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TOWARDS HEALTHY MICROCLIMATE OF CLOSED SPACES AND HABITATS

As over 90% of our lifetime we spend in closed spaces (at home, at school, at work), it is extremely essential for our health and well being to create and maintain an adequate and healthy microclimate in those spaces. The quality requirements for air temperature and humidity must be met, but also those applying to the air purity and air exchange. Modern habitats are increasingly affected by pollution not only from construction materials used, but also (and more importantly) from furnishing. Paints, glues, carpets, floor finishing, rubber seals in doors and windows as well as noxious and toxic substances in furniture substantially contribute to overall air pollution in closed spaces. Such a pollution may be several times higher than bio-influences, i.e. polluting factors generated by human organisms. It is then important to provide closed spaces with more efficient air-exchange systems. The outside air is also polluted, not only with exhaust products, but also with dust and pollen affecting the ever-growing allergic population. It is then essential to filtrate the outside air before its discharge into closed spaces. The situation calls for new, energy-saving methods of microclimate control based on mechanical ventilation supply systems with heat recovery and use of non-conventional, renewable energy sources.

1. INTRODUCTION

Over 90% of our life we spend in closed spaces (at home, in the office, at school). Thus it is essential for our health and well being to create and maintain in such spaces proper microclimatic conditions that are close to the optimal values. This task is collectively undertaken by several fields of science, namely heating, ventilation and air-conditioning.

There are several basic parameters that characterize microclimate: the temperature of air within a closed space, temperature of surrounding planes, relative air humidity, as well as air velocity and its purity.

Heating devices influence only the room temperature (and only during the heating period). Ventilation devices, apart from controlling the air temperature, provide a proper airflow rate and proper air purification through filtration and air exchange. Appropriate microclimatic conditions may be obtained only by fitting efficient and

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carefully selected air-conditioning devices. Such devices will provide required temperature, humidity, flow rate and purity of the air at all times, independently of outside climatic conditions and any technological processes taking place in the conditioned spaces [1].

Appropriate microclimate in closed spaces is maintained to provide either thermal comfort for people or climatic conditions required for proper and efficient operation of industrial processes. In this respect, the air-conditioning processes can be divided into comfort air-conditioning and industrial air-conditioning.

ASHRAE's (American Society of Heating, Refrigerating and Air-Conditioning Engineers) definition states that air-conditioning requires the control over all (or at least the leading three) of the physical and chemical parameters of the air within the closed space [2]: temperature, humidity, air flow organization (velocity), dust content, bacteria, odours, content of hazardous or poisonous gases and ionisation – in order to maintain proper microclimatic conditions in a given space.

For the purpose of the discussion about hygiene one may also cite an apt definition formulated by Humboldt: *The term 'climate' addresses all atmospheric changes that influence human senses*. Thus, apart from the above, climate has to do also with such factors as: acoustic distractions, lighting and other features.

It may be stated then that the main task of comfort air-conditioning is to protect human beings in the closed spaces from all or nearly all of hazardous or troublesome influences from the outside (not only from the outside climate). In cities and big industrial agglomerations, the closed spaces in buildings are generally fitted with air-conditioning or ventilation devices in order to safeguard people from the outside pollution. This is because in the centres of big cities it is practically impossible for people to work or rest with the windows being open, due to the noise from the outside (its peak value being 65 dB(A), measured at 0.5 m outwards from an open window) or outside air pollution. Much attention is recently given to proper ionisation of air, not only in habitats, but also in vehicles, especially passenger airplanes and space shuttles.

2. MICROCLIMATE AND AIR IONISATION

Ionisation of air particles is caused by decomposition of radioactive elements contained in earth crust, water and air itself, as well as cosmic radiation, static discharges in atmosphere, etc. Ions are electrically disturbed atoms or particles. Positive ions are those with electron shortage, negative – with electron surplus. Mean content of ions of both types in 1 cm^3 of atmospheric air is between 200 and 10,000 ion pairs save for the fact that positive ion content is somewhat higher than negative ion content; their ratio is equal to 5:4, respectively. In cities the ion density may reach 50,000/cm^3, and in closed spaces even 100,000/cm^3. Natural air ionisation is higher in summer and lower in winter; higher in the early morning hours and lower in the afternoon [3]. Such constant changes in natural air ionisation balance were the main factor that hindered early research into influence of air ionisation upon living organisms to be overcome only after proper tools for artificial air ionisation were devised (air ionisators – the second half of the XX century). Much earlier experiments have shown that after short summer storms, in the vicinity of waterfalls and water sprinklers as well as in the mountains and at the seaside the air is more "refreshing". Research has shown that the air in such conditions is rich in negative ions. Dust particles and bacteria contained in the air are generally positively charged. Stale and dusted air, rich in positive ion content, contributes to the feeling of tiredness and seriously affects the attentiveness and concentration of human beings.

Central heating systems in closed spaces increase the positive ions content. The higher the surface temperature of metal parts of the heating devices, the higher the production of positive charges in the surrounding air. At the same time, the negative ion content is lower than average. Sultriness and dry throat felt in well-heated rooms were initially attributed to a high content of heated dust rising from metal surfaces, but recent research indicates that these feelings are due to disturbances in the positive-negative ion balance in the heated air.

Research also shows that the decrease in negative ion content may come from pumping the air through metal ventilation ducts and heaters (metal surfaces are becoming negatively charged and the air stream carries positive ions), depending on the area of contact, air flow rate, air temperature and air humidity. FURCHNER [4] attributes this in large part to the affinity of negatively charged ions to the metal surface of air duct walls. Large, positive ions are also generated by human body [5]. Thus, in closed spaces with large groups of people the natural ionisation balance is disturbed. This problem is critical in public transportation vehicles, where the discomfort may seriously affect the work performance of people responsible for passenger safety (drivers, pilots, operators).

It is difficult and fairly expensive to increase artificially the negative ion content in closed spaces, hence improving the climatic conditions (restoring the natural balance of ions in the air) should be based mainly on reducing the positively charged ions generated in or transmitted to the closed space. As dust and smoke particles are in general positively charged, it is essential to remove dusted air and smoke from closed spaces by using proper air exchange (ventilation). Incoming air should be thoroughly filtrated before it leaves the ventilation shafts and enters the room. In order to reduce ion generation in heat sources (such as radiators and stoves) it may be advisable to maintain the lowest possible temperature of heating surfaces as well as to cover those surfaces with suitable layers of enamel or lacquer. Hence the best method of heating in comfort air-conditioning should be based on water heaters with low parameters of operation.

In this respect, in heating of habitats, offices and hospitals the heating devices should be operated at low parameters. This method is in accordance with modern trends. The most suitable forms of heating are those based on surface heating systems, e.g. floor and ceiling heating systems, provided that the surface temperature is low as dictated by physiological requirements of human body. This method allows an additional energy savings, resulting from the reduced requirements for comfort temperature of the air – this effect will be discussed later on. It must be stressed that in closed spaces equipped with surface heating units the temperature of surfaces should not for long be kept above 32 °C for ceiling and 23 °C for the floor. Higher temperatures are allowed only for floors in passing spaces and in rooms that are not occupied for long, e.g. in roofed swimming pools, lobbies, halls and washrooms. Prolonged staying in rooms with a floor temperature above 23 °C may cause unpleasant and even harmful conditions, such as swelling of legs, foot mycosis and circulatory disorders. If, on the other hand, the ceiling temperature is constantly above 32 °C, the occupants may complain of migraines and general ill disposition.

For the above reasons it seems that fitting floor-heating systems in occupied factory workshops is not advisable. Such systems may be used only in storage rooms.

3. THE NEED FOR ENERGY SAVINGS IN MICROCLIMATE CONTROL

United States	22.4%
China	13.4%
Russia	7.1%
Japan	4.9%
India	3.8%
Germany	3.5%
Great Britain	2.4%
Canada	2%
Ukraine	1.8%
Italy	1.7%

Fig. 1. List of top countries responsible for global warming effect. Percentage emission of carbon dioxide (1996)

Energy cost increases on the one hand and the need to protect the environment from further degradation caused mainly by pollution from energy sources exploitation on the other one calls for the limitation of energy spending on microclimate control in closed spaces. It must be stressed that energy expenditure on heating, ventilation, air-conditioning and hot water system calls for over 40% of total energy balance [6]. Today, with drastic cuts in energy-consuming technology in industry and promotion of energy-saving construction materials, the requirement for energy saving is still one of the main priorities.

At present, our country spends each year about 160 million tonnes of fuel units (coal) for energy production. This is an equivalent of 4 tonnes of fuel units per capita. Thus the statistical Polish citizen is responsible for emitting over 8 tonnes of CO_2 to the atmosphere. The impact of this on total pollution and, in consequence, the global warming effect, is grave. Poland is not among the leading countries in this respect (see figure 1), nonetheless we place 13 among the major polluting countries in the world.

The situation is alarming. Enormous iceberg has recently come off the Antarctic Peninsula. Few days later a gigantic fissure in the continental glacier caused a 70 km long crack. Doctor Rodolfo de Valle – a leading Argentinean glaciologist – warns that we are witnessing the end of the western part of the Antarctic continent, washed off by warm sea currents. Scientists prognosed such a fissure, but did not expect it before another decade. The process was hastened by the global warming effect. Further prognoses are worse than pessimistic. Some experts claim that the global warming effect is responsible for the recent wave of hurricanes, sea current changes and droughts in Africa and the USA.

Other experts in meteorology, especially Piers Corbyn and his colleagues from Weather Action organisation, seek to assure the public that the global warming is caused not so much by the Hothouse Syndrome, but by recent weather anomalies which are not as unusual as one may think. The results of research on ice layers taken from Greenland glacier were used to study and examine past meteorological conditions and all key incidents from the Earth's geological history, including major volcano eruptions. Deep drills in the ice cover have shown that its mean yearly temperature has fluctuated up to 7 K. Moreover, some 8200 years ago there was a sudden, significant cooling of global temperature by 4 K, which lasted continuously for 200 years. In the light of those findings, the Weather Action members claim that the present minor warming should be attributed to disturbances in the Sun's activity rather than to human influence. They stress that the *Hothouse Syndrome exists only in the minds of journalists eager to make front-page news*...

Hoping for ultimate and definite resolution of the ongoing debate, we should not forget our responsibilities. It is absolutely essential to limit wasteful exploitation of resources in order to preserve the environment and to reduce the use of non-renewable energy sources, in accordance with postulated idea that *The Earth and its resources are given to all and our generation has no right to waste them.*

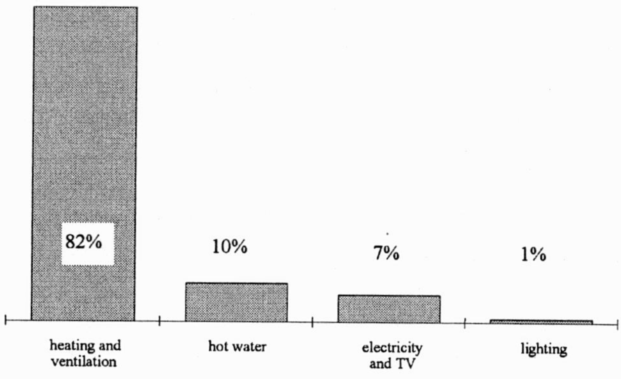

Fig. 2. Energy usage in a typical household

Figure 2 [7] shows schematic energy usage for average household in a developed country in our climatic zone. Regional values may slightly differ. Nonetheless, it may be stated that:

- major part of energy (82%) is spent on heating and ventilation; in this area therefore a considerable saving in energy is needed,
- hot water usage may be further reduced by equipping more households with separate hot water meters,

• electrical devices, due to considerable development in this area, are not to be considered as significant options for further savings,

• savings in lighting are to be considered financially insignificant, as energy usage for lighting cover only 1% of total expenditure.

It is fairly easy to reduce significantly the amount of energy used for heating by fitting the buildings with efficient thermal insulation. Major reduction of permeable heat loss allows for drastic re-evaluation of energy needs for heating and ventilation. Such a change of perspective may influence the rational microclimate control conditions. In order to exploit further this notion, we may stress that in our climatic zone, modern construction trends, especially in detached buildings, should be based (and in fact are based) on materials of high heat-resistance. The permeation factors are: 0.2 $W/(m^2 \cdot K)$ for outside walls, 0.15 $W/(m^2 \cdot K)$ and less for roofs, and $k \leq 2$ $(W/m^2 \cdot K)$ for modern windows, with significant reductions in windowpane areas compared with traditional construction. Heat usage for compensation of permeable heat loss is therefore reduced compared to the usage of heat for ventilation purposes. The requirements for ventilation are nowadays significantly higher. Modern microclimatic conditions in closed spaces are often unsatisfying. This is due to the recent increase in pollution values generated within the closed spaces, resulting from increase of high-radiation materials (concrete, hollow bricks, cement – even traditional clay brick is highly radiating) as well as paints, glues, floor finish, carpeting and furniture emitting health-detrimental substances.

All construction materials contain naturally radiating substances. But, with recent trends to re-use by-products from steel plants and power stations (furnace slag, fly ash) in cement manufacture, the radiation content in modern construction materials is significantly higher. As a result, ionisating radiation in closed spaces is more prominent. People in closed spaces are subject to various radiation types. Materials containing isotopes (potassium-40, radium-226, thorium-232) emit gamma rays influencing human body, whereas radon-222 emits alpha rays affecting human respiratory system. Radon emission comes mainly from walls and ceilings containing radium-226, but also from natural gas used in kitchen stoves. Radon is the main detrimental factor in radiation influencing human body.

Radon disintegration products integrate with small dust particles creating radioactive aerosols. Human body exposed to highly concentrated radon and radioactive aerosols receives radiation doses that may lead to high-latency neoformations in respiratory system. Based on data and demographic prognoses as well as on percentage distribution data concerning construction materials used in Poland, PEŃSKO and GEISLER [8] have prognosed serious genetic malfunctions and deaths due to cancerous diseases in Polish population between 1951–2010 as a result of exposal to additional ionising radioactivity in closed spaces.

It has been proved that tobacco smoking increases the carcinogenic effects of radon products upon human body. Such an interaction is synergistic, i.e. it is considerably higher than that, which results from summing up both causes. Research done in

Sweden shows that at the same exposure to radon, the risk of contracting cancer by people who have never smoked is four times lower than that for the majority of population and nine times lower than for persons who smoke on average one packet of cigarettes daily [9].

The only way to reduce the harmful effects of pollution generated in the closed spaces is to provide them with effective ventilation, i.e. air exchange.

4. THE NEED FOR EFFECTIVE VENTILATION

If we feel stuffiness and lack of fresh air in the room, we usually open windows. This may lead to a significant loss of valuable heat energy, especially in the cold seasons, because the warm air at the top escapes from the room. People generally air their rooms much too seldom. Lack of proper airing contributes to the increase in humidity and concentration of harmful substances. High humidity leads to condensation of water vapour in cooler, not properly insulated walls of construction elements. This creates favourable conditions for growth of fungi and mould (*Micromycetes*), regarded as one of the main causes of cancer of upper respiratory duct and lungs [10]. These species are often toxic, especially the *Aspergillus*, *Penicillum* and others. Fungous penetration affects at times the whole width of the construction element, together with insulation layers, which makes it very hard to remove. The air in rooms affected by fungi as well as the air within the construction elements has a high concentration of fungous spores. The spores infect human organisms and pollute the living spaces with microtoxins (products of their metabolism). Microtoxins entering human organisms, even in small quantities, produce disorders that may be latent and delayed in time.

Among the most common disorders caused by contact with fungi or fungous spores are allergies. Allergies are especially frequent in children, who develop chronic, recurring respiratory disorders, which may, if not treated, lead to asthma. Fungi cause also a range of other illnesses, such as mycoses, in particular mycosis of the lungs.

Only a proper and efficient ventilation using outside air may reduce negative results of such pollution. There is no need then, nor basis for decreasing the heat consumption in order to ventilate buildings (most notably of the residential type) by means of reducing the air exchange rate. The exchange not lower than n = 1/h should be maintained, and – in some cases – even increased.

It may be noted that the limit of outside air stream to the value of 8.5 m^3/h per person, introduced in 1981 in the USA, caused discomfort and the so-called sick building syndrome (Ger. *Gebäudekrankheit*). Therefore, since 1987, the rate has been increased to 35 m^3/h of outside air per person [11]. Polish requirements in this respect are significantly lower, although the rate of pollution generated (expelled) in an average household here is not, by any means, lesser.

It must be stressed that while the so-called "average" person (1.8 m^2 body area, working in a seated position, bathing on average 0.7 times a day, using fresh underclothes on a daily basis) expels noxious odours of 1 olf, an average smoker produces ca. 6–25 olf (12-years old adolescent: 2 olf, athlete: 30 olf). A considerable amount of noxious odours comes from linings and construction materials, e.g.: woollen carpets, 0.2 olf/m^2, synthetic carpets, 0.4 olf/m^2, PVC lining, 0.2 olf/m^2, rubber seals (in windows and doors), 0.6 olf/m^2. It has been shown that in a typical closed space there are pollution sources emitting 0.4 olf/m^2 on average (rarely below 0.1 olf/m^2). Therefore, if an office (or residential) space averages at 10 m^2 per person, a simple equation shows that, apart from the pollution produced by a given occupant, we deal with an additional pollution corresponding to that produced by four "surplus occupants". The above results were taken from research done by FANGER [11]–[13] at the outside air stream of 10 dm^3/s, i.e. 36 m^3/h per person, while less than 15% of occupants claimed discomfort.

As far as the heat requirements for ventilation are concerned, there are potential ways of their reduction, e.g. by re-using heat from the air removed or by using renewable energy sources such as ground [14], solar energy (by use of solar collectors) [15], or other sources by use of heat pumps. All those methods may be used with mechanical ventilation systems. Such projects, although successfully used in industrial and communal buildings, are still unreasonably considered controversial and costly with regard to residential objects. Careful analysis of the effects, however, shows that those methods are advisable and advantageous also in residential buildings [16]–[19].

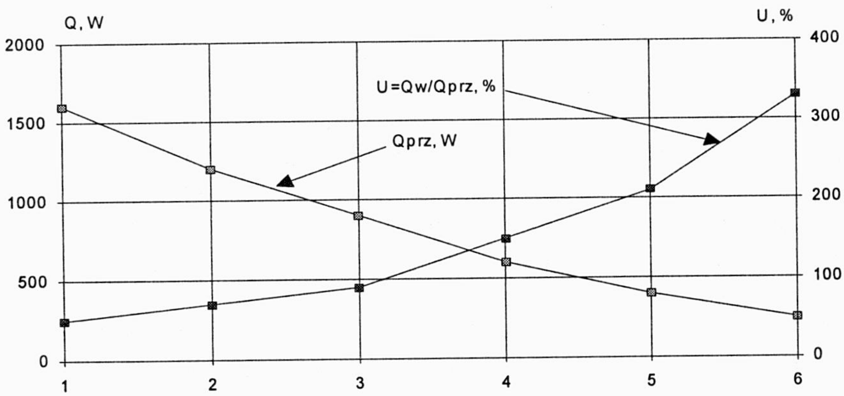

Fig. 3. Percentage increase of ventilation heat share as a function of permeable heat loss $U = Q_w/Q_{prz}$ (%) and decrease of permeable heat loss in recent years Q_{prz} – for cases 1–6 analysed in [20]

Analysis of heat requirements for heating and ventilation (for a semi-detached house with a single air exchange in all rooms) [20] has shown that over two decades (since 1982), as a result of progressive heat loss decrease in construction materials used, there has been a significant re-evaluation of heat requirement balance for heating and ventilation purposes. Figure 3 shows the results of such an analysis for consecutive country standards from 1958 (case 1) up to now (cases 3–5) with regard to well insulated buildings (insulation layer of 15–20 cm). The analysis fails to address some of the modern solutions based on the so-called "intelligent windows" and transparent walls, which through special panelling and transparent insulation layers and automatic control allow us to store such an amount of heat stream in the cold season that caters for almost total of the heat loss through those elements.

New generation of intelligent windows (which monitor and respond to outside conditions) are based on electrochemical processes or include microelements, enzymes and proteins embedded in the glass panels, which through chain reactions with certain substances in the surrounding air may not only change the colour of glass, thus controlling the insolation (incoming solar heat), but also respond to certain pollutants and other stimuli. According to Carl Lampert of Lavrence Berkeley Laboratory, total cost of such windows in office buildings may be fully recovered after 4–5 years of operation, since those solutions allow for considerable heat expenditure costs of up to 30–50% (especially cooling in the hot season). Such solutions are no longer in the realm of futurology, for similar windows have recently been fitted in Soto Bridge Museum in Kojima (Japan).

Implementation of walls with transparent insulation layers is yet another option in close perspective. Leading research in the field is done in Fraunhofer Institute in Freiburg and in Stuttgart.

The above solutions call for an important conclusion that in modern, energy-efficient housing industry the most important aspect is connected with heat requirements for ventilation (and not for heating) purposes. As a result, the microclimate control system may and should be based on another approach. It should be more concerned with ventilation requirements and enable more control over providing beneficial microclimate not only in the cold season, but also in summer.

5. ALLERGIES AS A RESULT OF AIR POLLUTION

According to data released by the Institute of Allergy in Belgium, in recent years there has been a drastic increase of allergy illnesses around the world. It is an inevitable result of ongoing deterioration of environment. Among the most hazardous factors are sulphur dioxide, nitric oxides and exhaust products from compression-ignited engines (Diesel). Those substances damage the mucous membranes of human organism, leaving path for allergenic infection.

Ephemeral rashes, occasional conjunctivitis, hay fever or noxious asthma fits are all caused mainly by disturbances in human immunity system. Normal immunological responses guard against infections from bacteria, viruses and parasites, bur even minor disorders within the complex immune system may cause disproportionate responses to typically harmless substances, such as pollen, saprophytes in dust or antibiotics. Typical symptoms are hay fevers and rashes, but in some cases more adverse reactions may occur, such as swelling of larynx leading to suffocation or sudden hypotension and disorders of circulatory system. Not treated or badly treated allergies may lead to asthma.

In the last 6 years in the USA death rate because of asthma has increased over 50%. In Switzerland, the cases of hay fever increased from 1% in 1960 to 12% at present. Allergies in Poland affect 50% of children and 1/3 of overall population in cities – most of the people affected are unaware of the real cause of their health complaints. Global population of people affected by allergies doubles every 10 years.

The outside air fed to closed spaces via ventilation systems should be filtrated in order to remove such particles as pollen, soot from diesel engines and other types of pollution affecting human immune system. Proper and efficient filtration may be obtained only with mechanical blowing of outside air stream.

6. OUTSIDE AIR STREAM

Outside air stream needed for obtaining satisfactory comfort and freshness is defined at 10 dm^3/s, i.e. 36 m^3/h per person, based on the assumption that only 15% of people are still dissatisfied. Such an assumption is needed, because it is practically impossible to satisfy each and every person due to varying individual preferences. Among all types of pollution generated in the closed spaces, those generated by human beings (bio-influences) are typically below 15%. According to FANGER [12] they amount to 13% only. The remaining part comprises pollution from furnishing and construction materials.

It is essential for the outside air stream to be properly managed. The 10 dm^3/s mentioned above (36 m^3/h per person) is the amount of outside air stream that should be blown in at the interval of typical mean temperatures of outside air – in our climatic zone it is a range between 0 and 26 °C. Reasonable quotas are used in German DIN 1946 standard (table 1). These quotas are not to be considered as absolute values

Table 1

Minimum outside air stream (DIN 1946)

Outside air temperature [°C]	Minimum outside air stream [m^3/h per person]	
	Smoking disallowed	Smoking allowed
–20	8	12
–15	10	15
–10	13	20
–5	16	24
0–26	20	30
over 26	15	23

– as the actual values of recent standards are higher. The point is that the air stream should be reduced in accordance with temperature decreases below 0 °C, as well as with outside air temperatures above 26 °C. The DIN Teil 2 allows for temporary limitation of outside air blown in by 50%, which is determined by energy saving needs. By analogy to the values given in table 1, for the needed outside air stream of 10 dm^3/s, as required to maintain comfort conditions, the minimum outside air stream volumes of our standards should hold as given in table 2.

Table 2

Nowadays proposed minimum of outside air stream

Outside air temperature [°C]	Minimum outside air stream	
	[m^3/h per person]	[dm^3/s per person]
–20	15	4
–15	18	5
–10	24	7
–5	30	8
0–26	36	10
over 26	25	7

Based on the chart of percentage of persons dissatisfied as a function of outside air stream values (figure 4 [11]), it may be noted that by limiting the amount of outside air blown in to the value of 18 m^3/h per person (5 dm^3/s) in the cold season with the outside air temperature of –15 °C, we get only ca. 25% of dissatisfied persons, which is an acceptable value.

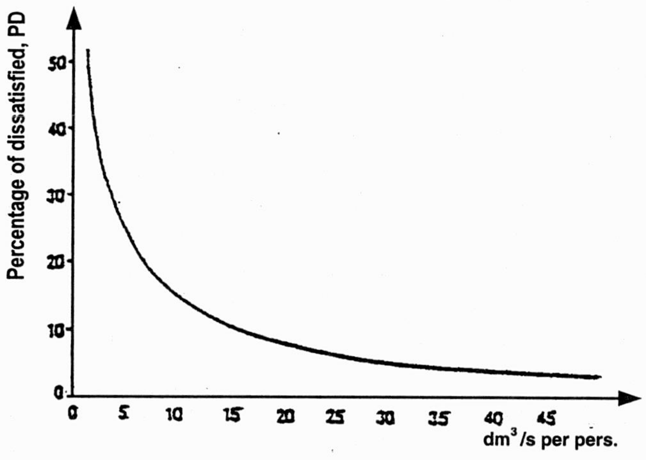

Fig. 4. Percentage of dissatisfied as a function of outside air stream [11]

Feeling of comfort or freshness depends on many factors, mainly on the choice of the method used for serving the incoming air to the closed space. The so-called microclimatic aeration (e.g. blowing the air through outlets in foot spaces in theatres) offers good comfort conditions at reduced outside air stream compared with the solutions based on air being discharged from ceiling outlets. The former method is considered more energy-saving.

It may be reminded for reference reasons that the suggested outside air stream volumes are as follows:

- for theatres, museums, cinema halls and sport arenas 20 m^3/h per person,
- for conference rooms, classrooms and restaurants 30 m^3/h per person,
- for office spaces 40–60 m^3/h per person,
- for air-raid shelters, however, only 10–15 m^3/h per person.

The above volumes apply only to spaces devoid of noxious pollution, as e.g. non-smoking areas. For spaces where smoking is allowed the actual values should be increased by 20 m^3/h per person.

7. ENERGY SAVINGS FROM COMFORT AIR-IONISATION

It is noteworthy to quote here the results of perennial study done in Stuttgart Fraunhofer Institut. At the onset, 800 high-rise buildings in Austria were monitored. The research proved that heat consumption in ceiling-floor heated buildings was by 19–38% lower than in radiator-heated buildings.

Later research was done at GSW condominium (Geislinger Siedlungs und Wohnungsbau GmbH), at the request of Federal Civil Engineering Ministry. The results of 10-year monitoring scheme were presented by Prof. H. REIHER [21]who tested three types of water heating systems:

- one pipe radiation heating with individual adjustment A,
- two pipe radiation heating controlled by outside air temperature B,
- floor and ceiling heating controlled by outside air temperature C.

The research covered initially 206 flats, and from 1963 – 604 flats. The comparative purposes were best fulfilled by three 8-condignation buildings erected at the same time in 1959/1960, of identical construction, situated identically and close to each other (see figure 5), and – most importantly – similarly populated. Heat consumption was measured using renowned Pollux meters. The authors present a tabular comparison of heat consumption levels in the flats for the whole 10-year period (1962–1972).

The research showed that heat consumption in flats heated by one pipe radiation devices (location A) was on average by 35% higher, and by 28% higher in those heated by two pipe radiation devices (location B) than in flats heated by floor and ceiling fixtures (location C).

On the basis of perennial studies and exploitation analysis, apart from energy-saving issues, the researchers arrived at the following conclusions regarding hygienic issues and ways of exploitation in the closed spaces tested.

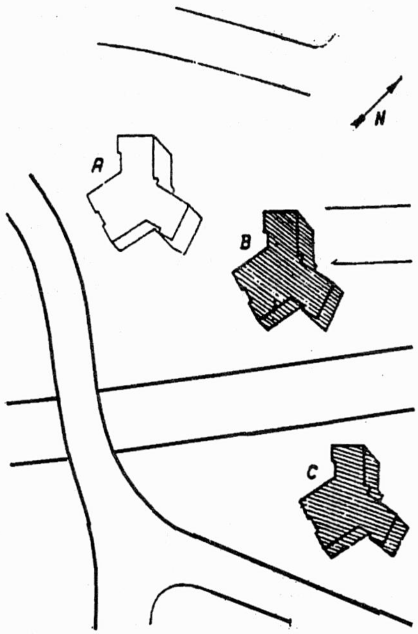

Fig. 5. Localisation of monitored buildings: A – one pipe radiation heating with individual adjustment, B – two pipe radiation heating controlled by outside air temperature, C – floor and ceiling heating controlled by outside air temperature

The ceiling temperature was close to human head temperature (32 °C), while that of the floor ranged from 20 to 23 °C and was considered by occupants as high enough. Occupants rated the microclimate in floor-ceiling heated rooms as comfortable. Lack of draughts was stressed as well as considerable decrease of dust travelling and settling on heating surfaces and in inaccessible areas. Favourable opinions pertained also to significant increase of usable space as well as lack of edged joints (typical of conventional heaters, e.g. radiators), a feature valuable in such spaces as hospitals, schools and other child-care institutions, etc.

The investment cost of floor-surface heating fixtures was 8–10% higher than that of conventional radiators. The floor-ceiling heating fixtures were of the Aktinotherm type, in which the ribbed pipes are placed within the roofing area, and the heat is transmitted via convection and radiation. Such a fixture allows for uniform temperature distribution along the surface of full, suspended ceiling, at relatively low inertion of the whole system. Such ceilings are also characterised by low sound penetration, typical of multi-layered roofing.

It is especially significant to compare energy consumption in locations B and C, as both those buildings use similar method of temperature control (automatic, based on outside temperature).

Reasons for such wide differences in energy consumption levels have been thoroughly analysed. Finally, the researchers took into account observations that showed significant differences in usage patterns at the analysed locations. The also noted that occupants of radiation-heated flats more frequently (almost regularly) opened the upper windowpanes. This is consistent with the observation that ionisation of air has a major influence upon the feeling of comfort in closed spaces. Because of a considerably higher temperature of heating surfaces in radiation-heated rooms than that of floor and ceiling surfaces in floor -surface heating and because of large metal surfaces and high dust content in the air, ionisation of air in radiation-heated rooms is less favourable. In floor–ceiling heated flats, due to lack of hot metal surfaces, the small ions that contribute to comfort feeling, usually negatively charged, will not precipitate, thus limiting the need to open windows in order to improve overall ionisation in the room.

Even a small degree of overheating, resulting in the decision to open windows, leads to considerably higher heat loss in radiation-heated rooms than in those heated by floor–ceiling fixtures. Airing the radiation-heated room leads to an escape of relatively hot air, because radiators are usually located next to the window and the air temperature in the upper area over the window reaches the highest level. In floor –ceiling-heated rooms the air temperature in the window area is much lower and usually close to that in the centre of the room. Hence the heat loss in such rooms would be considerably lower even in the cases when the room needs airing by means of opening windows. It must be stressed, however, that at low-temperature surface heating such need is marginal.

8. CONCLUSIONS

In addition to recent analyses that stress the need for providing a sufficient amount of outside air in habitats it must be noted that nowadays most authors, designers and contractors are in favour of controlled, mechanical outside air discharge in closed spaces. The air stream should follow the living pattern of the occupants: in the daytime the air should be discharged to living rooms and workrooms, and to the sleeping rooms at nighttime. The resulting slight overpressure in the building may additionally prevent inconvenient infiltration during cold seasons.

Such a solution is favourable from the energy-saving point of view and also for the reasons connected with an unacceptable outside air pollution. With hermetic casing, using only exhaust ventilation, the outside air infiltrating through gaps in rubber sealing in windows and doors is highly polluted (0.6 olf/m^2). High content of dust and pollen that affect the ever-growing allergic population also calls for proper and efficient filtration of air discharged into the rooms. Such filtration requires a considerable power to overcome the air filter resistance – this can be done only by using mechanical ventilation supply systems. In addition, such systems allow for partial recovery of heat from the used air as well as use of natural, renewable heat energy sources for initial treating of outside air, i.e. heating in cold seasons and cooling in summer [22]–[24]. The resulting energy savings are usually high enough to cover and even surplus the installation expenditures for such systems. Additional factor is the considerable limitation of environmental loss (due to heat recovery or use of non-conventional energy sources) resulting from the limited consumption of non-renewable energy sources.

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O ZDROWY MIKROKLIMAT NASZYCH POMIESZCZEŃ

Ponieważ ponad 90% swego życia spędzamy w pomieszczeniach (w domu, w pracy, w sszkole), przeto niezmiernie ważne dla naszego zdrowia i dobrego samopoczucia jest wytwarzanie i zachowanie w tych pomieszczeniach dobrego, zdrowego mikroklimatu. Spełnione muszą być wymagania jakościowe pod względem cieplnym i wilgotnościowym, ale także dotyczące czystości powietrza i jego wymiany. Obecnie w naszych mieszkaniach spotykamy coraz więcej zanieczyszczeń pochodzących nie tylko z materiałów budowlanych, ale zwłaszcza z wyposażenia wnętrz. Farby, kleje, wykładziny podłogowe i dywany, uszczelki gumowe w oknach i drzwiach oraz szkodliwe dla zdrowia tworzywa i substancje

stosowane do produkcji mebli są powodem znacznego zanieczyszczenia powietrza w pomieszczeniach. Te zanieczyszczenia są często kilkakrotnie większe od biopływów, czyli zanieczyszczeń pochodzących od ludzi. Dziś jest zatem potrzebna bardziej intensywna wymiana powietrza w pomieszczeniu niż dawniej. Tymczasem bywa, że powietrze zewnętrzne jest także zanieczyszczone, jeśli nie spalinami, to pyłkami kwiatowymi, bardzo uciążliwymi dla coraz liczniejszej grupy alergików. Powietrze zewnętrzne przed wprowadzeniem do pomieszczenia wymaga więc filtracji. Potrzebny jest nowy, elektrooszczędny sposób kształtowania mikroklimatu oparty na mechanicznej wentylacji nawiewnej z odzyskiem ciepła i wykorzystaniem niekonwencjonalnych, odnawialnych źródeł energii.