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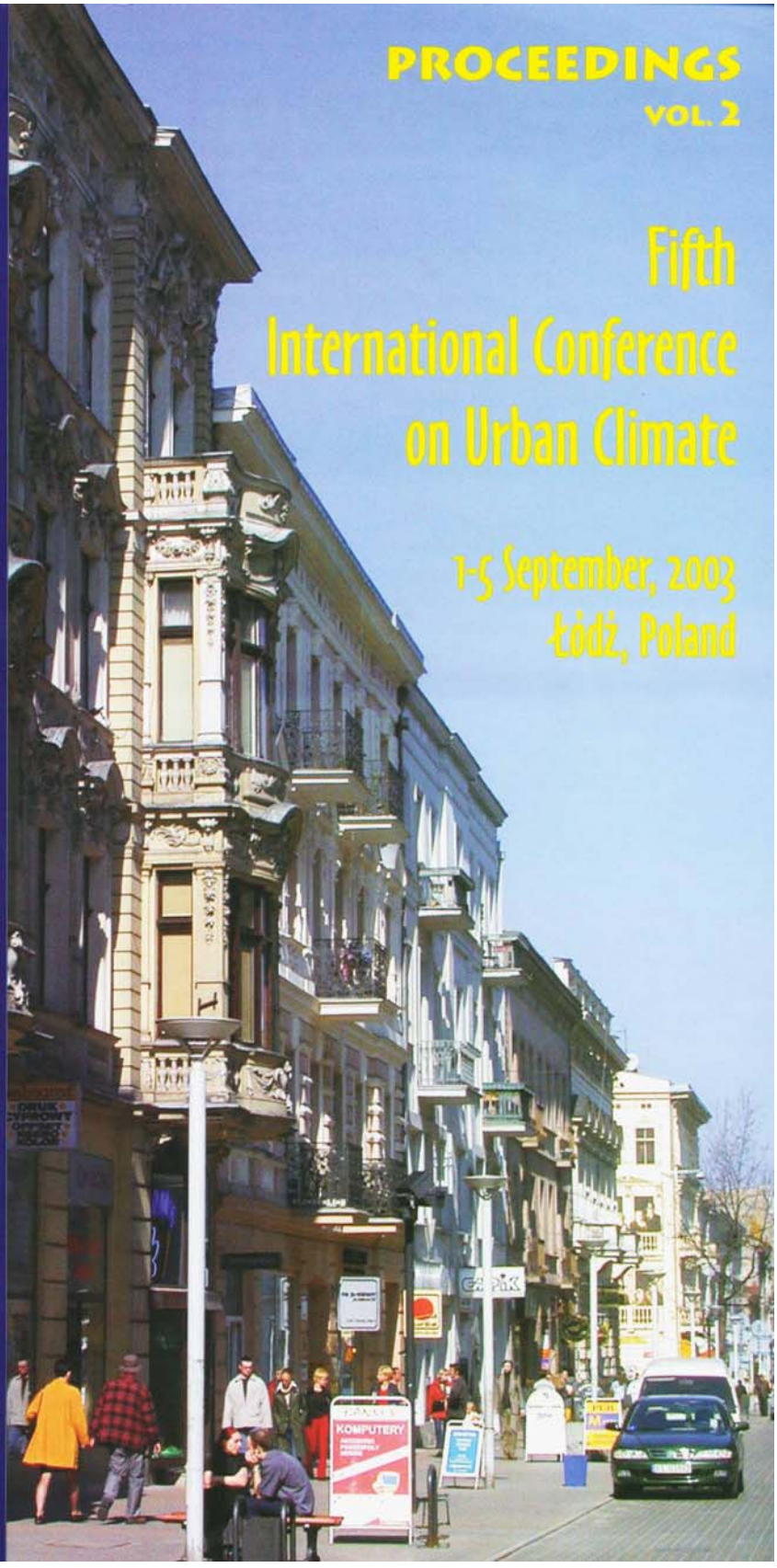

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HUMAN-BIOMETEOROLOGICAL ASSESSMENT OF THE URBAN CLIMATE: METHODS, RESULTS, DEFICIENCIES

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Abstract

A human-biometeorological assessment of the urban climate is required when the urban climate should be integrated into the urban planning process. Methods are available to assess the thermal and air pollution component of the urban climate in a human-biometeorologically significant manner. Exemplarily, the following results are discussed: physiologically equivalent temperature PET during a typical summer day at different sites within the Urban Canopy Layer in the northern downtown of Freiburg (southwest Germany) and annual frequencies of classes of the daily air quality index DAQx at different sites in southwest Germany. In spite of great efforts to develop suited assessment methods, they show some deficiencies up to now which are discussed.

Key words: human-biometeorological assessment methods, thermal and air pollution components of the urban climate, physiologically equivalent temperature PET, daily air quality index DAQx

1. INTRODUCTION

The consideration of urban climate as one of various criterions within the urban planning process requires a human-biometeorologically significant assessment of the components of urban climate that are most important with respect to urban planning, namely the thermal and the air pollution component. The thermal component covers the total energetic within the urban air characterized by radiation fluxes as well as sensible, latent, soil, building and anthropogenic heat flux. The air pollution component refers to all processes of the urban air pollution starting with the emission of air pollutants and ending in their deposition (Fig. 1). Different connections exist between both components, e.g. by the turbulent air mass exchange.

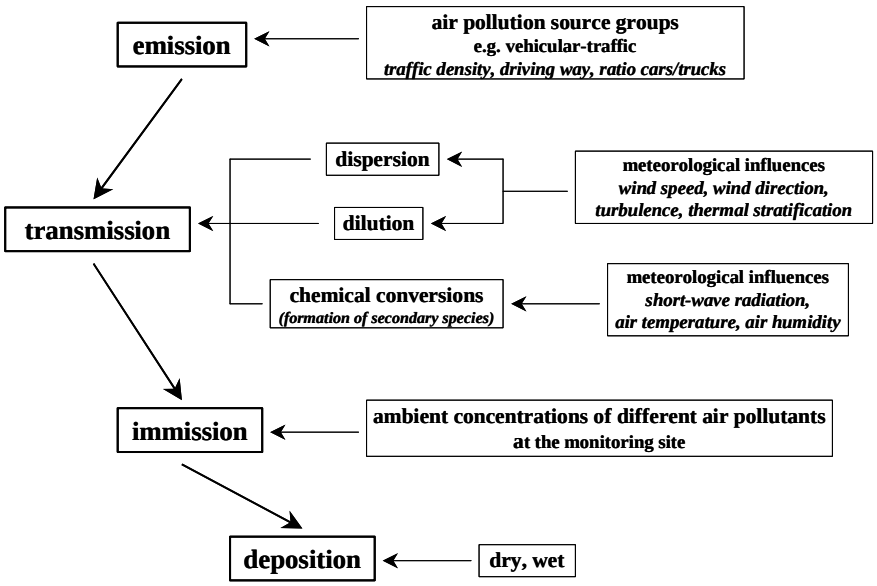

Fig. 1: Flow chart for air pollution processes with emphasis on meteorological influences

The objectives of this article is to give a short review on the current status of the human-biometeorological assessment of the thermal and air pollution component of the urban climate. It includes methods, exemplary results and still existing deficiencies.

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2. FUNDAMENTAL PRINCIPLES OF ASSESSMENT METHODS

2.1. Thermal component of the urban climate

The human energy balance represents the fundamental principle for the human-biometeorologically significant assessment of the urban thermal environment (Fig. 2). There exist some formulations for the human energy balance which can be distinguished by different approaches for single energy fluxes. On the basis of models for the human energy balance, thermophysiological indices such as PMV, PET or OUT_SET* were developed which enable an adequate assessment of the thermal component of the urban climate.

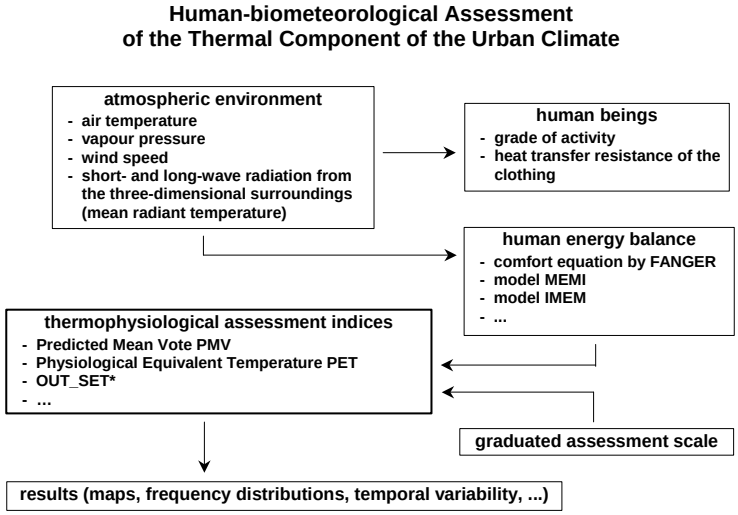

Fig. 2: Flow chart for the human-biometeorologically significant assessment of the thermal environment

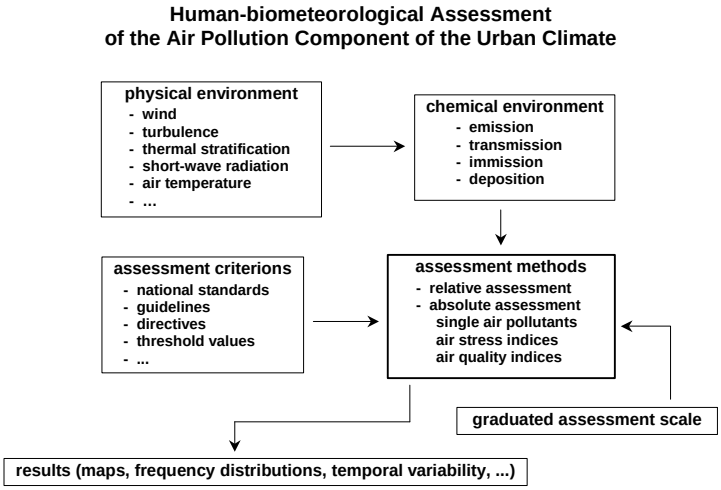

Fig. 3: Flow chart for the human-biometeorologically significant assessment of the air pollution environment

2.2. Air pollution component of the urban climate

National standards for the assessment of single air pollutants exist in almost every country of the world. However, these standards are insufficient in view of the persistent demands (e.g. from urban planners) for the assessment of the air pollution, which is not limited to a single air pollutant. Some indices for the assessment of air properties on the basis of frequently monitored air pollutants are available worldwide (Fig. 3). They can be categorized into two groups (Mayer et al., 2002a, b). The first group includes indices, which are expressed as the sum of relative concentrations of air pollutants or relative exceedings of threshold values for air pollutants. These indices are of a statistical character, because they have no relation to the well-being and health of people. They indicate mainly the content of air pollution in the ambient air and, therefore, are described as *air stress indices*. Impact-related

indices which are called *air quality indices* constitute the second group. Such indices are very rare, because it is difficult to quantify the impacts of air pollutants on the well-being and health of people. As an example, the methodology of the daily air quality index DAQx, which was developed in Germany (Mayer et al., 2002a, b), is to assign concentrations of ambient air pollutants to different pollutant-specific ranges. DAQx itself is represented by the highest index class among the considered air pollutants. The relation to the impact on people is given by different classified ranges of air pollutant concentrations, which are derived from epidemiological and toxicological investigations.

3. EXEMPLARY RESULTS

Results of assessment investigations for both components of the urban climate are mostly presented in form of maps, frequency distributions of exceedings of threshold values or temporal variabilities (Figs. 2 and 3). Maps are most suited for the application in urban planning, whereas a process analysis is possible by temporal cycles.

3.1. Thermal component of the urban climate

As an exemplary result for the assessment of the thermal environment of people in the lower Urban Canopy Layer (UCL), the physiologically equivalent temperature PET (Matzarakis et al., 1999) at different sites in northern downtown of Freiburg (southwest Germany) is presented for a typical summer day (Fig. 4). The objective of this experimental case study was the quantitative assessment of the thermal environment of people at different sites which were arranged within a circular place (radius: approximately 70 m). The major distinction between the sites was the sky view factor which was reduced at two sites by the canopy of chestnut trees. All meteorological parameters necessary to calculate PET were recorded by use of a specific mobile human-biometeorological measuring unit. The results in Fig. 4 reveal clearly lower PET values in the below-canopy space indicating a lower heat stress for people than at the other sites (PET values around 20 °C correspond comfortable conditions, higher PET values indicate increasing thermal stress). The lower the sky view factor and the higher the LAI of a tree canopy, the weaker is thermal stress for people in the lower UCL, because the main effect of a tree canopy in the daytime is the reduction of the direct solar radiation in the below-canopy space.

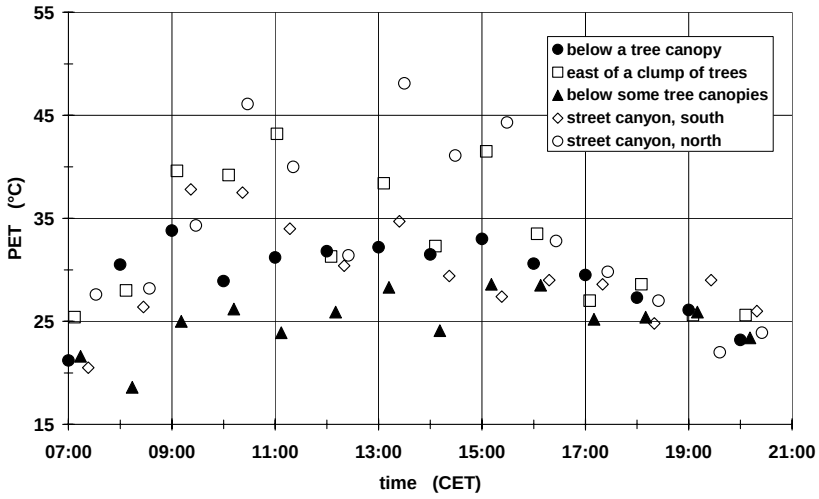

Fig. 4: Physiologically equivalent temperature PET at different sites within the lower Urban Canopy Layer in northern downtown of Freiburg (southwest Germany) on a typical summer day (19 July 1999)

3.2. Air pollution component of the urban climate

As an exemplary result for the assessment of the air pollution component, frequencies of classes of the daily air quality index DAQx are contained in Fig. 5. DAQx values were determined by the method after Mayer et al. (2002 a, b) for a triennial period (1996-1998). Air pollutant data necessary for the calculation of DAQx originated from three official air pollution monitoring stations in south-west Germany: Schwaebische Alb (far from emissions on a agricultural plateau), Ehingen (mean size city, 24.000 residents, with through roads and Industry), and Mannheim–Sued (larger city, 320.000 residents, with traffic and industry emissions typical of urban conurbations). The results for DAQx don't clearly reflect the qualitative assessment of the air pollution conditions which would be expected by people, i.e. air pollution decreases with increasing distance to emission sources. Ozone which exhibits generally higher values in areas with no anthropogenic emissions is mainly responsible for the slightly unexpected form of the frequencies of the DAQx-classes at the selected sites.

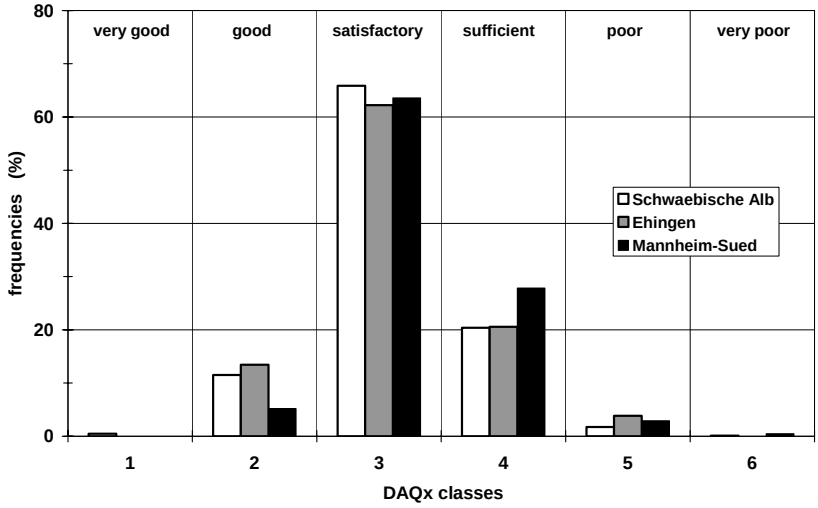

Fig. 5: Frequencies of classes of the daily air quality index DAQx at different sites in southwest Germany in the period 1996-1998

4. DEFICIENCES

In spite of modern methods to assess the urban climate which were developed in the last twenty years in the human-biometeorology and adjoining disciplines, there are still deficiencies which make the current assessment procedures difficult for the application in urban planning processes.
Some of these are: (1) There is a lack of thermal models directly relevant to outdoor situations. The assumption has often been that the conventional theory of thermal comfort developed for indoor applications can be generalized to outdoor settings without modification (Spagnolo and de Dear, 2003). (2) Adaptation effects are not considered in graded assessment scales. (3) Current thermophysiological indices enable the estimation of the thermal perception only for a collective of people and not for risk groups or single persons. (4) If thermal bioclimate maps have a high spatial resolution, for example 10 m, urban land use types with a high vertical dimension like buildings should be separately marked, whereas the assessment of the thermal environment should be limited to outdoor conditions. (5) Suited meteorological and air pollution data in an adequate spatial resolution and in a human-biometeorologically significant height (for example: 1.1 m above the ground level for the thermal urban bioclimate in Central Europe) are not always available to construct highly resoluted bioclimate maps. The only reasonable way to get these input data is the application of suited three-dimensional models because in contrast to different regression models, they can consider thermally induced regional and local circulation systems. Case studies with results in form of temporal cycles (e.g. diurnal courses) have the advantage that all meteorological or air pollution input variables for the assessment procedure can be measured directly. (6) There exist no targets for the assessment of both the thermal and the air pollution component of the urban climate which show a clear dependence on the urban land use. (7) There is a lack of suited impact-related air quality indices with relevance for urban planning. DAQx represents an index for the assessment of the daily air pollution situation, but due to its background and the air pollutants considered, it is primarily not suited for the assessment of the long-term air pollution situation. It is possible that a long-term air quality index considers not the same air pollutants than a daily air quality index.
Hence it follows, that further developments of human-biometeorological methods for the application to the urban climate in different spatial and temporal scales are necessary.

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