BIO-METEOROLOGICAL AND AIR POLLUTION CONDITIONS IN THE MEGACITY OF DHAKA, BANGLADESH AND THEIR EFFECTS ON PUBLIC HEALTH OF URBAN POOR POPULATION GROUPS
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Abstract
Climate and air pollution have profound impacts on human and public health. In particular, urban climates are believed to be hazardous. Nevertheless, there is a lack of research into urban tropical climates and epidemiological aspects of temperature and weather related diseases in the developing world, as these countries lack the adequate financial, technological and scientific means (Confalonieri et al. 2007, Roth 2007). However, the increase in the speed and extent of worldwide urbanization, often referred to as ‘urban turn’, is leading to the emergence of so-called megacities, more than three-quarters of which are situated in the developing world. Our research is focusing on the impact of the atmospheric conditions on urban poor population groups residing in so called marginal settlements, constituting about 40 per cent of Dhaka’s inhabitants (Burkart et al. 2008).

Key words: Urban Climate, Air Pollution, Public Health, Urban Poor;

1. INTRODUCTION
The influences and impacts of the atmospheric impact are complex. Major aspects of climate and urban climate in particular are physical and chemical in nature, both consequences of the modified urban meso-climate, often referred to as the urban heat island, and the high levels of air pollution. The heat-mortality and -morbidity relationship varies across time periods, regions and populations. Time series studies have shown that different cities and population groups exhibit different responses to heat (Hajat et al. 2005, Hajat et al. 2006, Kaiser et al. 2007, Klinenberg 2002, Smoyer et al. 2000). The underlying reasons for these differences are only partially understood. The demographic composition and socio-economic status of population groups might be of importance, reflecting the level of economic and technological development, pre-existing health status and the quality and availability of health care. Further, the degree of urbanisation, population density, urban design and morphology, and housing factors could be crucial in determining the atmospheric impact (Kilbourne et al. 1982, Patz et al. 2000). For these reasons knowledge derived from one area cannot be transferred directly into the context of another geographical and social setting.

2. DATA BASIS
For our analysis we compiled a set of data comprising atmospheric and health data. Meteorological data was received from the Bangladesh Meteorological Department (BMD). This data comprises three-hourly values of average, maximum and minimum temperature, humidity, radiation, cloud coverage, wind speed and precipitation at one measuring side in Dhaka and several selected cities. In addition, particulate matter and nitrogen oxides were measured at six sites in Dhaka. Within the ongoing campaign, four climatic stations, recording data in ten minute intervals and measuring indoor and outdoor values were installed in the city. Concerning health data, daily hospital data from ten clinics associated to the Urban Primary Health Care Project (UPHCP) were collected. These clinics treat predominantly urban poor population groups which are most likely to be vulnerable. The data dates back until July 2006, information previous to that date is not available. Daily data regarding the number of patients as well as information about the type of disease from which a patient was suffering and further personal information about the patient, such as age and sex, were digitised.

3. SEASONALITY OF (BIO-) METEOROLOGICAL AND THERMAL CONDITIONS
Bangladesh has a subtropical monsoon climate characterized by wide seasonal variations in temperature and rainfall. Our study attempts to investigate the seasonal variations of atmospheric and thermal stress and the seasonal variation in health outcomes associated to atmospheric conditions. Figure 1 a, b and c display the monthly average mean, maximum and minimum values of temperature and computed thermo-physiological indices for the measurement period 2008. Considering temperature, the highest mean values are reached in the months April, May and September. Between May and September monsoon rains cause a decrease in (mean and) maximum temperatures. Average maximum and minimum temperatures are the highest in April and May, while the highest monthly average (night-time) minimum temperatures occur in August and September. This can be explained by the reduced long-wave emission during nighttime in August and September, due to the higher water vapour content in the atmosphere. Low water vapour content in the atmosphere in May and April causes

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increased long wave emission during night-times and leads to relatively low night-time average temperatures in these months whereas the daytime maximum temperatures are highest. From a physiological perspective low night temperatures play an important role as the human body can regenerate during these periods. There is a variety of indices relating atmospheric conditions to human heat sensation and human thermo-physiological perception. Several indices consider the whole heat balance of the human body, requiring meteorological information about temperature, humidity, wind speed, turbulence and radiation in addition to the non-meteorological information about patient fitness and level of activity, clothing type, and physiological adaptation to a particular environment (Parsons 2003). The human thermo-physiological mechanism endeavours to maintain a constant core body-temperature which commonly requires that the internal heat generated by metabolism be transferred through the skin to the surrounding atmosphere. If this heat exchange is impeded, the core temperature starts to rise which results in health problems (Driscoll 1985, Robinson 2001). For our analysis we computed several thermo-physiological indexes; however found a strong correlation between these, indicating a similar information content. For further analysis we decided therefore to rely on the Heat Index (HI) as well as the Physiological Equivalent Temperature (PET). Figure 1 b and c display the seasonal distribution of HI and PET. While the Heat Index, which is solely considering temperature and humidity, shows maximum values during June, PET indicates maximum thermal stress during April and June. Which index gives reliable information about thermal conditions, however, cannot be decided without a plausibility check against the assumed adverse health effects.

Figure 1 a, b and c: Monthly average mean, maximum and minimum temperature (left), Heat Index (middle) and Physiological Equivalent Temperature (right) derived from three hourly values collected from Bangladesh Meteorological Department.

In an attempt to assess the urban modification of the climate the yearly and monthly differences in mean, maximum and minimum temperature for Dhaka and Mymensingh were calculated. It becomes evident that the differences in temperature are not equally distributed over the year but show a clear seasonal pattern (Fig.2). The highest differences between Dhaka and Mymensingh can be observed from March to May, whereby also the winter months from November to February display relatively strong differences, especially concerning minimum temperatures.

The difference in maximum temperature in April and May is 1.7 Kelvin expressing that for the months with the highest thermal burden Dhaka is exposed to and extra burden in comparison to Mymensingh. In November and December the temperature differences in Mymensingh and Dhaka arise mainly in minimum temperatures indicating that Dhaka cools down to a lesser extent and therefore constitutes lesser cold stress than Mymensingh.
4. SEASONALITY OF MORBIDITY AND SELECTED DISEASES IN DHAKA

Seasonal fluctuations in mortality as well as morbidity are a persistent phenomenon across populations. In Western countries of the northern hemisphere, mortality is typically higher in winter than in summer, while in tropical regions morbidity is highest during the warmer seasons (McMichael 2008, Rau 2007, Schär and Jendritzky 2004). Thereby, socio-demographic and socio-economic factors play as important a role for seasonal mortality as they do for morbidity and mortality in general. Several studies showed that the fluctuations between seasonal mortality are smaller the higher the socio-economic standard or the education level (Hajat et al. 2005, Hajat et al. 2006, Klinenberg 2002, Rau 2007).

For assessing morbidity daily hospital admission data were consulted as a morbidity parameter. For the analysed hospital admission data differing temporal and spatial distributions could be observed. Divided into separate disease groups, acute respiratory diseases (ARI) clearly increase during the cold season (Fig. 3). Temperature has a determining effect on acute respiratory infectious diseases and incidence rates are typically highest during colder months. However in 2008 a high incidence of ARI cases can also be observed from June to August. Concerning the high prevalence of ARI in winter months it is unclear to what extent the high levels of air pollution during this season are enforcing the occurrence of acute respiratory diseases. Exposure to airborne particulates leads to acute inflammation of the Airways, damages of lung tissue and a detraction of the immune system. In Dhaka, air pollution levels peak during the winter monsoon from the middle of December to the middle of March due to the stable atmospheric conditions and could therefore contribute to the elevated incidence rate.

![Figure 3: Temporal distribution of ARI cases in the UPHCP clinics between July 2006 and March 2009](image1)

Concerning diarrhoeal disease the incidence rate shows temporal differences with several minima and maxima occurring over time (Fig.4). However, no clear pattern or seasonal distribution could be observed. In tropical regions typically a summer peak of mortality can be noted which is ascribed to the dominance of fatal diarrhoeal diseases (McMichael et al. 2008). The differing occurrence of diarrhoeal diseases observed at the clinics of the UPHCP might be due to regional or local geographical, climatological and hydrological differences. The transmission pathways of pathogens and modifying factors are complex. The infection is generally spread from person to person via oral-faeces, food and drinking water. Epidemics are frequent in overcrowded populations promoting the growth of bacteria, stagnant water during low rainfall periods and the lack of dilution of sewage systems may further cause an increase in diarrhoea cases (Hashizume et al. 2007, Zhang et al. 2007). Deeper statistical analysis is needed in order to extract signals that are caused by atmospheric conditions but are confounded by other variables. Especially precipitation and river level should be taken into account and different lag periods need to be considered.

![Figure 4: Temporal distribution of diarrhoea cases in the UPHCP clinics between July 2006 and March 2009](image2)
Other environmental diseases showed seasonal and spatial differences as well. A decrease in hypertension during warmer months was detected. Tuberculosis cases—although comparatively rare—occur almost exclusively during the cold season. Further, tuberculosis prevalence displays clear spatial differences with some hospitals recording about five times the number compared to others. In the hospital admission data a slight increase in the occurrence of peptic ulcers during the hot season is noticeable.

5. CONCLUSION
Health hazards caused by the atmospheric environment pose a serious risk management issue, in particular against the background of a changing climate. In order to reach a better understanding of and to cope with this matter, further research into the interdependencies between human health and the atmospheric environment is vital, as well as research into the long- and short-term changes of climate. As the majority of populations which will be affected live in countries of the developing world, research should focus on this geographical region and deal with the specific problems arising there. However, health and climatological data for these countries is often hard to access, incomplete or of bad quality. Furthermore, the public health situation is subject to the highly dynamic processes of global change.

References
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