Natural humidification by functional Green Walls and PrimaKlima® plants as resource-efficient and hygienic alternative or complement to technical devices

Special plants and Green Walls are able to create comfortable indoor climates by cold evaporation in transitional periods and winter, which can be calculated and predicted, has no health risks and is environmentally friendly.

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Abstract

To moisten rooms, plenty of water must be evaporated. For this purpose the used technical humidifiers require a lot of energy and usually cause hygiene problems by microbial contamination. Since the 1990s, special PrimaKlima® plants are well known to transpire considerable humidity during the winter and thus improve the room air. Because these plants require plenty of light, the Green Wall system was developed for humidification in darker locations in the beginning of 2000. Both systems provide the moisture passively by cold evaporation into the air. Hence there are no aerosols. The plants grow in hydroponics substrate, which is made of inorganic material that inhibits fungi and bacteria in their growth. The impact of these plants and green walls can be calculated. The integration into building services at the planning stage is required.

Introduction

The positive effect of plants on human beings is indisputable. Especially effects of interior planting on health and comfort among workers and schoolchildren (Fjeld, 2000) are still being studied. The lush greenery mainly has a positive effect on our psyche and makes a major contribution towards a sense of comfort. Beside the psychological effects, which were recently confirmed by a study of the Bavarian State Research Centre for Viticulture and Horticulture (LWG) (Reimherr and Kötter, 2000), houseplants are also regarded to have positive indoor climate effects and contribute to reducing pollutant gases in the air. NASA has found in pioneering studies in the 1990s, a clear reduction of air pollutants. Both by physical effects, such as attachment to the leaf surface and also not plant-generated effects, such as pollutant abatement by soil bacteria metabolization (Wolverton, 1996).

Further studies at the University of Cologne and the Research Centre for Environment and Health, GSF,

Technical data:

Green Wall for Humidification:

- modular system with planted plates 60 cm x 40 cm x 5 cm
- clipped on stainless steel skeleton
- wall mounting: constituent wall, insulation, sealing, stainless steel structure, planting plate
- design capacity indefinitely
- average water delivery (depending on environmental factors) of 3 L/m^2 x d

PrimaKlima® Cyperus:

- 2 m high and 1 m^2 floor space, bright to sunny location
- water levy in section 2 L/d
- all systems indoor

Expected indoor climate performance:

- room air humidity increases at least 10-15% points

Figure 1. PrimaKlima® plants from left to right: *Cyperus alternifolius, Hibiscus sinensis, Sparmannia africana, Musa acuminata*

Oberschleißheim (Kötter, 2004a) showed that the plant itself metabolizes some pollutants, albeit in limited amounts and insufficiently to remediate rooms with concerning amounts of contamination. Only the active passage of air through so-called plants filters results in a significant reduction. But mould spores or bacilli can be blown out of the root zone in the air and then cause similar problems, as could be seen in some technical humidifiers in the past.

Materials and methods

For effective humidification there are special PrimaKlima® plants e.g. *Cyperus alternifolius*, *Musa acuminata, Sparmannia africana* and *Hibiscus sinensis*, which raise the humidity in winter by 30% to 50% and ensure a pleasant indoor climate (Fig.1.). These species transpire intensively even in winter.

Practically all other plants have no significant effect on the indoor climate. In particular typical hydroponic plants tend to be economical in their water uptake, even if the name suggests something else. Hydroponics is accepted in offices, hospitals, nursing homes and even in schools (Frenzel et al., 2010) as quite sterile and as a cultivation form that causes little germs emissions. In a standard planting depth of 19 cm, the upper range of about 6 cm is dry and therefore hostile to fungi, bacteria and small animals such as flea beetles (*Chrysomela sp.*), etc. PrimaKlima® plants require a lot of light, therefore Green Walls for darker locations were developed in early 2000. Based on ideas of the French botanist Patrick Blanc, these vertical gardens were developed for light poor rooms and to increase the humidity by Bernhard Häring and Manfred Radtke. Important for the water delivery is the inorganic substrate and not the plants themselves. The foam glass was originally developed for propagating cuttings and has fungicidal and bactericidal properties. An important part of the development was the modular construction (Fig.2.). Dense and flat plant growth is produced on rectangular foam glass plates and clipped piece by piece to the carrying structure on the wall. If single plates need servicing or something needs to be placed behind the green wall, only the affected plates need to be removed or swapped out. In a short time the plants grow and intertwine and single panels are no longer recognizable.

The evaporation rates of Green Walls and PrimaKlima® plants are very well known and therefore they can be incorporated in the calculation of the indoor climate. The developed biotechnological humidification is based on own studies of biogeochemical cycles of various houseplants depending on climatic parameters of the

Figure 2. Green Wall Sparkassa Ingolstadt: modular system (left) and later the connate plates (right) (photo by B. Häring)

room (Radtke, 1986). Most indoor plants evapotranspirate too little water in order to achieve a significant effect on room climate. Often plants enter a hibernation period with little physiological activity, which may also be induced by the lack of light in central European latitudes. Yet humidification is specially needed in the light poor winter and transition time when the air is dry because of heating.

In winter at 80 % relative humidity, a cubic meter of air at 0 °C holds only about 4 grams of water. If this air is heated to 22 °C, one cubic meter could hold about 20 grams of water vapour. However, since only 4 grams are present, the relative humidity drops to 20 %. The dry air now draws water from any wet surface in order to get closer to a stable balance. This air dries the mucous membranes of people in the room and thus paves the way for germs and bacteria to enter and more easily infect the human body.

The well-known comfort diagram (Fig.3.) shows that a pleasant environment for plants is at about 21 °C and 40 % relative humidity (RH). For optimal function of the ciliated epithelium of bronchi even 45 % RH are necessary.

Results and discussion

Plants are located in the potential gradient (water vapour) between dry air and moist soil. Trough the transpiration of water from the stomata, the capillary water flow in the plant is induced. If the genetics of a plant determine high-capacity vascular bundles in the stems, it can evapotranspirate plenty of water, given an optimal water supply. This is the case precisely at PrimaKlima® plants.

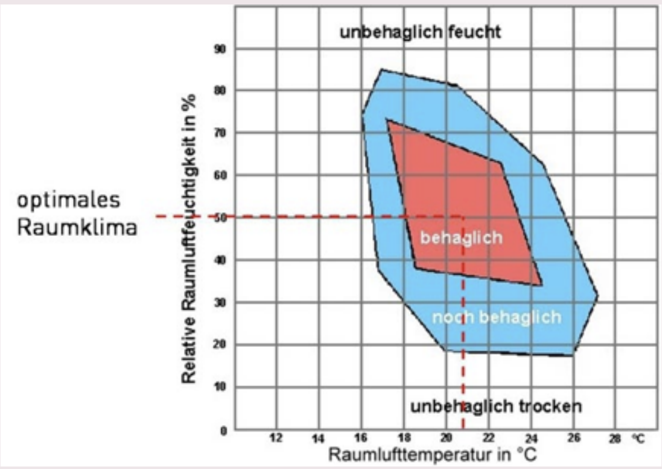

Figure 3. Comfort zone for the value pair room temperature - relative humidity (www.pluggit.com) [Optimales Raumklima = optimum room climate; Relative Raumluftfeuchtigkeit in % = relative indoor humidity in %; Raumlufttemperatur in °C = indoor air temperature in °C; Behaglich = comfortable; noch behaglich = yet comfortable; unbehaglich trocken = uncomfortably dry; unbehaglich feucht = uncomfortably humid]

Under favourable conditions one m^2 of „PrimaKlima® Cyperus" delivers about 2 L/m²/d of water vapour, other PrimaKlima® types provide about 1.2 L/m²/d of water vapour. This is sufficient to moisten none-air-conditioned rooms for a size up to 65 m³. Depending on the air exchange an increase in relative humidity of 10-15% points is expected. The required amount of plants in offices with air-conditioning systems varies depending on air exchange, number of persons and other parameters. Calculations incorporating climate-functional parameters from the living plants provide the required dimensions of the plantings.

If there is a lack of space and/or light then the Green Walls offer an option for green humidification. Mainly tropical groundcovers like *Philodendron scandens, Ficus pumila, Peperomia sp.* among others are used, which are characterized by tolerance to low light conditions and are appealing decorative elements. The evaporation occurs mostly directly through the porous surface of the inorganic glass foam. The cooling effect of evaporation causes convexion movement in the surrounding air, ensuring that there is a constant air exchange that removes humid air masses and distributes them in the room. Thus, the water turnover of the Green Wall per planted area is much higher compared to horizontal systems. The water turnover depends on the ambient humidity; it decreases with increasing relative air humidity, but does not fall to zero. For this reason, it is important to adapt the dimensions of the green wall to structural building conditions. Overhumidification in rooms can cause mould, component corrosion and other condensation damage. In fact, a muggy room ambient caused by excessive air humidity is a burden on employees or residents.

On average, approximately 3 L/m²/d are evaporated from the Green Wall for humidification. Watering the thin substrate layers is a technical challenge. Since the overall construction depth of the Green Wall should not be more than 10 cm, the water must be applied in careful dosification. There are installations with 20 m height and 30 m width in operation and no excess water should drip out of the bottom sections while ensuring enough water for the plants and the evaporation effect. A patented water supply by means of groove-channels and capillary fleece is used. This fleece sucks just as much water out of the channel as is needed by an only 2 cm thick substrate layer. Through watering breaks the substrate dries again, preventing the formation of biofilms. The used water is first purified (desalinated) in an osmosis system and then plant nutrients (fertilizer solution) are added in a very precise manner. Untreated water causes efflorescence (even drinking water leaves salts behind after evaporating), nutrient deficiency problems in plants and eventually the loss of porosity of the substrate. Although roots and their exudates acidify the substrate solution slightly, they can't "soften" the water nor desalinate it.

Figure 4. Vienna business agency – an office complex of the future (left) with Green Wall and PrimaKlima® plants (right)

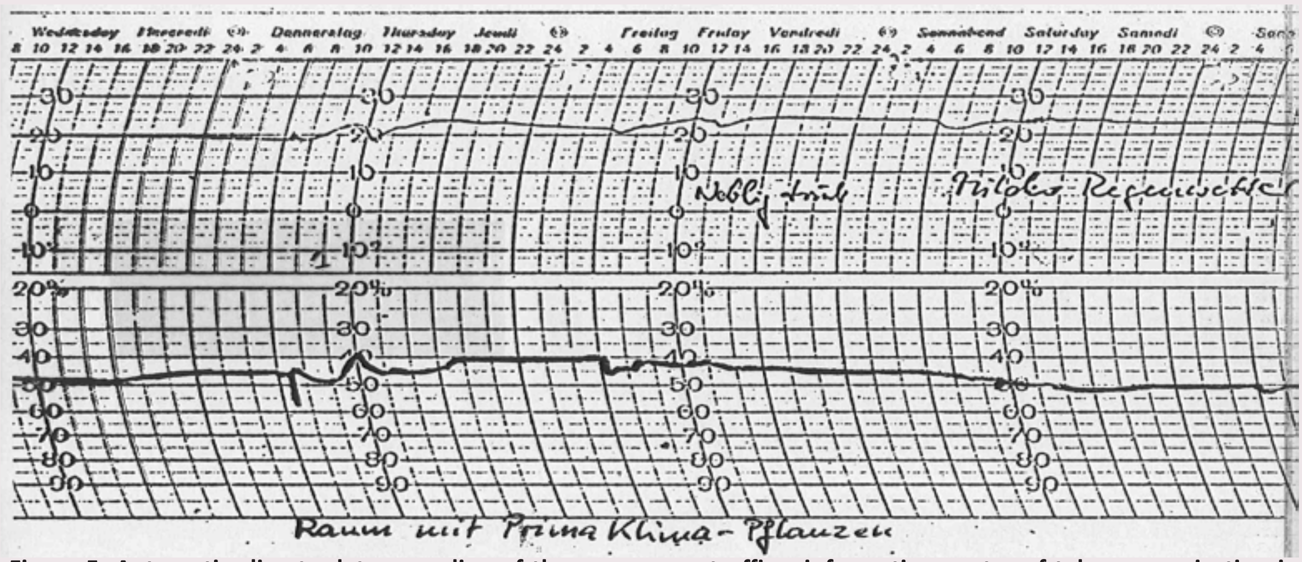

Figure 5. Automatic climate data recording of the german post office, information centre of telecommunication in Würzburg, Germany, 1988; thick line = humidity, thin line = temperature

Studies done by the FH Weihenstephan (Köhler et al., 2004) have shown that a significant air moistening of offices and homes with ordinary houseplants is not achieved. Practical research done by the Bavarian State Research Centre for Viticulture and Horticulture (LWG) with PrimaKlima® Cyperus in planters with water reservoir shows that the measured humidification of room air through Cyperus is enough for non-air-conditioned offices and homes (Hanke, 2005). Unfortunately, there are very few users, who are willing to publish their measurements. These include the electronic company „Gautzsch“ (Kötter, 2004b), „energy base“ in Vienna (Vienna Business Agency, 2008; Figure 4) as well as the German post office information centre of telecommunication in Würzburg. Figure 5 shows a plot of the indoor climate of a German post office. With PrimaKlima® plants a comfortable indoor climate was created by the humidity was constantly kept above 40% even during the winter months. In the years before (without plants) the humidity was less than 25%.

For the Green Walls only unpublished statements of well-known users exist, which although positive are scientifically of little value. Decisive for the success of all functional plant based systems is the patented calculation method of the water balance in rooms under given circumstances and choice of plants and system (DPMA, 2012). Thus, natural humidification of indoor ambient air through plants can be integrated into the planning of a building and its climate regulation technologies as shown e.g. in Figure 6 for the company Komsa, Hartmannsdorf, Germany.

Figure 6. OASE, KOMSA AG, Hartmannsdorf-Sachsen, 2012 Klimakonzept IB-HRP, Veitshöchheim, Germany (photo by B. Häring)

Conclusions and outlook

Functional greening is a resource-preserving, efficient solution to create a healthy, comfortable indoor climate during winter months. The cold evaporation is hygienic since no aerosols are created and the transformation from liquid to gaseous form occurs directly on the wet surface. Both PrimaKlima® plants and Green Walls for air humidification are decorative and have positive effects on the psyche of people through the visible living green highlights in the room.

Unfortunately, plagiarisms and over-promise in the green plant related sector are very frequent. For purely decoration purposes there are many possible and valid alternatives. Air-humidification though is a special subject, which can lead to major problems in buildings and disappointments by users if done without proper knowledge and expertise.

Acknowledgements

The bionic ideas of Dr. Ing. Max Mengeringhausen, MERO, Würzburg inspired me to start thinking this way, looking for solutions for our daily lives in natures examples. His central idea comes from closer inspection of grass blades. The nodes in the blades stiffen the plant although most of the blade is hollow. Without nodes the blades could not grow so long or they would have to be solid and heavier. A solution of nature, which Mr. Mengeringhausen applied in technology. MERO built with his MERO-nodes large cantilever space frames (e.g., Ericsson Globe Stockholm, 1987, Berlin main station, 2006) with minimal use of materials and excellent strength and stiffness. In a similar way, functional greening offers solutions based on natural models to supplement or replace technology.

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