1 School of Public Health, University of Washington, Seattle, WA, USA
2 Global Programs (Urban, Resilience, Land), The World Bank, Washington DC, USA
3 School of Public Health, University of Haifa, Haifa, Israel
4 Monash Sustainable Development Institute and School of Social Sciences, Monash University, Melbourne, Australia
5 Ministry of Public Health, Doha, Qatar
6 Environmental Health Governance, Geneva, Switzerland
7 Department of Sociology, University of Maryland, College Park, MD, USA

Correspondence to: MB Das
mdas@worldbank.org

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HEALTHY DRY CITIES

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**

Howard Frumkin,[1] Maitreyi Bordia Das,[2] Maya Negev,[3] Briony C Rogers, Roberto Bertollini,[5] Carlos Dora,[6] Sonalde Desai[7]

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."

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

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.

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 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.

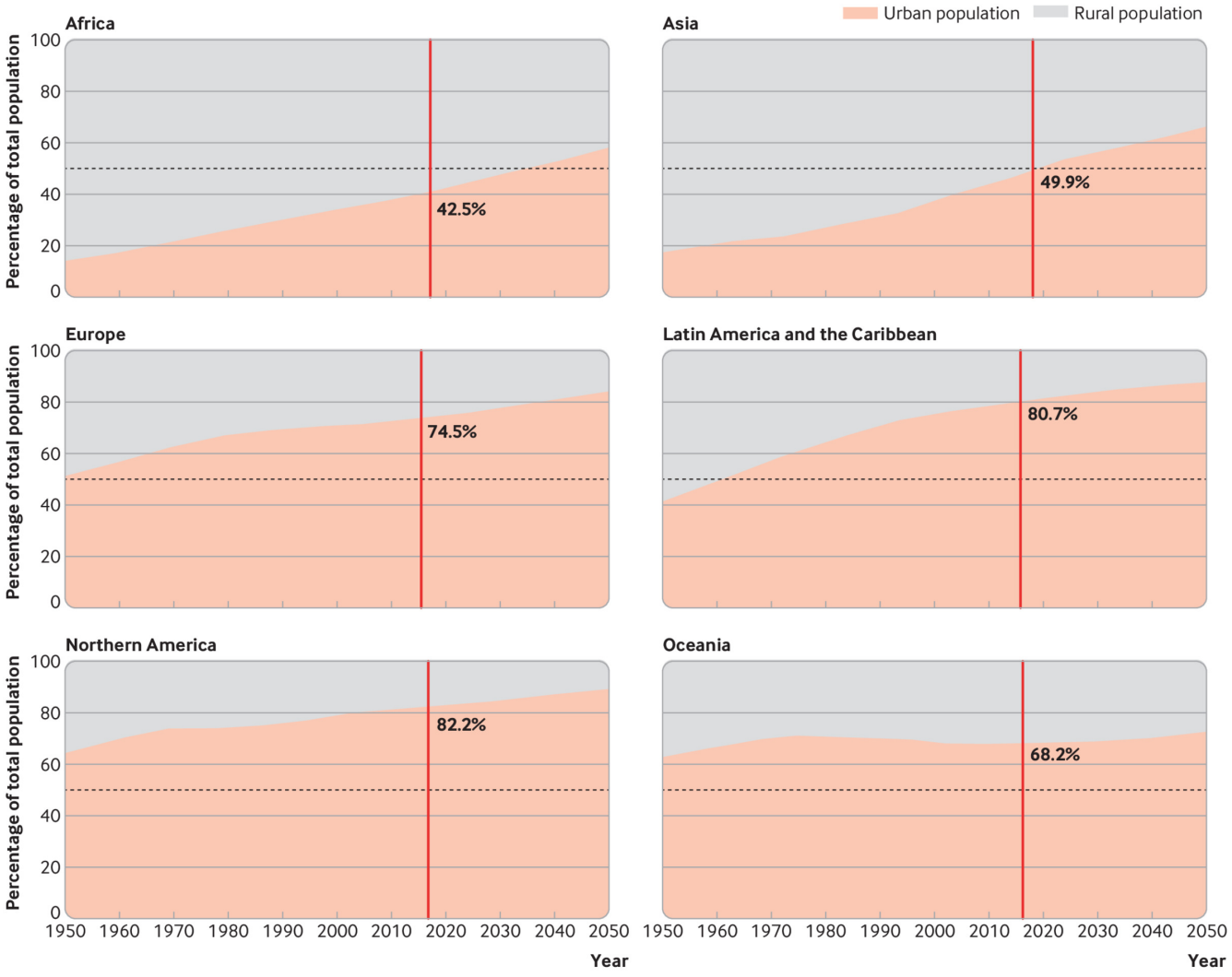


Fig 1 | Growth of urbanization by world region 1950-2050[13 14]

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]

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.

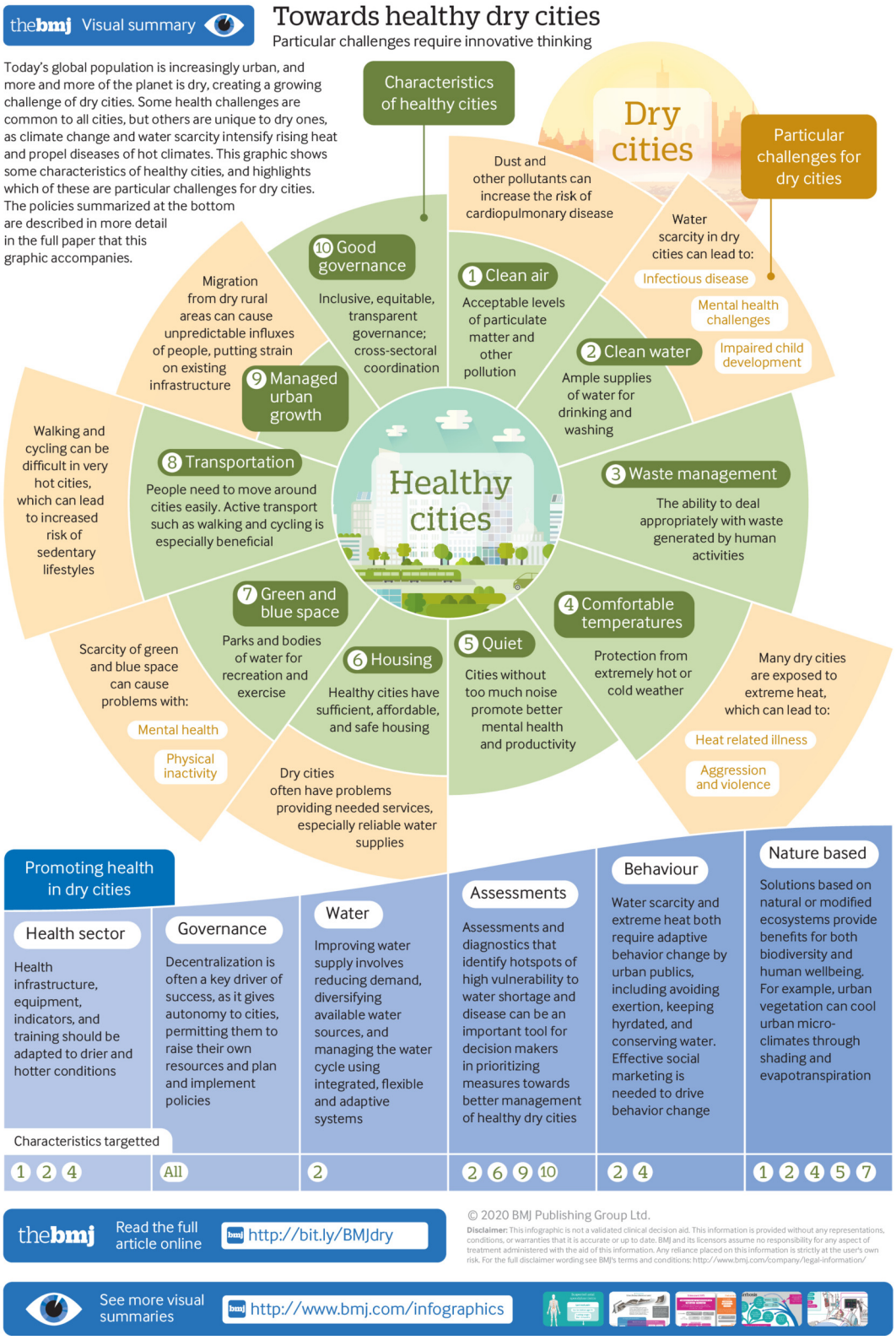
The general principles of social marketing—simple, clear messages, repeated often, from a variety of trusted sources—are highly applicable.[100] Messaging should be evidence based,[23] involving target communities and offering practical advice that increases self-help.[101] Messages are most successful 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]

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



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