

Optimization of the Odor Microclimate

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The odor microclimate is formed by gaseous airborne components perceived either as an unpleasant smell or as a pleasant smell. Smells enter the building interior partly from outdoors (exhaust fumes - flower fragrance) and partly from indoors (building materials, smoking cigarettes - cosmetics, dishes). They affect the human organism through the olfactory center which is connected to the part of brain that is responsible for controlling people's emotions and sexual feelings: smells therefore participate to a high level in mood formation. Sweet smells have a positive impact on human feelings and on human performance. Criteria for odor microclimate appraisal are presented together with ways of improving the odor microclimate (by stopping odors from spreading within a building, ventilation, air filtration, odor removal by plants, deodorization, etc.), including so-called AIR DESIGN.

Keywords: odors, microenvironment, hygiene, indoor air quality, microclimate.

An optimum odor microclimate can be ensured by suitable changes in (a) the source of odors, and (b) the transfer field between the source and the exposed subject.

1 Changes in the source of odors

Reduction or, if possible, removal of the source of odors, is the most effective way: Construction materials that do not release an odor, and production technologies without odor sources should be preferred. Two examples of effective ways are quick setting coatings and waste baling presses.

Quick setting coatings were developed in France. They consist of a great number of low-molecular compounds and of so-called photo-initiators, which, when radiated by UV rays, rapidly (within a second) change low-molecular compounds into high-molecular compounds.

Natural materials are preferred for wood preservation, especially beeswax applied directly to cleaned wood.

Waste baling presses are available for home kitchens. Waste baling presses are produced by the Lescha Company (Leonard Schmid, Augsburg, Germany). A baling press can form part of a kitchen furniture suite (Fig. 1). Waste (including champagne bottles) is pressed into a polyethylene package of small volume (1/4 of the original volume) (Fig. 2). Thus, of course, any odors, or microbe release from the waste is avoided.



Fig. 1: The Lescha-Mollpack waste baling press integrated into kitchen furniture



Fig. 2: The product of the waste baling press: a small polyethylene package

2 Changes in the transfer field between source and subject

Such changes can be made in the following ways:

- a) stop the odors from spreading within the building,
- b) supply an adequate quantity of outdoor air to the building interior, i.e., suitable ventilation,
- c) air filtration,
- d) introduction of plants,
- e) chemical deodorization,
- f) intensive air ionization,
- g) neutralization with ionized ozone,
- h) bake-out procedure.

2.1 How to stop odors from spreading within a building

The most effective method is to be careful about the air streams produced by infiltration and by indoor heat sources. Staircases should be divided into several hermetic parts, and the sources of odors should be confined to the upper part of the building.

The most serious problems occur in tall buildings, as a consequence of the stack effect (thermal upward pressure). According to some measurements, there is a negative pres-

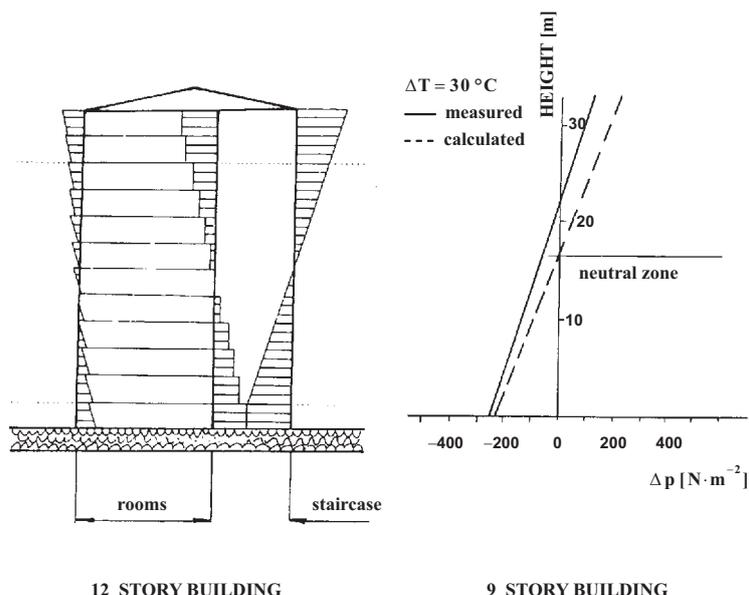


Fig. 3: The air pressure distribution within a nine-story building. On the left, a schematic representation of the air pressure in a building; on the right, calculated and measured air pressure.

sure in the lower part of a 16 to 30-storey building of 120 to 160 $\text{N} \cdot \text{m}^{-2}$. There is an underpressure of about $30 \text{ N} \cdot \text{m}^{-2}$, even at the front door of the nine-storey buildings often constructed in Europe (Fig. 3). This means, in practice, that in order to open a house-door sized about $1 \times 2 \text{ m}$ it is necessary to use a force equivalent to 6, 24 and 32 kg. The effect of the thermal uplift is increased vertically through the whole building (shafts, staircases), and there is intensive spreading of odors within the building if the staircase is not divided into several hermetic parts, or if the odor sources (kitchens, laboratories, etc.) are not located in the upper part of the building. If this is impossible, at least hermetically sealed doors should be used from the staircase to the apartments or offices.

2.2 Adequate quantity of outdoor air-ventilation

Pettenkofer's classic value provides a basic measure for rooms where people are the main source of air pollution. For optimum concentration of CO_2 1000 ppm = $1800 \mu\text{g}/\text{m}^3 = 0.1 \text{ vol.}$ he prescribes $25 \text{ m}^3/\text{1-person}$. According to ASHRAE Standard 62-1989R this value can be accepted (after rounding to $7.5 \text{ l/s} \cdot \text{person} = 27 \text{ m}^3/\text{h} \cdot \text{person}$) for an unadapted person, while for adapted persons it is decreased to $2.5 \text{ l/s} \cdot \text{person}$ ($9 \text{ m}^3/\text{h} \cdot \text{person}$). By these values applying the quantity of air delivered into a room can be adjusted to the number of people: with the increasing number of people the CO_2 concentration also increases, and thus the air rate

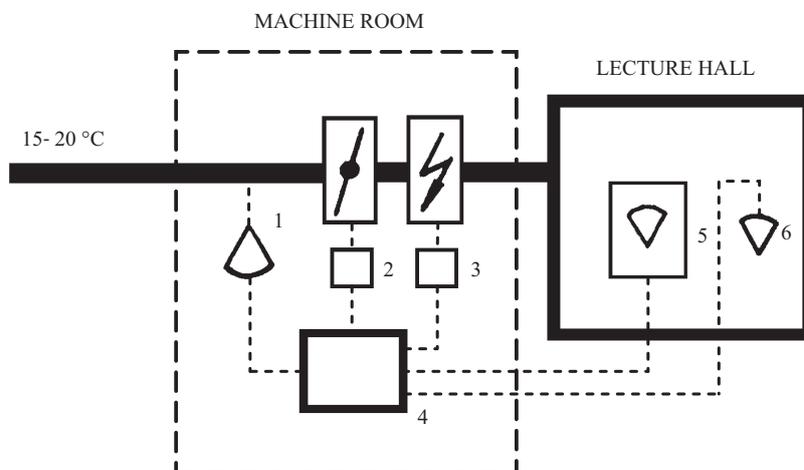


Fig. 4: The microclimate in a lecture hall controlled by a thermostat and a CO_2 sensor (1 air rate sensor, 2 controlling flap, 3 electrical heater, 4 control unit, 5 room thermostat, 6 CO_2 sensor)

must be increased, e.g., by increased fan rotations controlled by a CO₂ sensor in the room (see Fig. 4). Energy also increases, savings, an important factor, are made as a result of decreased energy consumption for warming outdoor air.

The following equation should be used in the rooms where odor agents, released from building materials, are decisive for outdoor air rate:

$$R_B = \frac{G_B}{3.6(\rho_{iTVOC} - \rho_{eTVOC})} \quad [l/s \cdot m^2] \quad (1)$$

where

R_B = minimum outdoor air rate related to 1 m² of floor
[l/s·m²],

G_B = TVOC rate produced within an interior
[µg/h·m² floor] (see Table 1),

ρ_{eTVOC} = TVOC concentration in outdoor air
[µg/m³] (see Table 2),

ρ_{iTVOC} = prescribed TVOC limit
[µg/m³] (see Table 2 and Fig.6).

The required outdoor air rate is the sum of the two air rates (if they occur), i.e., calculated from TVOC and based on CO₂.

An air change (the number of times that the air in a room is changed during one hour) is often prescribed. Thus the outdoor air rate can be obtained if the air change is multiplied by the room volume. The value calculated in this way, can differ from the outdoor air rate, which is estimated from the air rate necessary for one person, as it is evident from the following examples.

Example 1: Lecture hall crowded with students. The outdoor air rate related to one person can be lower than the prescribed value, e.g., 27 m³/h·person, i.e., too low, even if high air change six has been taken into account.

Example 2: A hangar in which one person is repairing an airplane. The outdoor rate related to one person can be much higher than the prescribed value, e.g., 27 m³/h·person, i.e., excessively high, even if only air change one has been taken into account.

The outdoor air rate related to one person is decisive in each case, i.e., if calculations are based on air change, the re-

Table 1: TVOC Emission rates in a building interior

Location	TVOC [µg·h ⁻¹ ·m ⁻² floor]		Author	Note
	Mean	Range		
Existing buildings, offices	1,550	100–4,890	EUR 14449 EN (1992)	Converted olf value
Working hours (9–11)	360	132–691	Ekberg (1993)	
Night-time (5–7)	–	90–467	Ekberg (1993)	
Schools (classrooms)	1,550	620–2,780	EUR 14449 EN (1992)	Converted olf value
Kindergartens	2,060	1,030–3,810	EUR 14449 EN (1992)	Converted olf value
Assembly halls	2,570	670–6,790	EUR 14449 EN (1992)	Converted olf value
Dwellings	720	360–1,080	EUR 14449 EN (1992)	
New PVC floor tiles	795	450–1,400	Brown and Crump (1993)	
Low-polluting buildings (target values)	–	260–510	EUR 14449 EN (1992)	Converted olf value
Solid flooring materials (vinyl, carpet, chipboard)	Typical below 55		Crump et al (1997)	Emission rates constant
Wall and ceiling materials			Crump et al (1997)	Emission rates constant
Plasterboard	max 6			
6-mm plywood	max 10			
15-mm plywood	max 12			
Bitumenised fibre board asphalt	max 30		Crump et al (1997)	Emission rates constant
PVC skirting board	Below the detection limit		Crump et al (1997)	
Polythene spacer	4 when heated to 40 °C			
Rockwool (cavity wall)	Below 15		Crump et al (1997)	Emission rates declined slowly

Table 2: TVOC and CO₂ concentrations in outdoor air

Location	TVOC [$\mu\text{g}\cdot\text{m}^{-3}$]	CO ₂ [ppm]	Source	Note
At sea	0	300–340	ICAO 1964, EUR 14449 EN	Converted decipol value
In a city, good air quality	14 15–18	350	EUR 14449 EN Ekberg 1993	Converted decipol value
In a city, bad air quality	71 23–98	350–400	EUR 14449 EN Brown and Crump, 1993	Converted decipol value

sults must be proved by calculations of air rates related to one person. Furthermore, if recirculation is used in an air handling system, the outdoor air rate must not be lower than 10 % of all air delivered into the room.

2.3 Air filtration

There must be a special material for odor absorption: activated carbon, charcoal or synthetic resin (e.g., amberlite). Odors can also be removed by an odor scrubber (odor washer), a biowasher, catalytic burning, biofilters, and even by plants [6].

Activated carbon has better odor-removing properties than charcoal (carbonized wood). It is produced by the impact of hot steam (800–1000 °C) and zinc chloride on charcoal. This process enlarges and purifies the cells. As a result, the internal surface is enlarged up to 500–1500 m²/g, i.e., in aver-

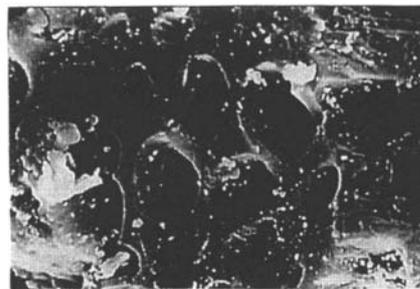
age to an unbelievable value of 1000 m²/g. Other kinds of coal and peat are also used and, even coconut shells (see Fig. 5).

Activated carbon absorbs very little air humidity, and does not change the chemical or psychrometric condition of the air. The odor removal efficiency depends on the contact period of the gas with the carbon. For least 80 % efficiency, and an air velocity of 2.5 to 3.0 m/s, the thickness of the carbon layer should be 2.5 cm. The efficiency depends on the carbon retention: the absorbed odor quantity [g] is related to 100 g of carbon (see Table 3).

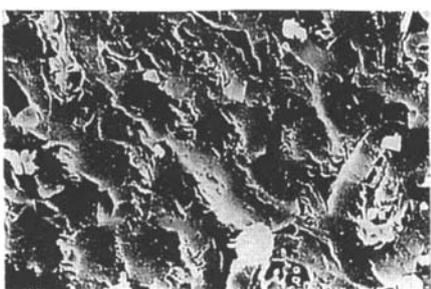
Activated carbon is mostly applied in air cleaners. It is evident from the retentions presented in Table 7 that this device is not efficient against all odors in the same way: some odors are trapped very efficiently (e.g. human body odors), others are only slightly reduced, e.g., fish odors (odors of preparations for plant protection).



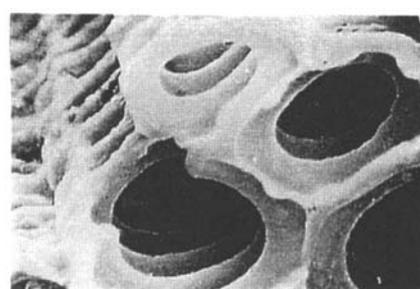
Carbonised Wood



Activated Coal



Carbonised Coconut Shell



Activated Coconut Shell

Fig. 5: Microscope photos of carbonized and activated coal

Table 3: Retention values for activated coal (charcoal)

Odor agent	Retention [%] [g/100 g coal]
Solutions	25 to 35
Exhaust gases	20
Body odor	35
Ether	15
Onion, garlic	15
Antiseptics	30
Tobacco smoke	25
Aliphatic mercaptans (oil refineries, chemical industry)	1
Aromatic mercaptans (oil refineries, chemical industry)	15
Aliphatic amines (fishing industry)	1
Higher hydrocarbons (>C ₁₄) (chemical industry)	15
Aliphatic chlorohydrocarbons (chemical industry)	15
Plant protection chemicals (agriculture stocks, chemical industry)	0.2

2.4 Odor removal by plants

Indoor plants can be used as room detectors and CO₂ consumers, and some are also able to clean the air from acetone, benzene, CO, ethanol, formaldehyde, methanol, SO₂, toluene and some VOCs (see Table 4). A lawn can be effective in an atrium: an area of 15 × 15 m is a sufficient source of oxygen for a family with four members, and it also cleans SO₂,

CO₂ and hydrogen fluoride from the air. It has not been explained satisfactory what is going on with these absorbed chemicals: whether they are only stored, or perhaps used for energy consumption. It has already been proven by NASA that some of them nourish microorganisms that grow on and near the roots. Therefore flowers in a vase or plants growing in hydroponics are useless for this purpose. Potted plants growing in substrate enriched by active carbon are benefi-

Table 4: Odor removal by plants

	Odor agent	Source	Affecting plants
1	Acetone	Body odor	Lily
2	Benzene	Office solvents	Chrysanthemum
			Gerberum
			Lily
3	Ethanol	Alcoholic beverages	Lily
		cleaning agents	
4	Hydrogen fluoride	Glass processing	Grass
5	Formaldehyde	Wood products, especially	Aloe
		plywoods and chipboards	Azalea
		parquet sealants	Philodendron
		cork	Gum-tree
		laminates	Lily
		glues	Poinsettias
		cleaning agents and	

	Odor agent	Source	Affecting plants
		disinfectants	Tulip
		cosmetics	
		open fireplaces	
		gas cookers	
		tobacco smoke	
		textiles	
6	Methanol	Cleaning agents	Lily
7	Sulphur dioxide	Cars, boiler rooms	Grass
8	Toluene	Cleaning agents	Arek palm, Lily
9	Trichloroethylene	Cleaning agents	Lily
10	VOC	Cleaning agents	Philodendron
		carpets	Golden potos
		glues	
		paintings	
		rubbish	
		solvents	
11	Exhaust fumes	Cars	Chesnut tree

cial. One well-developed plant with air streaming uniformly around it at a velocity of 0.10-0.15 m/s should be used for 9 m² of floor area.

2.5 Deodorization

Deodorization is the masking of odors: covering an unpleasant odor by another, stronger and more pleasant smell, a so-called deodorant: formaldehyde, acetaldehyde, ozone, etc. However deodorants cannot be used in high concentrations owing to their toxicity: e.g., an ozone concentration should not exceed 0.1 mg/m³ (0.5 ppm).

Deodorization has been known for a long time. Incense has been used for ages. It is made by cutting the shrub *Boswellis carteri*. From notches cut into the tree, milk juice flows, which forms yellow balls in the air, called incense (alibanum). It contains 4 to 7 % of ethereal oils. If it is burnt on glowing coals, pleasant smelling smoke is produced. Nowadays incense is used as an ingredient in scented candles, and

is mixed with scented woods to produce a special smelling material used during Christmas.

2.6 Intensive air ionization

Odors can also be removed by intensive ionization of the air, i.e., by forming negative aeroions of high concentration. Even the typical odor of a bar can be removed during the night in this way, so that the room can be used for serving breakfast the following day. Air cleaners equipped with ionizers thus have a new field of application.

2.7 Neutralization with ionized ozone

Ionized ozone is a very effective oxidant: the molecules of odor agents are cracked and changed into water vapors, carbon dioxide and other substances (without bad smells). The ozone concentrations must be watched carefully due to its toxicity. This method should be applied at night, when no

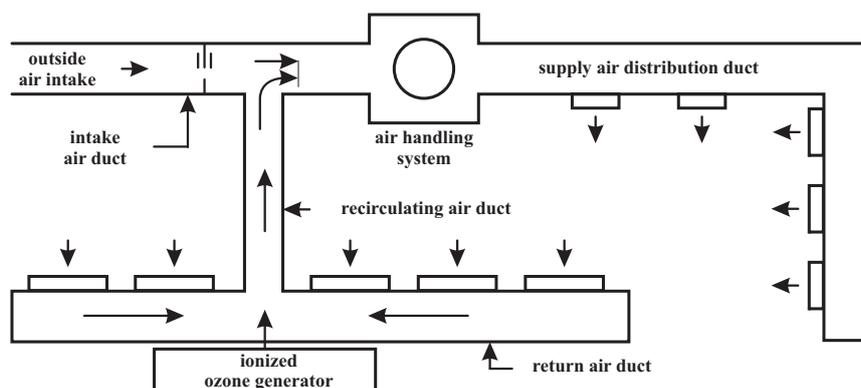


Fig. 6: Odor removal by ionized ozone

people are present. Ionized ozone is supplied to recirculated air (see Fig. 6).

2.8 Bake-out procedure

A new way of removing VOC from a building interior is the so-called BAKE-OUT PROCEDURE: the indoor temperature is raised to 30–38 °C for two or more days, and simultaneously the ventilation is increased [4]. This is even required by the authorities in the State of California. Practical experience has not yet been reported in the literature.

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