

Public Health Adaptation to Climate Change in Large Cities: A Global Baseline

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Abstract

Climate change will have significant impacts on human health, and urban populations are expected to be highly sensitive. The health risks from climate change in cities are compounded by rapid urbanization, high population density, and climate-sensitive built environments. Local governments are positioned to protect populations from climate health risks, but it is unclear whether municipalities are producing climate-adaptive policies. In this article, we develop and apply systematic methods to assess the state of public health adaptation in 401 urban areas globally with more than 1 million people, creating the first global baseline for urban public health adaptation. We find that only 10% of the sampled urban areas report any public health adaptation initiatives. The initiatives identified most frequently address risks posed by extreme weather events and involve direct changes in management or behavior rather than capacity building, research, or long-term investments in infrastructure. Based on our characterization of the current urban health adaptation landscape, we identify several gaps: limited evidence of reporting of institutional adaptation at the municipal level in urban areas in the Global South; lack of information-based adaptation initiatives; limited focus on initiatives addressing infectious disease risks; and absence of monitoring, reporting, and evaluation.

Keywords

climate change, cities, public health, adaptation tracking, monitoring and evaluation, systematic assessment

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It is now widely accepted that the global climate is changing and that we are locked into some degree of future warming. The Intergovernmental Panel on Climate Change (IPCC) estimates a rise in average global temperatures between 1.8°C and 4°C by 2100, with significant consequences for human health.^{1,2} Urban populations in particular are expected to be adversely affected, as many cities worldwide are growing rapidly and often concentrate population and economic activity in geographical areas of high risk.³ Notwithstanding global efforts to limit the temperature increase to 2°C over the next century, temperature will rise around 0.6°C by 2050 even in the unlikely scenario that emissions were to reduce to zero immediately. This is compounded by a failure to date to meet even modest global emissions reductions targets, highlighting the need for adaptation measures to complement action on greenhouse gas emissions.² Adaptation refers to the process of adjustment to actual or expected climate change and its effects.⁴ In the public health context, adaptation is synonymous with prevention and may constitute policies, strategies, or interventions to avert the negative health impacts of climate change.^{4,5} While a number of opportunities for urban health adaptation have been identified, the task of managing health risks from climate change remains a significant challenge for local governments.⁶

The health risks from climate change have been well-documented in the last decade.^{2,3} Changing infectious disease patterns,⁷ water and food insecurity,⁸ extreme climatic events,⁹ declining air quality,¹⁰ and low-quality housing² have been identified as major threats to global health this century. Risk in cities is compounded where the number of people exposed is amplified due to high population density and rapid migration.^{11,12} Every year, 67 million people migrate to cities, with around 90% of this growth occurring in developing countries.¹³ By 2030, 60% of the world's population is expected to live in urban centers and more than 2 billion people are predicted to live in dense informal settlements (slums), often located in low-lying coastal areas.^{13,14}

Climate effects on health are also exacerbated by characteristics of the urban built environment. For example, the frequency, intensity, and duration of extreme heat events is worsened by the urban heat island effect: greater retention of heat by the dark surfaces of buildings and pavement relative to reflective vegetation produces localized pockets of warmer temperature.¹² There is increasing evidence that municipal authorities are aware of the risk from climate change. A recent survey of 110 city governments found that 88 cities reported risks from temperature increase, and 43 cities reported risks from storms and floods.¹⁵ Adaptation measures, however, have been shown to reduce the negative health effects of extreme heat in urban areas.¹⁶ The 2003 European heat wave was associated with 70,000 excess deaths, leading France to implement a heat wave warning system involving the retraining of health care professionals, changing spatial planning practices, and development of new physical infrastructure.¹⁷ The strategy was deemed effective when 4,400 fewer deaths than

anticipated were recorded during the subsequent 2006 heat wave.¹⁶ Examples such as this demonstrate that adaptation strategies and actions can significantly reduce the health burden from climate variation on urban citizens.

Indeed, there is increasing pressure on health professionals and policy makers across scales to protect the public's health in the face of climate change.¹⁸ This pressure reflects a shift from a recognition of the problem into action. The *Lancet's* two Climate Change Commissions in 2009 and 2015, for example, refer to climate change as both the greatest global health *threat* (2009)⁶ and the greatest global health *opportunity* (2015)¹⁸ of the 21st century. As part of this effort to tackle climate change, the Lancet Commission and the World Health Organization have called for systematic monitoring of progress on adaptation to identify success and areas where progress is lagging.^{18,19} In the case of mitigation, progress can be quantified using conceptually simple (if technologically complex) metrics by measuring the change of greenhouse gases over time; for adaptation, there are no similar standard metrics.^{20,21} Tracking the planning and implementation of adaptation policy has therefore been used as a reasonable proxy to measure progress in the absence of direct indicators.²²⁻²⁵

Despite the magnitude of the risks and the importance of monitoring progress, however, we have little knowledge on whether cities are planning for adaptation in general and with regard to the health risks of climate change in particular. This gap constrains our knowledge of how adaptation is taking place and whether the response is commensurate to the risks. In the context of this gap, this article identifies and characterizes the state of public health adaptation planning in urban areas globally with more than 1 million people. Specifically, we investigate five key questions for assessing health adaptation planning in cities: (a) which cities report the greatest levels of adaptation activity, (b) which health risks are generating the greatest levels of adaptation response, (c) what types of adaptation are being reported, (d) what stage of adaptation urban municipalities are at, and (e) whether reported adaptation initiatives are new or mainstreamed. These questions allow us to characterize and compare the state of *reported* urban government health adaptation activity globally and establish a baseline against which future progress can be measured.

Identifying comparable datasets for comparing adaptation across countries or municipalities remains a significant challenge in tracking adaptation.^{21,22} Data and knowledge regarding adaptation measures are difficult to find, and thus systematic analyses of adaptation largely rely on adaptation *reporting*.^{21,24,26} Though imperfect, using adaptation reporting as a proxy for adaptation measures remains the only option at present. Reporting of adaptation is in itself important as a proxy for prioritization of adaptation and for adaptive capacity. A lack of adaptation reporting hinders sharing of experiences and best practices, transparency, and effective monitoring and evaluation. Accordingly, in this article, we are not comparing actions themselves, but rather comparing reporting of actions.

Methods

Data Collection

To assess the state of public health adaptation in cities, we used systematic data collection methods.²² We analyzed health adaptation planning in urban municipalities larger than 1 million people as per the United Nations definition of “urban agglomeration.”²⁷ To simplify the language translation effort required, we excluded cities in those countries in which fewer than five large cities spoke a common language, leaving a total of 401 large cities. Languages included are: English, Spanish, and French (spoken by the researchers) and Chinese, Arabic, Russian, German, Portuguese, Farsi, Korean, Japanese, Turkish, and Indonesian (using hired translators). Urban agglomerations often contain several municipalities. In the majority of cases, the namesake and most populous municipality was included for analysis. In the case of London, United Kingdom, and Santiago, Chile, the urban agglomerations are highly fragmented and the central municipality is small. In these two cases, the metropolitan government was included instead: the Greater London Authority and the Region Metropolitana, respectively. The final dataset contains 401 urban areas (90% of 449), with Chinese cities ($n = 92$) notably constituting close to one fourth of all cities (see Appendix A of the supplementary materials for a list of all cities reviewed).

Climate change planning documents from municipalities were used as the data source for identifying and characterizing adaptation taking place. The documents were publicly available and accessed online. The documents were retrieved on a city-by-city basis using the search engine Google via a two-step process. The first step was to identify the city’s municipal website through a Google search of the city’s name. Subsequently, we scanned the site for climate change planning documents, either on the website itself or as standalone documents linked from the website. If no relevant documents were found on the website, an additional Google search was performed using the search terms *climate change* and the city name. The first 50 results (five pages) were reviewed based on title and page description from Google. Climate change planning documents were classified into four categories: (a) Municipal Adaptation Plans (MAPs), which focused exclusively on climate change adaptation and outlined the risks posed by climate change as well as the municipality’s responses; (b) Climate Action Plans (CAPs), which covered both mitigation and adaptation activity by the municipality; (c) adaptation web pages of municipal government websites, which outlined the adaptation activities of local governments but did not consist of standalone documents; and (d) adaptation documents developed by consulting firms or other external research groups in partnership with the municipality. Documents falling under category (d) were only found for Minneapolis, United States, and Cape Town, South Africa. For these two cities, we categorized the initiatives as “recommendations” because the

status and intent of implementation are unverifiable. Data were collected between January 2 and March 29, 2014, and any documents published after this date were excluded (see Appendix B for complete document inclusion and exclusion criteria and Appendix C for a list of documents reviewed). Data from the documents were used to produce a dataset of worldwide public health adaptation activity in cities. The use of publicly available climate change plans is consistent with adaptation tracking methods and provides consistency in the source of the initiatives, a key consideration in adaptation tracking studies.^{22,28}

A challenge in comparative policy research is to identify clearly what is being compared. A number of studies have sought to measure and compare adaptation progress, but they have often used conflicting frameworks and provide little agreement on what is understood as “adaptation policy.”²⁹ For example, some development-oriented initiatives have been considered “adaptation” because they alleviate underlying drivers of vulnerability (e.g., improved income or education),³⁰ whereas other studies have required adaptation to have a clear climate change lens.²⁹ In this study, we use the IPCC AR4 definition of adaptation as the “result of deliberate policy decisions based on awareness that conditions have changed or are about to change.”³¹ Documents were only included for analysis if they explicitly concerned climate change and the task of reducing vulnerability or increasing resiliency to climate change, as determined by a review of the document’s title and content. The database does not include information from non-governmental entities or cross-city international networks such as C40 Cities Climate Leadership Group. Documents focused exclusively on mitigation and sustainable development were also excluded from analysis. Sectoral plans were also excluded from analysis to facilitate comparison: although not every city has the same sectoral agencies, each city has a local government unit. This approach is consistent with previous adaptation tracking study designs.^{21,32,33} Policies and strategies that address current natural climate variability help reduce vulnerability to extremes, but adaptation policy must incorporate a consideration of changing future hazards and vulnerabilities. Our analysis excluded documents that address current or past climate risk without a consideration of how risk will change in the medium- and long-term future.

There are limitations in using publicly available municipal planning documents. First, the documents analyzed are only relevant to the municipal level and the findings cannot be generalized to the national scale. Different jurisdictions are responsible for different aspects of public health: although national levels commonly dictate broad policy directions, local governments plan and implement concrete strategies more quickly.²⁶ Second, there is a possibility that documents are already dated as there is a gap between document preparation and publishing and planning the initiatives themselves.

Finally, this study relies on adaptation reporting as a proxy for activity taking place. Thus we expect to capture the activities of governments with mechanisms for reporting and the capacity to produce planning documents. We do not argue,

however, that adaptation is completely absent where governments are not reporting it. Case studies on low-income urban areas have found that adaptation activity is often community-based or informal and goes unreported.^{23,34} Therefore, this study will not capture every action that increases the health resilience of urban dwellers and will only characterize government policy reported in publicly available plans. Nonetheless, it can be argued that public health requires government accountability in how policy is taking place and reporting on activities is an important indicator in itself.

Data Analysis

A systematic classification method was designed to quantitatively retrieve data related to health adaptation initiatives in planning documents (see Appendix D for coding examples). The following variables were collected for classification of each discrete initiative: health risk targeted, adaptation type, level of groundwork or action, and the importance of climate change as a driver of change (whether the initiative is new or mainstreamed). We also collected general information such as city location (latitude, longitude, country, and continent) and the title and language of the planning document.

Any initiative responding to the health risks of climate change was recorded for inclusion as an observation in the database. Health risks were defined and categorized as per the IPCC Fifth Assessment Report chapter on human health.² These health risks include extreme temperatures, floods and storms, water and food insecurity, air quality, and infectious diseases.² Initiatives addressing general health without specifying a risk were classified into a newly created category for “general health.” Similarly, initiatives alluding to extreme weather events without being specific about which risk they address (e.g., heat or flooding) were classified into a category for “general disaster preparedness.” Initiatives reducing vulnerability in other sectors (e.g., water supply or the built environment) may have implications for health without emerging from the public health sector directly. Rather than excluding these initiatives, we included them contingent on explicit evidence of recognition of the health benefits or prevention of harm.

Adaptation typology refers to the type of initiative being undertaken. The adaptation initiatives identified were classified into one of seven categories: (1) management, planning, and policy; (2) practice and behavior; (3) information and research; (4) capacity building; (5) physical infrastructure; (6) warning or observation systems; and (7) recommendations (adapted from Biagini and colleagues³⁵). Initiatives were also classified according to whether they are groundwork or action. Groundwork initiatives enable the conditions necessary to adapt, whereas actions directly reduce vulnerability.³³ Initiatives classified as groundwork can be understood as the initial steps toward building resilience, whereas adaptation actions directly protect the public’s health from climate

risks. Examples of groundwork include mapping vulnerable areas, assessing different options to cool the urban heat island, analyzing weather data, and creating relationships among stakeholders. Examples of actions include increasing the number of trees in the city, instituting early heat warning systems, implementing pest management systems, and mandating green roofs on new construction. Finally, initiatives were categorized according to whether they are new or mainstreamed. New initiatives are standalone measures designed with the sole purpose of adjusting to the actual or expected impacts of climate change. Mainstreamed initiatives are meant to add an adaptive climate change lens to existing policies, programs, or actions.³³

Initiatives were recorded as observations and the variables as columns in a spreadsheet. Descriptive statistical analyses and figures were created using STATA (StataCorp version 13). QGIS (OSGeo) was used to create a cartographic map illustrating urban public health adaptation initiatives.

Results

Of 401 cities analyzed, only 42 municipalities (10%) report planning or implementing public health adaptation initiatives (Figure 1). From these 42 cities, we

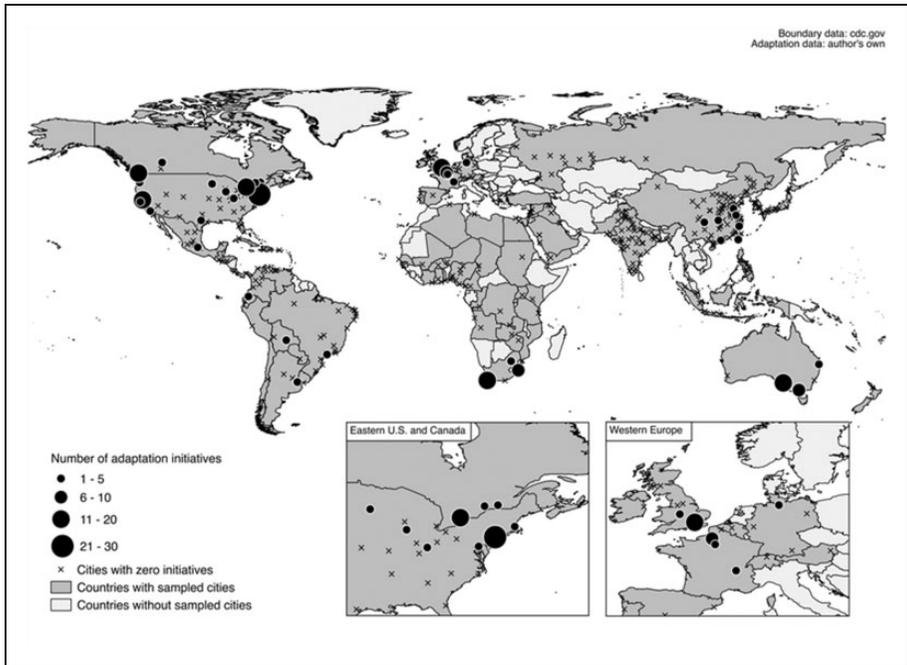


Figure 1. Geographic distribution of urban public health adaptation initiatives.

extracted 226 individual initiatives. Eight cities report 10 or more initiatives: New York City, Toronto, Sacramento, Vancouver, Adelaide, London, Melbourne, and Durban. New York City is the highest reporting city with 34 individual public health adaptation initiatives. On the low end, 10 cities report only one initiative: San Francisco, Edmonton, Zhongshan, Lyon, Bridgeport, Buenos Aires, Brisbane, Quito, Cincinnati, and Chongqing. In this section, we outline trends regarding geographic location of public health adaptation initiatives, health risks motivating change, adaptation typology, level of the initiative (groundwork vs. action), and whether initiatives are new or mainstreamed. Recommendations make up 9% (n=20) of total initiatives and are exclusively from Minneapolis and Cape Town. Both cities' adaptation plans were commissioned to external bodies and developed in partnership with the municipal government. All the initiatives described below are either in the planning process or have been implemented, unless noted as recommendations.

Health Adaptation Is Largely Being Reported in Cities of High-Income Countries

The majority of cities (67%, n=28) reporting any public health adaptation initiatives are in high-income countries, as per the World Bank's categorization of country and lending groups.³⁶ Another 31% (n=13) of cities reporting any public health adaptation initiatives are in upper-middle-income countries. In contrast, Santa Cruz, Bolivia, is the only city among the lower-middle-income countries or low-income countries to report adapting to the health risks of climate change. This trend suggests that public health adaptation reporting is patterned by national income and that municipal governments in high-income nations are more likely to plan and implement—or at minimum report on—public health adaptation.

Nonetheless, there are exceptions: Durban in South Africa reports high levels of adaptation initiatives relative to the median, despite being located in a middle-income nation. Notably, Durban is the only urban area among sampled countries in Africa to have published a dedicated and extensive planning document on adaptation to climate change. Durban also exhibits a significant focus on public health within its adaptation documents. As such, Durban can be viewed as a focal point for learning and sharing experiences on responding to—or at minimum reporting response to—the health risks from climate change. It is possible that urban areas in low- and middle-income countries are adapting but not reporting it. This may be explained in part by a lack of reporting capacity; however, the high variation in adaptation reporting within regions of similar capacity, such as within South Africa, where 43% (n=3) of urban areas with >1 million people (n=7) report any public health adaptation initiatives.

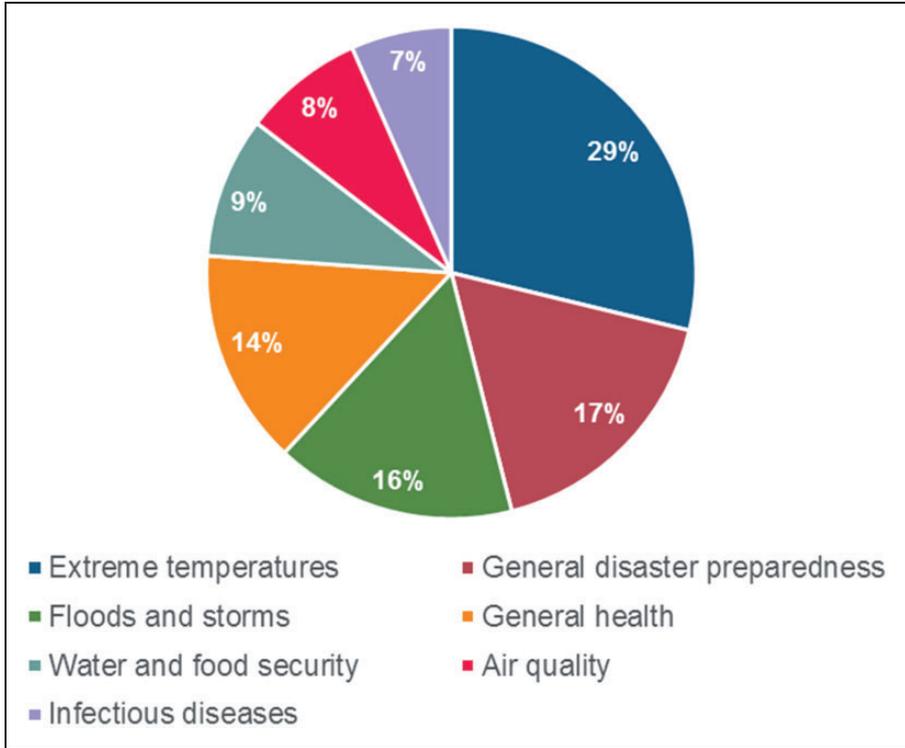


Figure 2. Adaptation types as percentages of total number of adaptation initiatives.

Preparations for Extreme Temperatures and Natural Disasters Are the Most Frequent Initiatives

Initiatives addressing extreme heat- and cold-related impacts are the most frequent (30%, n = 67), followed by general disaster preparedness responses (17%, n = 38) (Figure 2). Although the category for extreme temperatures includes cold-related effects, all of the temperature-related initiatives targeted heat. Common initiatives addressing heat risks include mapping the urban heat island to identify the most vulnerable locations (Baltimore), identifying areas with deficits of green spaces (Los Angeles), providing dedicated cool public spaces during heat waves (Sacramento), providing information about how to stay safe while outdoors during heat waves (Melbourne), and regularly ensuring water drinking fountains function correctly (Vancouver). General disaster preparedness activities often involve building redundancy and safe failure in preparation for extreme weather. In New York, for example, there is emphasis placed on ensuring the operation of critical services through protection from physical

damage.³⁷ Initiatives preventing damage from disasters include (from New York) retrofitting existing hospitals in the 500-year floodplain, installing backup generators for pharmacies, establishing temporary ambulatory clinics in vulnerable areas, and updating emergency response plans to account for increased potential of climatic-induced events (e.g., blackouts).

Floods and storms are the third most addressed health risks (16%, n = 36), followed by “general health” initiatives (15%, n = 33) and water and food security initiatives (9%, n = 20). Activities addressing floods and storms take the shape of mapping flood-prone areas (Boston), evaluating soft infrastructure’s potential for flood protection (New York), creating online data portals to allow flood risk management partners to share information (London), and planning and implementing integrated flood management systems in coastal communities (New York). General health initiatives target human health generally, but do not specify individual health risks. Initiatives of this type include expanding epidemiological analyses of health and environmental data (Sao Paulo), establishing systems to monitor the health impacts of climate change (Mexico City), vulnerability studies in the health sector (Paris), and enhancing awareness of climate health risks with leaflets (Hamburg).

Initiatives addressing air quality (8%, n = 18) and infectious diseases (7%, n = 16) are implemented less frequently. Air quality adaptation activities include increasing human resources allocated to air quality (recommendation for Cape Town), enforce pollution-related legislation (e.g., recommendation of black smoke legislation in Cape Town)³⁸ and increasing the tree canopy (Toronto). Initiatives to prevent the potential increase of infectious disease incidence include monitoring development in infectious disease vectors/pathogens (Hamburg), public awareness campaigns on conditions favorable to rodent or mosquito breeding (Durban), increase support for public health facilities to deal with diarrhea and dehydration (recommendation for Cape Town), and requiring drainage of untreated pools or other water features in homes and businesses that are not being maintained (Sacramento).

Mental health is not explicitly addressed by any initiatives, even though improved mental health has been identified as a significant co-benefit of green urban design.¹⁸ Mental health was originally left in data analysis as a type of health risk, but is absent from the figures and tables as none of the initiatives explicitly target mental health. UV radiation and land shifts were two other categories initially selected for classification due to their understood importance to morbidity, injury, and death,² but were eliminated when none of the initiatives addressed these risks in the context of human health.

Municipalities Favor Direct Adaptation Action Rather Than Soft Indirect Activities

From 226 extracted initiatives, 34% (n = 76) are groundwork activities and 66% (n = 150) are adaptation actions (Table 1). Practice and behavior (PB) initiatives

Table 1. Level of Adaptation Activity and Health Risks.

Health risk	Level	
	Groundwork	Action
Air quality	4	14
Heat- and cold-related	21	44
Floods and storms	9	27
General disaster preparedness	3	36
General health	9	23
Infectious diseases	4	11
Water and food security	8	13
Total	58	168

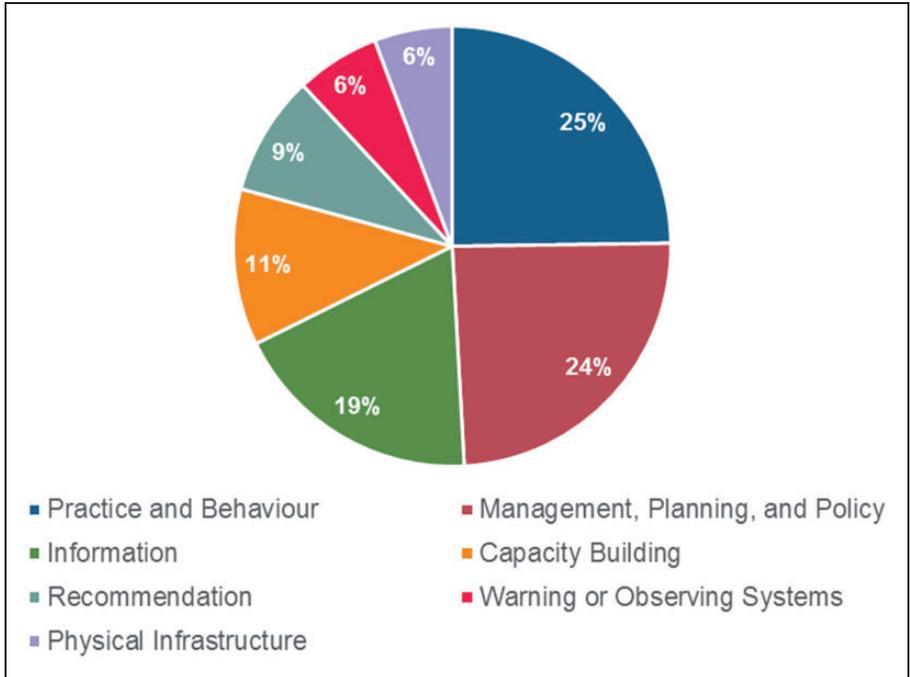


Figure 3. Health risks addressed as percentage of total number of adaptation initiatives.

are the most frequent adaptation type (25%, n = 56) (Figure 3 and Table 2) and can be characterized as changes of behavior directly associated with building resilience on the ground.³⁵ Initiatives of this type evident in adaptation of urban

Table 2. Cities by Adaptation Types and Health Risks.

Health risk	Adaptation type					Warning or observing systems
	Capacity building	Information and research	Management, planning, and policy	Physical infrastructure	Practice and behavior	
Air quality	Sacramento	N/A	Sacramento	N/A	Austin, Baltimore, Chicago, Marseille	Cape Town Ottawa, Toronto
Heat- and cold-related	Durban, Melbourne	Adelaide, Baltimore, Durban, London, Melbourne, San Francisco, Toronto, Vancouver	Chicago, Hamburg, Marseille, Montreal, Paris, Sacramento, Toronto, Vancouver	N/A	Adelaide, Birmingham, Chicago, Cincinnati, London, Los Angeles, Lyon, Marseille, Melbourne, New York, Ottawa, Paris, Sacramento, Toronto, Vancouver	Johannesburg, Ottawa, Toronto
Floods and storms	Chicago, London, Melbourne, Vancouver,	Boston, London, Melbourne,	Adelaide, Birmingham, Boston,	New York	Melbourne	Minneapolis Toronto

(continued)

Table 2. (continued)

Health risk	Adaptation type						
	Capacity building	Information and research	Management, planning, and policy	Physical infrastructure	Practice and behavior	Recommendation	Warning or observing systems
		New York, Portland	Brisbane, Edmonton, Jingzhou, Marseille, Montreal, New York, Sacramento, Vancouver				
General disaster preparedness	Durban, Jingzhou, New York, Sacramento,	New York, Wenzhou, Yangzhou	Adelaide, Austin, Bridgeport, Kaohsiung, Linyi, New York, Ottawa, Sacramento, Seattle, Sao Paulo, Vancouver	New York	Mexico City, New York	N/A	Yangzhou, Zhonshan
General health	Adelaide, Birmingham, London,	Baltimore, Birmingham, Buenos Aires,	Adelaide, Austin, Birmingham,	New York	Adelaide, Linyi,	N/A	Marseille

(continued)

Table 2. (continued)

Health risk	Adaptation type					
	Capacity building	Information and research	Management, planning, and policy	Physical infrastructure	Practice and behavior	Warning or observing systems
	Toronto, Wenzhou,	Durban, Marseille, Paris, Seattle, Sao Paulo, Toronto, Vancouver	Hamburg, Jingzhou, London, Melbourne, New York		Toronto, Vancouver	
Infectious diseases	Durban, Sacramento,	Baltimore	Marseille, Montreal	N/A	Adelaide, Durban, Kaohsiung, Ottawa, Sacramento	Cape Town Chongqing, Hamburg, Mexico City
Water and food security	Durban	Durban, New York, Toronto	Adelaide, Durban, Quito, Santa Cruz, Seattle	N/A	Adelaide, New York, Sacramento, Santa Cruz, Vancouver	N/A

areas are improving drainage in identified vulnerable locations (Melbourne), implementing permeable pavement surfaces (Toronto), improving sanitation in informal settlements (recommendation for Cape Town), and raising awareness among consumers regarding food hygiene practices during extreme heat events and power cuts (Adelaide). Management, planning, and policy initiatives are the second most reported type (24%, $n = 55$), often constituting direct changes in how management of resources takes place, thematic priorities in city plans, and changes in legislation. Example initiatives of this type include establishing emergency response plans (Austin), allocating budget for vulnerability research (Bridgeport), enacting legislation to limit air pollution (recommendation for Cape Town), and incorporating response to climate change impacts into health care provision and social services (London).

Information and research are less frequently reported ($n = 42$, 19%). This type of initiative is stressed by the *Lancet's* Commission on Climate Change as among the most important activity as it helps parse out potential risks and vulnerabilities. Initiatives of this type include developing vulnerability assessments (Paris), exploring improved approaches for vulnerability mapping (Marseille), and undertaking research to understand the impacts of climate change (Melbourne). Capacity-building initiatives can be understood as softer, more indirect activities and constitute an even smaller share of total initiatives (12%, $n = 26$). These types of initiatives include expanding public awareness (Durban), training workshops (London), creating information kits for health managers (Melbourne), and improving capacity to respond to emergencies through community education and outreach (Jingzhou).

The difference between direct and soft initiatives can be illustrated with a comparison of Los Angeles's (LA) and Toronto's approaches toward green roofs. The city of LA encourages homeowners to build green roofs and provides information on the benefits of impervious and reflective roof surfaces.³⁹ It can be understood that LA is providing conditions enabling for change with encouragement and information. Meanwhile, Toronto in 2010 instituted legislation (municipal bylaw) requiring all types of new construction to have green roofs, including residential, commercial, institutional, and industrial development.⁴⁰ This legislation change directly reduces vulnerability to climate change impacts as green roofs mitigate the intensity of the urban heat island and provide permeable surfaces for improved rainfall drainage.

Warning or observation systems constitute only 6% ($n = 14$) of total initiatives and often take the shape of early heat warning systems or flooding forecasting systems (Chongqing). Physical infrastructure initiatives are the least frequent (6%, $n = 13$) and can be found exclusively in New York. These initiatives adjust the architectural design of nursing homes and adult care facilities to increase flooding resistance so these institutions can continue functioning during storms.³⁷

Table 3. Category of Adaptation Activity and Health Risks.

Health risk	Category	
	Mainstreamed	New
Air quality	10	8
Heat- and cold-related	13	52
Floods and storms	15	21
General disaster preparedness	17	22
General health	13	19
Infectious diseases	6	9
Water and food security	8	13
Total	82	144

Most reported initiatives are new (74%, $n=168$) and not mainstreamed (36%, $n=82$) (Table 3). New initiatives involve the creation of new plans, strategies, or measures with climate change as the primary motivator for change. Mainstreamed initiatives, on the other hand, enhance, intensify, improve, or bolster the adaptive capacity of existing policies. The difference between new and mainstreamed initiatives can be illustrated with a comparison of Melbourne's and Sacramento's extreme heat plans. Melbourne is developing a program to provide community members with information about staying safe in the heat.⁴¹ This initiative is new and thus requires resources from the municipality: human resources to deliberate on and select the appropriate policy instruments to implement the initiative and financial resources to prepare and disseminate the heat awareness program. Sacramento's effort to update its heat response plan to include climate change effects is an example of a mainstreamed initiative.⁴² The heat response already exists, so the paths for implementation are already in place. Sacramento, therefore, will require fewer resources, namely in the form of information, to add climate change as a consideration in its heat response plan.

Discussion

To our knowledge, this article is the first global baseline of municipal reporting on urban public health adaptation initiatives. The key finding is that a large majority of municipalities sampled (90%) are not reporting implementation of any public health adaptation initiatives. This finding differs from results in previous self-reported, survey-based literature, where it has been found that approximately 35% of global municipalities report planning for the health risks from climate change.⁴³ Among the municipalities reporting adaptations, public health adaptation planning is still in its early stages.

Extreme heat, floods, storms, and other unspecified disasters are the most addressed health risks of climate change in municipalities (23, 17, and 17 cities report planning for these risks, respectively). However, there remains a large adaptation gap because studies have found that a number of cities reported recognition of risk from extreme heat (88 cities) and more frequent storms (43 cities), suggesting a time lag between cities' self-reported recognition of risk and the formation of actual plans.¹⁵ Notably, only 6% of heat-related initiatives are early warning systems, despite evidence that the use of these systems is growing in many large cities.⁴⁴ The majority of heat-related initiatives found in this study aim to reduce the long-term effects of the urban heat island through green infrastructure projects. Green infrastructure initiatives include expanding the urban tree canopy and converting rooftops into vegetable gardens. Although heat early warning systems focus exclusively on protecting citizens from extreme heat, green infrastructure provides wider co-benefits. Green urban design can promote active lifestyles through the production of a more appealing urban environment, thus improving public health.⁴⁵ The number of added benefits from green infrastructure, beyond reduction of the urban heat island, may explain why cities report a relatively low number of heat early warning systems compared to green infrastructure.

Direct actions, in the form of management, planning, and policy and of practice and behavior changes, are the most frequently reported urban public health adaptation initiatives. These baseline results highlight a key gap in adaptation: a very small percentage of cities report any planning toward climate change health risks. Other gaps identified include limited adaptation in the Global South, lack of information-based adaptation initiatives, few initiatives addressing infectious disease risks, and the absence of monitoring, reporting, and evaluation (MRE).

Although cities in high-income countries (and, to a lesser degree, upper-middle-income countries) have begun reporting on adaptations that respond to the projected health impacts of climate change, there remains an important gap in our understanding of adaptation in the Global South, where populations will be most affected by the health impacts of climate change.¹⁸ The lack of evidence of reporting on urban health adaptation planning in India (100% of sampled cities non-adapting, $n = 43$ cities sampled) or China (92%, $n = 86$) is particularly notable, two countries where more than one third of the world's population lives.⁴⁶ Populations in the Global South will be faced with disproportionately high health impacts of climate change. Moreover, the existing considerable inequalities within urban areas in the Global South will be exacerbated by climate change, where the health burden among the urban poor will grow, particularly among those living in slums and informal settlements.⁴⁷ The absence of reporting on adaptation planning in urban areas of low- and middle-income countries may correspond to a lack of resources, knowledge, and institutional capacity to adapt, or simply to lack of reporting of adaptation measures.^{48–50}

In other contexts, institutional capacity and good governance have been shown to be drivers of adaptation.³² The complexity and uncertainty surrounding the pathways between climate change and health heighten the challenges faced by urban planners, public health officials, and health professionals.^{3,51} To reduce vulnerability, urban adaptation in the Global South must sustainably manage rapid urbanization and reduce poverty and disaster risks.⁵² Although adaptation may be occurring in the absence of reporting, lack of reporting in itself reflects lower prioritization and a proxy for reduced adaptation capacity, thereby constraining oversight, sharing of experiences and best practices, and monitoring and evaluation mechanisms.

Although identifying problems and objectives, assessing risk, identifying options, and appraising options have been identified as some of the first steps in adapting to climate change,⁵³ half of the adapting cities (55%, $n = 23$) do not report any information-based adaptation initiatives. These findings suggest a potential lack of climate change and health research or information for local governments. One of the Lancet Commission's primary recommendations is to "Invest in climate change and public health research, monitoring, and surveillance to ensure a better understanding of the adaptation needs and the potential health co-benefits of climate mitigation at the local and national level,"¹⁸ emphasizing the importance of research and information for public health adaptation to climate change. It is possible upper-level governments are filling this gap and providing information to lower-level governments, as is the case in Canadian jurisdictions.²⁶ Similarly, the Swiss national government plans to support adaptation in the cantons, municipalities, and cities by supplying targeted information, ensuring the transfer of knowledge between levels.⁵⁴ Among academic sources, literature on best practices for urban adaptation tends to focus on the developed-country context (e.g., New York City,⁵⁵ European cities,⁵⁶ and Canadian municipalities⁵⁷), despite the significant adaptation barriers related to low capacity in developing countries.^{58,59} Adaptation science is needed specifically for cities in the Global South to investigate ways of planning and implementing adaptation in the context of low governance capacity (e.g., limited material and financial resources).

Climate change is expected to alter patterns of vector-borne infectious diseases and food- and water-borne infectious diseases and increase disease incidence and prevalence.^{2,60,61} For example, the incidence of Lyme disease has risen swiftly in Europe and North America, where the geographical range and upper temperature limits of ticks, the disease vector, are spreading northward.^{62,63} Likewise, climate change is projected to expand the geographic area suitable for dengue transmission globally.⁶⁴ Infectious disease transmission will also be mediated by non-climatic factors, such as adaptation or socioeconomic development.⁶⁴ Despite the many infectious disease risks associated with climate change, our findings suggest infectious disease risks are not consistently being addressed by adaptation initiatives (Figure 2). Given the pervasive health risks

posed by infectious diseases and climate change, the issue has received disproportionately low attention and focus at the local level. Although it is possible national governments are filling this gap due to the inter-jurisdictional nature of some infectious disease threats, Panic and Ford's⁶⁵ review of national-level adaptation initiatives addressing infectious disease risks in Organisation for Economic Co-operation and Development countries demonstrates that adaptation for infectious disease risks also remains a gap among many national-level governments. The need for community-based adaptation to the health risks posed by climate change and stakeholder engagement have been highlighted in the literature.⁶⁶

Among the municipal adaptation plans reviewed, there is little evidence of monitoring, reporting, or evaluation (MRE) of adaptation in reducing vulnerability or increasing resilience. Vancouver is one of the exceptions among the urban areas sampled and includes provisions for annual reviews in its municipal adaptation plans.⁶⁷ MRE is needed to track and assess outcomes of adaptation initiatives and interventions; ensure accountability and efficient allocation of resources; target, justify, and monitor adaptation funding; and facilitate comparison of adaptation achievements.^{21,68,69} Stakeholder engagement in adaptation planning and MRE is essential for ensuring the needs of vulnerable populations are addressed in public health adaptation, particularly among poor and marginalized groups in the Global South.⁶⁶ MRE of public health adaptation initiatives remains a gap that must be addressed in urban adaptation planning.

A lack of MRE evidence in adaptation plans, however, does not mean that MRE is not taking place, because reporting bias is a limitation of this study. Governance capacity has been found to be a determinant of whether governments publish their climate change plans for the public,³² and low-capacity government may be unfairly penalized in this study due to non-reporting of adaptation activity taking place. Differences in public information disclosure norms across cities and countries may also have affected the availability of climate change documents. There is evidence that vertical coordination across different levels of government is crucial for planning effective public health policy.⁷⁰ This study focused on the city scale, and evidence of interactions with other levels of government, especially the national government, may not appear in municipal climate planning documents. Additionally, cities may have sectoral agencies (e.g., water supply authorities) that produce climate planning documents, but these were excluded from analysis by the study design. Finally, search comprehensiveness is a limitation for any adaptation tracking study, and there may be publicly available documents that are not accessible via web.

A second limitation is that this study tracks reported adaptation initiatives, but the methods presented here cannot verify whether the initiatives have been implemented in reality or whether they have successfully reduced vulnerability to

climate risk, a common challenge in adaptation MRE.²⁹ Lack of sufficient detail and unclear language often obfuscated whether reported initiatives are in the planning stage or have been implemented.

Conclusion

Adapting to the health risks of climate change is paramount to ensuring populations' well-being.^{18,71,72} The current and projected health impacts of climate change vary by region, but are expected to exacerbate existing inequalities and burdens of disease,⁴⁶ and specific risks may include extreme weather events, changing patterns of infectious diseases, deteriorating air quality, declining food security, and mental health impacts.² In this article, we have used a systematic approach to empirically review and characterize reporting on public health adaptation in 401 urban areas globally. We find that most urban areas ($n=359$, 90%) are not reporting any public health adaptation initiatives. This finding suggests there is a significant gap between the risks faced by cities and municipal responses to these risks.

The few urban areas reporting public health adaptation initiatives are primarily in high-income countries, indicating a significant gap in health adaptation reporting in low- and middle-income countries. The limited research- and information-based initiatives, the lack of initiatives addressing infectious disease risks, and the absence of MRE have also been identified as important gaps in urban public health adaptation to climate change. The methodological framework employed in this study can be applied in the future to measure progress on global urban public health adaptation, yet is premised on addressing reporting bias across nations, particularly in the Global South. In light of mounting health risks² and growing financing for adaptation,²¹ this type of standardization in adaptation tracking is necessary to measure progress at a global level.²²

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