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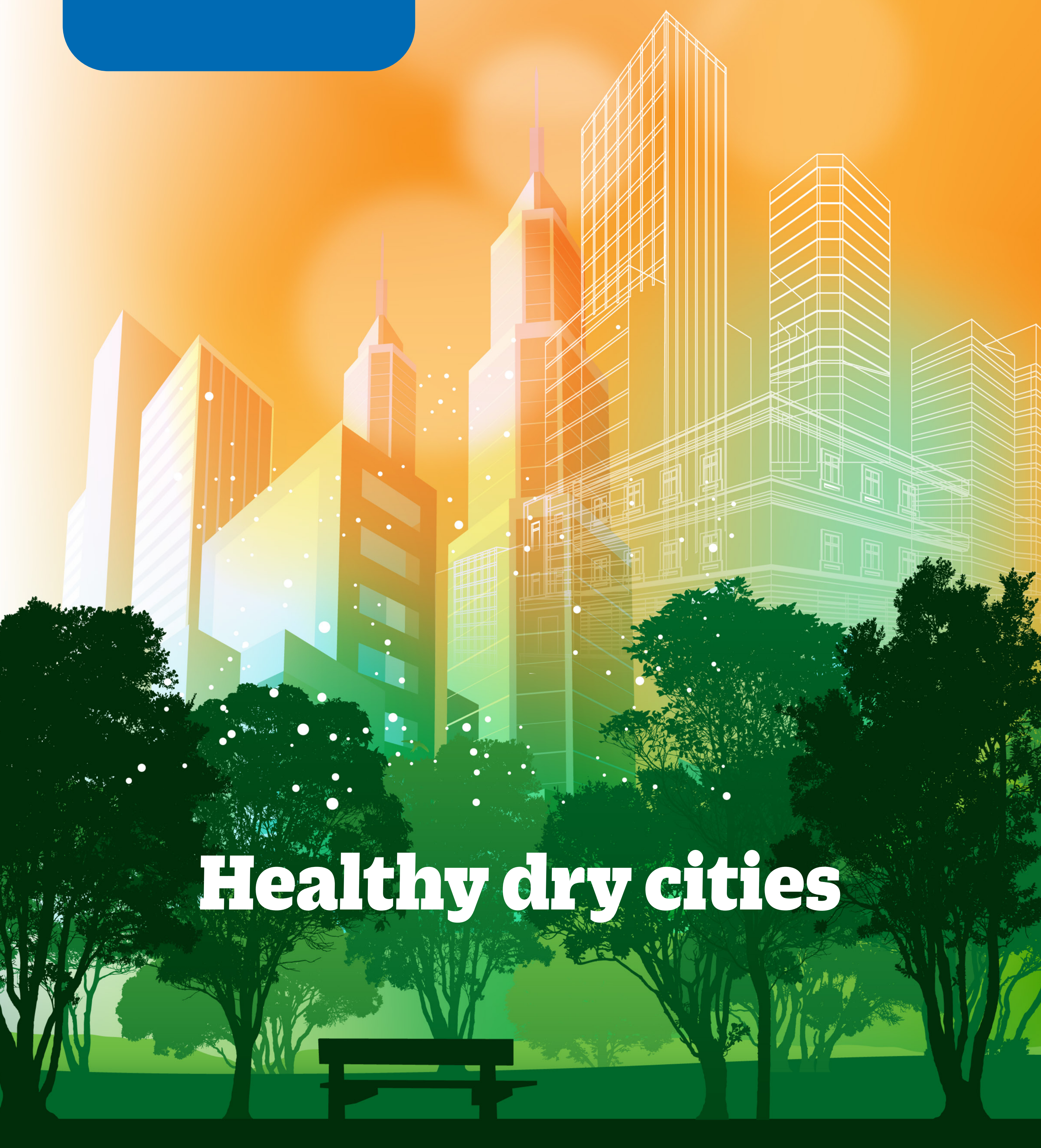

Healthy dry cities

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Protecting health in dry cities: considerations for policy makers

Increasing health and wellbeing in cities that experience water scarcity presents challenges, but can be done, say **Howard Frumkin and colleagues**

Water has always been essential for cities to survive and thrive. The earliest cities, from 4000 BC, were founded near water sources. Conversely, water scarcity might have contributed to the demise of ancient cities such as Tikal in present day Guatemala and Angkor in present day Cambodia.[1 2] Water deprivation was also used as a weapon in ancient times; when Sennacherib of Assyria ransacked Babylon in 689 BC, he destroyed the city's water supply.[3]

Dry cities present complex challenges in a dynamic world. The supply of water in many cities will increasingly fall short of demand, with diverse and potentially severe effects on health. In a world of pervasive inequalities, water scarcity is likely to hit the most vulnerable hardest. The challenge of achieving health in dry cities is intensified in the setting of resource scarcity, state and societal fragility, and weak institutions.

The inter-relation between human health and the environment needs to be central to planning and management of both water and health systems. Promoting health and wellbeing in dry cities is essential to achieving the sustainable development goals. Innovation will be key to progress; it requires foresight, strong institutions, and action from many people.

Today's global population is increasingly urban, and the world is increasingly hot, with dry regions becoming drier. Dry cities have scarce water relative to demand. An estimated 150 million people live in cities that have perennial water shortage.[4]

Some cities are dry because of their location in arid environments, with low levels of fresh water, precipitation, or both. In the year 2000 about 27% of the world's urban area was in drylands.[4] Many of the world's most water stressed countries are in the Middle East and North Africa (box 1). Doha, Abu Dhabi, and Dubai in the Gulf region, and desert cities, including Cairo (Egypt) and Windhoek (Namibia), Antofagasta (Chile), Trujillo (Peru), Phoenix, and Las Vegas (United States) are widely recognized as "dry cities."

Other cities are dry because of a temporary scarcity of water, or drought, influenced by factors including local hydrology, climate, and human activities.[6 7] Semi-arid regions may have dry cities if drought strikes, if demand grows much faster than supply and/or if the city cannot keep pace owing to poor governance or inadequate infrastructure. Such cities include Cape Town (South Africa) and Gaborone (Botswana). Other cities, such as São Paulo (Brazil) and Chennai (India), historically have had ample water supply, but have recently confronted scarcity. Still others, such as Los Angeles (US) and Bangalore (India), are forecast to become short of water in coming years.

KEY RECOMMENDATIONS

- Strengthen health systems in dry, hot areas, including their ability to engage in multisectoral adaptation planning
- Develop national policies that give greater autonomy to cities, and policies in dry cities that build systems that are inclusive, transparent, and accountable to residents
- Invest in better management of water resources, including better technology and management of demand and supply
- Invest in better tools and diagnostics to guide water system management
- Develop effective social marketing, which can drive change in public behavior, protecting health and conserving water
- Invest in nature based solutions, which provide foundations for sustainability and wellbeing

How to define a healthy dry city

The covid-19 pandemic shows how health crises can emerge in urban areas and how water availability is crucial for good hygiene and containment of disease through handwashing and proper sanitation. A healthy city is "continually creating and improving those physical and social environments and expanding those community resources which enable people to mutually support each other in performing all the functions of life and developing to their maximum potential."[8] This definition emphasizes that health, at the urban scale, has both physical and social dimensions.

The physical dimensions include elements of the natural environment—ecosystems both within cities and in their surrounding regions[9]—and aspects of the built environment. These include traditional characteristics of urban health, such as water, sewage and waste infrastructure, air quality, and housing, as well as urban design, transportation systems, food systems, and parks and greenspace, which have only recently resurfaced as public health concerns after decades of neglect.[10 11]

The social dimensions of healthy cities include not just the extent of poverty and inequality or access to health and social services and to employment, but also the sense of community and social cohesion, as well as the opportunity for all inhabitants to assert their social identity, freedom, and autonomy, and to have voice in urban governance.[12]

All cities share health challenges, but dry cities have some unique challenges, as climate change and scarcity of water intensify rising heat and propel diseases of hot climates. A healthy dry city manages its physical and social environments when water is scarce to optimize the health and wellbeing of all its inhabitants. Healthy dry cities are achievable with the right policies and institutions, and with the space for innovation.

Broader context matters

Dry cities, and their quest for health, exist in the setting of increasing urbanization, inequality, environmental hazards, and climate change, and the coexistence of different health risks.

Urbanization

More than half (>55%) of the world's population live in urban areas, and this level is projected to rise to two thirds by 2050. This

Box 1: The world's most water stressed nations[5]

Extremely high baseline water stress

Qatar, Israel, Lebanon, Palestine, Iran, Jordan, Libya, Kuwait, Saudi Arabia, Eritrea, United Arab Emirates, San Marino, Bahrain, India, Pakistan, Turkmenistan, Oman, Botswana

High baseline water stress

Chile, Cyprus, Yemen, Andorra, Morocco, Belgium, Mexico, Uzbekistan, Greece, Afghanistan, Spain, Algeria, Tunisia, Syria, Turkey, Albania, Armenia, Burkina Faso, Djibouti, Namibia, Kyrgyzstan, Niger, Nepal, Portugal, Iraq, Egypt, Italy

led the United Nations in 2018 to identify urbanization as one of four "demographic mega-trends," the others being population growth, aging, and international migration. Yet patterns of urbanization vary among and within countries. Asia and Africa are expected to see the fastest growth in urbanization (fig 1). A rise in absolute numbers of urban dwellers will also be concentrated in these continents.

Much urban growth will be in arid regions. According to one estimate, urban areas in arid regions globally will nearly double in size by 2030, from just below 300 000 km^2 to almost 500 000 km^2.[15] With growth in demand for water exceeding growth in supply, the number of people living in cities with perennial water shortage is projected to reach almost one billion by 2050.[4] Migration is a key driver of urbanization and is driven in part by factors such as droughts and natural disasters. Migration can place pressure on cities that may already be water scarce.

Inequality

Although cities and towns often offer opportunities for people, and have better infrastructure than rural areas, they are beset by high levels of inequality. Almost one fourth of the world's urban population, over a billion people, lived in informal settlements ("slums") in 2018, most in Asia and Africa.[16]

Slums are associated with poor quality housing, water, sanitation, and other services, leading to, among other outcomes, higher rates of disease and death.[17,18] Rich households, on the other hand, are often located in areas with piped water and during water shortages can build storage facilities, tap into underground wells, and pay for delivered water. Only 38% of households among the poorest fifth of India's urban population have access to indoor piped water compared with 62% of the richest fifth.[19]

Environmental hazards

Urban residents are subject to diverse environmental hazards, including air and noise pollution, high levels of waste generation, and deprivation of green space and blue space (natural streamfronts, riverfronts, and coastlines). For instance, 97% of cities with over 100 000 inhabitants did not meet air quality guidelines in 2016.[16] Increasing pollution, especially in countries that are rapidly industrializing and have lax environmental controls, also threatens water quality.[20,21]

Waste generation is correlated with economic development and urbanization, and thus low and middle income countries, with the least capacity for sustainable waste management,[22] are likely to see the largest increase in waste production. Water scarcity can amplify the effects of urban environmental hazards—for example, by concentrating water pollutants and limiting provision of green space.

Covid-19 has highlighted particular health challenges of water scarcity and heat. Examples include the difficulty of handwashing when water access is limited[23,24]; the difficulty of socially isolating indoors when the temperature is extremely hot; and the paucity of green space and parks—important assets for restoration during the pandemic[25,26]—in hot, dry places.

Climate change

Climate change amplifies the challenges of dry cities in at least two ways—namely, by reducing water availability and by increasing heat. Reduced water availability results from reduced rainfall in regions that are already dry. Rising temperatures increase evaporative loss of surface water and reduce summertime flow in snowmelt fed rivers.[15,27-31] Additionally, dry weather can be punctuated by sudden heavy rainfall, a well recognized phenomenon in arid regions.[32,33]

An estimated 1.8 billion people are affected by abnormal rainfall (both high and low) every year.[34] This disproportionately occurs in developing countries, and particularly cities. In addition, many coastal cities, including some in arid regions, are experiencing saline intrusion of their water tables, due to a combination of sea level rise, withdrawal of groundwater, and settling of the city.[35-38]

Dry cities are often also hot cities. Global projections of heating trends[39] and studies in dry cities such as Mashhad (Iran),[40] Delhi (India),[41] and in major Chinese cities[42] indicate that water scarcity and heat will intensify in tandem in many cities.

Double burden of health risks

Cities and towns, especially in low and middle income countries, are characterized by the coexistence of infectious diseases such as HIV/AIDS, tuberculosis, pneumonia, dengue, diarrhea, and covid-19, and non-communicable diseases such as heart disease, cancer, and strokes—the so called double burden.[43,44] Additional health burdens such as violence and injuries, including road traffic injuries, and mental health problems, also exist.

Such coexistence is seen across the world in settings as diverse as Accra, Ghana,[45] Pune and Maharashtra, India,[46,47] and in many Chinese cities.[48] Some infectious diseases thrive in hot cities where water is scarce. Therefore, health systems, especially in low and middle income countries, have to be simultaneously prepared for diseases of both richer and poorer contexts. Dry cities, in addition, confront unique health hazards, some of which relate directly to water scarcity, whereas others are caused indirectly.

Specific health considerations

Infectious disease

Waterborne and water related infections, caused by bacteria such as *Escherichia coli*, *Vibrio cholera*, and *Salmonella typhi*, and viruses such as rotavirus, hepatitis A virus, and poliovirus, are major causes of childhood deaths and malnutrition across the lifespan. Clean water, free of microbiological contaminants, is essential for infectious disease control.

When the water supply is unreliable, people resort to informal sources of water such as street vendors and to home water storage, both of which are associated with water contamination. Household drinking water containers can be breeding grounds for mosquitoes such as *Aedes aegypti*, the vector of dengue fever,[49] which threatens 2.5 billion people worldwide and is on the rise.[50,51] Similarly, re-wetting after drought can alter water table levels, vegetation, and aquatic predators, all of which affect mosquito populations.[52] Access to water in healthcare facilities is essential, because shortages undermine safe childbirth[53] and hinder control of hospital infections.[54]

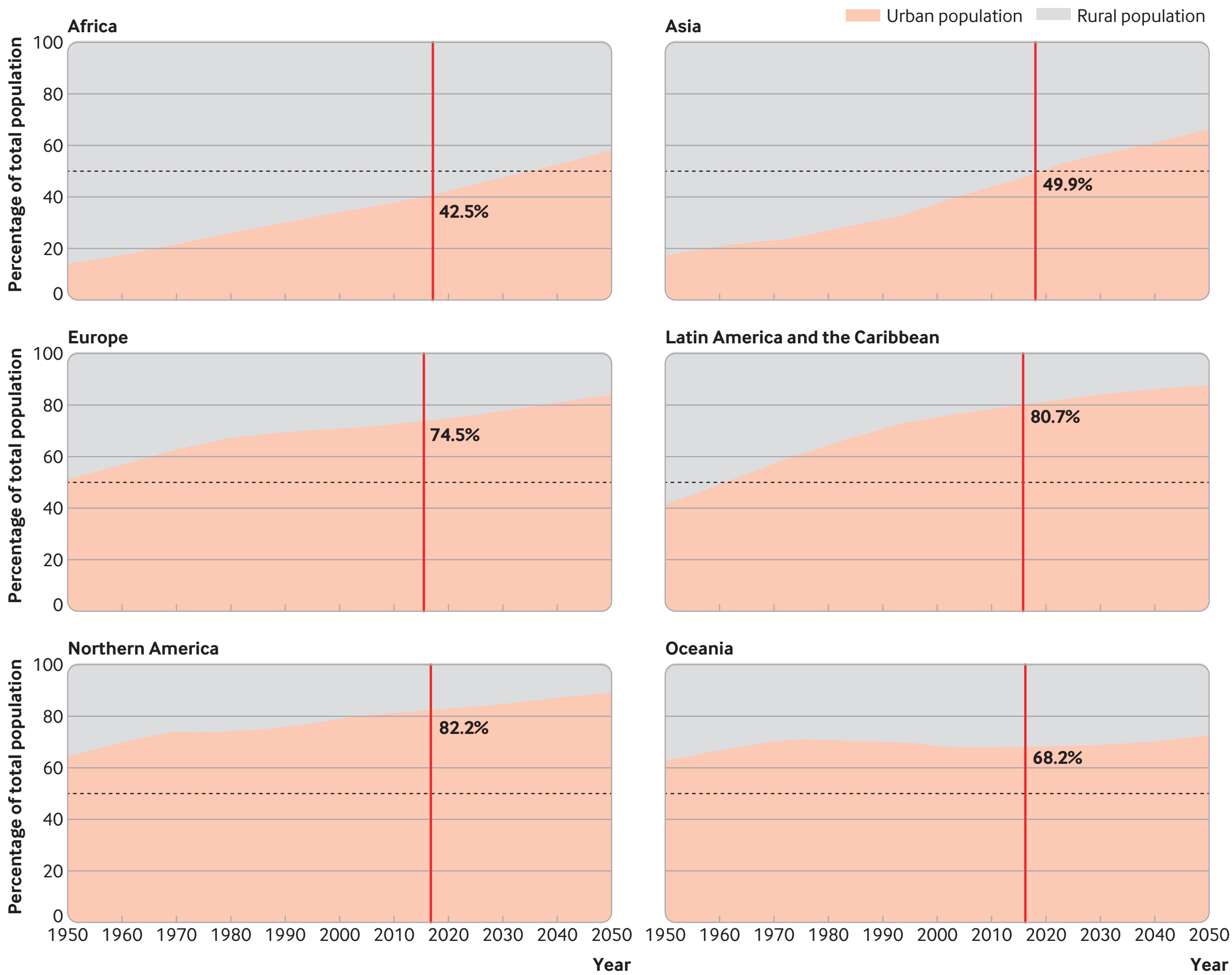

Fig 1 | Growth of urbanization by world region 1950-2050[13 14]

An additional link between water scarcity and infectious disease is the use of wastewater in agriculture. In arid countries in the Middle East and North Africa, water scarcity increases the use of black and gray water for crop irrigation—a useful adaptive measure but a hazard if the water is inadequately treated.[55] Contaminated food may then enter the urban supply.

Non-communicable disease

Water scarcity and heat also affect the risk of non-communicable diseases. Severe heat exposure, especially without readily available water for hydration, has health effects ranging from mild symptoms to more severe respiratory and neurologic difficulties, heat stroke, and mortality.[56]

The scarcity of water, especially when linked to high temperatures, may aggravate the risk of non-communicable diseases in other ways: stress (cardiovascular risk), reduced availability of fresh foods (metabolic syndrome), kidney damage, reduced sleep quality (cardiovascular risk), and reduced physical activity. Older people and those with pre-existing health conditions are especially vulnerable, as are those who are poor, socially isolated, and who lack access to facilities such as cooling centers.[57 58] Other groups at considerable risk are outdoor workers such as construction workers, police officers, and street vendors, and industrial workers in non-air conditioned facilities.[59 60]

Heat can also lead to increased ground level ozone and air pollution from fine particulate matter. These exposures increase the risk of cardiopulmonary disease, including risks of symptom aggravation, hospital admission, and death.[61]

Mental health

Water scarcity threatens mental health in rural populations, related to economic losses from crop failures, humiliation and shame over financial struggles, and social isolation in times of drought.[62] Displaced rural populations may bring these problems when they migrate to cities—compounding the mental health impacts of migration itself.[63] In addition, the constant stress of lack of clean water for domestic use, the burden of having to fetch water from public water points, and the threat of flooding, contribute substantially to anxiety and depression. Often, this burden falls mainly on women, who are responsible for managing water for domestic use. Furthermore, lack of sanitation and water affects women when they are menstruating, after childbirth, and during the menopause, often with deleterious consequences for their health and dignity.[64]

Violence and conflict

Some evidence links high temperatures with aggressive behavior, violent crime, and possibly suicide.[65-68] Such societal tension can escalate into armed conflict. In addition, several dry cities are in areas with already fragile states. The links between the scarcity of natural resources and armed conflict are controversial,[69] but some studies suggest that intrastate or interstate competition for resources such as water may be increasingly associated with armed conflict.[70] Armed conflict, in turn, undermines the health of both combatants and civilians in many ways.[71 72]

Child development

Evidence links childhood exposure to drought with poor growth throughout childhood[73] and with long term effects on health, including disability, in adult life.[74] Several mechanisms may operate, including poorer nutrition due to reduced agricultural output, increased gastrointestinal and respiratory infections due to scarcity of clean water, and reduced resources for childcare and education due to poverty.[73]

Sweetened beverages are an additional pathway from water scarcity to child development. When water is unavailable or expensive, parents may provide their children with sweetened drinks instead, increasing the risk of obesity, diabetes, and heart disease. Popkin et al[75] found that providing filtered drinking fountains, water bottles, and advice to children at school led to increased water ingestion by 1.1 glasses a day and to a 31% reduction in their risk of being overweight.

Promoting health in dry cities

Policy has a critical role in ensuring that cities do not suffer from being dry and that the health of their residents is promoted. Although the health sector is central, many solutions are multisectoral.

Health systems

Health systems in dry cities, especially in low and middle income countries, can be strengthened by investing in leadership, governance, health workforce, information systems, essential medical products and technologies, service delivery, and financing.[76]

For example, health infrastructure and equipment should be adapted to drier and hotter conditions, the health workforce should be trained for morbidity exacerbated by drought, health information systems should be timely and include drought related health indicators, and accessible healthcare should be provided.[77] A study that examined adaptation of the health system to heat and water scarcity in 13 low and middle income countries identified further examples of resilience, including a malaria early warning system in Kenya and safe reuse of wastewater in Jordan.[78]

Urban governance

With respect to urban governance, systems approaches based on collaborative, cross-sectoral planning and implementation are most successful.[79] Decentralization permits cities to raise their own resources and plan and implement policies.[80] Municipal policy makers need to invest in institutions that will facilitate better management of water demand and supply. These include water utilities, health infrastructure, and regulatory and enforcement agencies.

Another characteristic of good urban governance is accountability to residents, with city governments making information publicly available, investing in public education, and strengthening citizens' voices. Civil society has a critical role in urban governance, facilitating the government-citizen collaboration. Non-government organizations are often also service providers and policy analysts and advocates. Cape Town's recent water crisis shows the importance of integrating equity and justice issues as part of water and health governance.[81]

In India, non-governmental organizations successfully promoted large scale toilet blocks in informal urban areas, including community based schemes in which users maintain the facilities based on sense of ownership. Intersectoral partnerships and stakeholder engagement, including local communities, are fundamental in the healthy cities movement and promote community empowerment and urban health.[82] Finally, cities can provide help and incentives for innovations led by non-state personnel such as citizens' groups and the private sector. There are good models for urban water and health governance, but few examples in the context of dry urban environments.[83]

Improve supply and manage demand

Water resource management includes both technical and administrative solutions. Strengthening the resilience of a city's water supply requires reducing water demand, diversifying available water sources, and incorporating technologies that allow the whole water cycle to be managed as an integrated, flexible, and adaptive system.[84 85]

For example, recycling of wastewater and harvesting of stormwater provide alternative sources to substitute or supplement scarce drinking water supplies, while also creating a range of additional environmental benefits.[86] For example, by 2010 Melbourne recycled more than 20% of its wastewater, providing 3% of its annual municipal demand through recycled wastewater and captured stormwater. These developments were driven by government targets set both to reduce pollution discharges to waterways and to provide alternative water supplies during Australia's millennium drought, and tight regulation ensured water quality that protects public health.[87 88]

Storage options such as aquifer recharge and rainwater tanks retain water for later use during dry periods. Desalination has been an important tool for many cities,[89] but has some disadvantages. It requires large amounts of energy, which often comes from fossil fuels; it produces large quantities of brine[89 90]; and it removes iodine from seawater, which may contribute to iodine deficiency disorders.[91]

Regional approaches

Even as cities take initiatives in managing water scarcity, regional approaches are needed because watersheds do not respect political boundaries. Competition between urban and rural areas for water is common and is often politically charged.[92] Yet, there are also examples of equitable distribution of water resources and of water sharing between geographical areas.[80 93 94]

For example, a complex legal and administrative structure in the US state of Arizona governs the allocation of water between agricultural irrigation and domestic use in cities.[95] Finally, policy on water tariffs and pricing is highly contested and political. Some argue that it brings market discipline to a typically underpriced commodity, whereas others maintain that it disadvantages poorer people and makes a commodity of something better viewed as a human right.[96 97]

Assess risk

Assessments that identify hotspots of high vulnerability to water shortage and disease can be an important tool for decision makers in prioritizing measures towards better management of healthy dry cities. For example, an assessment in Brazil calculated vulnerability based on poverty, education, and access to piped water.[98] Another assessment in China included additional indicators such as the length of water supply pipelines, number of beds in healthcare institutions, built-up area, and population density.[99] The covid-19 pandemic presents an opportunity to develop new tools and methods for better assessments.

Behavior change

Water scarcity and the extreme heat that often accompanies it require city dwellers to adapt. Some of this change can directly protect health, such as avoiding outdoor exertion during hot times of the day, carrying water and keeping hydrated, and being alert to signs of dehydration and hyperthermia. Other behavioral changes benefit health indirectly by conserving water.

The general principles of social marketing—simple, clear messages, repeated often, from a variety of trusted sources—are highly applicable.[100] Messaging should be evidence based,[23] involving target communities and offering practical advice that increases self-help.[101] Messages are most successful when there are high levels of social cohesion and trust[102]—a basic requirement for community health resilience. The most effective media to use—newspapers, radio, television, social media, or trusted voices such as members of the clergy—will vary across and within cities and subpopulations.[103]

Nature based solutions

Solutions based on natural or modified ecosystems provide benefits for both biodiversity and human wellbeing.[104] For example, street trees, vegetation, irrigated green space, and green technologies (such as biofilters, constructed wetlands) can cool urban microclimates through shading and evapotranspiration,[105-107] as well as control stormwater pollution and flows. Trade-offs need to be made explicit and addressed; for example, trees may provide shade that reduces the need to air condition buildings, but at the cost of increased water demand.[108] Nature based solutions also provide opportunities for physical activity, passive recreation, and social connection which may contribute to the prevention of non-communicable diseases and improve mental health.[109]

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Infographic: Towards health dry cities

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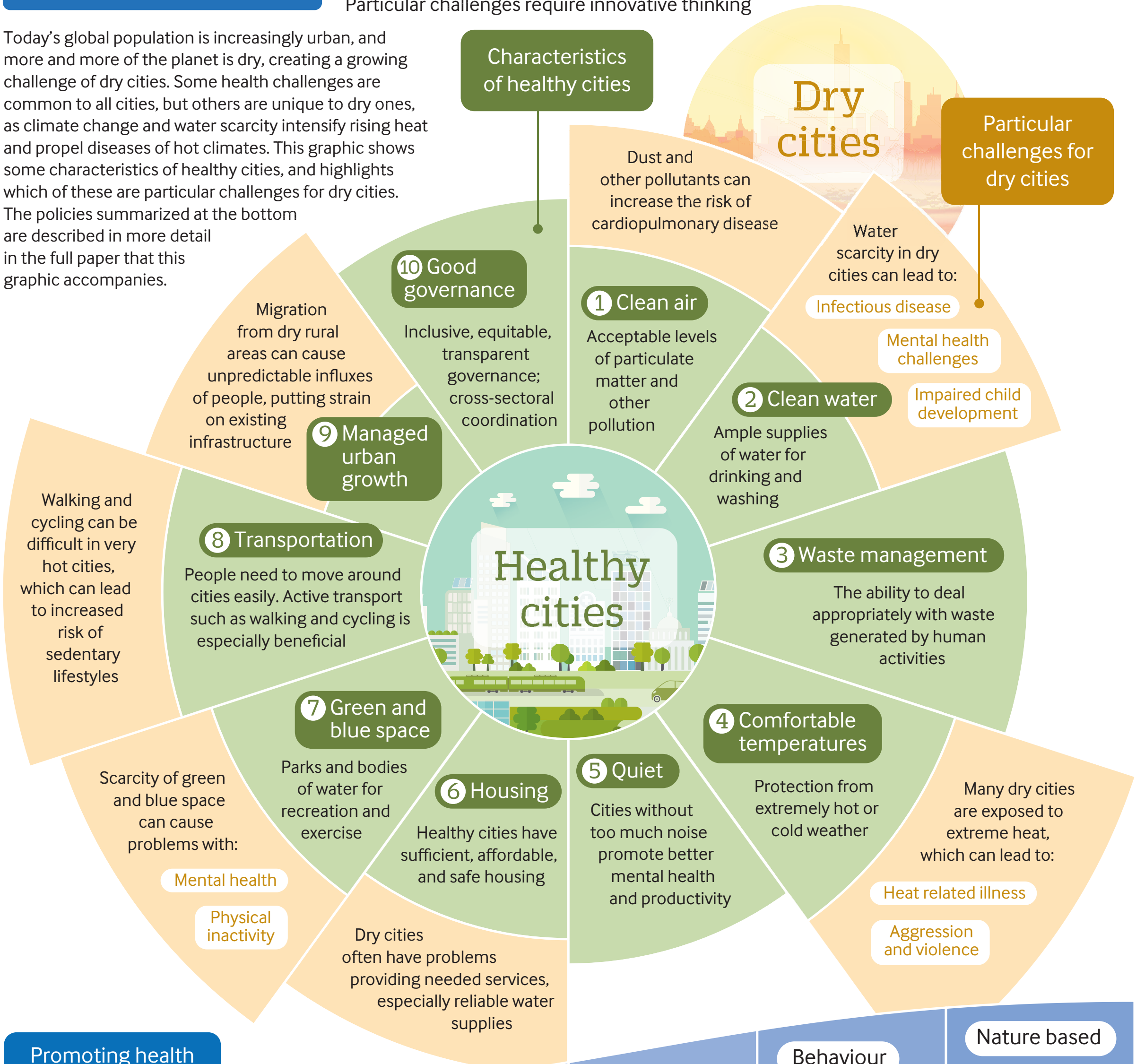
thebmj Visual summary

Towards healthy dry cities

Particular challenges require innovative thinking

Today's global population is increasingly urban, and more and more of the planet is dry, creating a growing challenge of dry cities. Some health challenges are common to all cities, but others are unique to dry ones, as climate change and water scarcity intensify rising heat and propel diseases of hot climates. This graphic shows some characteristics of healthy cities, and highlights which of these are particular challenges for dry cities. The policies summarized at the bottom are described in more detail in the full paper that this graphic accompanies.



Promoting health in dry cities

Health sector	Governance	Water	Assessments	Behaviour	Nature based
Health infrastructure, equipment, indicators, and training should be adapted to drier and hotter conditions	Decentralization is often a key driver of success, as it gives autonomy to cities, permitting them to raise their own resources and plan and implement policies	Improving water supply involves reducing demand, diversifying available water sources, and managing the water cycle using integrated, flexible and adaptive systems	Assessments and diagnostics that identify hotspots of high vulnerability to water shortage and disease can be an important tool for decision makers in prioritizing measures towards better management of healthy dry cities	Water scarcity and extreme heat both require adaptive behavior change by urban publics, including avoiding exertion, keeping hyrdated, and conserving water. Effective social marketing is needed to drive behavior change	Solutions based on natural or modified ecosystems provide benefits for both biodiversity and human wellbeing. For example, urban vegetation can cool urban micro-climates through shading and evapotranspiration
Characteristics targetted: 1 2 4	All	2	2 6 9 10	2 4	1 2 4 5 7

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An agenda for better health in hot and dry settings

As increasing numbers of people are at risk of health harms related to water scarcity, **Carlos Dora and Roberto Bertollini** call for an urgent agenda to promote research and action

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Today, two billion people live in water scarce environments,[1] face related health risks,[2] and their number is rapidly growing. However, no framework exists to protect their health. Health leaders are yet to take up opportunities for health protection in dry environments that could also save resources.

Some options are available now—for example, health systems can switch to water saving taps, reuse waste water,[3] and harvest rainwater.[4] The water savings can help replenish and support parks and other green infrastructure, protect against floods, and create opportunities for outdoor physical activity to improve mental health,[5] enable children's contact with nature,[6] and reduce excess city temperatures ("the urban heat island effect").[7]

Opportunities to promote health extend well beyond the realm of healthcare. Connection to public transport, and shaded cycling and walking routes, while enabling better access to healthcare also increases healthy social interaction.[8] In parts of the world where people spend much of their time indoors because of the heat, adequate space and ventilation will help reduce the spread of infections like covid-19.[9]

Water availability has a beneficial effect on non-communicable diseases by encouraging local fruit and vegetable agriculture and reducing consumption of sugar sweetened beverages if water fountains are installed in public spaces and schools.[10]

Cross sectoral advantages are often overlooked by standard measures of health risks,[11] but considering drivers of health risks in other sectors, such as land use, buildings, transport, and agriculture, helps identify ways to reduce disease burden through better sanitation and hygiene, reduction in non-communicable diseases, and improved child health and nutrition.

Preventive action

An urgent agenda of research and action is required to develop more efficient and effective societal responses to the health risks unique to water scarce settings, which affect a growing number of people worldwide.[12] Firstly, health risks must be mapped to their root causes, including in sectors other than health. Opportunities for synergistic preventive action can be identified, along with gaps, constraints, and enabling factors. Existing knowledge, tools, and initiatives can be shared.

Secondly, we should engage communities, policy makers, and researchers, to identify barriers, motivate them to develop a better response to health risks, and obtain support to implement pilot schemes.

Thirdly, leading cities and regions can cooperate to move from analysis to policy and program implementation by agreeing ways to track progress, identify success, and exchange learning.[13] One approach would be to drive the response by convening a coalition for health in dry environments, bringing together interested groups from civil society, research, and philanthropy that is geared towards action and implementation.

These initiatives would find synergies with existing global, regional, national, and local agendas and funding mechanisms, such as those to combat climate change, desertification, and water shortages.[14]

Success will only be achieved if health systems in dry cities strengthen their capacity to work with and influence other sectors,[15] drawing on experience from the Health in All Policies and Intersectoral Action for Health agendas promoted by the World Health Organization and championed by several countries.[16] Health leadership will be central to prioritizing, funding, and implementing this agenda in dry cities, as well as safeguarding women's health concerns and reducing health disparities experienced by poor people and members of disenfranchised minorities.[14]

An ambitious agenda along these lines can unlock the potential for health protection in dry environments and contribute much needed adaptation to an increasingly water scarce world. This month delegates at the World Innovation Summit for Health will discuss health challenges in dry cities.[17] They are well placed to commit to lead and support such a collaboration and can launch a network, develop the discipline,[18] and realize this agenda.

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Planetary health approaches for dry cities: water quality and heat mitigation

Water sensitive cities show how holistic approaches can counter the health and wellbeing problems associated with urban dryness, write **Tony Wong, Nigel Tapper,** and **Stephen Luby**

About 1.6 billion people live in countries with water scarcity, and this number is projected to double in two decades.[1] Cities tend to conflate and amplify the challenges this brings, adversely affecting the health and wellbeing of their inhabitants.

Global increases in population and urbanization have increased demand for natural resources such as water. Climate change has exacerbated the effect of these trends, and many cities now have insufficient water supply to meet demand.[2] Long term adaptation of global cities to climate change is crucial, especially as it can also improve the urban environment, provide health benefits, and mitigate further climate change.

Many responses to 21st century water challenges continue to rely on entrenched technocratic approaches of the 20th century such as trunk supply of potable water for all purposes. Contemporary approaches to improving population health, however, emphasize holistic responses with social as well as physical dimensions, as Frumkin and colleagues highlight.[3]

New or adapted water infrastructure should be integrated, flexible, and adaptive, incorporating "nature based solutions." Simultaneously, social resilience should be strengthened to improve health outcomes, including through raising community awareness of water insecurity and the behavioral changes needed and building societal capacity for innovation. Governments need to create the environment in which such transformations can occur.

Contemporary urban water management affects population health in two ways. Firstly, water scarcity can reduce the quality of water accessed by urban populations, worsening health and wellbeing, particularly among poorer and more vulnerable populations. Secondly, increasing frequency and intensity of heat waves affect population morbidity and mortality. We use our experience of managing water in informal settlements in developing countries to show the challenges that these communities face, with possible solutions that approach water scarcity holistically.

Integrated urban water management and water sensitive cities

Over the past decade, city planners, water authorities, practitioners, and researchers in Australia have collaborated to envision "water sensitive cities," and their principles are now emerging in city design.[4] This new model has emerged in scientific, policy, and practice domains and is embodied in concepts such as integrated water cycle management.[5] This is a vision of holistic urban water management incorporating physical and social dimensions, including water availability for potable and non-potable uses such as industry and agriculture; safety from flooding; safety from waterborne diseases and urban heat; health and wellbeing associated with biodiversity and ecological health; and social cohesion associated with green public spaces.

Integrated water cycle management aligns with planetary health framing.[6] Although the challenges of water security are acute in dry cities, the water sensitive cities approach is relevant in all climates.

Two key principles of water sensitive cities are that our cities are water supply catchments and that they provide ecosystem services. In essence, water sensitive cities efficiently use the diverse water resources available within their boundaries, including recycled water and stormwater; enhance and protect the health of urban waterways and wetlands; and mitigate flood risk and damage.

Water sensitive cities create public spaces and green infrastructure that harvest, clean, and recycle water, increase biodiversity, sequester carbon, and reduce urban heat island effects (whereby cities tend to be hotter than surrounding rural areas). A third principle espouses building and nurturing the social capital within cities for climate adaptation and resilience. These social-technical concepts reframe our water governance arrangements and can improve the health and wellbeing of communities vulnerable to diminishing water security.

Protecting water quality

Water scarcity affects access to water of sufficient quality, as well as quantity. Sources used for drinking, washing, and recreation that are contaminated with fecal waste expose the community to serious health risks; fecal-oral transmitted diseases are a leading cause of death for children globally. These challenges are not confined to dry settings. Many cities in wetter climates are still challenged by seasonality and variability of water availability, water quality, and equitable access to suitable water sources.

A common response to increasing demand and diminishing capacity is to supply water for only a few hours a day. But intermittent supply can recontaminate treated water with fecal organisms as contaminated water can intrude through joints and cracks in the water network as it is intermittently depressurised, further worsening health outcomes.[7,8] The pathways are often associated with groundwater contamination caused by poor sanitation and drainage services, contamination from floods, and anthropogenic pollution of waterways.

Contaminated water sources (including groundwater) and living environments profoundly affect the health and wellbeing of people living in slums or informal settlements. These people are among the most disadvantaged urban dwellers, lacking conventional trunk infrastructure approaches of the 20th century, and bearing the brunt of increasingly severe droughts and floods.[9,10] They show the intrinsic link between ecological and population health. No access to clean water and sanitation, combined with poor drainage and a lack of flood management, exposes residents to multiple fecal contamination pathways. Frequent floods expose residents to a high level of environmental fecal contamination, with their vulnerability exacerbated by extreme events arising from climate change.

Framed by planetary health principles, a water sensitive cities approach developed alternatives to current sanitation solutions for informal settlements. A randomized controlled trial in Indonesia and Fiji is evaluating these interventions for improvements to population health and wellbeing, and also ecological health.[11] This research may offer an alternative to failed 20th century approaches by deploying nature based solutions that respond to social and physical context.

The interventions, formulated through a community co-design process, combine

Fig 1 | Water sensitive slum upgrading interventions providing flood-free and contamination-free access to dwellings with a sewage network and wetland technology for safe sanitation services at Batua, Makassar, Indonesia

established approaches to water, sanitation, and drainage services with nature based technologies that fit into dense urban communities. This effort combines expertise from many disciplines, including epidemiology, water engineering, ecology, landscape architecture, urban water governance, and behavioral science. The interventions concurrently aim to tackle water scarcity, non-existent or inadequate sanitation services, flooding and associated contamination, and a degraded water environment from poor land use and industry practices. Specifically, they include access to a variety of sources of water with quality that is fit for purpose, safe collection and treatment of sewage and grey water, improved flood protection and drainage, and the use of nature based systems to improve the ecological health and quality of the natural and built environment. Underpinning the success of all of these interventions is the change in attitude, behavior and day-to-day practices of residents. Figure 1 shows the development of a water sensitive intervention in a typical slum environment, providing flood-free access to dwellings with local sewage collection and treatment through a constructed wetland built along the accessway.

Co-designing the interventions with communities is essential for capturing specific biophysical context of fecal contamination pathways such as sanitation practices, flood vulnerability, drainage efficacy, and locations of daily activities, including children's play, domestic solid waste disposal, and household cooking and washing. The process also raises communities' awareness of their environment and vulnerability to fecal contamination and thus strengthens community resilience to improve hygiene practices. The participatory co-design promotes community understanding of the functional roles and benefits of hybrid nature based interventions and willingness to take responsibility for operating and maintaining the interventions. These include periodic maintenance of mechanical parts, desludging of the communal septic tank, maintaining healthy wetland plants, and routine surveillance of the operational efficacy of the interventions.

Reducing mortality and morbidity from urban heat

Increasing heat wave conditions expose cities and towns to another public health concern. Extreme heat events in Australia, for example, have caused more deaths since 1900 than any other natural hazard. An examination of extreme heat events in Australia from 1844 to 2010 found the number of deaths attributed to heat exposure was 4555 (55% of total deaths caused by natural hazard) compared with 1221 from flooding, the next highest cause of death. Causes of death were assessed from several sources including the media, government reports, and death certificates, and the estimated number of deaths attributed to heat exposure is a lower bound estimate.[12]

Post-event analysis shows clear temperature thresholds or tipping points across all climate zones of Australia, with little adverse health response below thresholds but substantial rises in adverse health outcomes above them. A study in Melbourne (which has a dry hot summer climate) identified an average 24 hour temperature threshold of 28-30°C,[13] above which mortality increased by 15-17% for people older than 65 (fig 2).

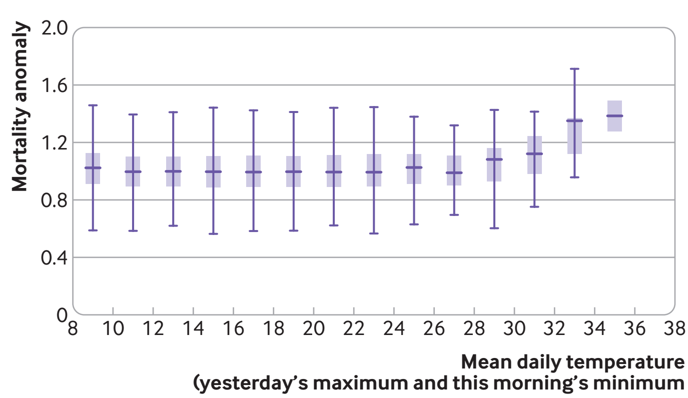

Fig 2 | Mortality anomalies (excess deaths) associated with heat among >65 year olds for Melbourne, Australia. Mortality rises substantially for temperatures above 28-30°C[13]

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A subsequent study developed a heat vulnerability index[14] that extended the heat threshold concept to all Australian capital cities, including those with wetter and humid sub-tropical and tropical climates. This work showed clear spatial patterns of vulnerability relating to socioeconomic factors and led to better preparedness among the population and emergency services along with targeted cooling interventions that have saved lives.[15]

Strategies to reduce temperatures by 1-2°C at the critical heat thresholds will reduce heat related mortality and morbidity. For example, installing fountains and misting systems increases direct evaporative cooling; creating lakes and ponds provides surfaces that stay relatively cool in daytime. Urban greening such as forests, parks, vertical gardens, and other nature based features contribute to cooling through evapotranspiration and shading (fig 3). But all these strategies increase water demand. The principle that cities are water supply catchments indicates that recycled water and stormwater could be used.

Intrinsic link between ecological and population health

The potential health benefits of a water sensitive approach are not confined to dry cities. Evidence based policy drawing on the many dimensions of urban design and water management could improve the health and wellbeing of all communities. Water sensitive city approaches highlight the intrinsic link between ecological and population health, and how urban water management can benefit both aspects. They also highlight the importance of supporting physical interventions by building or strengthening social resilience, through greater community awareness and society's capacity for fostering transformative change.

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Stephen Luby is director for research at Stanford's Center for Innovation in Global Health. He has worked full time on health research in low income countries for the past 25 years, including living in Pakistan for five years and Bangladesh for eight years. He is particularly interested in developing and evaluating approaches to counter the perverse incentives where people earn money by destroying the environment and health.

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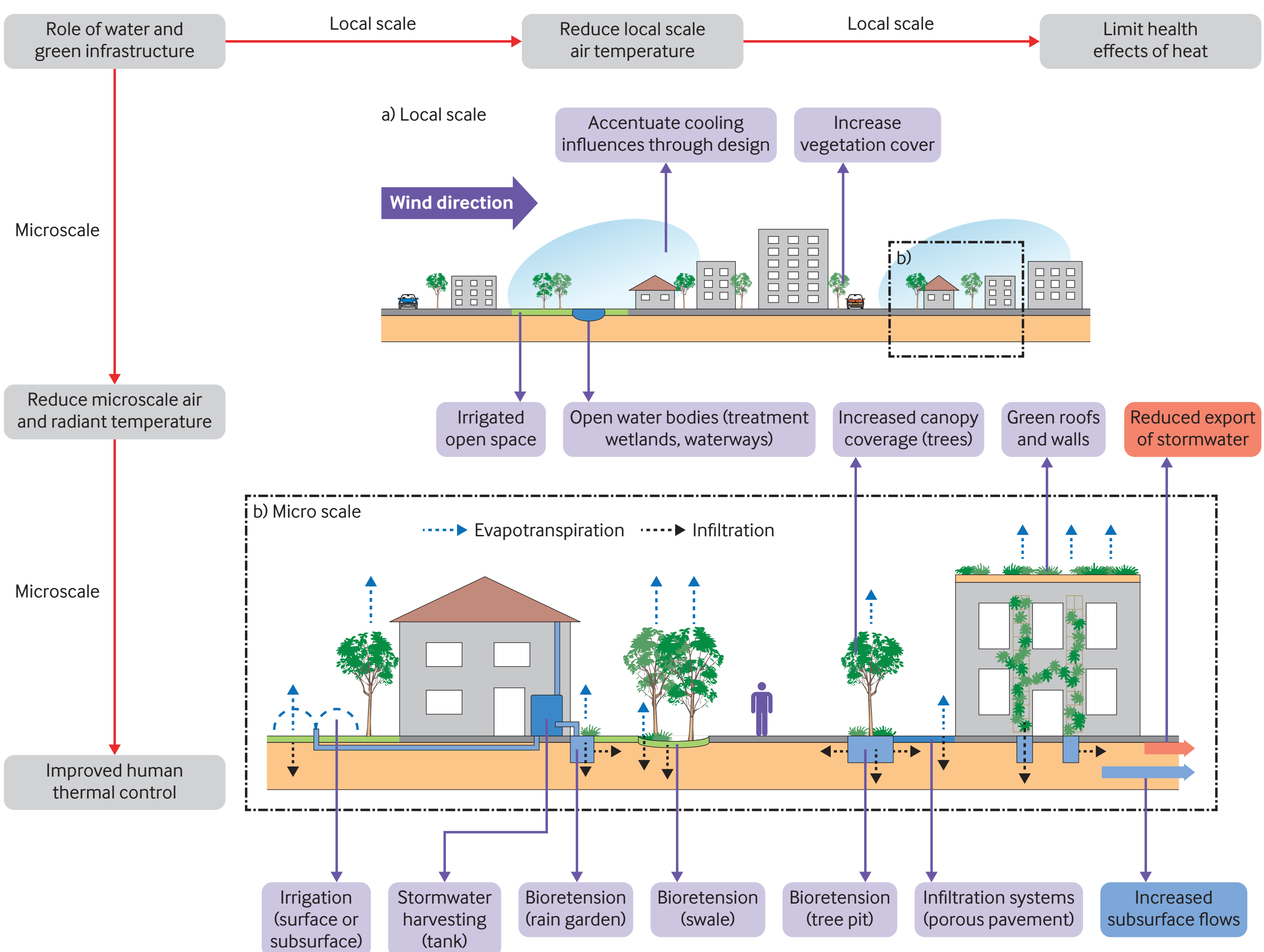

Fig 3 | Water sensitive city cooling technologies[15]

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Protecting health in dry cities: from evidence to action

Cities in the US and beyond are increasingly claiming heat readiness as the climate crisis escalates, while starting to recognize its disproportionate burden on poorer residents. But are their plans sufficient, and can they implement them fast enough? **Mara Kardas-Nelson** reports

Throughout July 2019 school students and volunteers meticulously mapped the outdoor air temperature across the US city of Yonkers in New York state. Although water scarcity is not a concern in the area, the 200 000 residents of Yonkers are increasingly affected by heat—and some demographics more than others.

The spatial temperature data collected were then compared with maps showing tree density and surface materials, such as concrete and asphalt. These factors help to create the "urban heat island" effect, whereby cities tend to be hotter than surrounding rural areas. The data were also compared with maps showing residents' wealth and historically "redlined neighborhoods," where government and banks have systematically denied neighborhood development and housing loans for people of color.

This work found something striking: Yonkers' once industrial south west neighborhood, still a poorer residential area mostly home to people of color, is on average several degrees hotter than the city's leafier, whiter, more suburban areas.

Temperature differences can lead to health inequalities. Heat kills more than 600 Americans a year, according to the Centers for Disease Control and Prevention,[1] and likely contributes to many more. And heat related morbidity and mortality are expected to rise, particularly among vulnerable populations.[2]

The project in Yonkers was led by GroundWork, a non-profit organization founded by the National Park Service and the Environmental Protection Agency. It partnered with Vivek Shandas, a professor of urban studies and planning at Portland State University who studies the interplay between socioeconomic and racial inequalities and heat vulnerability.

Shandas was not surprised by the findings. Across the US, people of color are more likely to live in neighborhoods rich in impermeable surfaces, densely built from old, heat trapping materials like brick, and lacking trees and parks. Throughout America, poorer neighborhoods can be as much as 7°C warmer than wealthier neighborhoods nearby.[3]

Countrywide, Shandas and colleagues have shown that economically marginalized and racially segregated neighborhoods are on average 2.6°C hotter than non-redlined areas.[3] Groups like GroundWork are using these findings to press for investment in parks and sustainable, heat ready housing in such neighborhoods.

Preparing for heat

The non-profit advocacy organization the Union of Concerned Scientists estimates that by the middle of the 21st century more than 90 million Americans will be exposed to at least 30 days a year when the temperature exceeds 40.6°C—compared with just 900 000 today.[4] With heat waves regularly affecting cities from Phoenix, Arizona, to Washington, DC, the need to adapt to this sweltering new norm is clear, but cities' climate adaptation plans are often lacking,[5] and solutions are deficient in political will and funding.

Cities have proposed various responses: warning systems that help residents to plan by stockpiling water, limiting physical activity, and using air conditioned public buildings designated as "cooling centers."[6] They've also suggested that installing drinking water fountains could reduce dehydration. Painting streets and roofs white might reduce temperatures, some cities claim.[7]

Cities from Los Angeles to Baltimore to New York have proposed increasing tree coverage. One of the oldest and simplest solutions to urban heat, urban planting at sufficient density can reduce temperatures.[8,9]

The Los Angeles advocacy group Tree People, funded by the US Department of Agriculture Forest Service, claims trees could cool adjacent air by up to 5°C and that one in four deaths due to heat in the city might be saved with increased tree cover.[10]

Brigitte Griswold, who leads the GroundWork project in Yonkers, told *The BMJ*: "Trees can solve multiple problems. They provide shade, help increase biodiversity, absorb heat when pavement releases heat in the night time, and encourage people to be outside and do physical activity."

Phoenix's grand plans

Temperatures regularly exceed 38°C in Arizona's Sonoran desert, home to Phoenix, the state's largest city. With climate change and as Phoenix grows, the city is getting even hotter; this summer was the hottest on record.[11] Things are expected to get worse: by 2060 the Phoenix area could have double the number of days a year over 43°C (there were a record 34 this year).[12]

Residents have sustained third degree burns from baking sidewalks. Arizona recorded more than 2000 heat related deaths over the 10 years from 2009 to 2019.[13] Last year, Phoenix recorded 200 heat related deaths, disproportionately in hotter, poorer areas where most residents are people of color.[14] Not all heat related deaths are captured in death records, so this is likely to be an undercount.

Phoenix aspires to be "heat ready" by implementing a warning system, painting streets white, shading bus stops, requiring new buildings to provide shade, and offering commuters cooled neck scarves.[15] Last summer, 200 homeless people used a temporary cooling center at the city's convention center. A city-wide aim for 25% tree coverage by 2030 could return Phoenix to the "city of gardens and trees," as it was known 100 years ago, before the highways and skyscrapers.[16] In 2014, the most recent data available, the city had just 13% tree cover.

But critics like Shandas argue that the city is not moving fast enough and that its fledgling, piecemeal interventions lack focus on historic inequalities. He points out that the city is not providing energy assistance to historically disadvantaged communities, even though access to air conditioning could mean the difference between life and death.

Poorer residents, such as those in Edison-Eastlake, want improvements to protect them from heat now, but planning and funding timescales can be five to 10 years.[12]

The city accepts that heat deaths "may be attributable to reductions in social service programs that directly or indirectly protect people from heat."[17] It also recognizes that heat affects poorer residents unequally and has projects focused on improving poorer residents' homes to resist heat. Phoenix aspires to have a holistic strategy for heat by 2021, with measurable goals. Until then, uncoordinated programs get just a few years of financial support at a time.

"Heat related efforts are scattered throughout the government, and heat is sometimes only one of several goals that a particular project or policy intends to address," says David Hondula, associate professor at Arizona State University. Funding is also often split among departments and external grants.

Dryness and heat mitigation

Increasing dryness is also a problem. The Salt, Verde, and Colorado rivers, which supply the city, suffer from overuse and persistent drought. The Colorado river is expected to shrink by a quarter by 2050 as a result of overuse and climate change.[18] Threatened water supplies put Phoenix's promise to increase tree cover at risk. About half of the city's water is already used for irrigation, with greater volumes needed when temperatures rise.[17]

The Sierra Club's Bahr worries that the city will miss its tree goal. "Often, when trees die or there's a storm, they're simply not replaced because there's no plan and funding for maintenance," she says. The city admits that trees have been lost faster than it can replace them, its tree budget much lower than in other US cities.[19]

Phoenix's chief sustainability officer, Mark Hartman, says that heat mitigation efforts have been "almost exclusively focused on vulnerable communities." He maintains that Phoenix is marching toward its "urban forest" goal, spending over $5m (£3.9m; €4.3m) to plant 4000 trees a year, with a new focus on low income areas that need cooling the most.

Cities putting ambition into action

Some cities around the world have put plans into action, with more comprehensive, longer term approaches. Singapore launched its Landscaping for Urban Spaces and High Rises policy in 2009. This requires all new building developments to include planting of the same footprint. With planting on rooftops, the sides of high rise buildings, and apartment balconies, the city is becoming greener.

Singapore's centralized government might explain its leadership in urban climate preparedness, Shandas says. But other cities are catching up. Arnhem, in the Netherlands, is removing 10% of its asphalt surfaces and adopting "cooling down" spots—with ponds and covered areas—near busy neighborhoods. These actions are alongside ambitious national goals to reduce greenhouse gas emissions to 95% of 1990 levels by 2050 to try to slow climate change.

Some US cities have ambition too. Ordinances in Los Angeles require tree planting, and all new public and private buildings must have reflective roofs, with a goal to reduce the average difference between urban and rural temperatures by 1.7°C by 2035.[20] Austin has suspended electricity shut-offs for poorer residents so they can keep air conditioning on.[21]

The US Union of Concerned Scientists advocates for a comprehensive, national approach, with minimum cooling standards in public housing and funding for cooling strategies, alongside ambitious cuts to carbon emissions (the US currently has no emissions reduction plan).[6]

Shandas supports coordinated government intervention countrywide, including energy assistance programs for poorer households and tax breaks to encourage new homes to use heat resistant building materials and roofs.

In the meantime, cities like Yonkers are taking small steps. After consulting with GroundWork, Shandas, and residents, the city is hoping to increase tree cover and offer solar power to low income residents. Empirical data are vital for making the case for investment, says Wilson Kimball, president and chief executive of the city's municipal housing. But funding is yet to be found.

Fledgling, pragmatic initiatives still count, Shandas emphasizes. "It's saying, 'Now that we have to maintain our roof, let's paint it white. Now that we have to establish a cooling center, let's plant trees outside.'"

But what he finds exciting is that policy makers like Kimball are paying attention to the interplay between heat and inequality. "How do we get systems that have created inequities to prioritize disinvested communities?" he asks.

Tackling the disproportionate impact of heat and dryness on poorer neighborhoods offers opportunities to improve people's lives in other ways. GroundWork's Griswold says, "You can't solve the problem without looking at public health, environmental health, racism, and poverty."

Box: What are Phoenix and Arizona doing to tackle climate change?

- Phoenix plans to be carbon neutral by 2050. But campaigners, including the non-profit Sierra Club, want more ambition and faster progress. It wants the city to declare a climate emergency and carbon neutrality by 2030.[22,23]
- Despite facing extreme and perpetual drought, the city has no plan to reduce water use. It also has no plan to cap development, despite being one of the fastest growing US cities and extremely car dependent, with 60% of its carbon emissions from transportation. Also, Phoenix's nuclear power plant relies on water and may not be able to operate in extremely hot weather.
- Arizona hasn't come close to reaching a goal to reduce greenhouse gas emissions to 2000 levels by 2020.[24] Critics such as Sandy Bahr, the Phoenix chapter director for the Sierra Club, accuse the state government of underplaying the looming climate crisis and its impacts. "The city has elevated the conversation about heat related health, but the state has really done nothing," says Bahr.
- Arizona's 2017 state-wide climate and health adaptation plan mentions "climate change" only once, focusing instead on monitoring extreme weather and educating citizens on preparation.[25] Its 2018 heat response plan notes that homeless, ill, and senior citizens are more at risk from heat but does not consider how to tackle the structural inequities such as racism and income inequality that can affect vulnerability.[26]

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City design for health and resilience in hot and dry climates

Cities in regions including the Middle East can use a variety of approaches to promote wellbeing among the people who live and work there despite dryness and heat, write **Maya Negev and colleagues**

The health of people living in cities is affected by urban design elements including density, distribution of land use, building design, transport infrastructure, green spaces, opportunities for social interaction, and accessibility to work, education, healthy food, and culture.[1,2] Several of these elements pose particular challenges when designing healthy cities in hot and dry regions such as the Middle East, where weather may constrain active transport, outdoor recreational physical activity, and outdoor socializing.

Studies of the impact of urban design on health in arid regions is scarce,[3] with most research from the global north. A climate and culturally sensitive approach can, however, inform adaptation of evidence from temperate climates to hot and dry climates (table).

KEY RECOMMENDATIONS

- Climate sensitive urban design: create compact cities with shaded public spaces, using trees and artificial shading
- Connectivity and accessibility: emphasize public transport with passive cooling in stations and cooling in buses, trams, and trains; shaded and safe pedestrian and bicycle lanes, providing access to work, leisure, and services; efficiency and electrification of vehicles, charged by solar energy
- Climate sensitive buildings: design for indoor thermal comfort, fresh air, and well controlled daylight and solar heating
- Redefine open space: use innovative arid landscape architecture for water efficient and health promoting parks and public spaces
- Culture sensitive urban design: strategies should be sensitive to social and cultural norms
- Resilience and adaptation to climate change: design cities, buildings, and transportation that maintain their functions in a changing climate

Challenges: rising dryness and heat

Urban design can mitigate for the lack of water and high temperatures, which present a dual challenge to designing urban environments that promote public health (fig 1).

Extreme water shortages, long dry summers, and high potential evaporation are barriers to green spaces, which are a common feature of heat mitigation strategies in healthy cities in temperate climates but are more difficult to establish and maintain in arid climates.

High temperatures and intense solar radiation can cause thermal discomfort and heat stress. High temperatures are also associated with increased morbidity and mortality[20]; even small reductions in heat stress can mitigate cardiovascular and respiratory morbidity.[21]

Cities in dry climates also have more intense night time urban heat islands than cities in temperate and tropical climates, though they often have modest daytime cool islands because they have more vegetation than the surrounding desert.[22]

These challenges are amplified by climate change, which has already resulted in rising temperatures and increased intensity, duration, and frequency of heatwaves as well as reduced precipitation in regions including the Middle East—trends that are expected to continue.[23] Climate projections suggest that heat related mortality risk in this region will increase 2-3 fold in the near future.[24,25]

Cities can adapt to climate change through resilience strategies—for example, by designing urban spaces, transportation systems, and buildings that increase their capacity to adapt to heatwaves and recover from hazards such as droughts and floods, while maintaining essential functions (box and table).[2,9]

Urban form for healthy hot and dry cities

Modern urban planning has been car centric and has encouraged urban sprawl everywhere, but healthy desert cities should be compact, following tradition.[2] Compactness is especially important in desert cities, because unlike temperate or tropical climates, open space that is left unirrigated grows no vegetation and is a source of dust.[30] While strategies to create compact, dense cities are undergoing scrutiny because of the covid-19 pandemic, hyperdense cities such as Hong Kong, Seoul, and Tokyo showed that avoiding large outbreaks is possible with timely public health measures.[31]

Urban form affects physical activity,[32] and well designed compact cities such as Amsterdam and Portland, Oregon, promote outdoor physical activities and social interactions in ways that reduce people's exposure to infection risk indoors—for example, by expanding sidewalks and prioritizing cycling paths. Compactness and connectivity also increase access by foot or bike, reducing reliance on public transport.[2]

"Nature based solutions" and "water sensitive cities"

"Nature based solutions" incorporate natural or modified ecosystems into urban design and have been shown to benefit human wellbeing in temperate climates as well as biodiversity.[33,34]

Vegetation can provide cooling in several ways. Tree canopies create shade and reduce land surface temperature by intercepting solar radiation. Evapotranspiration releases water vapor into the atmosphere through a combination of evaporation from water surfaces and soil moisture and transpiration from plants, which lowers air temperature while increasing humidity.[35] Living in areas which are cooler and with more vegetation is associated with reduced risk for heat related morbidity and mortality.[36]

Plants need a reliable source of water. This may be achieved through a "water sensitive city" approach, which integrates water cycle management with urban planning and design processes

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Table 1 | Design strategies to promote health in hot and dry cities

Strategy	Health benefits	Adaptation to hot and dry cities
Urban form		
Increased built density and land use diversity[4]	Encourages active transport (walking and cycling); improves accessibility to work, social networks, and health services	Short walking distances to reduce exposure to hot weather and solar radiation
Dense network of pedestrian and cycling paths[5]	Encourages active transport; improves accessibility	Shade is essential for pedestrians and cyclists
Compact urban design[6]	Encourages active transport	Narrow streets and courtyards provide shade in the day but increase nocturnal urban heat island intensity
Diverse range of water sources, including recycled water and harvested storm water[7]	Ensures water is available, even during dry periods	Seasonal rainfall patterns need to be considered in developing water resources strategy
Urban design details		
Green space with tree canopies adjacent to main pedestrian and cyclist areas[8]	Improves thermal comfort Exposure to fresh air Psychological wellbeing	Modest size to conserve water Waterbodies are usually not possible owing to water shortage Emphasis on shade trees
Spatial design that considers wind and natural ventilation[9]	Encourages active transport	Built form and shade elements should allow breezes to cool pedestrians and cyclists Moderately non-uniform building heights promote ventilation without introducing wind hazards and mechanical discomfort
Use of suitable color materials in public spaces and on walking and cycling paths[10]	Prevents surface heating and reduces heat emission	Colors should be relatively light to avoid surface heating, but not very light to avoid thermal discomfort and glare from reflected sunlight
Restriction of vehicle access and defined pedestrian and cyclist only zones[1]	Encourages active transport	Provide shade and green spaces in such zones
Priority given to cyclists and pedestrians over motor vehicles[1]	Encourages active transport; reduces road travel injuries	Convenient active transport reduces overexposure to heat and solar radiation
Transport planning and policy		
Increased accessibility and connectivity of public transport[11] Reduced distances from residential and work zones to public transport stops and connected walking and cycling paths	Improves accessibility; potentially encourages active transport as a component of public transport trips	Short walking distances to reduce exposure to hot weather Shaded or cooled public transport stops
Zoning codes specifying maximum vehicle parking instead of minimum requirements[12]	Discourages private vehicles	No special adaptation
Appropriate cycling and walking signs; pavement marking and street lights[13]	Encourages active transport; reduces road travel injuries	No special adaptation
Building design		
Walls and roofs protect from climatic extremes[14-17]	More resilience to disruptions in power supply and extreme weather Less morbidity and mortality, especially during heat waves Less dependence on air conditioning Mitigate for fuel poverty Less greenhouse gas emissions	Well insulated walls and roofs High thermal mass stabilizes indoor temperature High reflectance roofs Green roofs may require irrigation so are suitable only where water is plentiful Passive cooling, especially night ventilation to flush daytime heat
Windows promote natural ventilation, daylight, and passive solar heating, but protect from unwanted heat[18 19]		Moderate sized windows on north and south facing walls, small ones on east and west facing ones. Large equator facing windows if passive heating is required Windows open to allow cross ventilation Operable external shading Cool glazing provides light but reduces solar heat gain

to maximize available water resources while generating additional community wellbeing and ecological benefits.[37] This visionary concept emerged in Australia in response to challenges with traditional water planning based on historic rainfall patterns that are no longer reliable, and a recognition of the community's growing expectations for healthy, livable urban environments.[38]

Three key principles guide water sensitive practices.[39] Firstly, they access a range of water sources efficiently to ensure availability for public consumption and irrigation of open spaces, even in periods of drought.

Secondly, they increase and protect ecosystems including waterways, wetlands, river basins, and coasts—for example, constructed wetlands and biofilters capture, retain, and treat stormwater in the urban landscape, providing local cooling, greening, and reduced run-off pollution.[40] Such amenities have multiple health benefits for mental and physical health by offering greater opportunities for physical activity, passive recreation, and social connection.[41]

Thirdly, water sensitive communities value their city's green spaces and waterways, adopt behaviors that conserve water and reduce pollution, and support the policy and governance arrangements needed to deliver health and wellbeing outcomes through better water management.

For example, Melbourne, Australia, aspires to be a water sensitive city—it recycles wastewater and captures stormwater to supply water for non-drinking uses; biofiltration rain gardens have been implemented across the city; and its community feels strongly connected to water issues and policy decisions.[42]

Greening public space

In the hot and dry climate of the Middle East many cities lack the water required for urban greening. Adopting nature based and water sensitive urban design solutions that were developed for a temperate climate may be unsuccessful because rain is concentrated in the winter, followed by six to seven months of no rain.

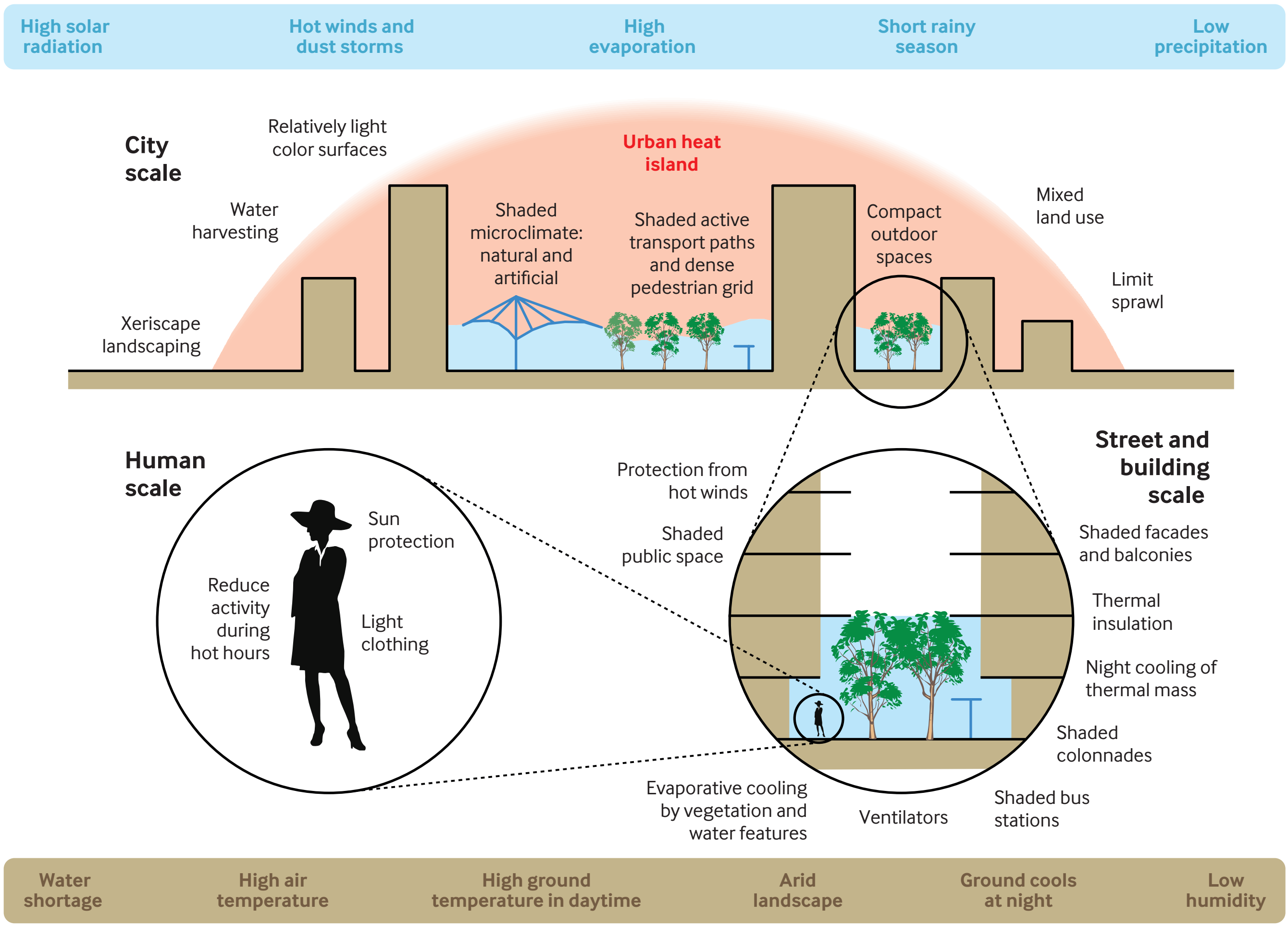

Fig 1 | Environmental conditions in hot and dry cities (blue and brown), and city, street, and building, and human scale means for designing a healthy city in hot and dry climate. Created by Eran Kaftan for the authors

In dry cities, public green space must be designed judiciously to target benefits to places most likely to be enjoyed by as many city residents as possible,[43] with consideration given to underprivileged neighborhoods, which are often neglected in this respect, and to social and cultural norms—for example, by providing zones for women.[44]

Smaller areas of green space compared with temperate climate cities reduce irrigation requirements. Because plants adapted to the desert minimize water loss by evapotranspiration, they have only a minor effect on air temperature and improve thermal comfort primarily by providing shade (in the case of trees) or by reducing heat emitted from the ground surface in the form of infrared radiation. Both benefits are localized, so vegetation should be prioritized for main pedestrian and cycling paths, plazas, and courtyards. Xeriscape gardening—that is, landscaping that reduces or eliminates the need for irrigation—can substitute for water intensive green spaces.[45]

Keeping cool in hot cities

Thermal comfort is not just about air temperature; it is also affected by radiant exchange, humidity, and air movement, and may be assessed by complex indicators such as the universal thermal climate index (UTCI).[46] Such indicators may be used to compare alternative designs for urban spaces to enhance resilience and to promote walkability and outdoor activity.[47]

In contrast to temperate cities, where exposure to sunshine is considered beneficial for mental health and vitamin D synthesis, cities in hot and dry climates should provide shade. Trees deliver cooling more efficiently, in terms of water use, than grass or other non-shading plants.[8] Artificial shading, such as fabric canopies, pergolas, or arcades, can provide solar protection in urban corridors and recreational spaces where vegetation cannot be planted. Shading reduces land surface temperature by intercepting solar radiation and significantly improves human thermal comfort. It is preferable to highly reflective pavement, which despite being cooler than dark surfaces increases the radiant load on pedestrians and has an overall negative effect on comfort.[48] It also reduces exposure to the ultraviolet light that causes sunburn and skin cancer.[49]

Promoting active and public transport

Urban transport affects mobility and access to jobs, education, goods, services including healthcare, and social networks, all with links to public health. Encouraging shifts from car travel to public transport and active transport (walking and cycling) can improve health in cities by increasing physical activity and exposure to green spaces while reducing air pollution, noise, social exclusion, injuries, stress, and community severance—that is, physical or psychological barriers to mobility caused by busy roads.[1 50] Health benefits from such a shift outweigh potential adverse effects of sustaining injuries while walking or cycling and exposure to air pollution, and reduce greenhouse gas emissions.[51]

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Box 1: Urban resilience initiatives in the Middle East

- The World Health Organization Eastern Mediterranean Regional Office (WHO EMRO) established in 1990 a regional healthy cities network initiative which 77 cities have joined, with a population of over 22 million from 13 countries including Saudi Arabia, Iran, and the United Arab Emirates.[26] The network improves urban resilience in line with the SDGs. After joining the network, cities are required to implement 80% of 80 indicators in nine health and resilience domains, including emergency preparedness and response, health governance, water and sanitation, and social capacities. The city of Sharjah (United Arab Emirates) was the first to be awarded as a healthy city in the region, after meeting 88% of the indicators (http://sha.gov.ae/en/sharjah_health_city/).
- The 100 Resilient Cities initiative of the Rockefeller Foundation (2013-19) endorsed cities in the region including Ramallah, Amman, Beirut, Luxor, and Tel Aviv-Yafo to develop strategic resilience plans. The Amman strategic plan, for example, sets to improve the transportation system, promote walkability, apply green building guidelines, manage water resources efficiently, and institutionalize planning in the city. The Ramallah strategic plan includes urban design dimensions such as increasing green spaces and establishing a formal public transport system to improve mobility of women.[27] Tel Aviv-Yafo adopted mandatory green building standards, pioneered bicycle and scooter rental schemes and developed an extensive network of dedicated paths for them, and is devising a climate change readiness plan that includes more shading and natural vegetation, cooling public facilities and public spaces, and mitigation of the urban heat island.[28] Tel Aviv-Yafo and Amman are also members of the C40 network of world megacities committed to addressing climate change.

However, hot and dry climates present unique challenges for designing healthy transport systems. Although the connections between transport planning and policy and public health are well researched,[1 50] best practices for application in hot and dry cities have not been synthesized.

For example, active and public transport may be hard to implement in hot and dry cities.[52] Research shows that warm temperatures (24°-30°C) and dry and sunny weather encourage walking and cycling over car travel, but higher temperatures and humidity have the opposite effect owing to thermal and mechanical discomfort.[52 53] Similarly, use of public transport, which often demands walking or cycling part of the route, is reduced in extreme weather such as very high temperatures.[11]

Evidence originates mostly from areas of temperate climate in Europe, North America, and Australia, although inhabitants of hot and dry climates may become acclimatized to different combinations of temperature, humidity, and solar radiation.

Evidence indicates also that women and older people are more sensitive to thermal comfort than men and younger adults. This is particularly relevant in Middle Eastern countries including Qatar, Iran, and Saudi Arabia, where women's clothing tends to be heavier and their skin more covered because of religious, social, and cultural factors. This might deter active transport and increase the existing gender divide in physical activity.[53] Restricted interactions between women and men are another barrier for women using public and active transport.

Public transport can be a healthy mode of transport, but it needs to be weather resilient: hubs should be sheltered and accessible, service should be reliable and frequent, and buses, trams, trains, and indoor stations should be thermally comfortable.[54]

Improving car efficiency and electrification are additional measures to promote health through reducing greenhouse gas emissions and air pollution.[51] Electricity should be decarbonized and generated from solar energy.[55]

Designing healthy buildings

Modern societies spend about 90% of their time indoors,[56] so the design of buildings has major implications for health and wellbeing. Improved indoor environmental quality has measurable benefits: increased ventilation and optimized daylight and views increase sleep duration[57] and improve cognitive performance.[58] Poor indoor environmental quality—primarily indoor pollutants, often characterized as "sick building syndrome"—is common in offices and schools owing to central air conditioning, adversely affecting attendance and performance.[59]

All buildings create an indoor environment distinct from outdoor conditions. The walls and roof form an enclosure that may be sealed or permeable to various degrees, depending on weather conditions, allowing exchange of heat, light, and air. The exchange can be controlled by mechanical systems, as in many modern buildings; by passive means, as in traditional construction; or by a mixture of the two. All climatic solutions should also be sensitive to visual and acoustic privacy, which are affected by social and cultural norms that vary among societies.

Climate sensitive design of buildings seeks to maximize the advantages of local conditions and mitigate their drawbacks, while minimizing the use of non-renewable resources, especially energy, to improve sustainability. In hot climates, this means limiting unwanted solar heating and integrating passive cooling to release excess heat to the environment, in addition to providing well controlled daylight and plenty of fresh air.

In a well designed house, a combination of internal thermal mass and external thermal insulation can keep indoor air temperature within a narrow band of 2-3°C without air conditioning, even if the diurnal outdoor temperature range is 15-20°C.[18] Excess heat absorbed in the building during the daytime can be released to the environment at night by opening strategically placed windows, to allow cross ventilation.[14] However, as heatwaves become more frequent and prolonged as a result of climate change, indoor conditions may exceed critical thresholds in many climates that rely on indoor cooling.[15] Many buildings constructed today will still be in service in 50 or even 100 years, so current building codes should be modified in response to modeled future climate.

The challenge for architects is to use innovative materials to reduce dependence on the ubiquitous air conditioners that now give occupants greater flexibility and improved thermal comfort compared with traditional vernacular passive cooling systems in buildings.[60] Well designed modern buildings perform better in extreme weather, reducing morbidity and mortality, and improve resilience to disruptions in power supply.[15] By reducing dependence on air conditioning, especially during heatwaves, buildings can also reduce greenhouse gas emissions and can mitigate for energy poverty, which affects nearly 1.3 billion people globally who have no access to electricity (mostly in hot climates) or for whom it is simply too expensive.[61]

Governance in healthy dry cities

Urban resilience is linked with most of the United Nations sustainable development goals (SDGs), particularly SDG 11: making cities inclusive, safe, resilient and sustainable, focusing on healthy living, and ensuring availability and sustainability of water and sanitation.

Increasing resilience in hot and dry cities will depend on governance that ensures timely, collaborative, integrative, and adaptive processes with a long term vision. Key barriers to adaptive and water sensitive urban governance include sectoral silos, fragmented policy and regulations, lack of vision and leadership, lack of incentives, limited practitioner capacity, inadequate funding and financing models, and lock-in to traditional practices.[62] Moreover, water shortage often requires national infrastructure, and innovative water storage and recycling requires capacity and often costly technology.[7]

Individual cities in the Middle East have taken local measures to increase urban resilience—for example, Saudi Arabian cities started adopting sustainable buildings, public transport, and urban greening strategies.[55] Examples include xeriscape gardening with natural elements in Riyadh, and green and blue spaces using recycled waste water south of Riyadh.[45]

Region-wide initiatives in the Middle East have also sought to improve urban resilience (box 1). Some of these include urban design measures to increase walkability and encourage green buildings. But mostly they are based on strategies from temperate urban areas adapted to the local climate and to climate change. To translate these plans into actions, cities might increase urban design and planning, coordinate between central and local levels of government, increase participation of all stakeholders, and allocate adequate resources.

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Mental health in water scarce cities: an unrecognized climate change pressure point

Water unavailability is one of many linked stressors increasingly likely to affect mental health in some city populations. **Azar M Abadi and colleagues** propose steps to protect vulnerable residents

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Several megatrends, including climate change, urbanization, and water stress, are converging to put additional strain on global mental health. The impact of water scarcity on mental health has been well characterized for rural populations[1]; the nexus at the intersection of water scarcity and mental health for urban dwellers deserves closer examination.

Mechanisms may include stress and insecurity felt due to water scarcity; displacement of families to urban areas; effects of dehydration on effectiveness of psychoactive medications; heat related aggression, violence, and suicide; and high mental burden on women for their efforts to find and procure clean water.

Water scarcity also contributes to mental health through myriad indirect pathways, including land degradation, famine, malnutrition, spread of disease, heat waves, and reduced air quality. Highly correlated stressors associated with water insecurity in urban settings mean that water stress is unlikely to be identified as a principal cause of mental illness.

Pathways linking water stress and mental health disorders

Urban migration is a common coping strategy for rural people exposed to drought. In this context, depression and anxiety resulting from the rupture of community and place bonds is a likely causal pathway.[1] Migration, particularly early in the life cycle, is a significant risk factor for several mental disorders.[2]

The impact of migration on mental health is greater among women, youth, elderly people, and people with disabilities.[3] Compromised mental health in care givers or parents is likely to directly influence not only concurrent child wellbeing but also developmental trajectories of child mental health thereafter.

Several studies link poor water access and quality to adverse mental health in urban settings, including in Iran,[4] Bolivia,[5] and the United States.[6] Women are at particular risk, studies in Bolivia,[7] urban Nepal,[8] and Odisha, India,[9] have concluded.

Climate change is increasing the frequency of compound hazards, wherein heat and water stress overlap.[10] Myriad studies have found high ambient temperatures associated with mental and behavioral disorders. Older people are more vulnerable to extreme heat.[11] Existing mental health issues like schizophrenia, schizotypal disorders, neurotic disorders, and disorders related to substance misuse are associated with increased morbidity and mortality at higher temperatures.[3 12] Lower socioeconomic status, homelessness, and living in slums were associated with adverse mental health outcomes in hot cities.[13]

Evidence informed solutions

Optimum management is likely to include strategies to manage water insecurity in urban settings,[14] increased mental health surveillance and service delivery, and protecting the most vulnerable people from the combined stressors that can exacerbate mental health concerns.

Focusing on interventions that are likely to benefit mental health is particularly important. Limited access to green and blue space can compromise mental health. Diminished active spaces exacerbates physical and mental health conditions.[15] Management of urban green spaces in wealthy and poor neighborhoods is central,[16] as is maintenance of and access to urban waterways.[17]

Sustained access to clean water is a key health determinant. Like other determinants, access tends to vary across familiar inequity gradients. Recognition of the impact of upstream drivers, such as neighborhood conditions or household financial status, and the differential impact on marginalized populations, is key.[18]

Some water and sanitation management strategies could exacerbate mental health threats. Recognizing the many hydro-social contracts that affect health between water managers and urban residents can help reduce harms. Recognizing the human right to clean, safe water has important implications for reducing harms.[19] Water management strategies need to be flexible and responsive. For example, a study in Australia reported that permanent water restrictions are not viable long term policy.[20] In addition, indiscriminate use of water pricing strategies to restrict demand, without consideration of impacts on economically vulnerable populations, is likely to worsen stresses and undermine mental health.[21]

Education, in health and water sectors and of the general population, is important. For example, health counselling about extreme temperatures can be included in the outpatient care program for patients with mental disorders.

Existing global mental health priorities highlight the need for a lifecycle approach and early interventions. Existing priorities also emphasize approaches that integrate family members and communities, and wraparound services should incorporate water insecurity into mental health programing.

More research needed

Evaluation and research are crucial to identify vulnerable populations and risks. More research, data collection, and mental health surveys are needed to create larger databases in real time and to identify vulnerable populations and allocate more funding to make these populations more resistant to water insecurity.

Climate change, urbanization, and water stress present challenges to livelihoods and services, from mental health surveillance

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and treatment provision to water sourcing to sanitation, that are already under substantial strain. Climate change has the potential to amplify trends and conditions that already strain systems to monitor and tackle population health challenges. These systems need to be updated to respond to looming additional burdens.

Thoughtful, proactive investments could blunt many of the worst effects. As with many other climate change impacts, however, there is worrisome potential for the world's most vulnerable to suffer most.

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Health in dust belt cities and beyond—an essay by Nick Middleton

Desert dust is associated with morbidity and mortality, and distant spread means lessons for mitigating the harms can be found by looking beyond cities in arid regions, writes **Nick Middleton**

Every year, usually sometime in December, the residents of cities in west Africa brace themselves for the Harmattan, an annual yellow haze caused by dust blown from the Sahara Desert. It's a time of traffic accidents and flight delays, increased risks of wildfires and medical ailments, from respiratory complaints to skin problems.

The situation is similar across the string of deserts and semi-deserts stretching from the Sahara through the Middle East and central Asia to the Gobi Desert of China and Mongolia (fig 1). The world's greatest dust sources are in this swathe of drylands, dubbed the "dust belt," but airborne dust also affects dry parts of the Americas, Australia, and southern Africa.[1]

Globally, an estimated two billion tonnes of fine particles are raised by winds from the world's dryland soil surfaces each year. Urban areas in drylands are worst affected by these seasonal outbreaks, but fine soil particles are regularly blown over great distances, bringing dust haze to cities well outside areas considered dry. Desert dust is not just a desert problem; it has global ramifications. Dust comprises primarily mineral rock fragments with organic matter, a wide array of microorganisms, plus anthropogenic pollutants from the soil or picked up in transit through the atmosphere.[2]

Health impacts

Soil particles entrained by turbulent winds can rapidly create a thick dust cloud. The worst cases involve abrupt and total loss of visibility at ground level, which can cause road traffic accidents, sometimes resulting in multiple vehicle pile-ups.[3] A series of severe dust events in northern India in May 2018 uprooted trees and damaged housing, leaving more than 125 people dead and many more injured in cities and rural areas of Uttar Pradesh, Rajasthan, Delhi, and Haryana.[4]

A large and growing body of research has looked at numerous infections and diseases associated with desert dust. Exposure to dust in the atmosphere can result in conjunctivitis and dermatological disorders, whereas inhalation can cause respiratory illnesses such as silicosis (also known as desert lung syndrome). Many epidemiological studies show associations between exposure to high dust concentrations and increases in mortality and hospital visits and admissions owing to respiratory and cardiovascular diseases such as bronchitis, emphysema, and chronic obstructive pulmonary disease.[5,6] The effect of desert dust outbreaks on asthma incidence has also attracted considerable research, but dust is just one of a host of factors that might influence the development and expression of respiratory allergic diseases such as asthma.[7,8]

In the Sahel region of west Africa, outbreaks of bacterial meningitis are closely associated with the Harmattan season, although the exact nature of the association remains elusive.[9] In dryland parts of the Americas, dusty conditions are associated with an infectious disease known as valley fever.[10] In this case, a causal link is more clear cut. People contract valley fever by inhaling spores of a soil based fungus (*Coccidioides immitis* or *C posadasii*) that become airborne during dust storms (fig 2).

Air quality guidelines

Once inhaled, the size of the dust particle is the main determinant of where it comes to rest in the respiratory tract. A distinction is typically made between particles less than 10 microns in diameter (PM_{10}), which can enter the lungs, and those with a diameter of less than 2.5 microns ($PM_{2.5}$), which can reach deeper into lung tissue.

Based on evidence, the World Health Organization anticipates no minimum threshold for atmospheric concentration that would mean no adverse health effects,[11] but it still sets standards for acceptable air quality. National governments adopt WHO's limits or set their own similar guidelines.

Nonetheless, these limits are frequently exceeded during dust storms, sometimes by several orders of magnitude. The WHO guideline for the maximum acceptable 24 hour atmospheric concentration is a mean of 50 μg per cubic metre for PM_{10}. In Zabol, a city in southeastern Iran that frequently tops global league tables for atmospheric pollution, maximum PM_{10} levels during severe dust storms are more than 10 000 μg per cubic metre. Sometimes these storms continue for several days.

Managing dust sources

Many dust sources are naturally devoid of vegetation, but some environments have become susceptible to wind action through human mismanagement. These situations include agricultural fields left bare after

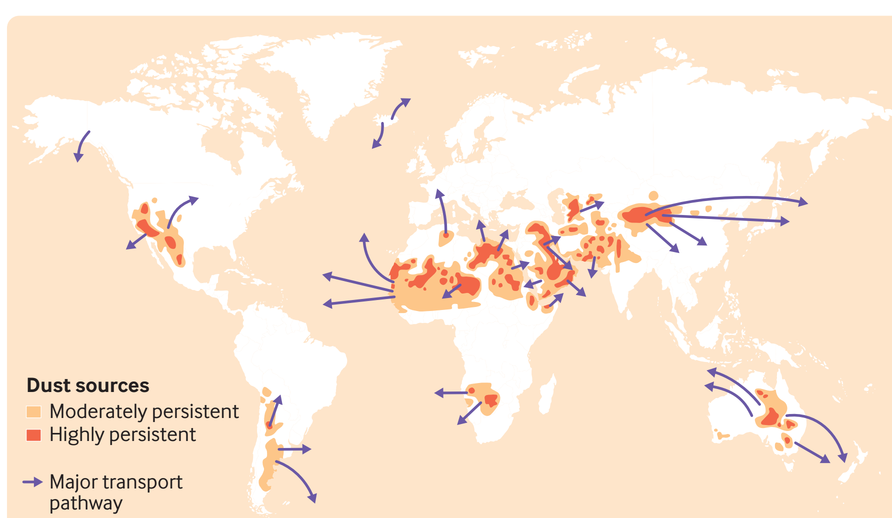

Fig 1 | Major global sources of desert dust and pathways of long distance transport (Modified from Muhs et al, 2014).[21]

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ploughing and harvests, and lake beds desiccated by society's overuse of water. Preventing emissions at source is the most obvious answer to problems presented by dust, and there are numerous tried and tested techniques to prevent wind erosion from agricultural soils.[12] Many of them involve maintaining or restoring some degree of vegetation cover to protect a surface.

Farmers use all sorts of technologies to control wind erosion. These include leaving crop residue in the field after the harvest and erecting windbreaks at right angles to erosive winds. Such barriers might comprise fences made of dead palm fronds, for example, or living plants such as trees or bushes, in which case they are called shelterbelts. Other policy options include set aside schemes designed to allow protective vegetation to grow on former farmland.

Great efforts have been made to promote these techniques to farmers in some parts of the world. In the Canadian Prairie provinces of Alberta, Saskatchewan, and Manitoba, where wind erosion is especially prevalent during recurrent drought periods, numerous initiatives to develop and promote wind erosion prevention were made in the 1980s. A marked reduction in dust in the Canadian Prairies from 1990 onward has been attributed to the positive effects of these soil conservation campaigns implemented by both government agencies and private non-profit organisations.[13]

Other dust sources are more dependent on sustainable water management. The desert city of Zabol receives dust from a series of shallow, marshy lakes that become dry during times of drought, but also when water is taken from rivers for agriculture and municipal use.[14] The lakes, which straddle the border between Iran and Afghanistan, are a unique series of wetlands in an otherwise extremely arid region. They are fed by rivers that flow from the Hindu Kush mountains, but several of these rivers have been dammed on both sides of the border to provide water to irrigation schemes and for domestic use in the region's towns and cities. The best hope for improving Zabol's air quality lies in an international agreement between the governments of Iran and Afghanistan governing water use in the region.

The economic incentive to reach an agreement has been assessed on the Iranian side of the border. In the Zabol region, dust storms cost an estimated $25m (£19m; €21m) a year in physical damage and loss of productive work hours.[15] Such economic assessments are few and far between. A rare valuation of dust related medical costs, in the US state of Arizona in 2007, showed that 1735 hospital visits for valley fever resulted in $86m in hospital charges alone.[16]

Impact mitigation

Preventing dust emissions at source is not always possible. Harmattan dust, for example, emanates from natural sources in the Sahara Desert, which are too large and remote to stabilize feasibly. In situations like this, a range of monitoring, forecasting, and early warning measures can be implemented to mitigate the numerous effects of dust in the urban environment.

In northeast Asia, governments and their meteorological services cooperate to produce forecasts of transboundary dust events based on an ensemble of computer climate models from China, Japan, and South Korea. South Korea is outside the Asian drylands, but the season of yellow haze created by dust from China and Mongolia is common enough to have a Korean name: hwang sa.

The South Korean approach to managing the risks associated with hwang sa offers lessons for responses elsewhere. In the

Fig 2 | Dust storm engulfs Khartoum Credit: Mahmoud Hjaj/Anadolu Agency capital, Seoul, the metropolitan government issues dust forecasts in weather reports, on the internet, and through emergency broadcasts. It also has a guide on its website advising on what to do before, during, and after a hwang sa event.[17] Alerts are issued when a mean hourly PM_{10} concentration of greater than 800 µg per cubic metre is expected to last more than two hours. The threshold concentration is noteworthy given that Seoul is over 1000 km from the nearest dust source.

During an alert, people are advised to close windows and stay indoors and to avoid secondhand pollution by thoroughly washing hands before processing food and cooking. If people must go outside, they are advised to wear protective glasses, a mask, and long sleeved clothes. Schools are told to cancel classes if necessary and to prohibit outdoor activities for kindergarten and elementary school students. Outdoor sports events and other open air activities should be stopped or postponed. When the yellow dust has dissipated, everything should be cleaned, and some facilities need to be disinfected.

Alerts of desert dust events are a simple way of reducing harmful health effects if they lead to behavioural changes that lower exposure. Studies of the large "red dawn" dust storm in Australia in 2009, the worst in terms of reduced visibility to have passed through the city of Sydney since the 1940s, found the incidence of adverse health outcomes in Sydney was reduced by public health messages and their widespread media coverage.[18]

A pressing matter

Dust storms do not typically result in the substantial destruction of infrastructure and loss of life associated with other natural hazards such as floods or earthquakes. But the cumulative effects on society can be substantial, not least because dust events occur more frequently than most other hazards. The disruption they bring to economic and social activity, including their diverse health effects, is an area of growing concern, albeit that dust events are also important for ecosystem functioning.[19] The effects of climate change only heighten these concerns. Member states of the UN General Assembly have adopted resolutions on combating sand and dust storms each year since 2015 because they realise that these atmospheric phenomena present a severe obstacle to achieving the sustainable development goals.[20]

Nevertheless, many gaps remain in our understanding of the relation between desert dust and the wellbeing of urban residents. In west Africa, a critical knowledge gap lies in the precise nature of the association between meningitis outbreaks and the dry, dusty atmospheric conditions of the Harmattan. In more general terms, evaluating the detailed health effects of dust as an individual component relative to numerous other risk factors is another gap. Filling these gaps can only improve the ways in which we deal with desert dust in the city.

Box: Recommendations for policy makers

- Protect ecosystems, promote agricultural practices that reduce soil erosion, and manage water resources judiciously in places with anthropogenic origins of this global environmental health problem
- Conduct assessments of dust risk and vulnerability as part of the Sendai Framework for Disaster Risk Reduction
- Implement dust monitoring, forecasting, and public health early warning measures to reduce dust exposure and harmful impacts

Nick Middleton has worked with several United Nations bodies on issues around sand and dust storms. One of his current workstreams is with the Asian and Pacific Centre for the Development of Disaster Information Management, a regional institution of the UN that is developing a sand and dust storms risk assessment and a regional plan of action to combat sand and dust storms.

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Dry cities can't be healthy without reducing inequalities

Women and other groups carry a disproportionate burden of the health effects of water scarcity. Policy makers should prioritize actions that minimize inequality and exclusion, while improving water management and health, especially in cities, writes **Maitreyi Bordia Das**

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Inequality and exclusion have deleterious consequences, not just for the people at risk of being left out but for all society. Worldwide, some individuals and groups have disproportionately worse health outcomes. They may be disadvantaged because of their age, gender, sexual orientation, ethnicity, occupation, disability status, religion or a combination of these.[1] Poverty exacerbates exclusion, but sometimes it is not the only driver. Water scarce or hot cities are no exception.

Water availability is essential to control covid-19. The pandemic shows that structural inequalities, rooted in historical circumstance, can affect outcomes in diverse places. In both the UK[2] and the US[3] for instance, black and ethnic minority people are at greater risk of getting sick and dying from covid-19.

Globally, although provision of water and sanitation services has made huge progress, there's much more to do. Urban Ethiopia, for instance, has substantially expanded coverage of piped water, but richer households are almost four times more likely to have piped water than poorer ones. In smaller Ethiopian towns, weaker infrastructure makes it difficult to connect households; in larger cities, poorer households simply lack the means to pay for services.[4]

Compounded risks

Dry cities often face multiple coexisting risks to the health of their residents. Poor air quality, for instance, affects older people and people with pulmonary diseases disproportionately. Health risks are also compounded when natural hazards overlay water scarcity, leading to destruction and infectious disease epidemics that affect poor and vulnerable groups more.

Cities affected by disaster or fragility have additional institutional and political challenges. Haiti, which is prone to both, for example, saw a drop in the provision and uptake of safe drinking water between 1990 and 2015. The decline was particularly manifest in urban areas, where, among other reasons, residents did not trust the quality of publicly provided water.[5] In other places as well, lack of trust in the state and service providers affects how especially minority groups perceive and use services.[6]

Several factors mediate the relationship between water scarcity and the health of the most vulnerable groups. Women are often singled out, because of their unique needs; specific groups of men are also compromised.

One study found that about 90% of women in Nigeria had no handwashing facility at their home or workplace.[7] Women who have to use communal toilets are at increased risk of harassment and assault. They may be more susceptible to urinary tract and vaginal infections. Menstruating women have particular needs for water and sanitation, magnified in crowded urban settlements.[8] Perimenopausal and menopausal women experience particular discomfort in hot climates and when water is scarce. Further, discussing women's reproductive health is often taboo, hindering women from voicing their needs.[9]

Water quality is implicated in various diseases and malnutrition, with long-term effects on wellbeing. Childhood illness also affects the mother, whose burden of care rises. If she is also malnourished it can trigger a cycle of poor health. Women are also often managers of household water, especially when it is rationed and stored, which puts them at risk of closer contact with contaminated water. Some men, such as sanitation workers or emergency responders, can also be prone to disease.

Policies for healthier cities

Policy is the most potent lever by which to effect change towards healthier cities. Policy makers need to prioritize solutions that lead simultaneously to better urban water management and health, while reducing inequality. What are some of the ways?

First, policy makers need to understand the nature of inequality and the consequences of existing policies. For instance, urban planners may not consider the needs of groups such as migrant workers or intravenous drug users, unless they are aware of how these groups may be excluded.

Second, policy makers need to ensure special attention to groups most likely to be left out. The growing "cultural competency movement" shows the need to target specific groups and to ensure they are not disadvantaged because of language or culture.[10]

Third, policy makers need to create conditions by which residents can drive their own solutions. Indigenous peoples in Brazil, for instance, are working with government, using their traditional knowledge to combat wildfires, which have impacts well beyond the Amazon.[11]

Fourth, policy makers need to strengthen transparency and accountability, so that city residents have confidence in systems and institutions. For example, mobile phone based surveys, such as those used in Sierra Leone and Liberia during the 2014 Ebola outbreak, offer real-time monitoring, and when publicly disclosed can increase citizen trust in the state and service providers.[12]

In sum, we are unlikely to achieve healthy dry cities without attention to inequality and to the needs of groups most likely to be left out.

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