

## **“Psychical Working Conditions in Hospitals”**

Physical and Chemical (as well as Psychological) Burdens in Hospitals

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Both the patients and the staff of modern hospitals are exposed to a wide range of physical, chemical and emotional influences, which may have a detrimental effect on their health. The occurrence of the disorders resembling “Sick Building Syndrome” and of allergic reactions is not uncommon in hospitals, for instance. The prevalence of asthma is in fact higher among hospital staff than in any other professional group. In addition to allergic disorders, skin diseases, respiratory complaints and irritation of the eyes and the mucous membranes, the dominant symptoms are neuropsychiatric in origin, for example headaches, poor concentration, tiredness and dizziness, which can also distinctly impair the work performance of those affected (BROWNSSEN, 1999; HODGSON, 2000; HODGSON et al., 2002). The detrimental effects described must therefore be minimised as far as possible. In this connection, it is particularly the physical and chemical influences which can be controlled. In doing so, the most sensitive sub-group of hospital users must serve as the yardstick in each case (see below). The following outline is intended to help discover the sources of such influences in hospitals along with possibilities for improving working and hospitalisation conditions. The associated risk of infection will not be dealt with in any detail (with the exception of mould formation on building materials or in HVAC systems) (for information on this issue, see HODGSON et al., 2000). The following key factors must be taken into account when assessing the *Psychical Working Conditions*:

### **1. Personal Factors**

1.1 Age

1.2 Sex

1.3 Previous illnesses

### **2. Anthropogenic Factors (Colleagues, Patients, Visitors, Suppliers)**

2.1 Cigarette smoke

2.2 Perfumes

2.3 Car traffic

2.4 Noise

### **3. Building-related Factors**

3.1 Building materials

3.2 Furnishings and renovation work

3.3 Total volatile organic compounds (TVOC)

3.4 Ventilation system (natural ventilation; heating, ventilation and air-conditioning (HVAC) systems)

3.5 Temperature and lighting conditions

3.6 Location of technical facilities

3.7 Electric, electromagnetic and magnetic fields

3.8 Wind power generators

### **4. Work-related Factors**

4.1 Working materials

4.2 Working place, equipment used

4.3 Stress

### **5. "Psychical Working Conditions" Checklist**

#### **1. Personal Factors: What needs to be taken into account in terms of chemical and physical influences?**

**1.1 Age:** Infants, children and elderly patients may react particularly sensitively, especially to microbial contamination (including mould!!) and to neurotoxic agents.

**1.2 Sex:** As a rule, women are more sensitive than men; and this is particularly true of pregnant women. Women more frequently suffer from allergies, asthma, chemical intolerance or MCS; and women are more often exposed to chemicals (disinfectants, detergents) in hospitals.

**1.3 Previous illnesses:** Staff or patients with, for example, atopias/allergies, asthma, intolerance phenomena (MCS = Multiple Chemical Sensitivity, EMS = Electromagnetic Sensitivity), a hyperreactive bronchial system, neurodermatitis etc., are generally particularly sensitive to chemical, and to some extent also to physical and/or biological influences. Special precautions must be taken for staff and patients with MCS in terms of chemical influences (e.g. use of unperfumed disinfectants and cleaning agents, no perfumes used by staff or other individuals, where necessary also special medication. Disinfection and renovation measures etc. must only be carried out in the absence of the patients and must be accompanied by suitable ventilation measures, no smoking in the building and so on).



## **2. Anthropogenic Factors (Colleagues, Patients, Visitors, Suppliers):**

**2.1 Cigarette smoke:** There should be no smoking inside the hospital. If this cannot be achieved, enclosed areas should be made available to smokers which are separate from the other areas in terms of their ventilation system. Smoking rooms should be individually ventilated; where a heating, ventilation and air-conditioning (HVAC) system is used the spent air must not be fed into the general ventilation system and the spent air from smoking rooms must be released as far as possible from the point at which fresh air is drawn into the HVAC system. Where rooms are aired naturally by opening windows, or when smoking takes place outdoors, it must be ensured that the cigarette smoke cannot re-enter the building again through other nearby windows. This must be taken into account when choosing the location of the smoking room or the outdoor smoking area.

**2.2 Perfumes:** Staff and patients should generally be encouraged not to use perfume, aftershave or other strongly perfumed products, since this may considerably add to the burden on indoor air. Additional measures must be taken where patients with MCS or allergies against fragrances are being treated: thus staff, patients, visitors and suppliers must be informed before visiting the hospital or commencing employment, that no perfumed products may be used, including hairspray, deodorant, laundry detergent etc. This must be rigorously enforced.

**2.3 Car traffic:** Outdoor facilities with heavy car traffic (visitors' car parks, taxi ranks, bus stops) should be located some distance from the building. The fresh air inlet of the HVAC system should face away from such facilities.

**2.4 Noise:** Day rooms for visitors and patients should be physically separated from the wards and patients' rooms. The locations for technical equipment or vehicle facilities (underground car parks?) should be chosen such that the noise they generate does not encroach upon working places and patients' rooms.

## **3. Building-related Factors:**

Extensive literature is available on this subject, to which readers are referred for more detailed information as well as for recommendations on materials and products (used here: TOMFORDE and KRUSE, 1992; BUI 1995; UBA, 2000; COUTALIDES et al., 2002, ÖKOTEST, 2001a+b and 2002 a+b, KATALYSE-Umweltlexikon, 2003). Furthermore, COUTALIDES et al. (2002) have developed a comprehensive planning aid entitled "**Planungsleistung Innenraumklima**" for new buildings and renovation measures, which aims to help forestall hazards. The authors also give general suggestions for the use of low-emission products right from the start. The ÖKO-TEST magazines (2001a+b and

2002a+b) also include tests of “stamps of quality” for building materials and similar products, showing that the German “Blauer Engel” (“Blue Angel”) by no means guarantees low levels of hazardous substances.

With all building materials, it is important to ensure that they are uncritical in terms of gases released into the air. Frequent and critical substances include, among other things, organic solvents, plasticisers (phthalates, polychlorinated biphenyls (PCBs = legacy contaminant)), biocides (insecticides, fungicides etc., to some extent legacy contaminants), formaldehyde and other aldehydes, polycyclic aromatic hydrocarbons (PAHs), organic tin compounds, fibre dust and moulds (microbial growth, e.g. due to faulty construction) as well as monomers of various plastics (styrene, isocyanates, vinylchloride, epoxides, methacrylates and so on). In terms of the symptoms or illnesses associated with exposure to individual substances, readers are referred to the brief descriptions of the substances published by the Katalyse Institute (KATALYSE - UMWELTLEXIKON-ONLINE, 2003; see also BUI, 1995 and ÖKOTEST, 2001a+b, 2002a+b).

Volatile substances initially release high concentrations of gases which then decrease rapidly but are nevertheless measurable at a low level in indoor air often for a considerable time, contributing to the burden to the air (see below). Due to their toxicity, highly volatile solvents are increasingly being replaced by semi-volatile solvents. These only release gas slowly, however they do so over long periods of time instead. In general, low-emission products should be preferred, as well as, in particular, low-solvent and largely odourless products (test for odour before use!) (cf. recommendations of the BUI 1995; UBA, 2000; COUTALIDES et al., 2002, ÖKOTEST, 2001a+b and 2002 a+b). Furthermore, with all mineral products a low level of natural radioactivity (radon) must be taken into account (TOMFORDE and KRUSE, 1992).

Many polymers release their starting materials (monomers such as styrene from polystyrene, isocyanate from polyurethane), at least initially. In some cases, reaction products are also released. The polymers themselves are often harmless to health, but manufacturing and disposing of them may be a considerable burden to the environment and may also pose a health risk to the workers in the corresponding factories. These aspects are only dealt with to a limited extent here, but they are relevant in environmental medical terms and can be studied in greater detail in BUI (1995).

While carrying out small-scale renovation work, and for a few days thereafter, extensive ventilation measures should be implemented; during this time no persons ought to remain in the renovated rooms (cf. recommendations of the UBA, 2000). In new buildings and following extensive remodelling, distinctly increased concentrations, e.g. of volatile organic compounds (TVOC=Total Volatile Organic Compounds: see 3.3), can be expected in the indoor air (COUTALIDES et al., 2002), at least during the first three months. During this time, sensitive groups of people (see above) should not remain in the rooms in question for extended periods of time.

As regards the examination, assessment and avoidance of damage through mould, readers are referred to the “Schimmelpilzleitfaden” published by the UBA (2002) (cf. also BÖGE et al., 2003).

### **3.1 Building Materials:**

**Wood for indoor use** should be free of all fungicidal and insecticidal agents, surface treatment agents should be solvent-free.

**Wood for outdoor use** may be protected by means of pressure impregnation, the use of organic biocides should be avoided.

**Derived timber products** should be free of all fungicidal and insecticidal agents; surface treatment agents should be solvent-free, bonding agents and also coatings may release formaldehyde in particular. The currently required tests/labels/quality seals are no guarantee for low emission levels; these should be verified by means of suitable measurements, or else such materials should be dispensed with entirely, or use as sparingly as possible. The release of formaldehyde may be considerably reduced through the addition of phenol and the use of coatings. Although isocyanate-bonded materials contain no formaldehyde, they too are problematic on account of their environmentally harmful production and disposal methods, as well as the initial isocyanate emissions. So-called OSBs (oriented strand boards) require comparatively little bonding agent and are therefore a low-emission alternative.

**Building blocks:** Natural building stones and artificial bricks made from clay and limestone should be preferred.

**Wallboards:** Plasterboards and damp-resistant boards should be free of fungicides, fibreboard must not release any critical fibre dust (dust barriers!).

**Bonding agents:** Mineral bonding agents (mortar, cement, gypsum etc.) should be preferred, organic bonding agents (usually for exterior rendering and repair fillers) may contain thermosetting resins (unsaturated polyester resins = UP, polyurethane resins = PUR, epoxide resins = EP, methyl-methacrylate resins = MMA) which may initially release isocyanate or the corresponding monomers, and which are problematic in terms of manufacturing and disposal, as well as during actual processing.

**Aggregates:** Mineral aggregates should be given preference, synthetic aggregates may consist of granulated plastics (e.g. PVC = polyvinyl chloride) or foamed plastics (e.g. polystyrene) and may release monomers, and they are problematic in terms of manufacturing and disposal.

**Additives:** Mineral additives should be given preference, organic additives may contain polyvinyl chloride (PVC), polymethyl-methacrylate (PMMA), ethyl-acrylate or other polymers made from styrene, butadiene or acrylonitrile, and (initially) release monomers, and they are problematic in terms of manufacturing and disposal. Polyvinyl acetate (PVAc) contains less problematic substances than, for example, PVC (contains a comparatively large number of additives such as plasticisers).

**Insulating materials:** Mineral insulating materials made of glass fibre, glass wool or rock wool must not release critical fibre dust (dust barriers). Some products contain synthetic resins as bonding agents, which may emit formaldehyde.

Foamed glass is glass that has been foamed using CO<sub>2</sub> and is glued in place in the form of boards. When using these, the special-purpose adhesives, which contain solvents and synthetic resins as well as bituminous sealing compounds, must be taken into account as emitters.

Fill made of expanded perlite (from volcanic rock) is low in terms of emissions, however moisture-repellent fill is impregnated whereby the ingredients depend on the product in question. Pressure-resistant fill may be soaked in bitumen and release PAHs.

Organic insulating materials made of coconut fibre, wood fibreboard or cellulose should be free of bitumen and of PAHs (cork that has been heated too far), formaldehyde-containing bonding agents and biocidal agents. Low-emission wood-wool building slabs and boards made from reed are also available, however here fireproofing considerations must be taken into account. When gluing together the products, the composition of the adhesive must be considered. Organic insulating materials should not be derived from monocultures or from endangered sources.

Insulating materials made from synthetic foams may consist of polystyrene (PS), polyurethane rigid foam (PUR) or phenol formaldehyde resin foam (PF), may release formaldehyde or monomers initially or in the long term, and are problematic in terms of manufacturing and disposal as well as during processing. In the event of a fire, highly toxic substances may be formed (e.g. dioxins, furanes, hydrocyanic acid, diisocyanates and others).

Assembly foams usually consist of polyurethane foam (PUR) and release isocyanates during processing, additives may include flame-proofing agents, propellants, catalysts, tensides, plasticisers, hardeners and filling materials. The flame-proofing agent TCPP (trichloroisopropylphosphate) is often found in samples of household dust.

**Waterproofing and sealing materials:** coal tar and pitch paints are tar products and may release PAHs (polycyclic aromatic hydrocarbons),  $\alpha$ - and  $\beta$ -naphthylamine, as well as phenol.

Bituminous paints or fillers contain bitumen and may release PAHs (as above).

Bituminous solutions contain up to 70% of organic solvents and must therefore on no account be allowed to release gases inside buildings.

Filled paints contain mineral fibres (formerly also asbestos) and must not release any fibre dust.

Hot-melt varnishes contain organic solvents.

Bituminous plastics consist of bitumen, thermosetting resins and artificial caoutchouc, which may emit PAHs, monomers of the synthetic materials as well as plasticisers and organic solvents, depending on their composition.

Mineral slurry-type seal coatings and rendering are made of silica sand, cement and chemical additives (polymer emulsion made of polyvinyl acetate or polyvinyl propionate). Synthetic rendering may contain solvents and preservatives.

Paper, cardboard, sheeting, strips: bituminous felt may release PAHs, plastic sheeting may emit plasticisers and volatile organic compounds (VOC), metal sheeting is glued so that here the composition of the adhesive (containing solvent?) must be taken into consideration.

Silification agents consist of low-molecular silicon compounds or silicone resins in organic solvents.

Synthetic sealing materials are based on silicone caoutchouc, polysulphide, polyacetate, polyacrylate and polyurethane (isocyanates!). These may contain amines as cross-linking agents, polyisocyanates as hardeners, organic solvents, fungicides, plasticisers (e.g. phthalates, formerly PCB!), and mineral fibres as filling materials (formerly also asbestos).

Joint sealant, particularly silicone fillers, may release a whole range of problematic compounds while hardening (products of the setting reaction) and sometimes contain fungicides and algicides. Numerous products contain considerable concentrations of organic tin compounds (TBT and others). Modified silanes (MS hybrids) have fewer emissions. These eliminate five times fewer reaction products than silicone sealants. Permanently elastic sealants without any emissions are not available. Acrylic joint sealants are not suitable for use in damp areas. Some products emit formaldehyde, halogenated organic compounds or contain considerable amounts of plasticisers (phthalates). Non-critical alternatives for sealing are, for example, gypsum, methyl cellulose filler, sealants made of caoutchouc or oil-based putty. However these materials are not suitable for all purposes (e.g. sanitary applications).

## 3.2 Furnishings and Renovation Work

Since furnishings are often renewed in the course of renovation work, these two areas are dealt with together here. In the entire area, critical emissions are highest during and immediately after renovation work and installing new furnishings, and decrease thereafter.

**Flooring materials (gluing flooring materials in place is particularly problematic: see adhesives):**

Natural flooring materials are made of linoleum or cork, for example. As a rule, linoleum produces few emissions, however moisture and microbial infection can lead to troublesome odours as a result of the emissions produced, as can the use of the wrong adhesive. New lino flooring may release aldehydes, which make themselves noticed in the form of unpleasant odours (check smell before buying!). Cork flooring sometimes contains bonding agents (synthetic resins) and sealants, which may consist of synthetic resin varnishes, PVC layers or polyurethane varnishes, and emit plasticisers, solvents, formaldehyde and so on. Here attention should be paid to the composition. These floor coverings have to be glued in place, so that attention must be paid to the composition of the adhesive.

Ceramic flooring (tiles, flags) is as a rule low in emissions, however the ingredients of tile adhesive, joint filler and so on may be a problem.

Synthetic flooring materials are usually made of PVC (polyvinyl chloride). PVC requires numerous additives and is problematic during manufacturing and disposal, as well as in case of fire (dioxins, furanes). Considerable concentrations of plasticiser (phthalates) and organic tin compounds have been found in PVC flooring. Synthetic flooring made from polyolefines is more favourable, since these require fewer additives and are low in emissions.

Textile flooring is made of natural yarn (mothproofing agents contain insecticides!) or synthetic yarn (polyacrylonitrile, polyester, polypropylene, polyamide). Furthermore, textile flooring usually includes a carrier (polyester, polypropylene, polyamide), a fixing agent (synthetic latex or styrene butadiene latex, which emits styrene, butadiene, 4-phenylcyclohexene) and a back coating (thermoplastics: PVC, PVAc, PP or plastic foams: polyurethane) which may release plasticisers or isocyanates. Textile backings should be preferred over foam backings. A test for odour should definitely be carried out.

Additional features of textile flooring include antistatics (glycol derivatives, phosphoric acid esters and so on), anti-soiling agents (fluorinated plastics), mothproofing agents (insecticides: incl. pyrethroids), antimicrobial agents (formerly also PCP!, formaldehyde), flame protection (incl. phosphoric acid esters, bromated compounds) and plasticisers (phthalates). "Pesticide-free" carpets may nevertheless contain pesticides as a result of secondary contamination, e.g. during storage or manufacturing. Preference should therefore be given to manufacturers who do not use pesticides.

*(For a tabular comparison of different flooring materials and recommendations, see BUI (1995): p 61)*

### **Materials for wallpapering:**

Preparatory work: wash primer contains organic solvents, sealers consist of polymer emulsions and may contain plasticisers.

Insulating wallpaper (applied under outer paper covering) consists of polystyrene foam (styrene) or polyurethane foam (isocyanates) and must be glued (see adhesives).

Paper wall coverings and wood-chip wallpaper are made of paper or paper with woodchips and are breathable, and can therefore be recommended (when used in association with low-emission paste and paint, where appropriate).

Textile wall coverings contain, for example, polyacrylonitrile (acrylonitrile) or UF resins (formaldehyde) and are not breathable.

Vinyl wall coverings are made of PVC soft foam and contain a number of additives (plasticisers and so on) and are not breathable. Acrylic wall coverings usually also contain plasticisers. Synthetic wall coverings as a whole are problematic in terms of manufacturing and disposal, as well as in case of fire.

*(For a tabular comparison of different wall coverings and recommendations, see BUI (1995): p 69)*

### **Adhesives:**

Physically binding adhesives contain thermoplastics or caoutchoucs as their basic ingredients:

Emulsion adhesives are polymer emulsions in water and contain few or no organic solvents, however they may contain preservatives (formaldehyde?).

Products with solvents contain turpentine oil (natural resin adhesive) or considerable amounts of organic solvents. Their use can lead to considerable contamination of indoor air, and they should not be used on large areas.

Chemically binding mixed adhesives contain thermosetting resins as their basic ingredient, which cross-link in the adhesive layer. These may contain silicone resins, melamine resins, dimethylacrylic esters, methyl methacrylates, epichlorhydrine reaction resins or polyisocyanates, and may release solvents, formaldehyde and, particularly while being applied, monomers (e.g. epichlorhydrine, isocyanates).

Water-soluble glues and pastes are used particularly for processing wood and paper. Glues made from natural substances include, for example, animal glues, casein glues and cellulose glues. In these cases, problems may be associated with the preservative used (formaldehyde?). Water-soluble synthetic-resin glues may, for example, contain polyvinyl acetate glues (formaldehyde-free, but not as durable) or condensation glues made using urea formaldehyde resin (formaldehyde) or other synthetic resins, and also include preservatives.

Pastes also usually contain preservatives (formaldehyde?). Pastes made of methylcellulose are recommendable. Special-purpose pastes contain, for example, polyvinyl acetate or polyvinyl alcohols and also include preservatives.

### **Wall paints:**

Emulsion paints contain water, natural or synthetic resins as bonding agents, pigments, preservatives (formaldehyde?) and as a rule only few organic solvents. Some products contain formaldehyde derivatives, or glycols (semi-volatile organic solvents). Preference should be given to products that are free of such substances.

Powdered emulsion paints are not mixed with water until just before use and therefore contain no preservatives.

As a rule, latex emulsion paints contain synthetic materials and are only necessary for walls that are subject to intense wear and tear. Plasticisers, formaldehyde or solvents (usually glycols) have been found in some products.

Casein paints contain water, casein powder, pigments, preservatives and hardly any organic solvents. They are more environmentally friendly than emulsion paints in terms of their ingredients and production methods, however they are less durable and more expensive. Other emission-free paints include size colours or lime paints (for details of advantages and disadvantages: see ÖKOTEST, 2001a)

When working on mineral surfaces, low-emission organosilicate paints may be used. However, the preservative must be taken into account here.

### **Varnishes:**

Varnishes contain comparatively large amounts of solvent. In addition, synthetic varnishes sometimes contain carcinogenic starting materials and manufacturing them is not very environmentally friendly. They should only be used where absolutely essential. In such cases, low-solvent products should be preferred. Products for treating parquet floors are particularly problematic; these may release large amounts of solvents (including semi-volatile glycols!) even weeks after being applied, and in the case of acidic hardeners also emit formaldehyde.

Alkyd resin varnishes contain approx. 40% organic solvents and polyester resins as bonding agents.

Acrylic varnishes contain up to 10% organic solvents (especially semi-volatile glycols) and polyacrylates as bonding agents, as well as in some cases preservatives (formaldehyde?) and plasticisers (phthalates).

Nitro-cellulose varnishes contain up to 80% organic solvents and cellulose nitrate as a bonding agent. "Biological varnishes" contain up to 30% natural organic solvents (citrus oil, balsam turpentine, isoaliphates) and natural resins (e.g. colophonium) as bonding agents. The ingredients are in some cases also allergenic and also contribute to the contamination of the indoor air. Here too, products that are low in solvents should be preferred. The product should, in particular, be low in terpenes and contain no delta-3-carene, since this has a highly allergenic effect.

*(For a tabular comparison of different types of varnish and recommendations, see BUI (1995): p 76ff)*

### **Furniture:**

Furniture made of PVC may contain a range of problematic ingredients (e.g. lead stabilising agents, tributyl tin oxide, plasticisers, flame protection agents and biocides). If plastic parts are necessary, polyethylene, polypropylene or polyacrylic are better choices.

Furniture made of pressboards contains resins including formaldehyde or polyurethane resins (isocyanates) as bonding agents, as well as veneer adhesives (formaldehyde?). Products with open cut edges emit more formaldehyde than those with covered edges. Furniture glued using PVAc (= polyvinyl acetate) or made from glued wood are more expensive but lower in emissions.

Melamine coatings consist of melamine resins and formaldehyde. Newly purchased furniture releases both these starting products as well as their reaction products.

Furniture varnishes may emit large quantities of organic solvents. Low-solvent products should be preferred (see "Varnishes" above).

Solid wood products should not come from regions where clear cutting is practised (wood from tropical forests!) and may only be used where this is not ruled out by hygienic considerations.

Wood glues also frequently contain formaldehyde.

Artificial leather is often made of PVC (see above) and increasingly of polyurethane (isocyanates).

In making upholstery and mattresses, the foamed material is mostly made using polyurethane (PU). The starting products for PU - isocyanates - are allergenic, toxic and in some cases suspected of being carcinogenic. Aside from the fact that manufacturing them is harmful to the environment, new products also release the isocyanates into the air. However this problem is reduced through the storage of new furniture. In addition to this, polyurethane foam may release a number of other substances (cf. BUI, 1995).

The natural materials used include cotton, sheep's wool, coconut fibre, natural latex (beware of latex allergies) or horse hair. However here the pesticide content must be taken into account.

Synthetic latex consists of styrene butadiene caoutchouc and may release the monomers as well as additional reaction products (vinyl cyclohexene, phenyl cyclohexene) as well as plasticisers. Carbon disulphide is used as a cross-linking agent. Like styrene, this is a nerve toxin.

*(For a tabular comparison of different materials and recommendations, see BUI (1995): p 81ff)*

### **3.3 Total Volatile Organic Compounds (= TVOC)**

In view of the multitude and diversity of the volatile compounds that may occur indoors, the indoor air quality cannot be judged on the basis of the concentration of a single substance.

One measure of indoor air quality is therefore the concentration of Total Volatile Organic Compounds, or **TVOCs**. This includes volatile organic compounds with boiling points ranging from 50-100 °C to 250-260 °C. Outdoors, TVOC concentrations in the air are around 10-40 µg/m<sup>3</sup>. This is also desirable indoors, though scarcely attainable. According to SEIFERT (1999), TVOC concentrations of 200-300 µg/m<sup>3</sup> or less should be aimed at indoors; adverse effects for the users of indoor spaces are not expected to arise below this. This should also be used as a guideline for sensitive groups of patients and staff (e.g. people with MCS, asthma, hyperreactive bronchial systems, infants and pregnant women). At TVOC concentrations between 300 and 1000 µg/m<sup>3</sup>, sensitive people may already exhibit adverse symptoms. At TVOC concentrations >1000-3000 µg/m<sup>3</sup> measures should definitely be taken to decrease exposure. These values were ascertained using charcoal as adsorbents. In more recent studies using Tenax® TA as adsorbents, higher values have been found and a tolerable TVOC concentration of 500 µg/m<sup>3</sup> was recommended (KELLER et al, 2004).

This approach is a pragmatic one and should not be regarded as being based on toxicological findings. In particular, the TVOC concentration cannot be taken as evidence that the concentration of contaminants is not harmful to one's health. There are several reasons for this: for one thing, it does not take into account that the indoor air may contain considerable concentrations of "indeterminate" VOCs. Furthermore, entirely different pollutants may be present at concentrations that are relevant to health (formaldehyde, moulds, microbial metabolites, isocyanates, biocides, PCBs and others). The specific composition of the TVOCs may also differ considerably despite a similar total concentration, and also lead to different adverse effects. Whenever TVOC levels are elevated, the individual substances should therefore always be additionally monitored (SEIFERT, 1999; KRINES, 2002). SEIFERT (1999) offers a minimum list of the compounds that should be individually quantified in order to determine the TVOC concentration. This includes glycols and glycolic ether as well as terpenes, but not formaldehyde or CO<sub>2</sub> (for an overview of reference values for individual substances as well as for TVOC, VOC and SVOC concentrations, see SEIFERT, 1999; COUTALIDES et al., 2002, KELLER et al., 2004).

Much the same is also true for the emissions from building materials and other products that are to be used indoors. The "Committee of the Health Assessment of Building Products" (=AgBB, *Ausschuss zur gesundheitlichen Bewertung von Bauprodukten*) has developed a general assessment concept for the licensing of such products. The AgBB comprises state and federal organisations (UBA, BgVV) as well as trade associations (AGBB, 2001).

In brief (for further details see AGBB, 2001) the TVOCs released by a product in a test chamber under defined conditions should result in concentrations below 10 mg/m<sup>3</sup> after 3 days, and <1 mg/m<sup>3</sup> (<1000 µg/m<sup>3</sup>) after 28 days. In addition, products must not emit more than 0.1 mg/m<sup>3</sup> (<100 µg/m<sup>3</sup>) SVOCs after 28 days. The concentration of "non-measurable VOCs" must also be below 10% of the permitted TVOC level. Carcinogenic, mutagenic and reproduction-toxic substances must not be released at all by building materials. In this context, products that have particularly low emission levels distinctly below the maximum permissible levels are classified as being "recommended".

However, these licensing criteria apply to new products, not to materials that have already been licensed or whose licenses are due to be extended (KRINES, 2002).

For an overview of the LCI levels (LCI = lowest concentration of interest) for individual substances in building materials and for additive formulas for calculating permissible maximum levels, see AGBB (2001).

### **3.4 Ventilation System (Natural Ventilation, Heating, Ventilating and Air-Conditioning (HVAC) Systems) (after BROWNSON, 1999):**

**Natural ventilation** is preferable to artificial ventilation. Airing recommendations should be observed in this context (frequent short bursts of airing instead of ongoing ventilation, cf. UBA, 2000). Rooms should be ventilated before work begins and at regular intervals thereafter.

When using artificial ventilation (**heating, ventilating and air-conditioning (HVAC) systems**), the following points should be taken into account:

Since incorrectly installed and poorly or rarely serviced HVAC systems are the most common cause of *Sick Building Syndrome* in hospitals, such systems should only be installed and serviced by suitably qualified companies. The servicing intervals should be observed. All humidification and dehumidification systems must be kept clean at all times, to avoid microbial growth. Both infective vectors themselves, as well as microbial toxins, allergenic substances and other metabolites may be distributed throughout the building by the HVAC system, leading to massive health impairment (cf. also UBA, 2002).

The air drawn in by the AC system should consist only of fresh air. There must be no sources of emissions in the vicinity of the fresh air inlet (e.g. shafts carrying spent air or exhaust from garages, engine rooms, laboratories etc.).

Indoor areas in which the indoor air is subject to additional contamination (laboratories, rooms with chemical disinfection units, store rooms for paints, cleaning agents or any kind of chemical, rooms with photocopiers or laser printers, kitchens etc.) should be fitted with independent ventilation systems. The spent air from these rooms must not be fed into the general cycle and should be released at a distance from the fresh air intake of the HVAC system.

Staff should be trained in the use of HVAC systems. Ventilation shafts must not be obstructed by furniture or other objects. **Complaints concerning the air quality must be taken seriously and investigated.**

The rate of exchange of the air in rooms should be at least 1/h (more when several people are allocated to a room, at least 40 m<sup>3</sup>/hour per person). Definitely higher ventilation rates are desirable. Ventilation rates up to 4/h should be discussed. In new buildings or following renovation measures, ventilation rates should be markedly increased.

The HVAC system should begin operating several hours before the start of work, not just when work begins, in order to remove contaminants that have accumulated over time. The HVAC system should remain active until the last member of staff has left the rooms in questions.

The relative humidity of the air should be at least 40-50%.

### **3.5 Temperature and Lighting Conditions**

Room temperature is very often a cause of discomfort to and complaints by users of indoor areas. However, it is experienced very differently by each individual, also depending on the activity of the person concerned. "Thermal comfort" also involves an adequate supply of fresh air, the absence of disagreeable draughts and the avoidance of excessively high or low humidity levels. Where possible, the temperature in individual rooms or working places should be individually adjustable. The same is also true of the lighting conditions (cf. COUTALIDES et al., 2002). These aspects have to be taken into account right from the start in designing the building, the ventilation system, the heating system and the shading from the sun.

### **3.6 Location of Technical Facilities**

Technical facilities should be located at a distance from those rooms which are used a lot by staff or patients. The site of technical facilities should not be a source of either noise or air pollution to rooms that are in general use. Furthermore, independent ventilation systems should exist for these sites. The spent air from such areas must not be released into the general ventilation cycle.

Any type of electric installation can be a source of electromagnetic radiation. Increased radiation levels should be avoided through the method of installation and the choice of location (COUTALIDES et al., 2002).

### **3.7 Electric, Electromagnetic and Magnetic Fields**

The exposure to electric, magnetic and electromagnetic fields can be reduced effectively through the choice of location, the planning and execution of the construction work, as well as through the method of use.

#### **Choice of location**

No high-voltage lines or transformer stations should be located near the building. A minimum distance of 500 m should be observed between the above emitters and buildings or highly frequented areas of the premises.

Radio transmitters, television transmitters, mobile telephone transmitters, radar equipment (airports, monitoring stations, ships), railway lines, trams, local rail networks should be taken into account when selecting the location. In view of varying power output, frequency and modulation of the emissions, no general recommendations can be given as to the distances to be observed. It is urgently recommended that expert advice be sought when selecting a location, including prior consultation with the relevant operators.

#### **Planning and Execution of Construction**

In planning and executing the construction work, it is helpful to distinguish three zones:

- **Zone 1:** areas only sporadically occupied by people (e.g. stairwells, switch rooms)
- **Zone 2:** areas occupied by people, in particular patients and staff, for extended periods of time (e.g. staff working areas, patient accommodation)
- **Zone 3:** areas occupied by highly sensitive persons for extended periods of time (e.g. patient accommodation for patients displaying electromagnetic hypersensitivity).

When determining the layout of supply cables, a star-shaped arrangement is preferable to a horseshoe arrangement, in order to reduce inductive effects.

#### **a) Rising mains and fuse boxes**

For zone 2 rooms, a minimum distance of 2 m should be observed, for zone 3 rooms a minimum distance of 10 m from rising mains and fuse boxes.

#### **b) Peripheral supply lines**

In zone 2 and 3 rooms in which people sleep, a mains disconnecter should be installed.

In zone 3 dormitories, a minimal electricity supply should be implemented using 12 V direct current and coaxial cables with mains disconnecters (only installing absolutely essential supply lines).

### **c) Electrotechnical equipment**

When choosing the location particularly of electrical boilers, washing machines and dishwashers, refrigerators, freezers, heat pumps, television sets and power supplies, the largest possible distance should be observed from sleeping places. In zone 3, a minimum distance of 10 m should be observed from sleeping places.

### **d) Lamps**

Halogen, fluorescent and energy-saving lamps that use transformers/capacitors should be avoided in zones 2 and 3. Dimmer switches should be dispensed with.

### **e) Telephone system**

The base station of a DECT telephone hooked up to the mains emits a constant high-frequency signal, pulsed at 100 Hz, whose athermal biological effects are strongly suspected of producing considerable adverse effects on health. Where possible, DECT telephones should therefore be dispensed with altogether. If DECT telephones are absolutely vital, a minimum distance of 10 m should be observed between the base station and any sleeping places in zone 2, in zone 3 a minimum distance of 30 m should be observed.

### **f) Outdoor installations**

High-power supply lines and transformer stations in the field of external installations should be installed as far as possible from sleeping places. A minimum distance of 10 m should be observed from zone 2 sleeping places, and 30 m from zone 3 sleeping places.

## **Electrical equipment**

### **a) Use**

Unnecessary electrical appliances should be dispensed with. Electrical appliances that are not in use for an extended period of time should be disconnected from the mains supply. Non-permanent extension cords should be disconnected from the mains supply if the appliances attached to them are not used for an extended period of time. Electrical appliances should not be left in standby mode; this can be achieved by means of a bipolar cut-out switch. Mains-operated electrical appliances should be entirely absent from zone 3 sleeping places.

### **b) Mobile phones**

The use of mobile phones should be generally prohibited throughout the entire hospital area.

### **3.8 Wind Power Generators**

In view of noise and ultrasound emissions as well as stroboscopic optical effects, the minimum distance to be observed between buildings or highly frequented areas of the premises and wind power generators is 20 times the overall height of the wind power generator.

## **4. Work-related Factors**

The individual chemical, physical or psychological burden experienced by members of staff may vary considerably, depending on their duties and place of work.

### **4.1 Working Materials**

#### **Cleaning agents and disinfectants:**

Particular attention should be paid to all tasks involving disinfection measures. The aldehydes frequently used here (formaldehyde, glutaraldehyde) as well as ethylene oxide pose a special risk to the health of the persons exposed to them. In particular, aldehydes are associated with the danger of a sensitisation of the exposed persons. However, exposure to disinfectants has also been associated with irritations of the mucosa, and with neuropsychiatric symptoms and asthma. The staff in radiology and endoscopy departments are particularly at risk (ELLETT et al., 1995; GANNON et al., 1995; VYAS et al., 2000; GUTHUA et al., 2001). Particularly sensitive groups of patients should not be exposed to disinfectants containing aldehydes either.

For this reason, the FKH-NF only uses aldehyde-free, alcohol-based disinfectants (cf. Table 1). Their efficacy is monitored by means of regular microbiological checks of the disinfected surfaces.

In the environmental ward (MCS patients), both cleaning and disinfection operations are carried out in the evening, ventilating at the same time. The disinfection measures are assisted there by means of the (labour-intensive) use of a steam cleaner. Instruments are disinfected in a room that is not accessible to patients. All disinfectants, as well as cleaning agents, detergents, washing-up liquids, hand-cleaners etc. are in addition free of perfumes or other strong-smelling components (other than alcohols).

When a large number of devices and instruments need to be disinfected, disinfection should be carried out in a closed system and in an independently ventilated room. All cleaning and disinfection measures associated with a high exposure to volatile substances should be carried out by staff wearing the appropriate protective clothing (cf. JORDAN et al., 1995).

**Table 1: List of Disinfectants and Skin-Care Products Used at the FKH-NF**

<b>Product:</b>	<b>Area of use:</b>
Baktolin 5,5	cleaning hands and skin
Baktolan 5,5	skin care
Sterilium	disinfecting hands (all wards)
Sterilium pure	disinfecting hands (environmental ward)
Cutasept F	disinfecting skin
Bacillol AF	quick disinfection of surfaces
Microbac Forte	disinfecting surfaces
Korsolex AF	disinfecting instruments
Dismoclean 41 STS	automatic bedpan cleaners
Microbac Food	surface disinfectant cleaners (food sector)

**Laboratories:**

All working places in which staff necessarily work with substances that may be harmful to their health (laboratories, darkrooms, pharmacies) should be subject to special monitoring. All the ventilation systems should be regularly serviced and checked. Staff working in these areas should be specially trained concerning the risk of handling, for example, solvents and gases, and in the use of protective clothing and suchlike, since the careless handling of such chemicals (often due to ignorance of the potential hazard involved) contributes towards a distinct increase in the health risk. All the chemicals used should be checked as to their potential health hazard, and the alternative with the lowest risk should be used in each case. Staff working in these areas should be subject to separate clinical monitoring. No working places associated with other duties (e.g. office or administrative functions) should be located in laboratory areas.

**Latex gloves:**

Latex from natural sources has a distinct sensitising potential. The sensitisation rate is high among hospital staff as a whole. The use of powdered gloves is particularly problematic since the allergenic substances in the latex bind to the powder's components and are thus distributed everywhere borne by the air. Accordingly, hospital staff (and patients) who do not use latex gloves, may also become sensitised. Wherever possible, alternatives to latex gloves should be considered, or else powder-free gloves with a low level in allergenic substances should be used. This should already be done pre-emptively. WOODS and EDLICH (1997) report on the occurrence of a latex allergy epidemic in a hospital due to the use of powdered latex gloves with a high level of allergenic substance, and on the very cost-intensive measures that subsequently became necessary.

## **4.2 Working Place, Equipment Used (see also Section 4.1)**

All technical equipment and data processing systems that are to be used by members of staff should conform to low-radiation standards.

Photocopiers and laser printers often emit not inconsiderable concentrations of ozone as well as toner components (solvents and metallic dusts). Such devices should not be located in the immediate vicinity of working places, but installed in separate rooms with good independent ventilation.

(for further details about the office sector, see ÖKOTEST Special Issue 17: Büro (1995) ([www.oekotest.de](http://www.oekotest.de)), specialist information "Umwelt und Gesundheit im Büro" published by the Bavarian Ministry of the Environment ([www.umweltministerium.bayern.de/service](http://www.umweltministerium.bayern.de/service)), and "Grundwissen Tonerstaub in Bürogeräten" ([www.sozialnetz-hessen.de/ergo-online/Arbeitsplatz](http://www.sozialnetz-hessen.de/ergo-online/Arbeitsplatz))

There should be no smoking at working places (see above).

Working places should be in rooms that are separate from all facilities associated with increased emissions of hazardous substances, noise, heat, electromagnetic radiation, odours etc. (see above).

(For laboratories, as well as cleaning and disinfection, see Section 4.1)

## **4.3 Stress**

Studies investigating the "Sick Building Syndrome" often also note a connection between psychosocial factors and an increased incidence of symptoms. Such factors include "stress due to a high workload", "having no control over working conditions", "job dissatisfaction" and "poor quality of staff cooperation". Accordingly, an improvement in the psychosocial climate will also lead to a lowering of symptom prevalence among members of staff (NORBÄCK and EDLING, 1991; NORDSTROM et al., 1995).

## 5. "Psychical Working Conditions" Checklist

This brief checklist is designed to check the main aspects of "psychical working conditions" in hospitals (for details and for further aspects (traffic, noise, psychosocial climate etc.) see Sections 1 - 4)

- C1. All building materials and the materials used for renovation work and furnishings are selected according to the criteria of low emissions (also in case of fire!), and harmlessness to health and the environment during manufacturing and disposal. This also applies to auxiliary materials (e.g. adhesives, joint fillers and so on). In particular, the use of materials including/consisting of PVC, polystyrene or polyurethane/isocyanates is avoided. All the materials used are particularly low in formaldehyde/formaldehyde derivatives, volatile and semi-volatile solvents and plasticisers, and free of biocides, organic tin compounds and heavy metals (for further critical substances and details see Section 3).
- C2. A test for odour is carried out prior to the purchase of any building materials used on large areas, of materials to be used in renovation work, and of furnishings,
- C3. When using building materials containing fibres, care has been taken to ensure that no fibres can be released into the indoor areas (dust barriers).
- C4. All legacy contaminants that may be harmful to health (in particular asbestos, PCBs, heavy metals and biocides (often: PCP and lindane) and microbial damage) have been removed/cleaned up.
- C5. In selecting sites, planning and executing building work, and in using the facilities, suitable measures are taken to minimise electric, electromagnetic and magnetic fields (cf. Section 3.7).
- C6. All hospital buildings are potential "sick buildings"; therefore initially all buildings are examined to determine whether the air quality in them is good and healthy, or not. All the causes of emissions that may be harmful to health are removed, replaced or cleaned up.
- C7. All rooms used by staff (and patients) are examined in terms of their "thermal comfort" for users of those rooms (cf. Sections 3.4 and 3.5: fresh air supply, temperature, draughts, shading from sun and so on).
- C8. All buildings are regularly examined for overt and hidden microbial damage of the building materials and damage due to damp, since these are associated with a special health risk (cf. UBA, 2002; BÖGE et al., 2003).
- C9. All heating, ventilation and air-conditioning (HVAC) systems are regularly checked by experts for current microbial soiling, cleaned and serviced. Only fresh air is fed into the system. The fresh air inlet lies a long way from all potential emitters. All rooms with a special emission potential (e.g. laboratories, darkrooms, pharmacies, disinfection units, workshops, garages) are ventilated independently. (For further details see Section 3.4)
- C10. Cleaning, servicing and renovation work is carried out outside normal working hours, where possible, and is accompanied by extensive ventilation measures.
- C11. Particular attention is paid to all tasks specifically associated with disinfection (cf. Section 4.1). The aldehydes (formaldehyde, glutaraldehyde) often used in this area present a special risk to the health of the persons exposed to them. In particular aldehydes involve the danger of sensitising the exposed persons.

- C12.No powdered latex gloves are used (these can lead to real latex allergy epidemics, cf. Section 4.1). After removing all powdered latex gloves and introducing powder-free gloves with low levels of allergenic substances, special cleaning measures have been carried out to remove all allergenic dust. All air-conditioning units and all the rooms into which allergenic dust could have been carried by the air-conditioning system, have been included in these measures.
- C13.All members of staff necessarily working with potentially harmful substances (e.g. in laboratories, darkrooms, pharmacies, disinfection units, workshops) are subject to special monitoring. Staff in these areas are specially trained in terms of the risks of handling, for example, solvents, disinfectants or paints, and in the use of protective clothing and so on. All the chemicals used are checked as to their potential health hazard, and in each case the alternative that involves the lowest risk is used. Safety data sheets are openly available for all such substances. All ventilation systems in the corresponding working places are serviced and checked regularly and frequently (cf. Sections 3.4 and 4.1).
- C14.Smoking is prohibited in the hospital (cf. Section 2.1)
- C15.No perfumed or strong smelling products are used. This also applies to cleaning agents, detergents, personal hygiene products etc. Staff and patients are requested not to use perfumes, aftershave, perfumed personal hygiene products or other strong-smelling products (perfumed lamps etc.). This must be implemented especially when sensitive groups of patients are treated (infants, pregnant women, patients with atopias/allergies, asthma, hyperreactive bronchial systems or MCS/Multiple Chemical Sensitivity)
- C16.The concentration of total volatile organic substances (TVOC: see Section 3.3) in the indoor air is below 1000  $\mu\text{g}/\text{m}^3$ . Efforts are being made to lower the TVOC concentration to <300-500  $\mu\text{g}/\text{m}^3$  (by means of the above measures, see also Section 3.3).
- C17.Are particularly sensitive groups of patients treated in the buildings (cf. Section 1)? In this case, particularly high standards must be set for the quality of indoor air (cf. Sections 2., 3. and 4.).
- C18.If patients with MCS are treated, point C14 is obligatory and must be extended to all other persons (visitors, suppliers etc.).
- C19.If patients with MCS or other sensitive groups of patients are treated, the concentration of total volatile organic substances (TVOC: see Section 3.3) in the indoor air must be below 200 - 300  $\mu\text{g}/\text{m}^3$  and if possible even lower.
- C20.If patients with MCS are treated, all building materials and materials used for renovation work and all furnishings must not only display low emission levels, but in particular they must be free of formaldehyde / formaldehyde derivatives and plasticisers (cf. Sections 3.1 and 3.2). Volatile solvents as well as other critical emitters must be minimised.

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