation should not be used other than for short-term exposures and medical treatments in its standard configurations, as animal tests have revealed that long-term exposures to such regimes may dramatically shorten lifespan [27]. Where possible, passive air ionisation measures, such as the specification of electrical items and materials that do not generate high charge, should also be adopted to help minimise creation of excess charge.

5.2. Relative Humidity / Dew Point temperature

Low humidity levels can inadvertently cause high levels of charge to be generated [28], thereby causing increased local concentrations and deposition of charged submicron particles, whilst reducing local concentrations of small air ions. Such conditions may often occur indoors when heating or cooling systems are used which inadvertently dry the air [9]. Localised incidences of low humidity can also be caused due to the heat generated by the use of electrical equipment, such as televisions and computers.

Humidity levels can be improved in several ways including the use of evaporative humidifiers, commercial humidifiers, and/or greenery in individuals' microenvironments. Though standard 'good practice' procedures suggest levels of approximately 45-50% relative humidity to help reduce electrostatic potential, more accurate and cost-effective control can be obtained through regulating dew-point temperature, as it is directly proportional to the air's absolute vapour content - there is little difference in voltage generated when relative humidity and temperature are varied and dew-point temperature is constant, but varying dew-point temperature greatly affects charge generation [29], indicating that regulating it may be a more effective way in which to mitigate excess charge. Interpolation of the Ministry of Health of The Russian Federation's standards [24] by the present authors would imply that the "ideal" dew-point temperature indoors may be ≈12ºC, and that ≥4ºC dew-point temperature is permissible (Figure 2).

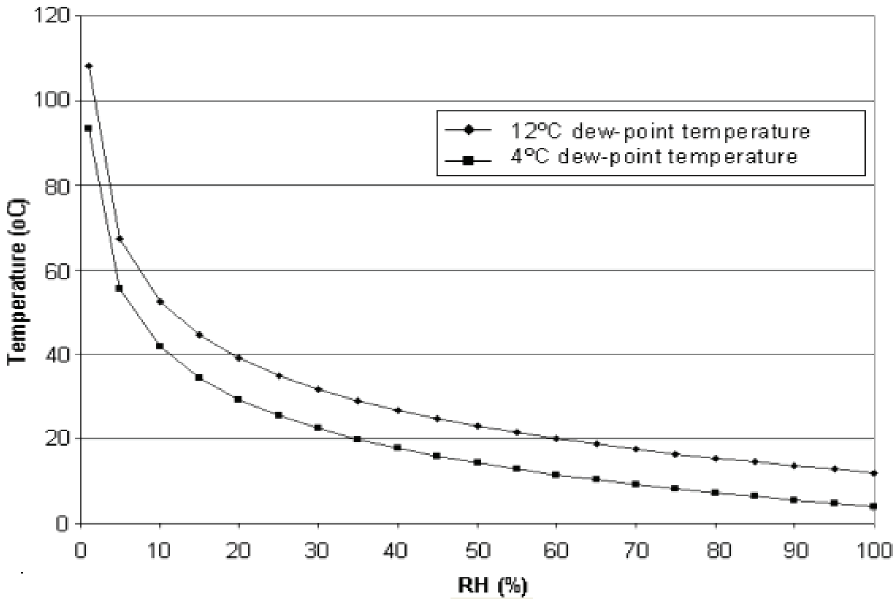

Figure 2a. Hypothesised Optimum & Minimum Acceptable Humidity Levels

As a demonstration of the effectiveness of humidity control in reducing electrostatic potentials; walking across a synthetic carpet at -3ºC dew-point temperature was found to generate a potential of 35 kV, whilst undertaking the same action at 17ºC dew-point temperature generated only 1.5 kV [28].

5.3. Grounding
Excess charge can often be inexpensively removed from conductive objects through grounding, though for materials which act as insulators, alternative solutions such as balanced bipolar ionisation, or increasing their conductivity, should be sought. Special care appears to be required when grounding individuals to ensure they are not exposed to pulse-transients from mains electricity through the ground, as these have been indicated as being potentially injurious to health [30].

5.4. Materials and Finishes Specification
Clothing and the materials and finishes used in individual microenvironments can greatly determine the degree of electrostatic charging that occurs, and can strongly influence the concentrations of small air ions, as well as charged and charge-neutralised dielectric submicron aerosols, including nanoparticles, present in individual microenvironments. Great care should be taken to ensure that materials that can gain high charge are not used, particularly when there is the possibility of materials at opposite ends of a triboelectric series coming into contact with each other [10]. Where possible conductive materials that generate low charge should be used along with the provision of adequate grounding opportunities.

5.5. Electric Field Regimes
Where possible, it is suggested that electric field regimes should be created which mimic beneficial natural electromagnetic phenomena, such as the vertical potential gradients created by “fair weather” fields. As past research has shown that exposure to more natural field protocols can (*in some instances*) substantially improve biological performance, including oxygen-uptake, immune-system functioning, activity-levels and mental performance, in comparison to Faraday-cage and distorted field-regimes [5, 7, 8], it is suggested that further detailed research in this area is required as a matter of urgency.

6. Conclusion
The electro-environment many people normally occupy in modern life is far from the optimum one that is obtainable. The degree of contamination individuals receive from nanoparticles and other submicron particulate matter, and their likelihood of succumbing to microbial infection and respiratory infections, such as asthma and COPD, appears to be significantly linked to the degree of charge and field regimes present in the microenvironments they occupy.

Whilst technology has made great advances, little thought is given presently to how humans are often masked/screened from electrical phenomena which can be used to create beneficial effects in individuals, such as increased work performance, and reduced incidences of stress, infection and ill-health. It appears that significantly healthier and more productive micro- and macro-environments can be created through the development and adoption of appropriate electro-hygiene protocols and intelligent building that seeks to create more natural electro-environments. The potential cost-benefits and end-user benefits of introducing such environmental measures appear substantial. Further research in this relatively unexplored and often forgotten area of research is urgently required.

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