

Doctoral Programme Public Health

SOCIAL AND ENVIRONMENTAL DIMENSIONS OF URBAN HEALTH IN CHINESE MEGACITIES

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Dedication

I dedicate this dissertation to my parents and grandparents.

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Abstract

Background and Aim

In the past three decades, China experienced a rapid economic growth and the Chinese urban population has increased threefold mainly caused by rural-to-urban migration. The rapid urban growth changes the cities' living conditions with different effects on human health, which is particularly pronounced in China's megacities.

About 190 million migrant workers make up a large proportion of the urban population in China. They show health-related characteristics that differ from the situation of the urban residents. Among other things, migrant workers are under a higher risk for infectious diseases such as HIV and their mobility may foster the spread of infections between urban and rural areas. The rapid urbanization also causes substantial urban environmental problems. China belongs to the countries with the highest levels of particulate matter (PM) air pollution that is considered to be the most serious air pollutant in Chinese cities.

The aim of this work was to obtain a comprehensive insight into the major urban health challenges in Chinese megacities. This research focused on two key urban health dimensions related to changing physical and social urban environments, (i) the urban PM air pollution and (ii) the rural-to-urban migration.

Methods

Firstly, a burden of disease assessment for the megacity of Hong Kong (HK) was conducted to describe the mortality-related burden of disease patterns of the Chinese urban population. Data were obtained from the HK statistical yearbook 2010 and from the HK Census and Statistics Department. The "Standard Expected Years of Life Lost" (SEYLL) measure was used to quantify the disease burden in HK by cause of death, sex and age for 2010.

Secondly, two systematic literature reviews were conducted. In the first review, meta-analyses were carried out (i) to determine the HIV prevalence among migrants in China at different migration stages and (ii) to compare the risk of HIV infection among different migration stage subgroups and compared to the general Chinese population. The second review was done to collect PM data from the megacities in the Pearl River Delta (PRD). Additionally, mortality data from municipal sources were collected. The data were used (i) to describe the PM pollution in the megacities in PRD, (ii) to compare these results with the existing air quality standards and (iii) to estimate the potential health benefits of PM reduction in terms of preventable PM-associated premature deaths per year (health impact assessment).

Thirdly, complementing the review on urban PM air pollution, own personal and ambient stationary PM_{2.5} air pollution measurements were conducted. For this purpose, in November and December 2011, 24-h personal and ambient PM_{2.5} data were simultaneously collected in most of the 12 districts of Guangzhou (GZ) (i) to ascertain the level of personal/ambient PM_{2.5} in GZ on a small spatial and temporal scale, (ii) to determine to what extent individuals, on average, were exposed to PM_{2.5} over 24h periods, and (iii) to study the relationship between the ambient and personal PM_{2.5}.

Results

In HK, 524,706.5 life years due to premature death were lost. The following SEYLL-distribution was observed: 78.8% non-communicable conditions, 12.7% communicable conditions, 8.5% injuries. This distribution corresponds to disease patterns of high-income countries worldwide representing a late stage of the epidemiologic transition. A closer look showed that certain communicable conditions, such as tuberculosis play a larger role in HK than in many other high-income regions. Further results indicated high values of PM air pollution in the studied cities that exceeded internationally recognized air quality standards. Particularly in GZ, the PM air pollution was high. The relationship between ambient and personal measurements differed strongly between the districts. Three districts showed moderate to high correlations between ambient and personal PM_{2.5} pollution over time. However, the overall correlation (all district values pooled) between personal and ambient PM_{2.5} air pollution over time was high (Spearman's Rho = 0.7; p = 0.01). According to the health impact assessment, PM air pollution is responsible for a large share of the burden of disease related to non-communicable diseases with thousands of premature deaths in HK and GZ. The review on the role of migration for the spread of HIV in China showed that the HIV prevalence among Chinese migrants ranged from 0-2.59% in the single review studies. The meta-analyses showed that the subgroup of migrants, who were recruited in urban areas after migration for the single studies, had the highest HIV prevalence (0.38%) as compared to the other subgroups and to the general Chinese population.

Conclusions

The results of this research highlight the increasing relevance of non-communicable diseases in urban China and indicate that this is related to both life style changes and environmental burdens like PM air pollution. Nonetheless, the findings suggest that communicable diseases are still of high public health relevance and that they are partly related to rural-to-urban migration. Consequent implementation of environmental protection laws and compliance with

air quality standards are needed to promote a healthy urban environment. Living and working conditions of migrant workers should be improved and educational measures should be taken to decrease migrants' risk for infectious diseases. Importantly, these conclusions must not lead to further stigmatization and discrimination of migrants within the urban societies. Reduced risk of infection among migrant workers and a better societal inclusion in the urban areas including better access to health care services would, in the long run, reduce the disease burden among migrants and additionally prevent epidemiological bridging from this group to the general Chinese population.

Zusammenfassung

Hintergrund und Forschungsziel

Chinas Wirtschaft wuchs besonders während der letzten drei Dekaden stark. Der Anteil der urbanen Bevölkerung hat sich in dieser Zeit verdreifacht, primär durch Land-Stadt-Migration. Die rasante Urbanisierung führte zu vielen Veränderungen der Lebensbedingungen, die Einfluss auf die Gesundheit der städtischen Bevölkerung haben.

Die ca. 190 Mio. Arbeitsmigrant_innen machen einen großen Teil der städtischen Bevölkerung aus. Im Vergleich zur Stadtbevölkerung weisen sie spezifische Gesundheitsrisiken auf. Sie haben unter anderem ein höheres Risiko für Infektionskrankheiten und ihre Mobilität kann die Verbreitung von Infektionen begünstigen. Die schnelle Urbanisierung verursachte beträchtliche Umweltverschmutzungen. China gehört zu den Ländern mit der höchsten Feinstaubbelastung (Feinstaub = Particulate Matter, PM), welche als wesentlichste Umweltbelastung in chinesischen Städten gilt.

Ziel dieser Forschung war es, einen tieferen Einblick in die wesentlichsten Herausforderungen megastädtischer Gesundheit in China zu gewinnen. Zwei Hauptdimensionen sich ändernder physischer und sozialer Umwelten im Kontext urbaner Gesundheit Chinas standen dabei im Fokus, (i) urbane PM-Belastung und (ii) Land-Stadt-Migration.

Methoden

Zunächst wurden die Krankheitslasten der Megastadt Hongkong (HK) untersucht, um die mortalitätsbezogenen Krankheitsmuster der städtischen Bevölkerung Chinas zu beschreiben. Es wurden Sekundärdaten des statistischen Jahrbuchs Hongkongs sowie des HK Census and Statistics Department analysiert. Die Maßzahl "Standard Expected Years of Life Lost" (SEYLL) wurde benutzt, um die Krankheitslast der Bevölkerung HKs im Jahr 2010 zu quantifizieren, differenziert nach Todesursachen, Geschlecht und Alter.

Zweitens wurden zwei systematische Übersichtsarbeiten angefertigt. Im Rahmen der ersten Übersicht wurden Metanalysen durchgeführt, um (i) die HIV-Prävalenz unter Migrant_innen in verschiedenen Migrationsstadien in China zu bestimmen und um (ii) die Risiken für eine HIV-Infektion zwischen diesen verschiedenen Migrant_innengruppen und mit der chinesischen Allgemeinbevölkerung zu vergleichen. Die zweite Übersichtsarbeit diente der Bestimmung der PM-Belastung in den Megastädten des Perlfloss Deltas (Pearl River Delta, PRD). Zusätzlich wurden Mortalitätsdaten von öffentlichen Datenquellen gesammelt. Die

PM- und Mortalitätsdaten wurden eingesetzt, um (i) den Grad der PM-Luftverschmutzung in den Megastädten des PRD zu beschreiben, (ii) um diese Ergebnisse mit Luftqualitätsstandards zu vergleichen und um (iii) potenzielle Gesundheitsgewinne, im Sinne vermeidbarer vorzeitiger PM-assoziierter Todesfälle pro Jahr, durch PM-Minderung zu berechnen (health impact assessment).

Drittens, ergänzend zur systematischen Übersicht über PM-Belastung in den Megastädten des PRD, wurden eigene personenbezogene und stationäre Außenluft-PM-Messungen durchgeführt. Im November und Dezember 2011 wurden zeitlich parallel in mehreren Stadtteilen PM_{2,5}-Messungen in Guangzhou (GZ) realisiert. Das diente (i) dazu, das Ausmaß der personenbezogenen und der Außenluft-PM-Luftverschmutzung zu beurteilen, und zwar mit möglichst hoher raum-zeitlicher Auflösung. Zudem sollte ermittelt werden, (ii) wie stark Menschen über 24 Stunden mit PM_{2,5} belastet waren und (iii) inwieweit die personenbezogene mit der stationären PM-Belastung verglichen werden kann.

Ergebnisse

In HK gingen 524.706,5 SEYLL durch vorzeitige Todesfälle verloren. Die ursachenspezifische Verteilung der SEYLL war: 78,8% nicht-übertragbare Erkrankungen; 12,7% übertragbare Krankheiten; 8,5% Verletzungen. Diese Verteilung spiegelt einen späten Status der epidemiologischen Transition wider und entspricht der Verteilung vieler Länder mit hohem Einkommen. Es fällt jedoch auf, dass bestimmte Infektionskrankheiten in HK eine größere Rolle spielen als in vielen anderen Regionen mit hohem Einkommen. Weitere Untersuchungen zeigten hohe PM-Belastungen in den Megastädten des PRD. Sie gingen weit über international anerkannte Luftqualitätsstandards hinaus, insbesondere in GZ. Die personenbezogenen und stationären Messergebnisse waren im Zeitverlauf miteinander assoziiert und differierten stark zwischen den Stadtteilen. Nur in drei Stadtteilen fanden sich moderate Korrelationen. Die Stadtteil-Durchschnittswerte der personenbezogenen und stationären Messungen korrelierten hoch im Zeitverlauf (Spearman's Rho = 0,7; p = 0,01).

Nach Schätzungen des health impact assessment ist die PM-Luftbelastung für einen beachtenswerten Anteil der Krankheitslast durch nicht-übertragbare Krankheiten verantwortlich, mit tausenden von vorzeitigen Todesfällen in HK und GZ. Die systematische Übersichtsarbeit zur Rolle der Migration und der Ausbreitung von HIV in China zeigte HIV-Prävalenzen, die zwischen 0 und 2,59% rangierten. Migrant_innen, die in Studien in Städten befragt wurden, wiesen mit 0,38% die höchste HIV-Prävalenz auf im Vergleich zu den anderen untersuchten Migrant_innengruppen und zur Allgemeinbevölkerung.

Schlussfolgerungen

Die hier vorgestellte Forschung beleuchtet die steigende Bedeutung nicht-übertragbarer Krankheiten, insbesondere im urbanen China und betont, die diesbezügliche Rolle der Lebensstiländerungen und der urbanen Umweltverschmutzung wie die PM-Luftbelastung. Die Ergebnisse lassen aber auch darauf schließen, dass übertragbare Krankheiten von großer Public Health-Relevanz sind und dass deren Ausbreitung im Zusammenhang mit Land-Stadt-Migration steht. Die konsequente Umsetzung von Umweltschutzgesetzen und das Einhalten von Luftqualitätsstandards sind wesentliche Komponenten, um eine gesunde städtische Umwelt zu realisieren. Darüber hinaus sollten die Lebens- und Arbeitsbedingungen von Arbeitsmigrant_innen verbessert und Bildungsmaßnahmen ergriffen werden, um die Infektionsrisiken in dieser Population zu minimieren. Von größter Bedeutung ist, dass diese Schlussfolgerungen nicht zu weiterer Stigmatisierung und Diskriminierung von Arbeitsmigrant_innen innerhalb der städtischen Gesellschaft führen. Es ist vielmehr wünschenswert, dass Arbeitsmigrant_innen nicht primär als vorübergehend benötigte Arbeitskraft in den Städten angesehen werden, sondern als integraler Bestandteil der städtischen Gesellschaft. Die Minderung der Infektionsrisiken unter den Arbeitsmigrant_innen und die verbesserte soziale Inklusion, auch hinsichtlich des Zugangs zum öffentlichen Gesundheitssystem, verbessert nicht nur die Gesundheit der Migrant_innen selbst, sondern verhindert auch die Ausbreitung von übertragbaren Erkrankungen in der Gesamtbevölkerung.

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List of abbreviations

China CARES	China Comprehensive AIDS Response
CR	Concentration-Response
DALY	Disability-Adjusted Life year
GBD	Global Burden of Disease
HIA	Health Impact Assessment
HIV	Human Immunodeficiency Virus
PM	Particulate Matter
PRD	Pearl River Delta
SEYLL	Standard Expected Years of Life Lost
WHO	World Health Organization
YLL	Years of Life Lost

List of publications that form the basis of this Ph.D. thesis¹

Paper 1

Plass D, Chau PYK, Thach TQ, **Jahn HJ**, Lai PC, Wong CM, Kraemer A (2013) Quantifying the burden of disease due to premature mortality in Hong Kong using standard expected years of life lost. *BMC Public Health* 13 (1):863 (IF: 2.08)

Paper 2

Jahn HJ, Schneider A, Breitner S, Eissner R, Wendisch M, Krämer A (2011) Particulate matter pollution in the megacities of the Pearl River Delta, China – A systematic literature review and health risk assessment. *Int J Hyg Environ Health* 214 (4):281-295 (IF: 3.809)

Paper 3

Jahn HJ, Kraemer A, Chen X-C, Chan C-Y, Engling G, Ward TJ (2013) Ambient and personal PM_{2.5} exposure assessment in the Chinese megacity of Guangzhou. *Atmospheric Environment* 74:402-411 (IF: 3.110)

Paper 4

Zhang L, Chow EP, **Jahn HJ**, Kraemer A, Wilson DP (2013) High HIV Prevalence and Risk of Infection Among Rural-to-Urban Migrants in Various Migration Stages in China: A Systematic Review and Meta-Analysis. *Sex Transm Dis* 40 (2):136-147 (IF: 2.594)

¹ Papers are sorted according to the common thread running through this thesis

1 INTRODUCTION

This section provides an overview over urbanization processes and the association between urban life worlds and the inhabitants' health worldwide and particularly in China.

1.1 Urbanization worldwide and in China

“Urbanization [...] is one of the most powerful, irreversible, and visible anthropogenic forces on Earth” (Sánchez-Rodríguez et al. 2005). It is a complex process accompanied by many changes including changing social organization and structures, changing housing conditions and markets impacting the inhabitants' health (Mauser et al. 2006). Urbanization processes are coined by changing lifestyles, changing patterns of wealth among urban subpopulations, and changing technology and services use (Lu and Liu 2006). Many factors play a role for urban growth, including the geographical location of settlements, natural population growth, and international as well as national or internal (rural-to-urban) migration, political developments, and the increasing global economic integration and globalization (Cohen 2004; Cohen 2006; UN-HABITAT 2008). Many large cities play an important role on local, national, and international scales. They are centers of economic development, innovation, and employment and they are hubs of modern lifestyles, culture, science and research, education, health care provision, governance and political developments (Cohen 2006; Leon 2008; Krämer et al. 2011). Worldwide, the urban population increased more than fivefold between 1950 (0.75 billion) and 2011 (3.6 billion). As of 2008, more people are living in urban than in rural areas (UN-HABITAT 2010) and planet earth is moving into the so-called urban age (UN-HABITAT 2012b). It is projected that this development will go on with a 72% increase from 2011 to 6.3 billion, about 68% of the world's total population in 2050 (9.3 billion). It is further projected that until 2050 the worldwide population growth takes place only in the urban areas and that the rural population will shrink after about 2022 (UN-DESA 2012).

Particularly in the developing world, the urban population increases rapidly. Within the past two decades, the urban population in developing countries increased weekly on average by about three million people. It is expected that the increase continues to a projected 5.3 billion people living in urban areas in developing countries in 2050 (UN-HABITAT 2008). Contradictory to earlier observations, the increase of the urban population will predominantly occur in the larger cities of more than one million inhabitants. Particularly megacities with 10 million inhabitants will grow in numbers and size, predominantly in Asia, an expression of

the concentration of the world's population in very large urban areas (UN-DESA 2012). Comparing the Fig. 1 and Fig. 2, it illustrates the strong urban growth in the developing world and in particularly the emergence and growth of large cities including megacities with 10 million or more inhabitants in Asia (Kraas 2003; Sánchez-Rodríguez et al. 2005).

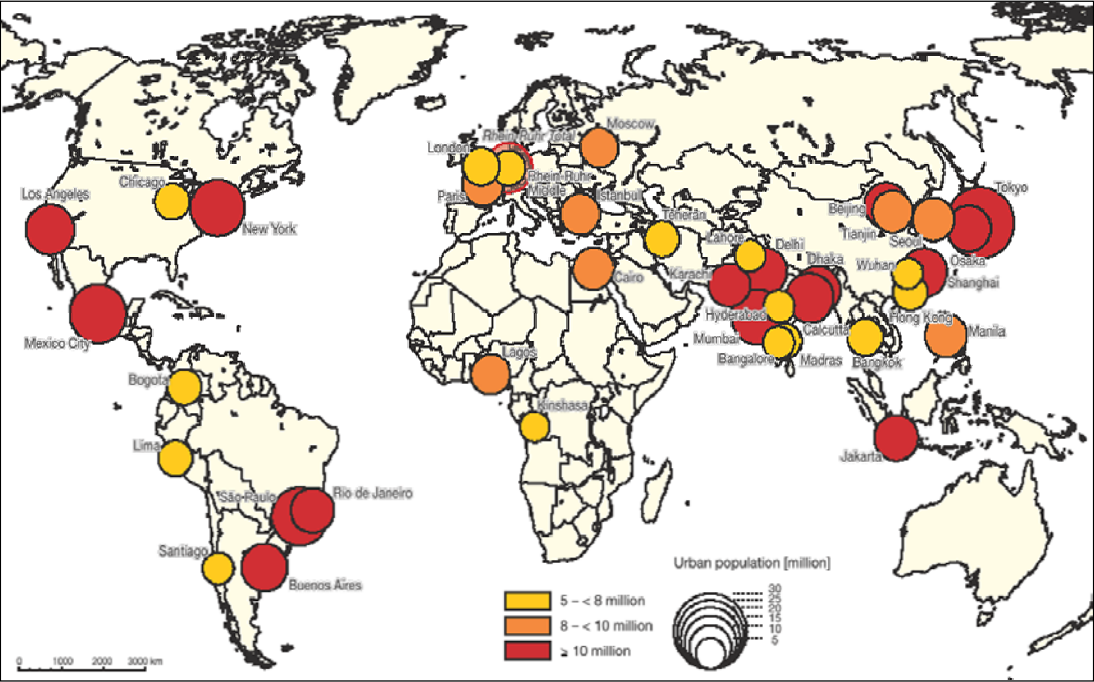


Fig. 1 Cities with 5, 8 and 10 Million inhabitants in 2000
 (Source: Kraas 2003; data source: UN-DESA 2002 Cartography: R. Spohner)

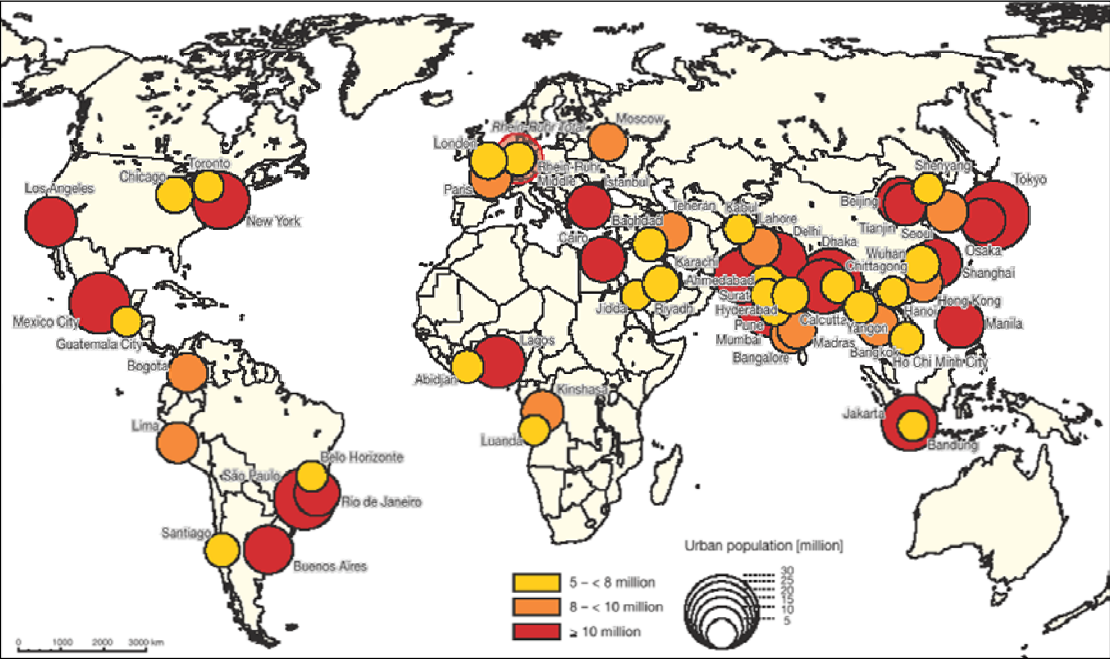


Fig. 2 Cities with 5, 8 and 10 Million inhabitants in 2015
 (Source: Kraas 2003; data source: UN-DESA 2002 Cartography: R. Spohner)

Urbanization in China

Depending on different definitions of urban populations and varying analyses by scholars, in the late 1920s and early 1930s, the urbanization rate in China was about 10 to 20% (Keyes 1951). In 1978, the urbanization rate was 18%, increased to 31% in 1991 (Zhang and Song 2003) and to 41% in 2003 (Yan et al. 2006). In the past three decades, the Chinese urban population has increased threefold (Gong et al. 2012) and in 2011, for the first time the urban exceeded the rural population (Fig. 3) with 690.79 million urban inhabitants (51.27%) living in 657 cities (UN-HABITAT 2012a).

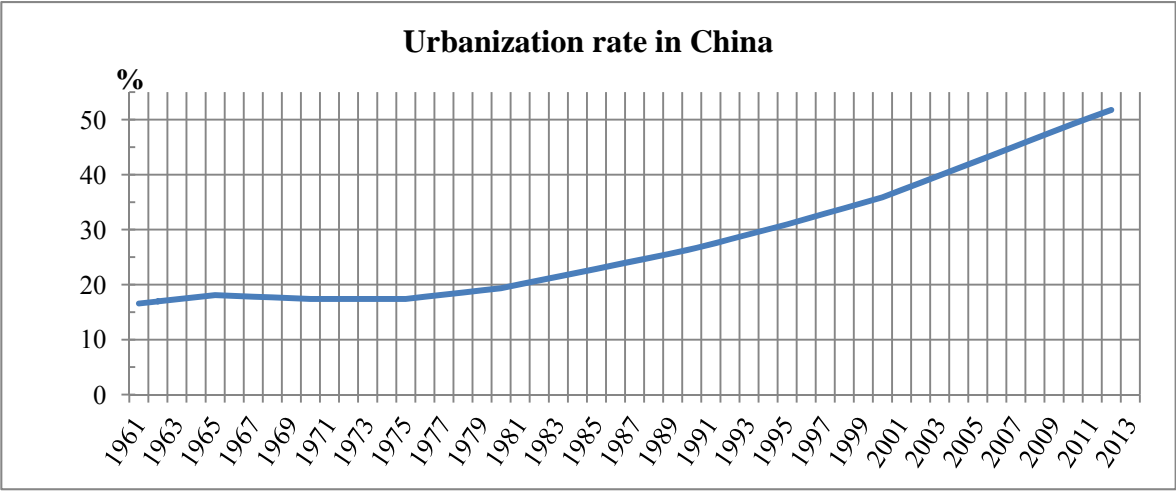


Fig. 3 Proportion of the urban population in China
(Data source: World Bank 2013 [own diagram])

According to year-end data 2012, reported by the National Population and Family Planning Commission of China, the urbanization level was 52.57% (National Population and Family Planning Commission of China 2013). This trend will continue in the foreseeable future (UN-HABITAT 2012a; Gong et al. 2012) and a further increase of urbanization in China is expected of about 68% for all of China and even 80% for the eastern parts of China in 2030, which is comparable to urbanization levels of western European countries (UNDP China and CASS 2013). For the year 2050, an urbanization level of up to 75% is estimated (Zhan 2005; UN-HABITAT 2012b).

Migration as a driving factor for urbanization in China

The main reason for urban growth in China is the internal rural-to-urban migration and to a lesser extent the natural growth (Gong et al. 2012). According to official Chinese statistics, the proportion of migrants in large cities is nearly 40% with about 260 million migrants accounting for about 17% of the total Chinese population (National Bureau of Statistics in China 2012; Gong et al. 2012). With about 80%, rural-to-urban migrant workers constitute the

vast majority of the migrants in Chinese cities (Ling et al. 2011). In the foreseeable future, there is no slow-down of rural-to-urban migration expected. Instead, it is projected that within the next two decades further 310 million additional migrants will stream into urban areas. This will be an unprecedented extent of national migration worldwide (UNDP China and CASS 2013). Keyes already described in 1951 that rural-to-urban migration was a major driving force for the urbanization in China. At that time, the destinations of migrants were mainly the coastal cities with increasing economic importance, where industrialization and trade processes started following the western economic models, such as in Guangzhou, Hong Kong, and Shanghai (Keyes 1951). Today, the prosperous coastal cities, many of them located in the Pearl River Delta (PRD) in the Guangdong Province in the South of China, still belong to the cities receiving a large share of migrants (Gong et al. 2012). Fig. 4 shows an example of large rural-to-urban migration streams in China between 2000 and 2005.

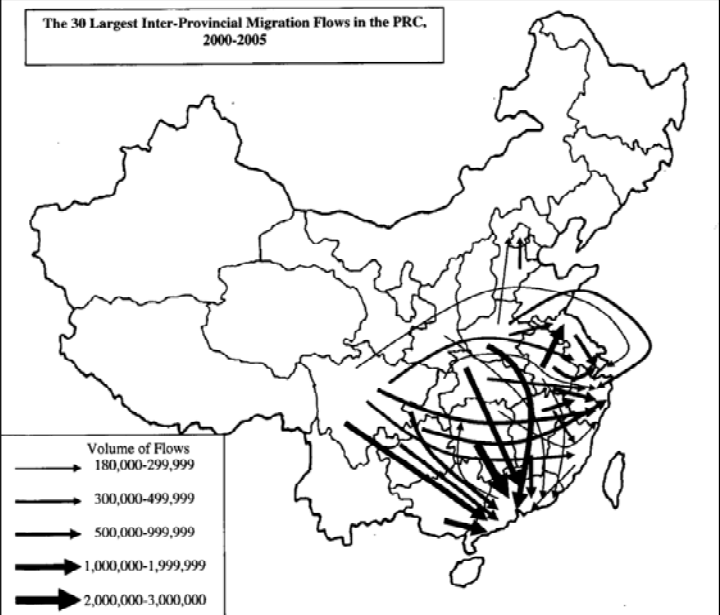


Fig. 4 Rural-to-urban migration streams in China between 2000 and 2005
 (Data source: State Council, Population Census Office and Department of Population Statistics, State Statistical Bureau [2007], quoted in Chan [2008:16])

The reasons for this impressive extent of internal migration are diverse. Due to the surplus of workforce in rural areas, young people in rural areas frequently face difficulties to obtain jobs (Huang and Pieke 2003; Liu et al. 2003). Besides this, many young people in rural areas perceive farming as not attractive in terms of income (Chai and Chai 1997; Li 2007) and not every young individual is willing to work as a farmer. Many “would rather do any work in a city than work on a farm in their home village” (Huang and Pieke 2003:13). Many migrant workers seek better employment in the large urban centers in China to improve their socio-economic situation (Shen 2002; Chan 2008, 1994; Huang and Zhan 2005; Li 2007; Liu et al. 2003; Gransow 2013). Additionally, many young people look for better and higher education in the highly developed urban areas (Fan 2002) and they are attracted by new life experiences

related to an urban lifestyle beyond the aspiration of income improvement (Huang and Pieke 2003; Chai and Chai 1997; Huang and Zhan 2005; Li 2007). Altogether, one can state that the manifold rural-urban differences in terms of economical, social, cultural and political respects create a significant conglomerate of various push and pull factors fuelling the ongoing internal rural-to-urban migration in China.

1.2 Urban health in general and in China

The rapid population growth worldwide and the concentration in cities have manifold effects for the long-term development of humanity (Sánchez-Rodríguez et al. 2005) and thus also on the health of the inhabitants of urban areas. Health is a complex concept that is influenced by cultural, political, socio-economic, demographic, psychological, genetic, social, behavioral and environmental determinants (Galea et al. 2005; Gong et al. 2012; Schulz 2011). The differentiated life-worlds in cities make it even more difficult to understand the contribution of single factors to the health status of city inhabitants and the study of urban health requires an even more multifaceted approach (Jahn et al. 2011a). The urban environments influence health in various ways, both in positive as well as in adverse aspects. Cities may provide better health care services, better education and more income sources compared to rural areas. However, the urban environment may threaten its inhabitants, particularly the ones with low socio-economic status, by adverse living and working conditions and produce health risks due to environment pollution. Therefore, cities can be understood as resources providing places with chances and opportunities but they are also places that can inhere risks for health and well being (Harpham 2009; Stephens and Satterthwaite 2008; Gruebner et al. 2011). The influence of the urban environments on health is not equally distributed. Cities in developing and transitional countries are often coined by strong population growth. The fast urban growth can, e.g., lead to a lack of governability (Kraas 2003) and poor infrastructure including the lack of safe drinking water and sanitation. Such conditions may cause higher rates of mortality and morbidity compared to regulated cities in high-income countries that have been established over a longer period of time. In large cities in developing countries, one can observe significant socio-economic differences between subpopulations leading, e.g., to unequal access to health care services for the socially disadvantaged subpopulations like rural-to-urban migrant workers. Also within the same countries, there can be large differences between cities regarding health influencing factors. Smaller cities show often very different characteristics compared to large cities or megacities in the same country. Therefore, the

location and the actual stage of development of a certain city need to be taken into account when studying urban health and its particular influencing factors (Galea and Vlahov 2005).

Urban health in Chinese megacities

The aspects described above also count for the mega-urban areas in China. The rapid urban growth in Chinese cities has and still changes the cities' characteristics and living conditions with different effects on human health (Gong et al. 2012). Particularly the Chinese "open door policy", introduced in 1978, led to many changes within the last three decades including strong economic and population growth and overall development (Liu et al. 2003). However, these substantial changes took their toll on Chinese cities. These changing conditions have influenced the health of the urban inhabitants and two key dimensions of changing urban conditions should be emphasized in the context of urban health in China: firstly, the urban environmental pollution and secondly, the rural-to-urban migration. As mentioned above, millions of peasants streamed into the prosperous cities and facilitated the fast urban development and economic growth (Huang and Pieke 2003; Tunon 2006; Wong et al. 2007; Seeborg et al. 2000; Zhan 2005). However, although migrant workers constitute a large share of the urban population in China, they face many health-related disadvantages compared to their local urban counterparts. (Gong et al. 2012). The rapid economic development in China, however, produced – besides other health threats – an unprecedented level of urban air pollution, particularly in the mega-urban areas in China like in PRD.

The described increasing trend of worldwide urbanization, particularly in transitional and developing countries in general and the specific situation in urban China as a country of growing international leadership, underline the relevance of the scientific field "urban health" in China. The basis of this cumulative dissertation therefore is the focus on the mega-urban health in China by the example of the two major dimensions in Chinese cities, namely the urban particulate matter (PM) air pollution and the rural-to-urban migration.

2 AIM, OBJECTIVES AND RESEARCH QUESTIONS

The general aim of this dissertation is to obtain a comprehensive understanding of major urban health challenges in Chinese megacities. To this end, two crucial dimensions of urban health in Chinese cities have been focused on, i.e., urban PM air pollution and internal rural-to-urban migration.

Objectives

- I.) To describe the epidemiological stage of a megacity in China to attain a better insight into recent epidemiological developments (epidemiological transition) by means of a burden of disease assessment based on Hong Kong municipal secondary data of the urban population of Hong Kong (paper 1).
- II.) To provide a differentiated picture of the urban PM pollution in the megacities of PRD based (i) on a systematic literature review (paper 2) and (ii) on a comprehensive personal and ambient in-situ PM measurement campaign (paper 3).
- III.) To estimate the potential health benefits in terms of preventable premature PM-related deaths per year in megacities of PRD if the PM level could be reduced to a certain lower level of PM air pollution. This was done by means of a health impact assessment (based on data collected in the framework of the above-mentioned systematic literature review of published studies and municipal data sources [paper 2]).
- IV.) To investigate in which extent internal migration in China between rural and urban areas may play a role in the spread of HIV infections in China by means of a systematic literature review and meta-analyses (paper 4).

Research questions

- I.) What are the epidemiological disease patterns in Chinese megacities stratified for age groups and gender (stage of the epidemiological transition)?
- II.) How high are the levels of urban PM_{2.5} and PM₁₀ (particles with an aerodynamic diameter ≤ 2.5 and ≤ 10 μm , respectively) pollution in megacities of PRD and how strongly do they differ from national and international air quality standards and guidelines?
- III.) How many premature deaths per year that are attributable to urban PM air pollution in megacities of PRD could be prevented if the actual level of PM_{2.5} and PM₁₀ in the respective city could be reduced to levels proposed by national and international air quality standards and guidelines?
- IV.) How high are the levels of urban PM_{2.5} and PM₁₀ pollution in the megacity of Guangzhou on district level measured by (i) stationary ambient and (ii) personal PM_{2.5} sampling and what are the relationships between the two?
- V.) Does the enormous extent of internal migration streams in China influence the spread of infectious diseases like HIV in the country?

3 THEORETICAL ORIENTATION OF OWN RESEARCH

Urban health in China is a broad scientific field and research approaches require theoretical guidance and conceptual orientation. Such research calls for a specific understanding of urban life-worlds and living conditions as well as their multidimensional associations with city inhabitants' health. The following section provides theoretical and conceptual considerations of this research that were the basis for the presented findings of the author's empirical work.

3.1 Conceptual framework of the DFG-funded Priority Programme SPP 1233

Most of this research was conducted within the framework of the Priority Programme SPP 1233 *Megacities – Megachallenge: Informal Dynamics of Global Change* funded by the German Research Foundation (DFG). The core topics investigated by SPP 1233 indicate major aspects of urbanization and related processes in Asian megacities (rectangles in Fig. 5). Beside the vertical relationships between these core topics and the aspects of urbanization (circles in Fig. 5), these aspects and related processes are also interlinked among each other – a complex netting of reciprocal associations. All these dynamic processes can have effects on the city inhabitants' health and therefore, public (urban) health can be understood as a cross-sectional topic (Fig. 5). Since the subject matter of the presented research is health in Chinese megacities, two key dimensions of urban health in China, namely rural-to-urban migration and urban air pollution (red circles) have been focused on.

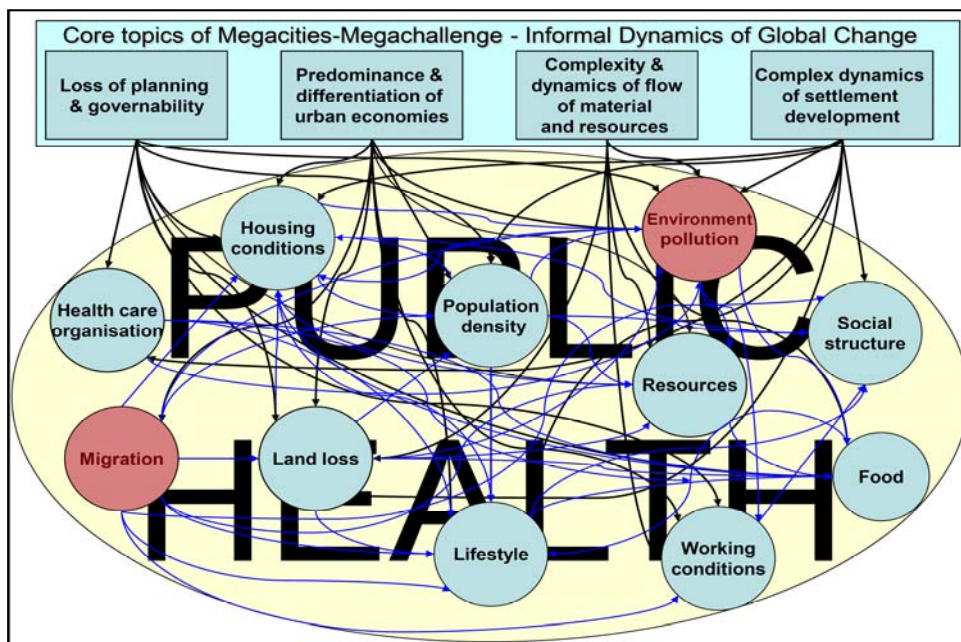


Fig. 5 Core topics of SPP 1233 and their influences on major processes of mega-urbanization and their relation with public health
(Source: Jahn et al. 2011a, own diagram)

Study region

Within SPP 1233, PRD was chosen as study region. For the here presented research on internal rural-to-urban migration and urban PM air pollution, this study region was ideal. The PRD is a highly urbanized region with a high density of very large cities. They are home to many migrants and they are strongly affected by urban air pollution. Three of the four included papers (Plass et al. 2013; Jahn et al. 2013; Jahn et al. 2011b) focused on cities in PRD, namely Guangzhou, Shenzhen, and Hong Kong. The fourth paper (Zhang et al. 2013) on internal rural-to-urban migration and its role concerning the spread of HIV throughout China necessarily reflects the situation of the whole country.

3.2 Health-related transition theories

Health-related transition theories, like the theories of demographic and epidemiologic transition, are useful to interpret the actual age-structures, fertility and mortality rates and the spectrums of health and disease in a population. Such information and its development over time allows conclusions about the demographic and the epidemiologic stage of the society or population in focus. Therefore, demographic and epidemiologic transition theories can set a framework for designing public health research and measures taking into account the demographic stage and the epidemiologic health and disease patterns of a focused population (Jahn et al. 2011a). For instance, particularly the health and disease spectrum of people living in developing and transitional countries are affected by rapid societal changes including demographic and epidemiologic changes. These countries often face the so-called *double burden of disease*. On the one hand, they still suffer from conditions that nowadays play only a minor role in developed countries (e.g. communicable infections/diseases, perinatal conditions, traffic-related injuries). On the other hand, they also experience increasing morbidity and mortality caused by chronic and non-communicable conditions (e.g. cardiovascular diseases, cancer, diabetes) (Boutayeb 2006; Amuna and Zotor 2008).

Demographic transition

The demographic transition theory describes fundamental socio-demographic changes and related stages within a society: Pre-transitional societies naturally showed fairly stable population sizes with high mortality and high fertility rates. Over time, many societies could reduce mortality through social and economic development and the fertility remained high, which led to rapid population growth and an extension of life expectancy – the first stage of the demographic transition (Smith and Ezzati 2005). In some European countries, fertility

rates declined causing slower population increase in these countries at the end of the 19th century. Later, the same development was observed in many other countries including developing and transitional countries (Ulrich 2006) – the second stage of the demographic transition. With continuing development and further fertility decrease, balanced low fertility and mortality rates could be observed in various countries resulting in aging populations with more or less stable population sizes (Lee 2003; Smith and Ezzati 2005).

Epidemiologic transition

Related to the demographic transition and further societal changes, Abdel R. Omran developed the theory of epidemiological transition and pointed out:

“Conceptually, the theory of epidemiological transition focuses on the complex change in patterns of health and disease and on the interactions between these patterns and their demographic, economic and sociologic determinants and consequences. An epidemiologic transition has paralleled the demographic and technologic transitions in the now developed countries of the world and is still underway in less-developed societies”

(Omran 1971:161).

The epidemiologic transition theory describes changing health and disease patterns in societies before and parallel to the demographic transition. According to this theory, there is a shift in morbidity and mortality characteristics, namely the reduction of the disease burden due to communicable infections, such as malaria, bronchitis, influenza, pneumonia or diarrhea, to non-communicable conditions chronic diseases, such as cardiovascular diseases, cancer, and diabetes (Smith and Ezzati 2005; Lucas 2004; Grundy 2004). The demographic and the epidemiologic transitions are interrelated and since the stages of both the demographic and the epidemiologic transition status have impact on public health, both theories should be taken into account while studying relevant aspects of population health.

3.3 Theoretical basis of this research and major dimensions of urban health in China

Since urban health is influenced by many different determinants, multidisciplinary research approaches are required. In the past, studies on health in cities usually applied one of the three approaches:

1. Differences between urban and non-urban areas
2. Differences between cities in the same or in different countries
3. Differences in one city (Galea et al. 2005).

Applying these approaches, many different protective and risk factors and related health outcomes have been studied. However, most of the studies did not explore why and how cities may affect health. This may be due to the fact that it is challenging to investigate all relevant complex and interwoven factors influencing urban health and to operationalize them into a set of empirically verifiable set of research questions (Galea et al. 2005).

Therefore, it is challenging to derive an all-encompassing picture of mega-urban conditions in China and its various influences on the inhabitants' health and well-being. Chinas megacities are coined by different geographical distributions of risk factors and resources influencing the urban populations' health and they are unequally distributed among the different subpopulations within the cities. Furthermore, Chinese megacities differ among each other, what makes the topic of *mega-urban health in China* even more complex, as well as the fact that the health determining factors are interrelated with each other. However, large cities in China also share some important characteristics. They form the basis of this research.

Galea et al. (2005) suggested a conceptual framework for urban health that is suitable as a guiding principle for the research of this doctoral thesis (Fig. 6). The underlying concept of this framework suggests that several levels of health-related factors influence the health of urban populations in various ways. This perspective reflects the complexity of urban health and related risk and protective factors and underlines the need for a theory-guided understanding of urban health in China. The basic assumption of this conceptual framework is that *major global and national trends* (like suburbanization and globalization) and *municipal determinants* (like markets, housing, civil society) shape physical and social environments (not explicitly mentioned in Fig. 6). The physical and social environments for their part define the urban context in which local factors, the *urban living conditions*, produce their effects on the *health outcomes* of urban populations. In conclusion, one can state that Galea and colleagues (2005) emphasized the role of the physical and social environments and their crucial meaning for urban living conditions as most proximal factors influencing urban inhabitants' health (Fig. 6).

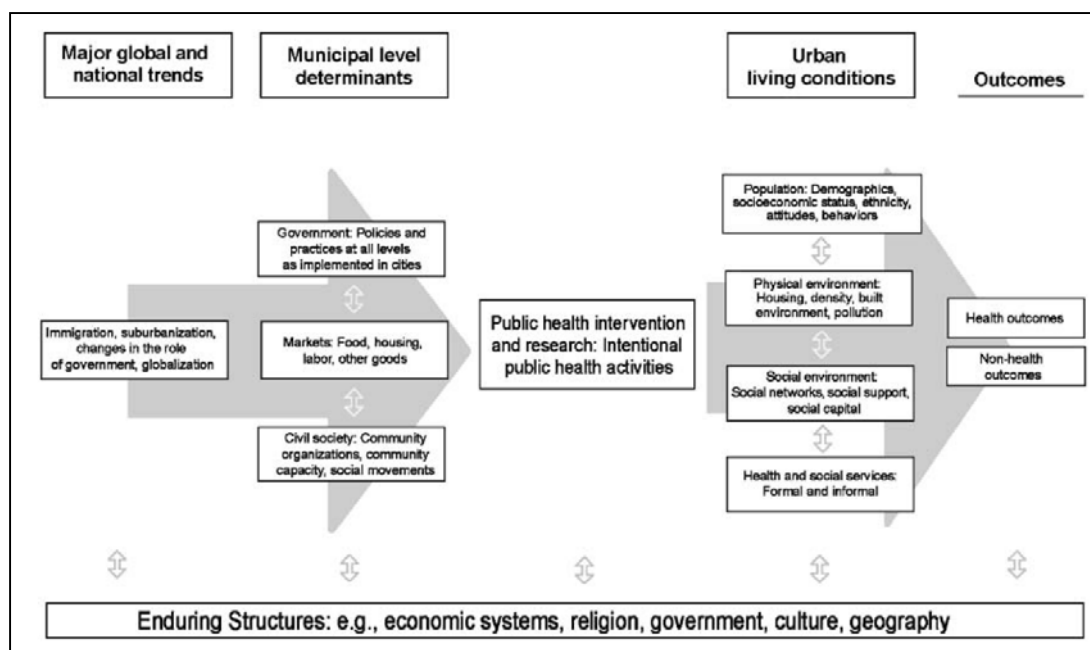


Fig. 6 A conceptual framework for urban health
(Source: Galea et al. 2005:1020)

Following this concept, which was also confirmed by other scientists studying urban health (Schulz 2011), **this research focuses on two major dimensions of the urban physical and social environments** that shape urban living conditions and with that the health of Chinese megacities' inhabitants. Firstly, the urban particulate matter air pollution in China (representing one major dimension of the physical environment) and secondly, the internal rural-to-urban migration in China (representing one major dimension of the social environment).

3.3.1 Urban particulate matter air pollution and health in China

Data from the Global Burden of Disease (GBD) Study showed that ambient PM pollution caused about 76.2 million *disability-adjusted life-years* (DALYs)². Based on this result, ambient PM pollution ranked 9 with respect to the worldwide DALYs caused by certain risk factors. Three percent of overall DALYs and 22% of all DALYs attributable to ischaemic heart diseases are caused by ambient PM pollution (Lim et al. 2012b). Urban air pollution (all urban pollutants including PM) cause about 1.3 million premature deaths per year and middle-income countries like China are disproportionately affected (WHO 2012).

² The DALY is a frequently used *summary measure of population health* within the GBD framework. The DALY allows combining the impact of mortality and the effects of non-fatal conditions on health expressing, e.g., the burden of disease caused by a certain risk factor in one single unit (Murray 1994).

Literature reviews and meta-analyses on air pollution and health effects indicated associations between short-term and long-term PM air pollution and increased morbidity and mortality (Rueckerl et al. 2011; Schulz et al. 2005; Brook et al. 2010; US EPA 2009; Beelen et al. 2014; Katsouyanni et al. 2011; Schwartz 2011; Cesaroni et al. 2014). For instance, Gan and colleagues found an increase of coronary heart disease hospitalization and mortality related to urban traffic pollution in Vancouver (Gan et al. 2011) and traffic air pollution was also associated with the onset of myocardial infarction in Augsburg (Peters et al. 2004). More specifically, PM pollution was shown to be associated with all-cause mortality (Pope et al. 2002), cardiopulmonary mortality (Dockery et al. 1993; Pope et al. 2002; Pope et al. 1995) and lung cancer mortality (Pope et al. 2002; Dockery et al. 1993). Lall et al. (2011) found that urban PM_{2.5} pollution was related to respiratory and cardiovascular hospital admission in New York City. Another study found that a decrease of PM pollution was associated with an increase of life expectancy (Pope et al. 2009b). It was further reported that an increase of PM was associated with a decrease of heart rate variability, which is a marker for cardiac mortality, particularly in individuals with cardiovascular diseases or metabolic syndrome (Hampel et al. 2013; Park et al. 2005; Wu et al. 2010; Schneider et al. 2010; Park et al.).

China's fast development after the economic and political reforms caused a high demand for energy. The increasing need for energy and its production by coal combustion (accounts for about 70% of energy production in China), increasing transportation and industrial activities caused many environmental problems including poor air quality (Zhang et al. 2007).

Among many world regions, East Asia, to which China belongs, is most burdened by ambient air pollution. The GBD study data show that ambient PM air pollution ranks 4 in this region (worldwide rank 9, see above) in terms of attributable DALYs (Lim et al. 2012b). Particularly urban air is of major concern in China. The country belongs to the countries with the highest levels of PM pollution worldwide (Wang et al. 2013; Chan and Yao 2008; Chen et al. 2012). Large Chinese cities belong to the most polluted ones worldwide – 16 out of the 20 most polluted cities on earth are located in China (Roseland and Soots 2007). It is estimated that around 300,000 premature deaths per year are caused by urban PM₁₀ pollution (WHO 2009) and PM is considered to be the most serious air pollutant in Chinese cities (Committee on Energy Futures et al. 2007). PM pollution showed effects in different Chinese cities. For instance, during hot days in Wuhan, China it was found that a 10 µg/m³ increase in PM₁₀ concentrations was associated with a 3.28% mean percentage increase (95%-confidence interval [CI] 1.24-5.37%) of cardiovascular mortality (Qian et al. 2008).

The large cities in PRD, that is one of the economic hubs in China, are burdened by urban PM air pollution, particularly in Guangzhou, the largest city in and the capital of the Guangdong Province (Chan and Yao 2008; Chan et al. 2002; Jahn 2012). International studies on PM pollution in Guangzhou from 2002 to 2007 reported PM_{2.5} average levels ranging from 70.6 µg/m³ to 96.5 µg/m³ and PM₁₀ levels ranging from 124.7 µg/m³ to 255.6 µg/m³ during different time periods (Jahn et al. 2011b). Taking into account the proposed WHO Air Quality Guidelines for average annual PM_{2.5} (10 µg/m³) and for average annual PM₁₀ (20 µg/m³) (WHO 2006), this level of PM pollution underlines the public health relevance of the topic.

3.3.2 Internal rural-to-urban migration and health in China

As addressed in the introductory part, internal migration and urbanization in China are inextricably interlinked. Migrant workers in Chinese cities constitute a large proportion of the urban population in China. They show many health-related characteristics that deviate from the situation of the local urban residents'. From a public health perspective, the sheer extent of internal migrants and their deviating health risks emphasize the need for migration-related urban health studies in China. Particularly the underprivileged rural-to-urban migrant workers are highly disadvantaged in terms of health risks. They constitute about 80% of all internal migrants in China (Ling et al. 2011) and they "are a special group in urban cities in China" (Wong et al. 2007:33) sharing some essential characteristics with respect to urban health: Usually, they are young with an age of about 15 to 39 years (Zheng and Lian 2006) and the majority of migrant workers is male. According to the China 2000 census, 75.6% of the migrants were married (Wong et al. 2007) and had a higher education level as the rural settlers, who did not migrate. Migrant workers have usually a low socio-economic status and are commonly less educated in comparison to the urban residents (Hesketh et al. 2008). They are therefore mostly engaged in low-income jobs in the cities (Huang and Pieke 2003).

Migrant workers usually do not have the chance to obtain a permanent urban residency permit after migration, the local urban *hukou* (Chinese household registration system) (Huang and Pieke 2003; Chan and Buckingham 2008; Ling et al. 2011). Internal migration in China is strongly associated with the hukou system. Therefore, the hukou system needs to be considered when analyzing internal migration processes and migrants' health in China (Chan 2008). Besides many hukou system relaxation policies in the past, holding a local urban hukou still plays an important role with respect to state-provide services, such as health care, pension or education because holding a local urban hukou facilitates the utilization of such state-provided services. Although special migrant health insurance schemes exist in some

cities (Liang 2009), not all employers provide these insurances. Therefore, many migrants still have to cover their health expenses out of pocket in case of illness.

Due to their low socio-economic status, migrant workers usually live in low-standard, crowded housing conditions, often with poor hygiene posing the risk for infectious diseases (Fan 2006; Zheng and Lian 2006). They are frequently engaged in the dirtiest and most dangerous jobs (Ling et al. 2011) and suffer from a higher workload than the local urban residents (Wong et al. 2007). These unhealthy or dangerous conditions are also responsible for severe injuries (Human Rights in China 2002; Wen 2006) and can cause cardiovascular and musculoskeletal diseases as well as and mental impairments (Zhang et al. 2010).

Migrants are also under risk for impaired mental health problems because they often suffer from high stress levels, social discrimination and exclusion because many urbanites do not consider the rural-to-urban migrants part of the urban society (Wong et al. 2007; Huang and Pieke 2003; Wong et al. 2008b).

Furthermore, the low educated migrant workers suffer also from the lack of health education. For instance, their knowledge about sexual and reproductive health is often limited and they frequently lack knowledge about health care facilities in their neighborhoods (Amnesty International 2007).

The low level of education and health knowledge may also be related to risky behavior. Rural-to-urban migrant workers are more likely to be engaged in risky behaviors, such as unsafe sex, having multiple sex partners or providing and using commercial sex increasing the risk for sexually transmitted diseases and HIV (Li et al. 2009; Zhu et al. 2005).

Focus: migration and HIV

In this thesis, migration and related health consequences in China represent the urban social environment dimension. One of the topics of major public health concern in China is the epidemiology of HIV. Therefore, this thesis deals – among other things – with the association of internal migration and its role for the spread of HIV in China. The following section goes more into detail regarding the risks for acquiring and transmitting HIV.

An estimated 780,000 people were HIV positive in China in 2011, a prevalence of approximately 0.058% of the total Chinese population (MOH China et al. 2011). Studies on HIV infections among migrant groups show inconclusive findings with large differences ranging from 0-2.59% (Fu et al. 2005; Hu et al. 2003; Lu et al. 2006; Dai et al. 2007; Zhang et al. 2013). At the beginning of the HIV epidemic, most of the HIV-positive individuals (80%) lived in rural areas (Cui et al. 2009). Results derived from studies that are more recent

indicated that the epidemiological pattern of HIV infections changed over time. Nowadays, HIV is more prevalent in cities and not only high-risk groups like injecting drug users are affected anymore. Instead, heterosexual activity is the main HIV transmission route with a proportion of 44.3% of all HIV infections (Jia et al. 2011; UNGASS 2010).

As addressed above, rural-to-urban migrants in China seem to be more likely to engage in risky behaviors promoting sexually transmitted infections including HIV. Particularly male migrants tend to engage in extramarital sex and tend to utilize commercial sex when being away from their spouses and families. Female migrants, however, seem to be more likely to offer commercial sex in case they face financial difficulties after migration compared to local urban residents (Zheng et al. 2000; Rogers et al. 2002; van den Hoek et al. 2001; Qian et al. 2005; Yang 2004; Zhu et al. 2005). Empirical findings indicated that 70-95% of female sex workers in China have some kind of migration history (Yang et al. 2005b; Zhou et al. 2010; Lau et al. 2002; Liao et al. 2003; Liao et al. 2006; Yang et al. 2005a; Hong and Li 2008).

Results from a cross-sectional study conducted among 605 marriage license applicants in China showed that significantly more migrants had multiple sexual partners in comparison to non-migrants (12% vs. 6%). The proportion of regular condom use (“often” or “always”) during sex with their spouses among those, who reported to have multiple sex partners, was low in both groups (9% of migrants, 8% of non-migrants). The knowledge about HIV infection and preventive measures was also low in both groups and the authors concluded that all in all the migrants are at greater risk of acquiring and transmitting HIV than the non-migrant population (Hu et al. 2006).

Another study comparing risk-taking behaviors between migrants and rural as well as urban residents in China concluded that migrants were more likely to be engaged in casual sex (0.5% vs. 0.1%) and to have multiple sex partners (11.2% vs. 2.2%), to utilize illegal drugs (1.1% vs. 0.5%), and to share needles during injecting drugs use (1.2% vs. 0.3%) (Chen et al. 2009). Injecting drug use and related needle sharing was the major route of HIV transmission in China until 2006 (MOH China and UNAIDS 2007) and still belongs to the most important risk factors for HIV spread in China. In addition to unsafe injection practices, injecting drug users are frequently engaged in commercial sex work. This is a combination of high-risk behaviors creating a highly dangerous risk profile among rural-to-urban migrant workers (Zhu et al. 2005). This mixing of risks constitutes also a bridging link to the general population and particularly to the wider (non-drug injecting) migrant population (Yang 2004).

The specific risk patterns of internal migrants are of substantial public health relevance. However, the migrants' mobility constitutes the main concern with respect to the HIV epidemiology in China. Particularly the rural-to-urban migrant workers are highly mobile because they travel back and forth between rural and urban areas, often over long distances, on a regular basis. This was recognized as one of the main risk factors for the spread of HIV (Zhang and Ma 2002; MOH China et al. 2010) and emphasizes the importance of the possible role of migration and the spread of infectious diseases for public health in China.

The wide range of discriminatory aspects makes migrant workers be at a particular risk for negative health effects. These kinds of disadvantages alone but particularly in connection with the potential role of migration in distributing adverse health consequences, e.g., in terms of infectious diseases, underline the significance of internal rural-to-urban migration from a public health perspective but also regarding the scientific field urban health.

4 METHODS

The research presented is based on a multi-method approach combining several types of quantitative methods (Hunter and Brewer 2003) to answer the research questions addressed in section 2. This section only provides a brief overview over the different methods used as they are explained in detail in the single papers that form the basis of this thesis.

4.1 Burden of disease assessment

First, a burden of disease assessment for Hong Kong was conducted to provide an insight into the mortality-related burden of disease spectrum of the Chinese urban population (paper 1). Hong Kong population data for 2010 were obtained from the Hong Kong statistical yearbook 2010 by the Hong Kong Government Logistics Department. Mortality data of the year 2010 were obtained from a dataset provided by the Hong Kong Census and Statistics Department. The dataset provided data on the cause of death, age and sex of each deceased individual. The death causes were classified according to the tenth revision of the International Classification of Diseases (ICD-10). The results allowed us to provide comprehensive assessment of SEYLL due to health conditions and injuries for Hong Kong in 2010 (Plass et al. 2013). The authors applied the "Standard Expected Years of Life Lost" (SEYLL) measure (provided by the GBD framework). The SEYLL were quantified by cause of death, sex and 19 age groups for the year 2010. The baseline SEYLL were calculated by multiplying the number of deaths (N) at a certain age of death with the remaining life expectancy (L) at age of death (x) →

$SEYLL = N \times L_x$. Additionally, a sensitivity analysis was done by replacing the WHO standard life expectancy with the local Hong Kong standard life expectancy. Furthermore, scenario analyses were calculated (i) by introducing a time-discounting and (ii) by using different assumptions of age-weighting (non-uniform age weighting [higher age-weights were given to productive age groups] vs. uniform age-weighting).

4.2 Systematic literature reviews, meta-analyses and health impact assessments

Secondly, two systematic literature reviews were conducted. National and international databases were searched for suitable studies. Subsequently, further relevant articles were identified through the reference lists of the initially identified publications. Studies for the final analyses have been included according to pre-defined in- and exclusion criteria.

One review (paper 4) was carried out (i) to determine the HIV prevalence among rural-to-urban migrants in China at different migration stages (before migration, post migration, return migration) and (ii) to compare the risk of HIV infection among these different migrant subgroups and compared to the general Chinese population. In this study, different meta-analyses stratified for the different migrant subgroups were done resulting in pooled HIV prevalence estimates with 95%-CIs for each of the subgroups. Additionally, analyses were conducted to calculate odds ratios with 95%-CIs comparing the risk of HIV infection among the different groups (migrant subgroups among each other and migrant subgroups vs. general Chinese population). Heterogeneity between the single studies was ascertained by the Cochran Q test and I^2 statistic. In case of high heterogeneity, random-effect models were applied. Otherwise, fixed-effect models were used. Furthermore, the factors responsible for the heterogeneities between the studies were identified by stratified meta-regression analyses. Potential publication bias was analyzed by the Begg and Mazumdar rank correlation test.

The other review (paper 2) was done to (i) describe PM_{10} and $PM_{2.5}$ air pollution levels in the megacities located in PRD, (ii) to compare the actual PM values with the existing national and international air quality standards and guidelines and (iii) to estimate the beneficial effects of a potential PM_{10} and $PM_{2.5}$ reduction. From the collected data, pooled means were calculated for the complete study period, for single years and for summer and winter seasons. Additionally, mortality data from municipal sources were collected. Based on the collected PM and mortality data, a health impact assessment was carried out following the recommendations by Cohen et al. (2004). This was done to estimate the potential health

benefits in terms of preventable PM-associated premature deaths per year in the respective megacities in PRD if the current level of PM pollution could be reduced to a certain lower level of pollution. In order to reflect the uncertainty about the concentration-response functions of PM and related mortality in the Chinese mega-urban context, a base-case analysis approach was applied with complementing sensitivity analyses. In addition to the base-case analysis, different PM concentration-response relationships were assumed and different air pollution reduction assumptions were made. Moreover, scenarios were applied with maximum city-specific concentration of the actual air pollution (scenario with truncation of the actual to a lower level of PM pollution).

4.3 Own personal and ambient PM_{2.5} air pollution measurements

Thirdly, complementing the systematic literature review on urban PM air pollution in the megacities of PRD, own personal and ambient in-situ PM_{2.5} air pollution measurements were conducted (i) to ascertain the level of personal and ambient PM_{2.5} in Guangzhou on a preferable small spatial and temporal scale, (ii) to determine how much PM_{2.5} individuals were exposed to over 24-hour periods (personal measurements), and (iii) to study the relationship between the ambient and personal PM_{2.5} levels (paper 3). During the months of November and December 2011, ambient and personal PM_{2.5} samples were simultaneously collected in nine and eight of the 12 districts of Guangzhou, respectively. Twenty-four hour time-integrated samples were collected each sampling day for the ambient sampling and every other day for the personal sampling. The sampling period was nearly one month long. The sampling started/ended simultaneously at approximately noon for each sampling day.

5 INTEGRATED RESULTS

In an integrated fashion, this section presents a selection of major results answering the aforementioned research questions.

5.1 Burden of disease in Chinese megacities using Hong Kong as an example

Findings from the background paper on urban disease patterns in large Chinese cities by example of Hong Kong (paper 1) show that in Hong Kong, 41,887 (female 44.4%; male 55.6%) deaths were registered in 2010 with males contributing 1.6 times more SEYLL in 2010 over the three main GBD disease groups (first level of GBD disease group

disaggregation)³ in comparison to women. Altogether, 524,706.5 life years due to premature death were lost (female deaths: 41.7%, male deaths: 58.3% of the SEYLL). 78.8% of all SEYLL could be attributed to group II conditions (non-communicable conditions). 12.7% of the SEYLL were contributed by mortality due to group I conditions (communicable, maternal, perinatal and nutritional conditions) and 8.5% of the SEYLL were contributed by group III conditions (injuries). Further information on the overall burden of disease represented by SEYLL is presented in Tab. 1.

Tab. 1 Standard expected years of life lost (SEYLL) by broad cause groups, Hong Kong, 2010

Cause group	Total			Female			Male		
	SEYLL	%	Rate per 100,000*	SEYLL	%	Rate per 100,000	SEYLL	%	Rate per 100,000
Group I	66568.5	12.7	947.7	27779.4	12.7	744.8	38789.1	12.7	1177.5
Group II	413537.0	78.8	5887.3	174861.2	80.0	4688.1	238675.8	78.0	7245.1
Group III	44600.9	8.5	635.0	16054.2	7.3	430.4	28546.7	9.3	866.5
Total	524706.5	100.0	7470.0	218694.8	100.0	5863.3	306011.7	100.0	9289.1

Group I: communicable, maternal, perinatal and nutritional conditions.

Group II: non-communicable conditions.

Group III: injuries.

*The rates presented here are rates per 100,000 population (inhabitants of Hong Kong).

(Source: Plass et al. 2013)

Investigating the SEYLL condition group spectrum over 19 different age groups (five year increments) shows that the mortality patterns strongly change with increasing age. 46.6% of all SEYLL in the age group 0-1 were attributed to group I conditions. This proportion decreased to less than 10% from the age group of 10 to 55 with a peak in the age group of 20-24 (13.6%). Beginning in the group aged 55-59 years, the proportion of SEYLL due to group I conditions again increased up to 28.1% in the last age group (85+). Group II conditions – overall representing the largest share of SEYLL among males and females – presented the lowest observed SEYLL proportions in the age group of 25-29 years (37.4%). The SEYLL due to group II conditions increased with age at the highest observed value in the age group of 60-64 years (87.5%). The share of group III conditions increased from the youngest age group onwards with a clear peak in the group aged 25-29 years (57.7%). Subsequently, a sharp decrease could be observed up until the age group of 45-49 year olds, followed by a constant but slower decrease towards the highest age group (85+). Within group III, self-inflicted

³ According to the GBD framework, there are different levels of disease group disaggregation created for the analysis of the burden of disease in populations. Depending on the analyses, different levels of disaggregation are applied, e.g., for population comparisons → 1st level: group I (communicable, maternal, perinatal, and nutritional conditions), group II (non-communicable diseases), and group III (injuries); 2nd level: The three 1st-level groups are divided into major cause subcategories (e.g. cardiovascular disease as subcategory of 1st-level group II); 3rd and 4th level: Beyond the 2nd-level groups, two further disaggregation levels are used describing specific diseases and injuries (Lopez et al. 2006).

injuries were identified as an important cause for mortality accounting for 5.6% of the overall SEYLLs (males: rank 6; females: rank 7; total: rank 5). In particular, self-inflicted injuries among young men caused a strong disease burden. In the age group of 25-29 years, self-inflicted injuries alone were responsible for 50.5% of the total SEYLL in this age group.

5.2 PM pollution in megacities of PRD

The large share of non-communicable diseases corresponds to the living conditions in many large Chinese cities. One of the foci of this thesis is the urban PM air pollution that contributes to GBD group II diseases as highlighted in section 3.3.1. The research presented show that Hong Kong, Guangzhou and Shenzhen are strongly burdened by urban PM air pollution. Guangzhou suffered most from PM air pollution followed by Shenzhen. This pattern consistently appeared independent of the particle size, the year of data collection or the winter vs. summer season. The PM value ranges reported in the single studies were wide and differed strongly within and among the cities (PM_{2.5}: Guangzhou: 70.6-105.9 $\mu\text{g}/\text{m}^3$ [mean: 87.8 $\mu\text{g}/\text{m}^3$], Hong Kong: 31.8-54.5 $\mu\text{g}/\text{m}^3$ [mean: 40.3 $\mu\text{g}/\text{m}^3$], Shenzhen: 47.1-67.0 $\mu\text{g}/\text{m}^3$ [mean: 55.2 $\mu\text{g}/\text{m}^3$]; PM₁₀: Guangzhou: 124.7-255.6 $\mu\text{g}/\text{m}^3$ [mean: 169.5 $\mu\text{g}/\text{m}^3$], Hong Kong: 41.4-78.9 $\mu\text{g}/\text{m}^3$ [mean: 61.6 $\mu\text{g}/\text{m}^3$], Shenzhen: 75.1-95.9 $\mu\text{g}/\text{m}^3$ [mean: 83.5 $\mu\text{g}/\text{m}^3$]). Results from paper 3 confirmed a high level of PM air pollution in Guangzhou but showed an overall lower level of PM air pollution. The mean ambient and personal PM_{2.5} pollution over the entire sampling period was 77.7 $\mu\text{g}/\text{m}^3$ and 71.9 $\mu\text{g}/\text{m}^3$, respectively and differed substantially between the districts. The daily development of the ambient PM_{2.5} pollution on district level over the entire sampling period is shown in Fig. 7.

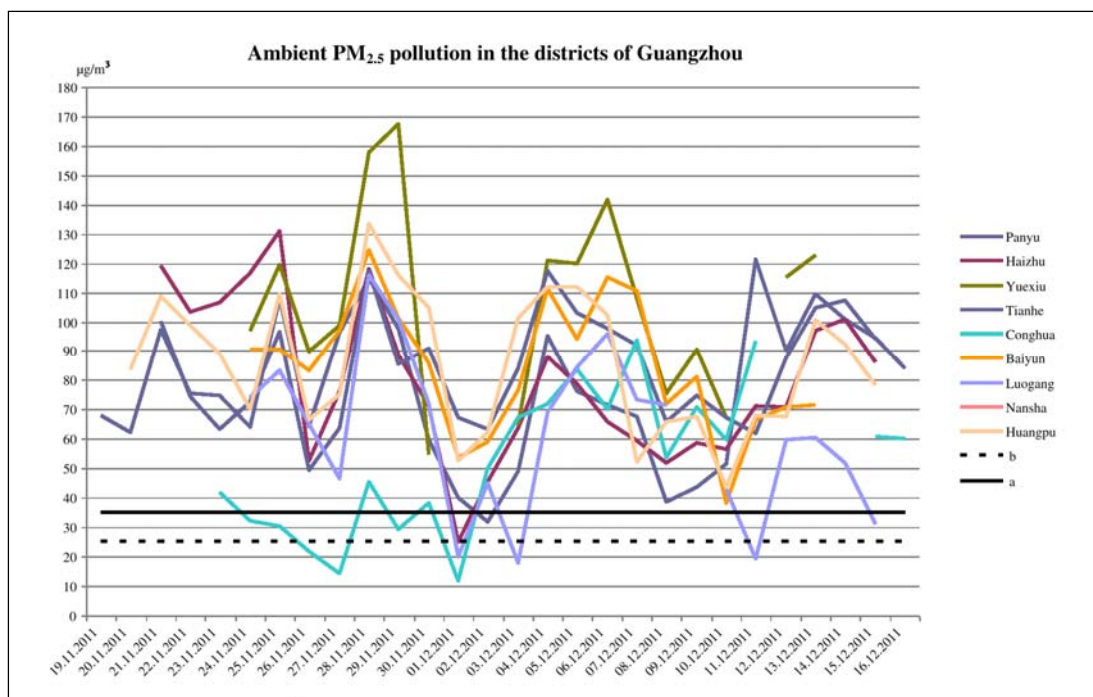


Fig. 7 Average ambient $PM_{2.5}$ concentrations ($\mu g/m^3$) per district over the sampling period.
a) U.S. EPA national ambient air quality standard for 24-hour $PM_{2.5}$; b) WHO Air Quality Guideline for 24-hour $PM_{2.5}$ (Source: Jahn et al. 2013)

The main ambient and personal $PM_{2.5}$ mass concentration results of the $PM_{2.5}$ pollution in Guangzhou on district level are shown in Tab. 2.

Tab. 2 Ambient and personal $PM_{2.5}$ mass concentrations ($\mu g/m^3$) measured in the individual Guangzhou districts over the entire sampling period

District*	Ambient average	Personal average
Yuexiu	106.6	53.9
Haizhu	80.1	71.5
Tianhe	84.1	85.1
Baiyun	84.7	83.6
Huangpu	86.0	–
Panyu	76.8	77.8
Nansha	65.5	63.4
Luogang	61.9	92.5
Conghua	52.4	45.4

Note: *Ambient measurements in $n = 9$ and personal measurements in $n = 8$ out of 12 districts (Source: Jahn et al. 2013)

The spatial variability of the ambient and personal $PM_{2.5}$ pollution between the districts, expressed by the coefficient of variance⁴ was 20.6 and 22.8%, respectively. Three out of seven districts showed moderate to high correlations (Spearman's Rho) between ambient and personal $PM_{2.5}$ pollution over time. The overall correlation (all district values pooled) between ambient and personal $PM_{2.5}$ air pollution over time was high ($r_s = 0.7$; $p = 0.01$) (see Fig. 8).

⁴ Coefficient of variance as percentage: standard deviation / average * 100

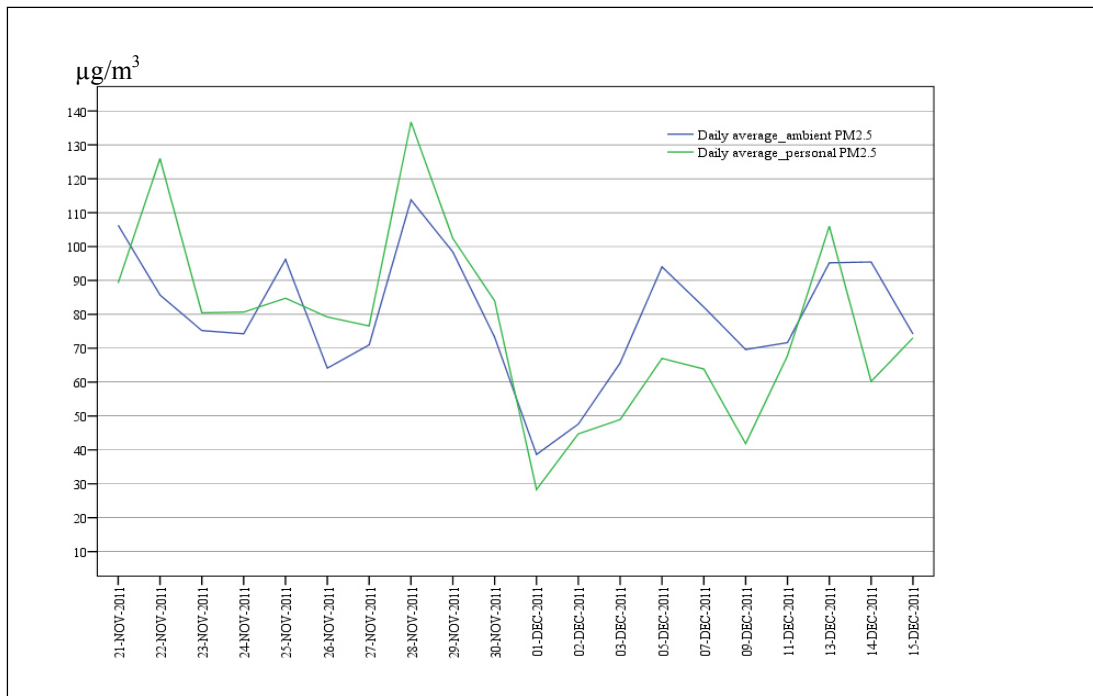


Fig. 8 Daily matched pairs of ambient and personal PM_{2.5} air pollution over the sampling period (Source: Jahn et al. 2013)

Findings of paper 2 and 3 confirm consistently elevated levels of urban PM air pollution in the megacities in PRD. When comparing the PM_{2.5} and PM₁₀ data results of the papers with national and international air quality standards and guidelines, it shows significant exceedances of air quality standards.

5.3 PM-related mortality in megacities in PRD

During the PM-related health impact assessment (paper 2), various different scenarios on air pollution reduction and a related potential decrease of mortality for Guangzhou and Hong Kong were calculated. The example of the first 3a case in

Tab. 3 shows that under these assumed conditions 222 (117-295) premature deaths per 100,000 population in Guangzhou per year could be prevented if the level of the estimated annual average of PM₁₀ air pollution of 169.5 µg/m³ could be reduced to an annual average PM₁₀ air pollution level of 40 µg/m³ (Chinese National Ambient Air Quality Standards class of annual PM₁₀ that corresponds the annual PM₁₀ EU air quality standard). Keeping all conditions constant but truncating the air pollution level of 169.5 µg/m³ to an assumed annual average level of 100 µg/m³ (PM₁₀ truncation for validity reasons, see paper 2 for further explanations) as shown in the first base-case scenario, it can be concluded, that annually 117 (91-164) premature deaths per 100,000 population in Guangzhou could be prevented (Tab. 3).

Tab. 3 Potential reductions in premature deaths per 100,000 population (and their lower and upper bounds) for different decreases in annual PM₁₀ pollution (review-study data)

Case	Shape of exposure function	Threshold ($\mu\text{g}/\text{m}^3$)	Upper concentration truncation ($\mu\text{g}/\text{m}^3$)	Reductions in premature deaths (lower and upper bound)
<i>Guangzhou (PM₁₀ annual average: 169.5 $\mu\text{g}/\text{m}^3$)</i>				
Base ^a	Linear	40 $\mu\text{g}/\text{m}^3$ ¹	100	117 (91;164)
Base ^a	Linear	20 $\mu\text{g}/\text{m}^3$ ²	100	150 (117;208)
1 ^b	Linear	40 $\mu\text{g}/\text{m}^3$ ¹	100	186 (62;289)
1 ^b	Linear	20 $\mu\text{g}/\text{m}^3$ ²	100	233 (82;347)
2 ^c	Linear	40 $\mu\text{g}/\text{m}^3$ ¹	100	91 (32;117)
2 ^c	Linear	20 $\mu\text{g}/\text{m}^3$ ²	100	117 (43;150)
3 ^a	Linear	40 $\mu\text{g}/\text{m}^3$ ¹	None	222 (117;295)
3 ^a	Linear	20 $\mu\text{g}/\text{m}^3$ ²	None	247 (199;324)
4 ^d	Linear	40 $\mu\text{g}/\text{m}^3$ ¹	None	42 (21;61)
4 ^d	Linear	20 $\mu\text{g}/\text{m}^3$ ²	None	48 (24;70)
5 ^e	Linear	40 $\mu\text{g}/\text{m}^3$ ¹	100	115 (62;161)
5 ^e	Linear	20 $\mu\text{g}/\text{m}^3$ ²	100	148 (81;203)
6 ^f	Linear	40 $\mu\text{g}/\text{m}^3$ ¹	100	94 (50;133)
6 ^f	Linear	20 $\mu\text{g}/\text{m}^3$ ²	100	138 (75;191)
<i>Hong Kong (PM₁₀ annual average: 61.6 $\mu\text{g}/\text{m}^3$)</i>				
Base ^a	Linear	40 $\mu\text{g}/\text{m}^3$ ¹	None ^g	43 (32;62)
Base ^a	Linear	20 $\mu\text{g}/\text{m}^3$ ²	None ^g	79 (61;113)
1 ^b	Linear	40 $\mu\text{g}/\text{m}^3$ ¹	None ^g	71 (22;122)
1 ^b	Linear	20 $\mu\text{g}/\text{m}^3$ ²	None ^g	129 (41;209)
2 ^c	Linear	40 $\mu\text{g}/\text{m}^3$ ¹	None ^g	32 (11;43)
2 ^c	Linear	20 $\mu\text{g}/\text{m}^3$ ²	None ^g	61 (21;79)
4 ^d	Linear	40 $\mu\text{g}/\text{m}^3$ ¹	None ^g	7 (3;10)
4 ^d	Linear	20 $\mu\text{g}/\text{m}^3$ ²	None ^g	13 (6;19)
5 ^e	Linear	40 $\mu\text{g}/\text{m}^3$ ¹	None ^g	42 (22;60)
5 ^e	Linear	20 $\mu\text{g}/\text{m}^3$ ²	None ^g	78 (41;110)
6 ^f	Linear	40 $\mu\text{g}/\text{m}^3$ ¹	None ^g	54 (28;77)
6 ^f	Linear	20 $\mu\text{g}/\text{m}^3$ ²	None ^g	98 (53;138)

^a Concentration–response function according to Künzli et al. (2000) – that is, RR: 1.04 (95% CI 1.03–1.06) for a 10 $\mu\text{g}/\text{m}^3$ increase in chronic (annual) exposure to PM₁₀.
^b Concentration–response function according to Hart et al. (2010) – that is, RR: 1.07 (95% CI 1.02–1.13) for a 10 $\mu\text{g}/\text{m}^3$ increase in chronic (annual) exposure to PM₁₀.
^c Concentration–response function according to WHO (2002) – that is, RR: 1.03 (95% CI 1.01–1.04) for a 10 $\mu\text{g}/\text{m}^3$ increase in chronic (annual) exposure to PM₁₀.
^d Concentration–response function according to HEI International Scientific Oversight Committee (2010) – that is, RR: 1.006 (95% CI 1.003–1.0009) for a 10 $\mu\text{g}/\text{m}^3$ increase in acute exposure to PM₁₀.
^e Assumed ratio between PM₁₀ and PM_{2.5} is 0.5.
^f Assumed ratio between PM₁₀ and PM_{2.5} is 0.65.
^g Annual average <100 $\mu\text{g}/\text{m}^3$.
¹ Reduction of current PM₁₀ annual mean to 40 $\mu\text{g}/\text{m}^3$: Chinese National Ambient Air Quality Standards (Chinese NAAQS) I standard.
² Reduction of current PM₁₀ annual mean to 20 $\mu\text{g}/\text{m}^3$: World Health Organization Air Quality Guidelines (WHO AQG).

(Source: Jahn et al. 2011b)

By the example of Guangzhou with a population of at least 12.7 million inhabitants (Guangzhou International 2010) and under the assumption that all inhabitants are on average chronically and equally exposed to urban PM air pollution, the results show that under the first PM₁₀ base-case scenario (reduction to 40 $\mu\text{g}/\text{m}^3$) 14,859 premature PM-related deaths per year could be prevented. Under the assumptions of the first 3a case, even 28,194 premature deaths per year could be prevented. Taking into account the total range of PM-related premature deaths calculated during all of the different health impact assessment scenarios on PM₁₀ reduction to 40 $\mu\text{g}/\text{m}^3$, the results suggest that 5,334–28,194 premature deaths per year could be prevented. Analogously for PM_{2.5}, the different scenarios resulted in 4,318–27,051 premature annual deaths that could be prevented, if the PM_{2.5} level was reduced to 25 $\mu\text{g}/\text{m}^3$.

5.4 The epidemiology of HIV and its association with rural-to-urban migration in China

Referring to the second major dimension of urban health in Chinese megacities, the massive internal migration in China, it was shown in the systematic review (paper 4) that the internal migration streams can influence the spread of infectious diseases like HIV in China. The HIV

prevalence among the Chinese migrants reported by the review studies ranged from 0-2.59%. Migrants, who were recruited for the single studies in urban areas after migration had a much higher HIV prevalence (0.38%; 95%-CI: 0.29-0.50%) representing a 6.70 (95%-CI: 6.05-7.41) times higher odds of HIV infection compared to the general Chinese population. Among these migrants recruited in urban areas, females showed an even higher HIV prevalence (0.69%; 95%-CI: 0.51-0.93%), reflected in a much higher OR of 12.18 (95%-CI: 11.11-13.35). The pooled HIV prevalence among migrants returning from urban areas was 0.18% (0.12-0.29%). Compared to the general Chinese population, their OR for HIV infection was 3.16 (95%-CI: 2.06-4.84). A correlation analysis showed that the HIV prevalence was positively correlated with the proportion of female migrants (Spearman's $Rho = 0.51$; 95%-CI: 0.23-0.71). The review studies reported that migrants show different risk behavior characteristics with regard to sexually transmitted infections including HIV compared to the general Chinese population and that they are highly mobile.

6 JOINT DISCUSSION

The research presented aimed at obtaining an understanding of major health challenges in Chinese megacities based on the conceptual framework for urban health suggested by Galea and colleagues (2005). Main results of the presented research will be discussed in this section against the background of the available scientific evidence.

6.1 Epidemiological transition in urban China: Mortality-related burden of disease

Using the example of Hong Kong, the results show that Chinese cities are already in a late stage of the epidemiologic transition. Urban China shows a long life expectancy (Hong Kong: females: 86, males: 80.1 years in 2010). The GBD group II conditions contribute most to the overall SEYLLs (79%) and the share of group II conditions rises with increasing age. This development is confirmed for all of China by results obtained in the framework of the GBD Study examining the burden of disease expressed by DALYs in China. From 1990 to 2010, China was able to reduce its burden of disease due to group I conditions by 64% whereas the burden of disease resulting from group II conditions could be reduced merely by 24% (Yang et al. 2013). Lin and colleagues also found that the development towards more non-communicable conditions takes place in China and pointed out that this happens faster in urban areas. The authors concluded that this is due to changing living conditions such as

increasing environmental pollution and lifestyle changes such as changing diet and lack of physical activity (Lin et al. 2010). Similar results were found by Cai and Chongsuvivatwong during their research on rural-urban differentials of premature mortality in Yunnan, China. Their results show that rural areas lag behind the epidemiological transition in urban China. They concluded that rural areas still suffer more from communicable diseases compared to urban and sub-urban areas. However, this study from Yunnan Province also confirmed that non-communicable diseases contribute most to the overall mortality suggesting a double burden of disease in remote rural areas in China (Cai and Chongsuvivatwong 2006).

At first glance, GBD group I, II, and III patterns identified in paper 1 correspond to the general disease patterns of high-income countries with the by far highest share of disease burden is caused by group II conditions and relatively small shares of group I and III conditions (Institute for Health Metrics and Evaluation 2013; Mathers et al. 2006). However, a closer look shows that in Hong Kong, GBD group I conditions play a larger role as compared to other high-income countries with 12.7% of total SEYLL. Exemplarily, a comparable study conducted in Spain, showed a smaller mortality rate due to group I conditions with only 6.5% of total SEYLL (Gènova-Maleras et al. 2011) and data published by the Institute of Health Metrics and Evaluation shows a similar share of GBD group I conditions with only 7.3% of all YLLs in high-income countries worldwide (Institute for Health Metrics and Evaluation 2013). After disaggregating the three main GBD groups into specific diseases/condition groups and analyzing their single contributions to the overall burden of disease, one can identify more differences in comparison to other high-income countries. For example, in this study it was found that lower respiratory infections (3rd level of disaggregation) were the leading cause of SEYLL among women in Hong Kong with 529.1 SEYLL/100,000. In contrast, Gènova-Maleras et al. (2011) reported that among Spanish women, lower respiratory infections merely ranked 9 (year 2008) in terms of SEYLL.

In summary, however, one can state that although the proportion of group I diseases is not as low as in many other high-income countries, the relatively small share of SEYLL disease burden caused by communicable diseases follows the usual pattern of high-income countries worldwide in a late stage of the epidemiological transition.

6.2 PM-related mortality in urban China by the example of Hong Kong and Guangzhou

Paper 2 and 3 reported high values of PM air pollution in the studied cities that by far exceeded internationally recognized air quality standards and guidelines as described in detail in section 5.2. Viewing these results in relation to the findings reported in paper 1, it is noteworthy that health conditions related to urban PM air pollution contributed to a large share of the overall SEYLLs in Hong Kong. *Cardiovascular diseases* ranked 2 with 21.7% and *respiratory diseases* ranked 5 with 4.6% of the total SEYLLs. On the next (third) sublevel of the GBD disease group disaggregation, the group *Trachea, bronchus, and lung cancer* (subgroup of *Malignant neoplasms*) alone contributed 10% to the total SEYLLs. These three diseases groups (cardiovascular diseases, respiratory diseases, Trachea, bronchus, and lung cancer) together added up to 36.3% of the total SEYLLs. Although paper 1 does quantify the contribution of PM air pollution to the total SEYLL in Hong Kong, these results suggest that PM cause a considerable amount of premature deaths in urban Hong Kong. This assumption is in line with findings reported in paper 2. Depending on different health impact assessment calculation scenarios, PM air pollution is most likely responsible for thousands of premature deaths in Hong Kong. For instance, applying the second PM_{2.5} base case scenario, it was estimated that the impact of ambient PM_{2.5} exposure (at the time on average 40.3 µg/m³) relative to the WHO Air Quality Guidelines (annual average of 10 µg/m³ PM_{2.5}) cause approximately 109 excess deaths per 100,000 population per year in Hong Kong (95%-confidence interval: 59-152). **Taking into account the number of inhabitants in 2010 (population of 7,024,200) and assuming an equal PM air pollution exposure throughout Hong Kong, about 7,656 (95%-confidence interval: 4,144-10,677) premature deaths could be prevented by PM_{2.5} air pollution reduction to WHO guidelines.** The different scenarios mathematically applied during the health impact assessment reflect the unavoidable uncertainty of these kinds of analyses. The methods applied do not definitively provide one valid number of premature deaths that could be prevented per year by PM air pollution reduction. However, these analyses show that the health impact of PM air pollution on the inhabitants of Chinese megacities is of highest public health relevance. Having a look on the PM data from the same study (paper 2) concerning the megacity of Guangzhou, one can expect a higher level of PM-related mortality as shown in section 5.2. The strong PM air pollution in Guangzhou is confirmed by paper 3 that can be viewed as an extension of paper 2 in terms of the PM exposure assessment. Paper 3 focused only on the highly PM-burdened

megacity in PRD, Guangzhou, and went more into detail. It demonstrated the spatial distribution of PM_{2.5} air pollution on district level and compared personal and ambient exposures over 24 hour periods. Applying this approach, a more comprehensive picture of urban PM air pollution in Guangzhou was drawn. On average, the ambient PM_{2.5} levels were lower compared to findings from paper 2. Nonetheless, both personal and ambient PM_{2.5} levels still significantly exceeded the WHO 24-hour PM_{2.5} air quality guideline (25 µg/m³) as well as the US Environmental Protection Agency's National Ambient Air Quality Standard for 24-hour PM_{2.5} mean exposure of 35 µg/m³ (currently there are no Chinese PM_{2.5} air quality standards enacted by the Chinese government). The Yuexiu District, for instance, a densely populated district with residential areas but also with a lot of commercial activities and a high road traffic load, was strongly burdened by ambient PM air pollution. On average, a PM_{2.5} mean value of 106.6 µg/m³ was measured over the three sampling weeks apparently representing a substantial health threat to the exposed inhabitants. The spatial variation of the personal and ambient PM_{2.5} pollution between the different districts was 22.8% and 20.6% (coefficient of variance), respectively. This reflects the considerable variability of PM levels between the districts. This was also shown by another study conducted in Guangzhou by Huang and colleagues (2007). They reported spatial differences of urban PM air pollution related to different kinds of land use in Guangzhou. Measurements in industrial districts and districts with a high traffic load showed much higher PM_{2.5} values in comparison to urban sites with low traffic and less industry (Huang et al. 2007). As mentioned under 5.2, **the correlation analysis between personal and ambient measurements over the complete sampling period over all districts resulted in a relatively high and statistically significant correlation ($r_s = 0.7$, $p = 0.01$). However, results of the personal and ambient PM_{2.5} correlation analyses on district level showed only three moderate to high and statistically significant correlations.** On the one hand, ambient PM exposure has some effects on the personal (indoor) exposure, e.g. due to the exchange of air between ambient and indoor air (Gerharz et al. 2009; Lim et al. 2012a; Huang et al. 2007). This speaks for an association between personal and ambient PM levels. On the other hand, the small number of moderate/high correlations between personal and ambient PM_{2.5} exposure on district level suggests that personal exposure and stationary ambient measurement results do not necessarily correspond to each other. Among other things, this can be explained by urban living and working conditions: The individual exposure is strongly related to individual behaviors (Broich et al. 2012; Gerharz et al. 2009; Hampel et al. 2013; Lim et al. 2012a).

Urban lifestyles require people to spend most of their time indoors (60 to 95% of the time) (Cao et al. 2005; Fishbein et al. 1991; Jenkins et al. 1992; Klepeis et al. 2001; Lim et al. 2011; Sarnat et al. 2006) and – although the indoor environment can potentially protect people from outdoor pollution – some typical indoor activities can also cause high levels of PM, such as cooking or cleaning (Hampel et al. 2013; Lim et al. 2012a). Second hand smoke indoors is another common source for PM pollution that depend on individual behaviors (Lim et al. 2012a) as well as commuting in the city, e.g., to and from workplaces (Gerharz et al. 2009). Considering these aspects, it is plausible that personal behaviors can strongly influence the level of PM air pollution on a small spatial scale that cannot be detected by only a few stationary air monitoring stations distributed over large areas in a city. Taking into account the results from the health impact assessment of paper 2 and the exposure assessment of paper 3, the need for better knowledge about the spatial and temporal development of PM air pollution in a large urban setting has great meaning for the health of the inhabitants and related public health interventions.

6.3 Rural-to-urban migration and its effects on the spread of HIV in China

Paper 1 reported that non-communicable conditions contribute most to the overall mortality in Hong Kong but showed also that Hong Kong suffers more from GBD group I conditions than many other high-income regions with 12.7% of the total SEYLLs. This makes it worthwhile to go more into detail with respect to the reasons for this relatively large share of GBD group I conditions in Hong Kong. Within this GBD group I, one of the second level disaggregation group, “Infectious and parasitic diseases”, account for 23% of GBD group I SEYLLs. Having a closer look on the specific diseases (third disaggregation level), one recognizes that particularly tuberculosis play a significant role. This was also reported by a study conducted by Wu et al. (2008). The authors also highlighted that internal migration contribute to the spread of tuberculosis and the maintenance of high tuberculosis-related disease burden in well developed urban areas in China. More specific, the presented research found that tuberculosis contribute 16.5% of all SEYLLs among the “Infectious and parasitic diseases” (rank 1 in this sublevel group) and 3.8% of all SEYLLs within the GBD group I diseases.

One of the most important influencing factors concerning the epidemiology and the control of tuberculosis in China is the internal rural-to-urban migration (Wei et al. 2009; Wang et al. 2007). This is associated with some of the typical characteristics of migrant workers described in detail in section 3.3.1. These characteristics are also related to poverty

like overcrowded, unsanitary housing conditions (Zheng and Lian 2006), work-related health hazards (Ling et al. 2011), poor education (Chen et al. 2013; Fan 2002), lack of tuberculosis-specific health knowledge (Wei et al. 2009), and restricted access to health care services due to the lack of hukou in the urban destinations (in mainland China) (Gong et al. 2012; Wei et al. 2009; Wang et al. 2007). However, mainly the migrants' mobility increases the risk of tuberculosis distribution in China (Wang et al. 2011; Zhang et al. 2006; Wang et al. 2007).

This thesis cannot provide empirical evidence that internal migration has an influence on the relatively high contribution of tuberculosis infection to the overall SEYLLs in Hong Kong. Nonetheless, paper 4 reported that **internal migration in China can influence the spread of an infectious disease as illustrated by the example of HIV**. Despite the fact that tuberculosis and HIV do have different transmission routes and related risk factors, one can still identify analogies concerning the role of internal migration in China for the spread of both communicable diseases. For example, health information/knowledge is relevant in terms of the transmission of tuberculosis and the same applies to HIV. Migrants often lack information about HIV risks and prevention, what may lead to a low level of awareness concerning the acquisition and transmission of HIV (Hong et al. 2006; Li 2007). Compared to local urban residents of the destination cities, migrant workers are also more likely to engage in unsafe injecting drug use (Chen et al. 2009) or in risky sexual activities like having multiple sex partners or utilize/offer commercial sex in the urban areas (Zheng et al. 2000; Rogers et al. 2002; van den Hoek et al. 2001; Qian et al. 2005; Yang 2004; Zhu et al. 2005). Furthermore, migrants' restricted access to health care services may additionally increase the risk for further HIV transmission and adverse health outcomes caused by HIV infection. Nonetheless – and again similar to tuberculosis –, the most important (migration-related) driver for the spread HIV within the country is the migration itself. The regular short-term migration between rural and urban areas (e.g. during the annual New Year or Spring Festival and the National Day holidays), was found to be one of the key risk factors for the spread of HIV (Zhang and Ma 2002; MOH China et al. 2010; Qian et al. 2005; Yang et al. 2007).

The theoretical considerations concerning tuberculosis-related disease burden in Hong Kong and China in general as well as the results of paper 4, allow the conclusion that the epidemiology of both addressed infections are influenced by the large-scale internal migration influencing the disease patterns in urban China in favor of communicable conditions.

7 CONCLUSIONS

7.1 Societal transformations in China

Changing living conditions, lifestyles and aging

For about 30 years, Chinese cities have been coined by rapid economical and population growth accompanied by increasing agricultural, industrial and commercial activities. These developments caused positive and negative effects on the increasing urban population and environments. On average, the wealth of the urban population increased substantially and the livelihood for large parts of the urban populations improved. As an effect of these transformations, education improved and living conditions changed, e.g., towards better hygiene due to the availability of improved water and sanitation in urban China (Gong et al. 2012). In addition, the spectrum of occupations changed with increasing economic growth and global integration in terms of international trade, technology and knowledge transfer. There are increasing numbers of high-skilled occupations in office settings leading to sedentary lifestyles and less physical activity. Furthermore, nutritional customs changed over time coined by increasing consumption of high-caloric western diet (Gong et al. 2012).

Moreover, the Chinese society aged in recent decades and this will continue in the foreseeable future caused by low fertility rates, decreasing mortality and longer life expectancy (Zhang et al. 2012; Cheng et al. 2011; Hvistendahl 2013). Most countries worldwide experience this development but China faces demographic aging on a comparatively high speed and on a large scale (Liu and Flöthmann 2013; Banister et al. 2010). Whereas in the year 2012 about 8.7% of the total Chinese population was in the age range of 65 and older (World Bank 2013), this age group is expected to account for about 18.2% of the total population in 2030 (UNDP China and CASS 2013) and 23% in 2050 (Liu and Flöthmann 2013). These rapid changes of the population age structure are partly related to family planning policies. In order to reduce the population growth, in the early 1970s the Chinese Government introduced the so-called “late, long, few-policy” that aimed at convincing the people – largely voluntarily – to have children later in their life, to wait longer between one and the next child and to have fewer children than generations before (Hesketh et al. 2005; Gong et al. 2012; Hesketh and Zhu 1997; Zhu 2003). In fact, the total fertility rate (births per woman) dropped significantly from 5.5 in 1970 to 2.8 in 1979 (World Bank 2013). In 1979, the Chinese government aimed at further population growth slowdown and enacted the formal one-child policy (Zhang et al. 2012). In fact, China’s family planning policies in

combination with rapid economic development, better living conditions, improved health care, and urbanization processes caused strong fertility reduction, increased life expectancy, decreased mortality and thereby lead to a rapidly aging society (Hvistendahl 2013).

Epidemiological changes and their analyses

Such described societal transformations usually take place in urban areas first. The UN-HABITAT reported that in many countries worldwide the epidemiologic transition occurred first in urban areas and subsequently spread to less urban and rural areas (UN-HABITAT 2001). Particularly in China, these transformations including lifestyle changes have adverse effects on the overall population health. These lead to increasing non-communicable diseases and multi-morbidity. Yang and colleagues also emphasized that such demographic transitions result in changing disease patterns and that health challenges due to demographic aging will intensify over the upcoming decades in China (Yang et al. 2013).

To better understand the local situation, e.g., in one specific city, an analysis of the disease patterns in populations provides useful information on the epidemiological and demographic stage in a population as demonstrated in paper 1. The situation in Hong Kong was analyzed and the results provide evidence that Hong Kong – as an example for the prosperous large and megacities in China – is already in late stage of the epidemiological transition. The disease patterns are comparable to other high-income regions with the highest burden of disease due to non-communicable and declining importance of communicable diseases. The results of paper 1 demonstrate that a detailed analysis of specific disease groups (second/third/fourth level of GBD disease group disaggregation) and their single contributions to the overall disease burden is advisable. Although the overall burden of disease in Hong Kong obviously follows the pattern of other high-income countries, certain conditions differ from the level of disease burden in other high-income countries as described in section 5.1.

The detailed information about disease patterns allows public health experts and epidemiologists designing public health research and interventions targeting vulnerable subpopulations in cities taking into account demographic and epidemiologic conditions. Considering the social transformations in urban China and related changes in epidemiological health and disease patterns, public health interventions should be based on detailed analysis of disease entities and their contributions to the overall burden of disease. Accordingly, priority should be given to the prevention of non-communicable conditions that clearly play the most important role in terms of the overall SEYLL-related burden of disease. Nonetheless, the thorough burden of disease assessment of paper 1 advises to put some attention on emerging

or re-emerging infectious diseases as well as to self-inflicted injuries that ranked 5 with respect to the overall mortality expressed by SEYLL.

The need for preparing the (public) health care sector against rising disease burden due to non-communicable and chronic diseases is particularly obvious when considering that the Chinese population is rapidly aging. Although many young people migrate from rural areas into the cities causing rapid aging in rural areas (Gong et al. 2012), urban areas have difficulties to cope with the increasing number of old inhabitants. Cheng et al. (2011), for instance, reported that the aging population in Beijing creates many challenges in regards to health and elderly care as well as the financial security of the elderly. The increasing number of elderly people calls for pension systems compensating the lack of supportive children. Wei and Hao, for instance, pointed out that the Chinese government should develop a sustainable pension scheme to meet the challenges of an increasingly aging society (Wei and Hao 2010). The Chinese government has recognized the wide range of challenges related to aging. The former Chinese President, Hu Jintao, emphasized that “progress shall be made to ensure that all the people enjoy their rights to education, employment, health and old-age care, and housing, [...] with the focus on the people's wellbeing” (GOV.cn 2012). Social rejuvenation seems to be one of the key elements to deal with aging and social security. The Chinese government recently relaxed the one-child policy to allow couples to have a second child if one parent is an only child (The Guardian 2013).

However, the aging process will continue and from a public health perspective, it is necessary that all stakeholders on national, provincial and local levels in China create a concerted initiative to cope with demographic aging. It is vital to decelerate demographic aging and to meet the needs of the large population of the elderly people with respect to health and elderly care and financial security to let them enjoy retirement with dignity.

7.2 Urban air pollution and health effects in China

As highlighted in paper 2 and 3, the rapid urbanization and continuing urban transformations not only caused demographic and epidemiological changes but led also to many adverse developments, particularly in terms of urban environmental pollution. This research took up the most frequent and probably most serious environmental problem in Chinese cities, the urban PM air pollution. In addition to the described societal changes, the continuous air pollution exposure in the cities increases the burden of non-communicable diseases. This is expressed, e.g., by the fact that in China ambient PM air pollution ranked 4 as attributable risk

factor in terms of age-standardized DALY rate per 100,000 population causing more than 25 million DALYs in 2010 (Yang et al. 2013). The results of the health impact assessments confirm this. Although these kinds of analyses inhere methodological uncertainties (see paper 2 for details), the loss of health due to urban PM air pollution was clearly indicated. The importance of the topic is currently once again acknowledged by media reports on urban air pollution reporting, e.g., that China's air pollution is at an unbearable and intolerable level damaging the peoples' health (Bloomberg News 2014; The Lancet 2014). For example, the United States of America Department of State reported $577 \mu\text{g}/\text{m}^3$ $\text{PM}_{2.5}$ in Beijing at 11pm on February 25, 2014 measured by its own monitoring station (USA Department of State 2014a), which is beyond the PM values considered in the US air quality index (Last level: "Hazardous" with values $> 300\text{-}500 \mu\text{g}/\text{m}^3$) (USA Department of State 2014b). Also, the Chinese Ministry of Environmental Protection recently released the news headline "Heavy air pollution observed in some cities during the Lantern Festival" and thereby acknowledging the severe air pollution, particularly heavy in the Beijing-Tianjin-Hebei region (MEP China 2014). The awareness of the Chinese government is confirmed by the fact that the State Council issued an *Action Plan on Prevention and Control of Air Pollution Introducing Ten Measures to Improve Air Quality* to protect the people's health (MEP China 2013).

The findings of this research call for increased awareness towards more environmental protection, not just on national and provincial governmental levels but also on the local level including city, district and sub-district level. Policy-makers should consider the environment not only as an exploitable source for wealth and economic growth but as a beneficial ecosystem providing a sustainable foundation for health and well-being. Concerted efforts by the government are needed with participation of (i) civic society groups like environmental and conservation organizations, (ii) scientists from different disciplines, and (iii) stakeholders of the industrial sector to realize, e.g. cleaner urban air, and to reduce environment pollution-related disease burden. Existing environmental protection laws and air pollution reduction strategies should be implemented more consequentially to create healthy cities in China.

In addition to paper 2, paper 3 added a better insight into the spatio-temporal distribution of PM air pollution in one megacity in China and highlighted the meaning of personal exposure measurements on a preferably small spatial and temporal scale. The consistent PM level differences over time between the districts as well as the relatively high overall correlation between ambient and personal measurements over all district averages speak well for the validity of the measurements and the related results. However, the differences found

between ambient and personal exposure on district level suggest that the explanatory power of stationary sampling in estimating the inhabitants' exposure levels and related health effects should be taken with consciousness. The findings suggest that the location within a large city and the personal behavior patterns play a crucial role in regards to the personal PM exposure.

Therefore, research on PM exposure should further take into account that personal living conditions and activities influence the personal PM exposure. Additionally, the relationships between ambient and personal PM pollution should be considered (Chen et al. 2012), which is vital to estimate the extent to which ambient PM levels can influence the personal (mostly indoor) PM exposure (Sarnat et al. 2005; Sarnat et al. 2006). Such information can help, for instance, to decide whether the ventilation of interior spaces (e.g. by opening windows) improves or deteriorates the actual indoor air quality and what behaviors may be appropriate or should be avoided to reduce PM-related health risks in indoor environments. To illustrate this, the US Government recommends "Everyone should avoid all outdoor exertion" because of possible health effects when the PM_{2.5} air quality index exceeds 300 (USA Department of State 2014b). On the other hand, staying indoors does not necessarily reduce personal PM exposure if no additional measures are taken to improve indoor air quality. Indoor activities can even deteriorate indoor air quality if interior space ventilation is avoided. As mentioned above, cooking or vacuuming can dramatically elevate PM levels indoors.

To obtain a more detailed knowledge of ambient vs. personal exposure relationships taking into account the different individual behaviors and related sources of PM, additional chemical composition analyses could be beneficial. The chemical components of PM indoors and outdoors can differ and their analyses allow distinguishing between indoor and ambient sources/pollutants and their health effects. Such measurements usually require ambient time-integrated filter-based PM sampling. Therefore, parallel personal and ambient continuous real-time as well as time-integrated PM measurements can be worthwhile. These different PM measurements should also be accompanied by activity diaries filled out by the subjects, by global positioning system devices to obtain time- and geo-referenced spatial information, and by devices collecting visual information like cameras. By combining these techniques, conclusion can be drawn on the relationship between personal and ambient PM pollution as well as on the personal exposure and sources over time, stratified for chemical components. During such studies, ultrafine particles should be more in focus. There is evidence that these are increasingly prevalent in the environment and cause additional health threats due to their

ability to translocate from the respiratory to the circulatory system and thus to extrapulmonary organs (Elder et al. 2006; Oberdörster et al. 2005; Oberdörster et al. 2004; HEI 2013).

The deepened understanding about ambient vs. personal PM exposures, the chemical components of PM and the contribution of activities and PM sources allows the specific development of interventions that reduce the health risks of PM pollution both on population and individual level outdoors as well as indoors.

Besides detailed exposure assessments, from a public health perspective it is most important to quantify the PM-related health risks. The association between PM and health effects has been studied extensively. In most epidemiological studies, approaches have been applied using aggregated PM and/or aggregated health data in terms of time and/or space related to PM pollution and the development of related (short- and long-term) health outcomes regarding morbidity and mortality (see section 3.3.1).

However, the direct health effects of a current PM pollution on individual level cannot be derived from such approaches. In epidemiological studies, rarely have own real-time personal PM measurements in combination with simultaneous measurements of subclinical physiological responses been conducted. More personal measurement studies should be conducted measuring real-time PM exposure and subclinical physiological responses simultaneously as hints for direct short-term PM health effects. Studies in this respect have been conducted taking into account different outcomes such as heart rate variability (Gold et al. 2000; Hampel et al. 2013; He et al. 2011; Liao et al. 2004; Park et al. 2005; Park et al. 2010; Schneider et al. 2010; Weichenthal et al. 2011; Wu et al. 2010), ventricular repolarization (Hampel et al. 2013; Hampel et al. 2010; Henneberger et al. 2005; Liao et al. 2010; Lux and Pope 2009; Yue et al. 2007), blood pressure changes (Ibald-Mulli et al. 2004; Dvornich et al. 2009), and endothelial dysfunction (Alexeeff et al. 2011; Schneider et al. 2008). However, only few of such studies conducted own personal PM sampling but used non-individual PM data and even fewer studies have been conducted in Chinese megacities with very high levels of PM pollution. Wu and colleagues (2010) studied continuous personal PM exposure and effects on heart rate variability in Beijing. This study solely focused on a specific occupational group (taxi drivers) that is not representative for the general population of Beijing. A recent review on the “ [...] up-to-date epidemiologic evidence of ambient air pollution, climate change and population health in China” stated that only few studies examined the relationship between air pollution and related physiological parameters and

postulated that future studies in China should assess the “[...] pathophysiologic link between air pollution and cardiopulmonary diseases in Chinese population” (Kan et al. 2012:18).

The majority of such studies have been conducted in North America (USA and Canada) or Europe with much lower levels of PM pollution as compared to urban areas in China. There is some uncertainty, whether results from studies conducted in countries with relatively low levels of air pollution can be transferred to the situation in large cities in China with much higher levels of PM pollution. It was reported that the PM concentration-response (CR) relationships may vary as a function of the air pollution level. Pope and colleagues, for instance, compared ambient PM air pollution to smoking regarding the caused health effects. It turned out that the CR function was flatter with increasing uptake of particulate matter. However, the flattening has only been shown at very high levels of PM uptake (Peters 2009; Pope et al. 2009a; Pope et al. 2011). Two studies conducted in Wuhan, however, concluded that a linear CR relationship between PM and different health outcomes are also likely at higher urban PM₁₀ air pollution levels above 140 µg/m³ (Qian et al. 2008) and even above 400 µg/m³ (Qian et al. 2007). Wang and colleagues, which compared four Asian cities (three cities from China) regarding health effects of urban PM pollution, came to the conclusion that CR relationships in highly polluted Asian cities seem linear in respect to all natural mortality but they also stated that the CR curves “[...] might be curvilinear, with the slope less steep at higher concentrations” (Wong et al. 2008a:1201).

Personal real-time measurements would provide a more accurate picture of the personal exposure in Chinese megacities and their short-term health effects. Besides the described exposure and health effects assessment, additional real-time information on physical activity and meteorological parameters should be collected as such factors can confound the subclinical physiological parameters to be studied as responses to the measured PM pollution.

Applying multiple methods is challenging but provide a better understanding of the physiological pathways that are still not completely understood, particularly regarding certain chemical components of PM and ultra fine particles as stated by well-recognized publications (Wu et al. 2010; Rich et al. 2012; Brook et al. 2010; US EPA 2009; Rueckerl et al. 2011).

7.3 Rural-to-urban migration and urban health in China

The urbanization processes and the related changes in the social and physical urban environments were strongly influenced by large-scale rural-to-urban migration processes in

China. Therefore, research on urbanization and urban health in China cannot neglect the topic of internal migration as one key factor in terms of urban health.

The large group of migrant workers facilitated the economic growth and urbanization. They streamed and still stream into the urban areas to build the cities and to work in factories and in the low-level service sector. They are usually engaged in the so-called three d-Jobs: *dirty, difficult and dangerous* (Zhang et al. 2003; Biao 2004; Ma and Xiang 1998; Ling et al. 2011). As described above, this highly mobile population is generally young and less educated than the local urban inhabitants. Migrant workers share some health-related characteristics and may be a source for the transfer of risky behaviors and communicable diseases between rural and urban areas in China.

Paper 4 addressed this issue and indicated that most people living with HIV in urban China have a migratory history and were identified with a higher HIV prevalence among rural-to-urban migrants in comparison to the overall Chinese population. The risk of infection differed strongly between the different migrant subgroups, e.g., with female migrants seem to be particularly at risk for HIV infection. The main conclusion of paper 4 was therefore that rural-to-urban migrant workers are at greater risk for HIV infection compared to the general Chinese population and they are likely to facilitate the geographical spread of HIV in China due to their high mobility. This paper showed further that migrants returning from urban to their registered rural home residence, regardless how long they stayed in the cities, had a much lower HIV prevalence than migrant workers who studied in the cities. This suggests that HIV-positive migrants rather stay in the cities instead of returning to their rural homes. This is particularly interesting given the fact that Chinese migrant workers commonly return to their hometowns of registration in case of serious disease (Peng et al. 2010; Chuanbo et al. 2010; He 2007; Fan 2006). At their place of registration (*hukou*), they would even be eligible to receive free basic HIV treatment as the Chinese government introduced a specific HIV treatment policy, called “China CARES” (China Comprehensive AIDS RESponse) (Zhang et al. 2011). The research presented does not provide evidence answering the question why HIV-positive migrants hesitate to return to their rural areas. It is possible that the quality of HIV treatment plays a role. HIV treatment is widely available in China but the quality of treatment varies strongly, at a lower quality in rural areas (Zhang et al. 2011). In the modern urban centers, high-quality treatment is available whereas the treatment in remote rural areas can be insufficient given the fact that HIV medication regimens are comprehensive and the administration of drugs require highly trained and experienced physicians. Besides the quality

of treatment, migrants may fear social discrimination in their rural hometowns as HIV-infected people are highly stigmatized in China (Liu et al. 2005). Infected migrants may therefore stay in urban areas because the urban setting provides usually higher treatment quality and more anonymity protecting them from discrimination.

Accordingly, HIV care in rural areas should be improved to enable HIV-positive migrants to receive high-quality treatment in their hometowns where they can benefit from social support by relatives. It is also preferable to reduce stigmatization by public anti-discrimination campaigns and by school-based HIV-related education. Specific educational strategies should target potential migrants in rural areas on community level. Health education could be offered to prepare young people against the risks in urban areas related to infectious diseases. Another approach is outreach services by health authority staff or by civic society groups. They could approach migrants at their typical residences in the urban areas. For instance, health education could be provided at workers' dormitories in cooperation with the local employers or in community health centers in "villages-in-the-cities" where many migrants rent cheap apartments. Employment agencies specialized in job placement of migrants are multipliers that could provide information on the prevention and health promotion as well as about local organizations dealing with health care particularly for migrant workers. Labor unions are also called to improve the health-related situation of migrant workers, particularly in terms of housing and working conditions, access to health care provision and further labor rights. In addition to flagship projects, which are certainly here and there present, such measures should be available on a large, nationwide scale in order to achieve a significant improvement.

Furthermore, – as migrants are not a homogeneous group – specific subgroup prevention and treatment as well as re-integration measures should be strengthened. For instance, female migrant workers have different needs in terms of sexual education compared to males or young, inexperienced migrants may have different expectations for the new life than older ones and could therefore be prone to different health risks.

For infected migrant workers, who prefer to stay in urban areas, access to free or affordable HIV treatment should be assured. One solution would be to further relax hukou-related health care utilization barriers to make sure that infected migrants are eligible to utilize health care services regardless of their hukou status. This is not only a question of social equity and human dignity but also a crucial factor in preventing further HIV transmission.

Beyond the frequently reported socio-economic disadvantages from which migrant workers in the urban centers in China usually suffer, this research shows to what extent these

inequities, in turn, result in health risks not only for the migrants but also for the general Chinese population. The higher risks for migrant worker of acquiring and transmitting communicable diseases and the potential function as infection vectors within China increase the threat of distribution of various causal agents to the farthest corners of the country.

However, these conclusions must not lead to further stigmatization, discrimination and social exclusion of migrants within the urban societies. It would be misleading to view migrant workers as a health threat for the general population. In contrast, migrants need the support by the civil society as well as by governmental institutions on local, provincial and national level to benefit more from healthy living and working conditions as well as from equal access to state-provided services including health care, housing, education, and pension. This would reduce socio-economic disparities, social tensions and discrimination between urban residents with local urban hukou and rural-to-urban migrants not benefitting from this registration status. It is desirable for the public perception of the rural-to-urban migrants solely as temporarily needed workforce without equal rights to change to the comprehension that this large share of the urban population is contributing to urban development and wealth. In the long term, this change in perception would also reduce the risk for infections among migrants and epidemiological bridging to other parts of the Chinese population and regions.

From a socio-political point of view one can conclude, that the systematic exclusion and discrimination of large parts of a population can result in adverse effects for the population as a whole. Currently and in the foreseeable future, China's development counts on further migration and many millions of additional migrants are expected to move to prosperous urban areas. From the public health perspective, it is not only important to improve the conditions of the migrant population for their sake but also for the health promotion and disease prevention of the entire Chinese population. It is therefore only logical to conclude that it is an issue of public and political responsibility to implement suitable measures to meet these challenges.

7.4 Limitations

The four papers that form the basis of this thesis have their specific limitations that were reported in detail in the single publications. Therefore, they will not be repeated in this section. However, this doctoral thesis has its own limitations that should be addressed.

All large Chinese cities differ from one another in many respects. This is due to the large size of the country and its long history with many substantial changes over time. Cities are

coined by different historical, ethnical, cultural, social, political, economic, environmental and climatic aspects. Taking all those issues into account is hardly possible and was not the aim.

This research was conducted in megacities of PRD, Guangzhou, Hong Kong and Shenzhen. They represent a modern, well developed and – from a western perspective – progressive and more open China. For many decades, the PRD has been one of the regions in China that received the largest share of migrants while showing the strongest economic growth and unprecedented social and environmental transformations. Hong Kong plays a specific role in China. It was the inspiration for the Chinese government to create the first special economic zone in mainland China, in Shenzhen, that is located just across the border from Hong Kong. It has its own – largely autonomous – administration and many sectors including the health care provision and other public services are governed differently from mainland cities.

Therefore, Guangzhou, Hong Kong and Shenzhen are in many respects not comparable to many other cities, particularly in less developed regions of China. This may affect the transferability of some of the results to all large Chinese cities. A representative picture of Chinese cities taking into account all their health-related characteristics could therefore not be drawn. However, the studied megacities share the challenges studied with all large cities in China (PM pollution and migration) and main patterns regarding the distribution of disease burden of the GBD groups are similar at least in the well-developed Chinese cities.

7.5 Final remarks

In summary, it can be concluded that the four papers forming the basis of this dissertation provide an overview of the epidemiological stage of urban China (paper 1) and took up two of the most important factors shaping urban health in Chinese megacities, (i) the urban air pollution (paper 2 and 3) and (ii) the rural-to-urban migration in China (paper 4). These factors represent the two overarching dimensions of urban living conditions and urban health as suggested by the conceptual framework for urban health developed by Galea et al. (2005), namely the physical and the social environments. The papers included in this thesis are heterogeneous. Nonetheless, in the context of the applied theory-based approach, it can be concluded that this research led to meaningful empirical findings that contribute to the aforementioned aim and objectives. A fuller picture of the most important urban health challenges in Chinese megacities could be drawn providing a reasonable empirical evidence for further research and public health interventions to improve urban health in China.

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Appendices

Declaration of originality

Bielefeld University, School of Public Health

Doctor of Philosophy (Ph.D.)

Declaration

The work presented is the result of independent investigation. Wherever the work is indebted to the work of others it has been acknowledged and cited. This thesis has not been accepted in substance for any other degree, nor is it concurrently being submitted in candidature or achievement of any other degree at any other university. I further declare that I have previously made no attempts to do a doctorate.

Bielefeld, 12. March 2014

Heiko Jahn

List of further publications by the Ph.D. candidate related to the topic of this thesis

Jahn HJ, Krämer A, Wörmann T (eds) (2013) Klimawandel und Gesundheit: Internationale, nationale und regionale Herausforderungen und Antworten. Springer-Lehrbuch. Springer Spektrum, Berlin, Heidelberg

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