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An investigation into thermal comfort and residential thermal environment in an intertropical sub-Saharan Africa region: Field study report during the Harmattan season in Cameroon

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ABSTRACT

Investigations on thermal comfort have attracted authors for years throughout the world and the most important findings are now the basis of international thermal comfort standards. There is little information available concerning occupant comfort and residential thermal environment in the intertropical sub-Saharan Africa. Thus the purpose for this study is to conduct a field study on comfort and residential thermal environments in a typical intertropical climatic region. A field survey has been conducted during the Harmattan season in two cities from the two climatic regions of Cameroon concerned by that wind. Specific study objectives were to evaluate and characterize some thermal perceptions of occupants in their residence, compare observed and predicted percent of dissatisfied, and discern differences between the study area and other climate zones where similar studies have been performed. It was found that the thermoneutral temperatures in both climatic regions range from 24.69 °C to 27.32 °C and, in traditional living room, it differs from that of modern living room with approximately 1 °C.

1. Introduction

Thermal comfort has been defined by Hensen as "a state in which there are no driving impulses to correct the environment by the behaviour" [1]. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) defined it as "the condition of the mind in which satisfaction is expressed with the thermal environment" [2]. As such, it will be influenced by personal differences in mood, culture and other individual, organisational and social factors. Based on the above definitions, comfort is not a state condition, but rather a state of mind. The definition of thermal comfort leaves open as to what is meant by condition of mind or satisfaction, but it correctly emphasizes that the judgment of comfort is a cognitive process involving many inputs influenced by physical, physiological, psychological, and other factors [3].

Thermal sensations are different among people even in the same environment. Conventionally, thermal discomfort is treated as a subjective condition while thermal sensation is an objective sensation [1]. Satisfaction with the thermal environment is a complex subjective response to several interacting and less tangible variables [4]. In other words, there is really no absolute standard for thermal comfort. In general, comfort occurs when body temperatures are held within narrow ranges, skin moisture is low, and the physiological effort of regulation is minimized [3]. Comfort also depends on behavioural actions such as altering clothing, altering activity, changing posture or location, changing the thermostat setting, opening a window, complaining, or leaving a space [3]. In 1962, Macpherson defined the following six factors as those affecting thermal sensation: air temperature, air speed, humidity, mean radiant temperature, metabolic rate, and clothing levels [3]. Thermal comfort is also a key parameter for a healthy and productive workplace [5,6].

In the literature, extensive research works on thermal comfort covering many aspects related to thermal comfort are found. These include establishing models [7,8] and indices [9], carrying out experiments in climate chambers [7,10] and field surveys [3,11], establishing thermal comfort standards and evaluation methods [12,13], etc. The most important findings are now the basis of national and international standards; e.g. Refs. [14,15]. They focused on correlations for thermal comfort criteria or on health issues like the Sick-Building-Syndrome [6]. These studies known as international thermal comfort standards such as the ASHRAE standards and the International Standards Organization (ISO) are almost exclusively based on theoretical analyses of human heat exchange. They have been conducted on limited-occupancy buildings such as offices and institutions of higher learning in the northern

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hemisphere and parts of the Asian region [4], and obtained data from special climate-controlled laboratories or climate chamber experiments performed in mid-latitude climatic regions in North America and northern Europe [11]. Moreover, these standards are suitable for static, uniformly thermal conditions and are based on the hypothesis that regardless of race, age and sex; human beings are thought to feel comfortable in a narrow, well-defined range of thermal conditions [2,11]. ASHRAE has commissioned a series of state-of-the-art, fully compatible field experiments across a variety of climate zones including temperate, hot–humid and cold [16]. Different climatic regions, such as the tropics, may require different levels of comfort parameter mandated in the standards.

There have been extensive studies to evaluate thermal comfort using test chambers, but the laboratory studies offer static and consistent conditions for measurement not possible in the field studies. It is now widely accepted that the previously used climate chambers fail to provide the participating humans with so called "experiential realism" in determining thermal comfort [16] since "real" people live in changeable, inconsistent environments, which may cause concerns when the standards are applied to residents living in real-world situations [11].

In recent years, different authors have encouraged field studies in addition to laboratory experiments, in order to get more reliable information about the actual workplace comfort and the relevant (interacting) parameters. Field studies also allow for analyses of other factors than those that can be simulated in chambers, as the subjects provide responses in their everyday habitats, wearing their everyday clothing and behaving without any additional restrictions [16]. The subjectivity in thermal experience and the interpretations flowing from a very complex interaction between the occupants and their environment has been the focus of a great deal of study and provides the theoretical underpinning to the adaptive approach to thermal-comfort studies [17].

Many field studies on the thermal comfort have been performed around the world [3–6,11,16,18–29], must of them were carried out in tropical, hot–arid, temperate and cold climatic zones. Throughout sub-Saharan Africa and particularly in tropical regions, there have been few literature reports of field study on occupants' comfort and residential thermal environment (e.g. Ogbonna et al. [4] in western Africa and Zingano [30] in eastern Africa). Ogbonna et al. [4] provided empirical data from Jos; a nigerian city in the tropical savannah region of Africa, about the range of conditions for which occupants in naturally-ventilated buildings are comfortable. Zingano [30] analysed data from eighteen meteorological stations evenly distributed throughout Malawi to discuss the importance of humidity to thermal comfort temperatures.

To the best of our knowledge, there is little information available concerning occupant comfort and residential thermal environment in the central Africa region in general, and particularly in Cameroon. Thus the purpose for this study is to conduct a field study on comfort and residential thermal environments in a typical intertropical climatic region during a hard climatic condition: the Harmattan season. Specific study objectives are to evaluate and characterize some thermal perceptions of occupants in their residence, compare observed and predicted percent of dissatisfied (PPD) and discern differences between the study area and other climate zones where similar studies have been performed.

2. Study area

Cameroon is situated between latitude of 2°N to 13°N, longitude of 9°E to 17°E and covers a land area of about 475 442 km^2 (Fig. 1). An equatorial climate with four seasons (two dry and two rainy) is found in the southern part and Atlantic Ocean coasts with approximately 3890 mm of precipitation per year. Abundant rainfall occurs from April to November, and practically throughout the year in the south-west mountains (approximately 10 000 mm per year). The climate tends to be of the sahelian type as one leaves the southern to the northern part of the country with two seasons (one dry and one rainy). The dry season lasts from October to April (700 mm of precipitation per year in the central plateau) and the north-west is semi-arid (380 mm of precipitation per year). Three main climatic regions are found: the southern equatorial region, which extends from 2°N to nearly as far as latitude 6°N; the sudanese region, wet and tropical, extending from 7°N to a little beyond 10°N; the sudano–sahelian region (10–13)°N, dry and tropical. The mean outdoor temperatures vary between 25 °C in the south, 21.1 °C in the central plateau and 32.2 °C in the north.

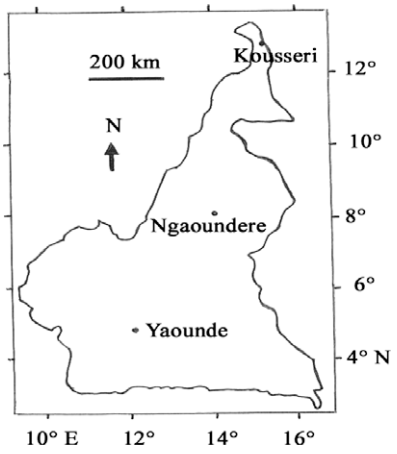

Fig. 1. Field survey.

Two climatic regions are concerned by the Harmattan wind; a cold-dry wind blowing from November to January: the Sudanese and the Sudano–Sahelian regions. The called wind dries skin, splits and wounds lips and feet, the atmosphere is foggy reducing solar radiation, low temperatures occur.

Two cities have been selected for this study, one from each region: Ngaoundere (7°19′N, 13°36′E) for the Sudanese region and Kousseri (12°04′N, 15°04′N) for the Sudano–Sahelian region.

The survey has been conducted during the period between November 2008 and January 2009.

3. Research methods

The approach to the thermal comfort survey is underpinned by the adaptive thermal comfort paradigm as prescribed by Chappels et al. [17], based on the theory that physiological and adaptive factors play equally-central roles in the perception and interpretation of thermal comfort. A field study experiment protocol for thermal comfort, consistent with ISO 7726 and ASHRAE standard 55-1992 has been adapted. A thermal-comfort questionnaire was used to gather information about the subjective thermal sensations and preferences. The questionnaire had seven broad topic areas namely: demographic information, clothing, activity level, thermal sensation, thermal preference, thermal acceptability, personal control of indoor thermal environment. The thermal sensation scale was the ASHRAE seven-point scale of warmth ranging from cold (−3) to hot (+3) with neutral (0) in the middle. The thermal preference scale was that of McIntyre, based on a three-point scale whether the respondent would like a change in the thermal environment [31]. Possible responses were "want warmer", "want no change", or "want cooler". A number of instruments have been used to measure some environmental conditions at the same time