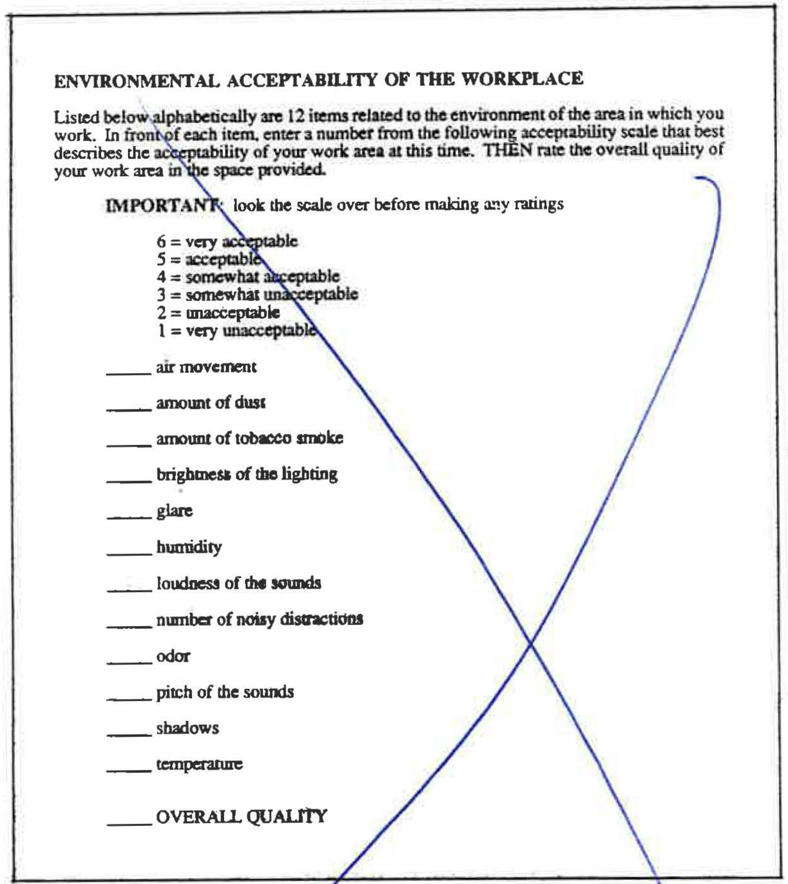

ENVIRONMENTAL ACCEPTABILITY OF THE WORKPLACE

Listed below alphabetically are 12 items related to the environment of the area in which you work. In front of each item, enter a number from the following acceptability scale that best describes the acceptability of your work area at this time. THEN rate the overall quality of your work area in the space provided.

IMPORTANT: look the scale over before making any ratings

6 = very acceptable
5 = acceptable
4 = somewhat acceptable
3 = somewhat unacceptable
2 = unacceptable
1 = very unacceptable

_____ air movement

_____ amount of dust

_____ amount of tobacco smoke

_____ brightness of the lighting

_____ glare

_____ humidity

_____ loudness of the sounds

_____ number of noisy distractions

_____ odor

_____ pitch of the sounds

_____ shadows

_____ temperature

_____ OVERALL QUALITY

Fig. 2. Rating Scale--Final Form

A HYPOTHESIS ON THE MECHANISMS OF THE HEALTH EFFECTS OF MECHANICAL VENTILATION AND WARM AIR HEATING

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Abstract

The natural background air contains an optimum mixing and concentration of air gas components. Well-being and health are assumed to depend e.g. on the stimulating effects of ozone, ion spectrum, and natural molecular energy excitation states of gases. Unphysiological molecular excitation states or configurations, especially of water and too low ozone concentration, are associated with mechanical ventilation and warm air (electric) heating. The hazardous health effect hypothesis of these changes is supported by epidemiological studies, clinical exposure experiments with humans, and biochemical cell metabolism and energy production (ATP) changes in ozone and ion exposure studies. The ageing ventilated air molecules undergo excitation/relaxation depending on the physical characteristics of space.

Introduction

Recently some research reports claim that mechanical ventilation as such can be a contributing factor to sick building symptoms (5,12). Anyhow, there seems to be a lot of controversy about which is the primary cause and mechanism of the appearance of the symptoms.

The purpose of this paper was to build up a model which could explain some of the sick building symptoms in terms of physical changes in air molecules effected by mechanical ventilation and warm air heating. The hypothesis is based on unexplained findings of ozone exposure responses in some reports, where data shows peculiarities which are not explained without extra assumptions about exposure pattern. Clinical and biochemical oxidant exposure responses show quantitatively a trend to curve linear concave effect dependency. Unsatisfactorily explained effects can indicate the existence of an enchanced energy generation in mitochondria and hexose phosphate shunt by optimum ozone and ion concentrations (1,6,7).

Mechanical ventilation and warm air heating as energy dissipator

Mechanical ventilation includes fans, which push or pull air trough narrow pipes into or from room spaces. The forced ventilation can be characterized by (1) fast and turbulent air flow in pipes and nearby inlets in rooms, (2) continuous pressure fluctuations in pipes, and so in occupied spaces.

Air pressure fluctuation and fast air blow make audible noise and often infra frequency noise, 0 - 20 Hz. The fans accelerate air masses, set molecules in turbulent, chaotic motion. According to the gas kinetic theory a great deal of molecules acquire an excess energy, besides linear translational motion, in the form of excited vibrational or electronic states of molecules. The water in the air can be expected to disintegrate by breaking the weak hydrogen bonds (indicated by the two dots below), which usually hold together the water molecule clusters like $H\text{-}O\text{-}H\cdot\cdot OH_2$ or $H_9O_4^+$ (M), where the oxonium ion H_3O^+ is combined with three further water (H_2O) molecules with or without an aerosol indicated by M (4,11). The strength of weak hydrogen bonds is 10 - 30 kJ/mole (a mole contains approximately 6 x 10^{23} molecules), this being the energy required to separate the pairs of molecules again.

In fact a lot of diatomic air molecules, oxygen O_2, and nitrogen N_2 (and triatomic ozone O_3) can be excited to vibrational nuclear modes by turbulent air flow without extra heating of air. The presence of small concentrations of impurities in the gas is very effective in the exchange of vibrational and transitional energy. According to quantum mechanics some of the possible excited electronic quantum states of the molecules are occupied due to molecule collisions. The water in air is dispersed into many chemically active molecule clusters (11).

The effective energy of dissociation via a complex formation is less than the bond energy: $AB + C \rightleftarrows AB \cdot C \rightarrow A + BC$ (A,B,C are molecules). The reverse process to dissociation, i.e. recombination of atoms (or molecules) in room temperatures (approx. 300 K), can be described by the scheme $B + C \rightleftarrows BC$, $BC + A \rightarrow AB \cdot C$. The bond energy of recombination varies usually from 0 to 16 kJ/mole (11).

Temperature effects

It is well known that increasing the indoor temperature by 1 - 3 degrees (>22 °C) celcius in critical or subcritical indoor environments, i.e. in known sick office buildings, a great deal of people get typical symptoms very soon. One of the molecular changes is a resonant exchange of vibrational energy from collisions of two diatomic molecules (11, p. 92 - 96). An important characteristic of the resonant exchange by vibrational quanta is that the mean exchange probability grows with increase in temperature (warm air heating). In contrast to this, lowering the temperature increase the recombination of air molecules and especially the water containing aerosols. Recombination and dissociation of ions in mechanical ventilation air flow change drastically the spectrum of ions.

The physiology of exposures, physics and chemistry of ozone and ions

Ozone has been present in the atmosphere for millions of years. It is formed mainly by the ultraviolet radiation of sunshine, and its turnover rate is rapid, with an average concentration of 40 - 60 ug/m^3 in the background air. Ozone appears to be cell toxic and lowers lung function at concentrations above 400 ug/m^3. In the presence of protonic solvents such as water, peroxides, e.g. hydrogen peroxide H_2O_2, and free ionic radicals are generated in membranes leading to some toxic effects. Ozone exposures have resulted in biochemical and physiological changes, which can be interpreted as nonhazardous (2,3,6,10). Veninga et al.(15) concluded that there exists a threshold value for toxicity, and that living organisms might have developed adaptive and defense mechanisms to encounter certain ozone concentrations (phylogenetic explanation).

Formaldehyde exposures produced a decrease but ozone exposures an increase in nasopalatine nerve response (frequency) to amyl alcohol in rats; increased trigeminalactivity resulted in inhibition of respiratory rate (8). Hence, ozone stimulates nerve function and vigilance. Anyhow, the sensory stimulus produced by ozone is different from the one produced by hydrocarbon organics jointly.

The results of Finnegan (12) and Robertson (5) are in principal in good agreement with this finding, because warm air heating and mechanical ventilation destroys inlet air ozone and changes the spectrum of ions (7). In natural ventilation air infiltration (or airing) doesn´t destroy the ozone or distort the ion spectrum of outdoor ambient air.

The ozone concentrations in indoor spaces are dependent on ventilation system functioning, airing, gas reactivity of indoor surface materials and furniture materials (9).

A simplified picture of the indoor quality determinants

The most healthy air is born far from industry and densily populated areas, probably near a seashore in mild climatic conditions. This countryside air is characterized by moderate humidity, low level of suspended particulates and man-made irritant gases, background level of natural air gaseous components such as ozone and a natural spectrum of ions. We can smell this fresh air in early summer mornings. Man has a powerful capacity to recover from smoke and irritant gases in breathing air. But a long lasting even low level impairment of breathing air makes vulnerable people sick, especially in a cold climate.

The most essential features of the indoor air are assumed to be:
(1) humidity and temperature, (2) ozone concentration, (3) ion spectrum and dissociation of the air water, (4) odors, (5) age of air (air exchange rate), (6) electrical properties of the space (7) hygroscopicity of dust (aerosols) and its concentration.

A phenomenological hazard function of mechanical ventilation

The following model can be presented with the support of preceeding considerations. Simply, a relative health hazard function, which depends on the physical and chemical gas (aerosol) phase changes supposed to be produced by mechanical ventilation, is expressed as:

$$H= F\ (D, T, W, K) = f_1(\text{dissipated energy in gaseous components})+f_2(\text{deviat ions from an optimum of temperature, humidity, gaseous and aerosol components, physical fields})+f_3(\text{kinetic energy of air}),\qquad (1),$$

where $f_1=f_1(D)$, $f_2=f_2(T,W)$, and $f_3=f_3(K)$. In a strict sense, it is impossible to separate F into the functions of f_i. The equation (1) is an additive formulation to show which of the effective factors could play the most important roles. All of functions f_1, f_2, and f_3 are functionally interconnected. The function f_1 is thought to contain the effects of excited molecules: vibrational modes of O_2, electronic configuration changes, ions like O_2^-, OH^- (M), H_3O^+ (M). The function f_2 expresses temperature, and humidity effects, and especially health effects depending on the ozone concentration deviations from the supposed optimum (40 - 60 ug/m^3). The function f_3 contains adverse effects of noise, draught and air turbulence. A natural formalation of the function f_1 is:

$$f_1(D)= k({}^{dE}/_{(W/Vi)})x(E_{tot}/V_r)\qquad (2),$$

where k= constant, dE= energy dissipated in the water (W) of the inlet air in a volume V_i (W/V_i= g/m^3), E_{tot}= total changed (in reference to an optimum level of natural ventilation) energy level in the room volume, V_r. So $E_{tot}= E_v - E_o$, where E_v= total energy dissipated in the inlet air, and E_o= an optimum i.e. minimum value from health viewpoint in an optimum comfort state. The second term of (2) describes the totality of molecular energy and configuration distortion. This in turn depends on ventilation and physical chraracteristics of the room. The term $dE/(W/V_i)$ is supposed to be proportional to the activation of the water in incoming air. dE is for the higher chemical acitivity (in energy units) of the air water molecules, and W/V_i is proportional to the relative humidity of incoming air (at constant temperature). So, $dE/(W/V_i)$ decreases when relative humidity rises. In winter time when W is very low this term reaches its maximum. E_{tot}/V_r decreases when the volume of room increases, and increases when the incoming air is heated. Taken together, a maximal health risk is experienced in winter time, in small rooms with electric warm air heating with mechanical ventilation.

The temperature dependent part of f_2 can be separated in the following way:

$$f_2(T)= b_0 + b_1\ T + b_2\ T^2 +b_3\ T^3 +b_4\ T^4\qquad (3a),$$

which in practice can be simplified to: $f_2(T)=bo+b_2T^2+b_4T^4$ describing temperature dependency of sick building symtoms. The dominant term is the square of temperature. Eq. (3a) is valid for the incoming air of mechanical ventilation. Eq. (3a) holds for all room temperatures, even when $T<T_0$ (consistent with vote comfort temperature, T_0). In mechanical ventilation, if $T < T_0$ some degrees celcius, the temperature effect would be reversed, and $f_2(T)= b_0' + b_1'(T - T_0)$, where $b_0' < 0$ and $b_1' > 0$ $(T - T_0 < 0)$. In this case the temperature hazard function may be health promoting if the temperature To is discomfort high. Assume a humidity function

$$f_2(W)= \begin{array}{ll} c_0 + c_1\ (W_0 - W)h(T) & \text{if } W < W_0,\ c1>0 \\ c_0' + c_2\ (W - W_0) & \text{if } W > W_0,\ c_2>0 \end{array}\qquad (3b)$$

In eq. (3b) the function h(T) can be approximated by the function $f_2(T)$. W_0 is an optimum water content per unit volume in an optimum temperature. W is the water content of incoming air in a unit volume. Assume a gas hazard function: $f_2(G)= f_2(O_3) + f_2(RO) + \ldots$The function $f_2(O_3)$ is of approx. second order in the concentration of ozone within a certain range (approx. 0 - 400 ug/m^3). Assume: $f_2(O_3)= c_0 + c_1(O_3) + c_2(O_3)^2$, c_0, $c_2 > 0$ and min $f_2(O_3)$, when (O_3)= 40 - 80 ug/m^3. Assume $f_2(E)= eE^2$, where E^2 stands for the square of changing static electric field strenght of the indoor space. The e is an empirical constant.

Practical concequencies. Natural ventilation is preferable if feasible. Fresh outdoor air should be brought into occupied spaces with minimum air handling.

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