

Mexico



View of Mexico City, which, centuries ago, was a beautiful lake. Photo credit: ©iStock.com/ isitsharp.

An aerial photograph of Mexico City, showing a vast, dense urban landscape with numerous buildings and structures. The city is surrounded by mountains, and the sky is blue with some clouds. The text is overlaid on a semi-transparent blue box in the lower-left quadrant of the image.

"In Mexico, water distribution is extremely uneven in quantity and quality, both for natural reasons and because of the historical evolution of our cities and productive activities. This condition makes us a country vulnerable to global climate change, since our ecological balances are very lean and much of the surface and groundwater resources that supply our cities are already overexploited. It is particularly worrying that over 70% of the surface bodies in the country show some degree of contamination; agricultural activities waste more than half the water used through improper practices; approximately 40% of the recorded species of fish are threatened, endangered or have become extinct due to the way their habitat has been affected, and that there are still 11 million Mexicans who do not have clean water" Mario Molina, Nobel Prize

Urban Water in Mexico

Coordinator

María Luisa Torregrosa

Contributing Authors

**Ismael Aguilar Barajas, Blanca Jiménez Cisneros,
Karina Kloster, Polioptro Martínez, Jacinta Palerm,
Ricardo Sandoval, and Jordi Vera**

Support

Amalia Salgado

Summary

Mexico's strong growth during the 20th century led to a significant concentration of the population in relatively small areas requiring large amounts of water, food and energy. Nearly eight out of every ten people live in urban areas throughout the country. Although there is good average water availability and supply service coverage has steadily increased, Mexican cities face growing problems with regard to water and sanitation services. This paper examines the current state of public water and sanitation services in the country and the main problems. It provides a general review of the population structure and the generation of cities, the types of water management and administration, sources of access, water quality, distribution, unequal access, water drainage in cities, sanitation, reuse, health risks, infrastructure and climate change. On the basis of this review, it proposes a number of recommendations for water policy in Mexico.

1. Introduction

During the 20th century, like other countries, Mexico experienced heavy urban development and the rapid growth of cities (Garza, 1990; Pineda et al., 2010), mainly due to the expansion of industrial activities and services and the increasing migration of the population that moved to cities, leading to their multiplication and rapid growth (Garza et al., 1995). This led to the concentration of the population in very small areas requiring large amounts of water, food and

energy, which generated large volumes of waste and thereby an environmental imbalance. Worldwide, the spaces occupied by cities account for less than 1% of habitable space (Jiménez, 2013), while 73% of total gross output is produced in 56 metropolitan areas (UN HABITAT, 2011).

In Mexico, nearly eight out of ten people live in urban areas (INEGI, 2010). Although there is good water availability on the whole across the country, and supply service coverage has steadily increased, Mexican cities face growing problems in regard to municipal water and sanitation, particularly for the low-income population, in terms of service continuity and water quality.

Fifty-three percent of all groundwater employed for all uses comes from overexploited aquifers (CNA, 2012a), while surface water sources such as Lake Chapala and the Cutzamala dam system, are threatened by pollution, competition with other users and climate variability. Likewise, the lack of water systems and high quality sustainable sanitation poses an enormous challenge to the country's economic wealth and social well-being.

Sewerage and sanitation services also face significant challenges. Although urban areas generally have high coverage, wastewater treatment coverage is extremely low.

The lack of high quality, sustainable water and sanitation systems poses an enormous challenge to the country's economic wealth and social well-being (Sandoval, 2012). Water availability per person has decreased due to population growth, but in the case of Mexico, the situation is serious because of the concentration of most of the population in urban, industrial and agricultural areas in central and northern Mexico, where there is less water available (Saltiel, 2008 in Sandoval, 2012). According to the General Census 2010, only 73% of households receive water every day.

The problem of achieving sustainable urban water service is more complex than having water or sanitary connections or importing water from other basins since urban areas require an extensive catchment area and space and financial resources for treating wastewater, which they discharge into a small area. Moreover, in cities, aquifer recharge areas are being paved and river banks invaded. On the other hand, climate variability and the effect of the heat island increase the risk of urban flooding.

2. Population growth and the structuring of cities

Mexico is a country of enormous contrasts. Its nearly two million square kilometers of biodiverse ecosystems are inhabited by over 112 million people with a broad variety of cultural backgrounds. Mexico is the eleventh largest global economy (considering the GDP for 2011) and a member of the Organization for Economic Cooperation and Development (OECD). It also has a high Human Development Index (HDI) (0.739 in 2010). However, these data conceal profound social contrasts and differences in access to water supply and sanitation among the inhabitants of the 31 states and the Federal District comprising the country (Map 1).

Map 1. Human Development Index for Mexican States



Source: <http://www.fotosimagenes.org/estados-de-mexico-por-idh>

Mexico has experienced different stages in regard to population growth. At the beginning of the 20th century, in 1900, there were only 33 towns with over 15,000 inhabitants, in which a total of 1.4 million people resided. From 1900 to 1940, a slow process of urbanization began that accelerated in the 1940s. By 1950, the number of towns with over 15,000 inhabitants rose to 84; by 1960 this number had risen to 119, covering virtually the whole country.

By 1990, Mexico had a total population of 81.2 million, 61% of which lived in 309 urban localities with over 15,000 inhabitants. Ninety-nine of these

were cities with over 50,000 inhabitants, 15 had over 500,000 and four (Mexico City, Guadalajara, Monterrey and Puebla) had over one million inhabitants (Garza et al., 1995). In 2005, the country's population totaled 103.2 million, of which 62% were in towns with over 15,000 inhabitants, in other words, the urban proportion was maintained.

The City System or National Urban System is composed of 56 metropolitan regions and 327 cities with over 15,000 inhabitants, where 56% of the population live. Moreover, over the past 30 years, the territorial expansion of cities has grown four times more quickly than the total population and three times more quickly than the urban population.

In the last census (INEGI, 2010), the country's population totaled 112.4 million, of which 70.2 million live in towns with over 15,000 inhabitants (62.5%), and 53.6 million live in 117 cities with over 100,000 inhabitants. Some of these cities are grouped into one of 56 metropolitan areas that currently exist in the country and concentrate a total population of 63.8 million inhabitants (57% of the country).

The urban population will continue to expand, exerting growing pressure on urban development and service delivery, particularly in areas of the country where natural resources (especially water)

are already scarce, with patterns of over-exploitation and whose quality is generally threatened (Map 2).

Cities have experienced uneven, scattered growth and a low density spatial model, meaning that the introduction of services is not only more difficult but also more expensive (Sandoval, 2012). Medium-sized cities (with between 500,000 and 1 million inhabitants) are growing faster and there will be more than 20 large cities (with over 1 million people) in 2030 (UN HABITAT, 2011). The most difficult problem will be faced by “the Mexico City megalopolis” which will be formed of seven metropolitan regions: Valle de México, Toluca,

Cuernavaca, Cautla, Puebla-Tlaxcala, Pachuca and Queretaro; all of which currently face water supply problems and have unsustainable supply conditions (Sandoval, 2012).

3. Water sources. Water availability and consumptive uses

Mexico is divided into 1,471 watersheds (Map 3), grouped or subdivided into 731 hydrologic basins for the purposes of publishing the availability of surface water.¹ The country also has 653 aquifers (*Diario Oficial de la Federación*, December 5, 2001). Most information on water resources is presented at the level of hydrological-administrative regions, basins, aquifers or in accordance with political-administrative criteria (states and municipalities). Therefore, much of the information in this section will be presented at that level rather than at the urban-metropolitan level as would be desirable. This is undoubtedly the first issue to be addressed: the need for information on water at the urban level for proper planning. This is perhaps a problem that should be solved by city mayors, who require this information to improve their decision-making process.

Approximately 37.5% of the total amount of water extracted in Mexico, comes from the subsoil while the remaining 62.3% is obtained from surface sources.

Map 2. Population Nuclei with over 500,000 inhabitants, 2009 projection



Fuente: Conagua, Subdirección General de Programación. Elaborado a partir de CONAPO, *Proyecciones de la Población de México 2005-2050*. México, 2007.
 SÍDESOI, INEGI y CONAPO, *Delimitación de las zonas metropolitanas de México 2005*. México, 2007.
 INEGI, *II Censos de Población y Vivienda 2005*.

1. On December 31, 2010, the DOF published an average annual availability of 731 watersheds.

This ratio varies depending on usage. Domestic supply and industry are largely dependent on groundwater sources, whereas for irrigation and power generation, surface water sources are mainly used.

Map 4 shows the 2,457 municipalities in the country. Pink shows those that are predominantly dependent on groundwater, while blue shows those that rely mainly on surface water. Municipalities in the states of Baja California and Baja California Sur, the whole of the Yucatán Peninsula and many of the municipalities in the interior in the northern part of the country (Coahuila, part of Nuevo León, Zacatecas, San Luis Potosí, Guanajuato and much of Jalisco) employ mostly groundwater sources for their consumptive uses.

In 2012, approximately 82.7 cubic kilometers (km³) of the total amount of water naturally available in Mexico were extracted. Of that amount, the water used to supply human settlements, which could be called urban water, was 12 km³. To this figure, one should add 3.3 km³ of water consumed by the self-supplied industry, usually located in urban areas. In other words, 14.5% of the water utilized in Mexico is assigned for public urban use, 4% for industrial use and 5% for thermoelectric power generation, while the remaining 77% is employed for agricultural purposes (see Table 1). Water used for urban public supply and the urban self-supplied industry, 8.8 km³ (60%), comes from groundwater while 40% is obtained from surface water.

The amount licensed for urban public use, employed by operating organizations to provide piped water services, rose from 9.57 km³ in 2001 to 12 km³ by 2012 (CONAGUA, 2013a), i.e. at a higher rate than the growth of the urban population. The three

states with the highest amounts of public urban use concessions are the State of Mexico, Mexico City and Sonora, whereas those with the lowest volume for

Map 3. Watersheds into which the country is divided



Source: CONAGUA, 2012b.

Map 4. Predominant source (either surface or groundwater) for consumptive uses at the municipal level, 2009



Source: CONAGUA, 2011.

Table 1. Consumptive uses grouped by origin of type of extraction source, 2012

Use	Origin		Total volume (km ³)	Percentage of extraction
	Surface (km ³)	Ground (km ³)		
Agricultural*	41.2	22.2	63.3	76.6
Public supply*	4.7	7.3	12.0	14.5
Self-supplied industry**	1.4	1.9	3.3	4.0
Electricity excluding hydro electricity	3.6	0.4	4.1	4.9
Total	51.0	31.8	82.7	100

Note: 1km³=1 000hm³=billion m³. The data correspond to volumes licensed to December 31, 2009. Numbers may not coincide due to the rounding of figures. * Includes agriculture, livestock, aquaculture, multiple and other sections from the REPDA classification. Also includes 1.30 km³ of water corresponding to Irrigation Districts pending registration. Includes the public urban and domestic sections under the of REPDA classification. ** Includes the industrial, agro-industrial, services and trade sections of the REPDA classification.

Source: CONAGUA, 2013a.

this use are Baja California Sur, Colima and Tlaxcala. Fifty-three per cent of this amount is obtained from groundwater sources. In 2001, the proportion of groundwater concessions for the provision of domestic piped water from underground sources was 65.4%, suggesting that there has been a reduction in the reliance on groundwater sources.

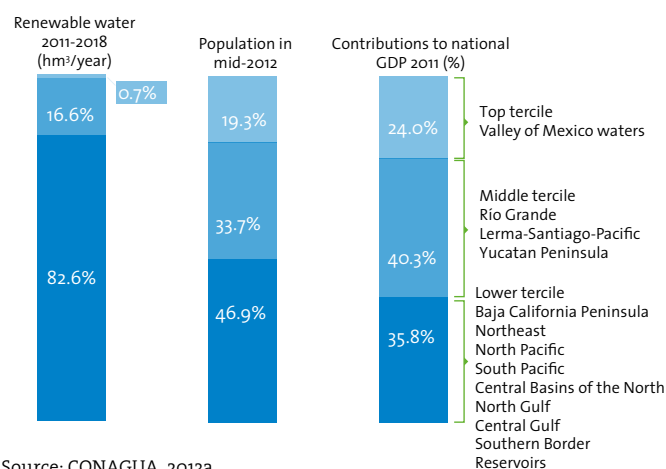
Map 5 shows the municipalities whose predominant consumptive use (over 50% of the total volume) is public urban use (marked in blue). In these municipalities, there is less agricultural irrigation, meaning that the water consumed is predominantly for domestic uses.

Map 5. Predominant Consumptive Use at the Municipal Level, 2009



Source: CONAGUA, 2011.

Graph 1. Regional contrast between development and renewable water, 2011



Source: CONAGUA, 2013a.

3.1 Water Distribution in Relation to Population Distribution and Wealth Creation

As discussed above, Mexico displays broad regional diversity when the population distribution of renewable water and the generation of the Gross Domestic Product (GDP) is analyzed. On the basis of Administrative Hydrological Regions (AHR), they can be classified into large groups according to their contribution to national GDP. For example, the 13th Water Region of the Valle de México alone, with 24% of GDP, accounts for almost a fifth of the national population, while having low amounts of renewable water. Conversely, the following group of hydrological-administrative regions, I (Baja California), II (Northwest), III (North Pacific), IV (Balsas), V (South Pacific), VII (Central Basins of the North), IX (North Gulf), X (Central Gulf) and XI (South Border) with a low contribution to GDP, have the highest amount of renewable water in the country, as can be seen from Graph 1.

These regional contrasts are also observed when analyzing the amounts of water licensed and therefore consumed for different purposes. The states with the largest volumes of water licensed for different uses are Sinaloa, Sonora, Michoacán and Chihuahua, main due to the large agricultural volumes they consume. Conversely, the states of Aguascalientes, Tabasco, Baja California Sur and Tlaxcala have smaller volumes of water under concession. The State of Mexico, Mexico City and Sonora are the states with the largest amounts of water concessions for urban use. In terms of per capita consumption, calculated on the basis of the amount of urban water concession, however, the top two states are Chihuahua and Sonora.

As regards consumption in Mexican cities, a recent study of 142 cities with over 50,000 inhabitants, comprising 51.5 million urban dwellers, showed that the flow rate provided is 171 m³/s (CNA, 2012b), in other words, that the mean amount of water supplied per capita in the country's largest cities is 288 liters per capita per day. This value fluctuates between cities with a high daily demand (over 575 l/inh. in cities such as San José del Cabo, Guaymas and San Juan de los Lagos, Jalisco) and those with a supply of less than 125 liters per inhabitant per day (Zinacantepec, Toluca Metropolitan Area; Acayucan, Veracruz and El Pueblito, Querétaro Metropolitan

Area). It is necessary to conduct a more detailed study to determine the reasons for these differences as well as the possibilities for improving the efficiency of urban water use.

3.2 Overexploitation of surface and groundwater in urban areas

The degree of exploitation of surface water in the country's 731 watersheds is calculated on the basis of their annual mean availability. The basins that currently have surface water available for concessions are shown on the map in green, while those with deficits are presented in red (Map 6).

Since the 1970s, groundwater resources and their exploitation have increased significantly. There were 32 overexploited aquifers in 1975, 80 in 1985 and 101 in 2011. A total of 53.6% of the groundwater for all uses is extracted from over-exploited aquifers. Map 7 shows the availability of groundwater by administrative hydrological region.

The Río Grande and Lerma Santiago hydrological-administrative region contains the largest number of overexploited aquifers in the country. In the North Central Basins, Aguas del Valle de México and Lerma Santiago regions, at least 25% of aquifers are overexploited. Conversely, none of the aquifers in the regions of the South Pacific, Northern Gulf and Southern Border and the Yucatán Peninsula are overexploited.

Recently, a study by the Mexican Institute for Competitiveness (IMCO, 2013) published several indicators to assess the urban competitiveness of the 77 major Mexican cities. The environmental indicators included data on the overexploitation of aquifers, more specifically the percentage of area that is over-exploited. Cities with more severe problems of aquifer overexploitation include Aguascalientes, Mexicali, La Paz, Ensenada, Tijuana, Los Cabos, Campeche, Ciudad del Carmen, Saltillo, Monclova-Frontera, La Laguna, Piedras Negras and Tecomán. As shown in Table 2, several of the country's cities lie on aquifers that do not experience a degree of exploitation of over 25%.

The Mexican government has several instruments, including closed areas, to deal with the exploitation of water resources, whether surface or underground. A closed area is a specific area of a

Map 6. Availability of surface water



Source: CONAGUA, 2013a.

Map 7. Availability of groundwater by administrative hydrological region



Source: CONAGUA, 2013a.

hydrologic region, watershed or aquifer, which the state regulates by setting the volume of extraction, use and discharge that may be authorized. Closed areas can be decreed due to the deterioration of the water as regards either quantity or quality, effects on hydrological sustainability or damage to surface or groundwater. In the case of groundwater, by December 2009, 145 closed areas had been announced between 1948 and 2007.

3.3. Water in Mexico's Peri-urban Areas

Urbanization in Mexico has followed a similar pattern to other countries in Latin America and much of the rest of the world. When the recurring crisis of world capitalism revealed the limits of the import substitution development model, Latin American countries and Mexico in particular, undertook industrialization in their own territories, thereby accelerating urbanization. Like so many others, Mexico City expanded exponentially, superimposing different areas and cultures. This gradually shaped a growth model towards the periphery, which, although driven by industrial development, did not always meet with appropriate government regulations for territorial occupation. In many places, population growth came up against (and indeed continues to do so) the ways in which governments produce territorial zoning and discourage the progress of housing towards areas classified as conservation areas. At other times, the communities of origin themselves are the ones that refuse to address the issue of population growth in their territories. This is how informal, irregular and even illegal urban spaces begin to emerge in periurban zones. The growth restraining mechanism used in almost all cases is the denial of services to the population, including water, as an essential element for building dwellings.

Peri-urban areas are thus characterized as transitional spaces between rural and urban settings, where specific relations and cultures from the two areas coexist, enabling the creation of

new forms of water supply. Some of these options are more or less autonomous, independent of the government option based on formal mechanisms establishing network access as the only alternative. Among the different forms of water supply found in various studies are commercialization through water trucks, where people buy water or community arrangements for the construction, maintenance and operation of the local system, usually based on high investment by the residents themselves (by working on tasks and serving in honorary positions to administer the system, payment of regular and special quotas, etc.). In addition to infrastructure aspects, these mechanisms also include self-management regulations that include the control and monitoring of systems and the implementation of sanctions. In this respect, the ways in which the territory is built create a complex mosaic of water supply alternatives, many of which produce original, independent forms that even contradict government arrangements (Palerm, 2013; Torregrosa et al, 2006).

Therefore, it can be said that in response to the state's withdrawal from the capacity to ensure the supply of universal quality water, viable alternatives emerge such as more or less autonomous, informal, irregular and illegal community arrangements, which, together with a broad spectrum of the water market, whether formal, informal or illegal, provide solutions to what the state is unable or unwilling to resolve. In these territories, the regulations and mechanisms of access and operation of the water supply system are built on a day to day basis and are part of the daily struggle for a better quality of life.

Table 2. Overexploitation of Aquifers in Major Mexican Cities, 2012

% Aquifer surface Overexploited	Cities
> 90%	Aguascalientes, Campeche, Ciudad del Carmen, Ensenada, La Paz, Los Cabos, Mexicali, Monclova-Frontera, La Laguna, Piedras Negras, Tecomán, Tijuana and Saltillo.
Between 75% and 90%	Colima-Villa de Álvarez, Chihuahua, Manzanillo, Tapachula and Tuxtla Gutiérrez
Between 50% and 75%	Celaya, Durango, Juárez and Valle de México.
Between 25% and 50%	Guanajuato, Irapuato and León
< 25%	Acapulco, Cancún, Cárdenas, Ciudad Obregón, Ciudad Victoria, Coatzacoalcos, Córdoba, Cuautla, Cuernavaca, Culiacán, Chetumal, Chilpancingo, Guadalajara, Guadalupe, Guaymas, Hermosillo, La Piedad-Pénjamo, Los Mochis, Matamoros, Mazatlán, Mérida, Minatitlán, Monterrey, Morelia, Nuevo Laredo, Oaxaca, Ocotlán, Orizaba, Pachuca, Pánuco, Poza Rica, Puebla-Tlaxcala, Puerto Vallarta, Querétaro, Reynosa-Río Bravo, Rioverde- Ciudad Fernández, Salamanca, San Francisco del Rincón, San Juan del Río, San Luis Potosí, Soledad, Tampico Tehuacán, Tehuantepec-Salina Cruz, Tepic, Tlaxcala-Apizaco, Toluca, Tula, Tulancingo, Uruapan, Veracruz, Villa Hermosa, Xalapa, Zacatecas and Zamora-Jacona.

Source: Prepared by Jordi Vera, using information from IMCO, 2013.

Table 3. Main cities in Mexico with their population, flow produced and average

State	Locality	Population	Population with service		Flow produced (l/s)	Supply average (l/inhab./day)
			(Inhabitants)	(%)		
Federal District	Mexico City	8,609,001	8,367,691	97	31,418	315
Jalisco	Guadalajara	3,952,185	3,873,141	98	9,586	210
Nuevo León	Monterrey	3,702,161	3,686,612	100	11,076	258
Puebla	Puebla de Zaragoza	1,830,376	1,767,777	97	3,615	171
Baja California	Tijuana	1,619,270	1,586,885	98	3,589	191
Chihuahua	Juárez	1,360,865	1,320,039	97	5,437	345
Mexico	Ciudad Nezahualcóyotl (conurbated municipality of Mexico City)	1,096,911	1,085,942	99	2,472	195
Yucatán	Mérida	878,059	834,156	95	3,000	295
Mexico	Naucalpan de Juárez (conurbated municipality of Mexico City)	834,525	817,835	98	1,300	135
Chihuahua	Chihuahua	831,211	764,714	92	3,992	415

Source: CONAGUA, 2012c.

Table 4. Evolution of drinking water coverage in urban areas, 1990-2012

Year	Total population in private dwellings	Inhabitants (millions)			Percent Coverage (l/inhab./day)
		With service	Without service	Beneficiaries	
1990	57.3	51.2	6.1		89.4
1995	66.7	62	4.7	10.8	92.9
2000	71.1	67.3	3.8	5.3	94.6
2005	76.1	72.3	3.8	5	95.0
2010	84.4	81	3.7	8.7	95.6
2010*	85.4	81.5	3.9	0.5	95.4
2012*	87.9	84.0	3.9	1.3	95.5

Adapted from: INEGI, 2010.

4. Drinking water supply in urban areas

4.1. Current status of drinking water coverage and access in the country

Table 3 shows some of the most densely populated cities in the country, including Mexico City, Guadalajara, Monterrey and Puebla. In these cities, coverage is above average, fluctuating between 97% and 100% of the population (CONAGUA, 2012c). Mexico City and Monterrey consume the largest volume of water. In both cases, the urban water supplied travels long distances through complex hydraulic systems. The case of Mexico City and the Cutzamala system are the best known example of this.

As regards the mean provision of the ten main Mexican cities, Juárez and Mexico City are the two cities with average supplies exceeding 315 liters per inhabitant per day, while cities such as Puebla and Naucalpan have the lowest water supply (under 172 liters / inhabitant/day).

In December 31, 2012, 92.0% national drinking water coverage was recorded, when 1.7 million inhabitants were incorporated into the service for the first time (CONAGUA, 2013b). At the state level, 25 Mexican states recorded coverage of over the national average, with Yucatán and Colima leading with over 98%. By contrast, Chiapas, Oaxaca and Guerrero have less than 80% coverage. In urban areas, the evolution of piped water coverage (1990-2011) is shown in the Table 4.

4.1.1 Coverage in relation to income groups

Nationwide data of this nature is unavailable. However, there are several studies that address the problem at the level of localities, *delegaciones* (boroughs) and municipalities. These studies reveal the fragility of official figures, since, even in cities with good network coverage such as the Federal District, the issue of receiving supplies water in shifts, irregular grid connections and the supply of significant sectors of the population by water trucks is significant and qualifies the coverage figures mentioned in the official data. With regard to official information, there are studies at the neighborhood level in urban areas of the country (Urban Marginalization Index 2010, CONAPO), where the degree of marginalization of the inhabitants is known and may be linked to piped water coverage.

An indirect indicator of water vulnerability is the availability or otherwise of water tanks, cisterns and underground cisterns known as *aljibes* (water tanks containing between 500 and 10,000 liters). This

indicator was available for the first time as part of the expanded questionnaire of the INEGI Population and Housing Census 2010. Given that the piped water service in the Mexican cities is provided in shifts, this indicator reflects the water vulnerability of residents who lack these water supply systems. As can be seen in Table 5, inhabitants of major urban areas are less vulnerable than those of rural areas.

4.2 Characterization of services by continuity, water quality and water leaks in the system

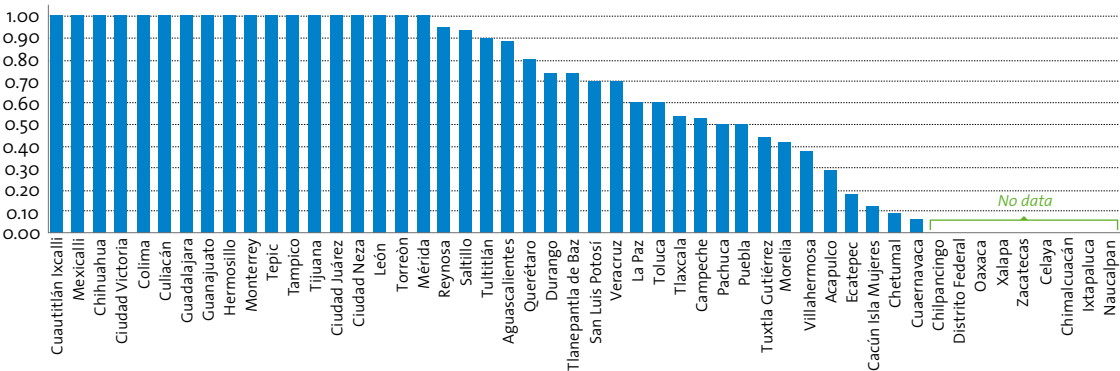
Data on continuity of service nationwide were collected for the first time in the INEGI Census 2010. However, these data are not available for urban areas in the country, but only for the national mean and the 31 states and the Federal District. The data show that the states of Baja California, Chihuahua, Quintana Roo, Nuevo León and Tamaulipas have the best water service, since more than 95% of dwellings are supplied with water on a daily basis. By contrast,

Table 5. Availability of water storage systems by size of locality

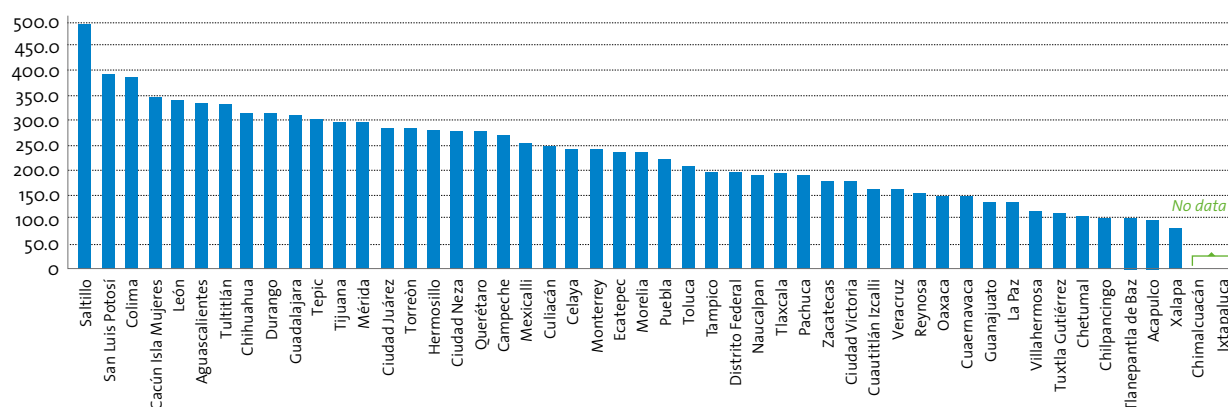
Size of locality	Equipment	Inhabited private dwellings	Availability		
			Available	Unavailable	Unspecified
Mexico	Water tank	28,643,491	55.1	43.6	1.3
Mexico	Cistern or underground cistern	28,643,491	25.8	72.8	1.4
Under 2500 inhabitants	Water tank	6,282,646	36.2	63.0	0.8
Under 2500 inhabitants	Cistern or underground cistern	6,282,646	11.3	87.9	0.8
100,000 or more inhabitants	Water tank	14,317,340	63.3	35.0	1.9
100,000 or more inhabitants	Cistern or underground cistern	14,317,340	34.6	63.5	1.9

Adapted from: INEGI, 2010.

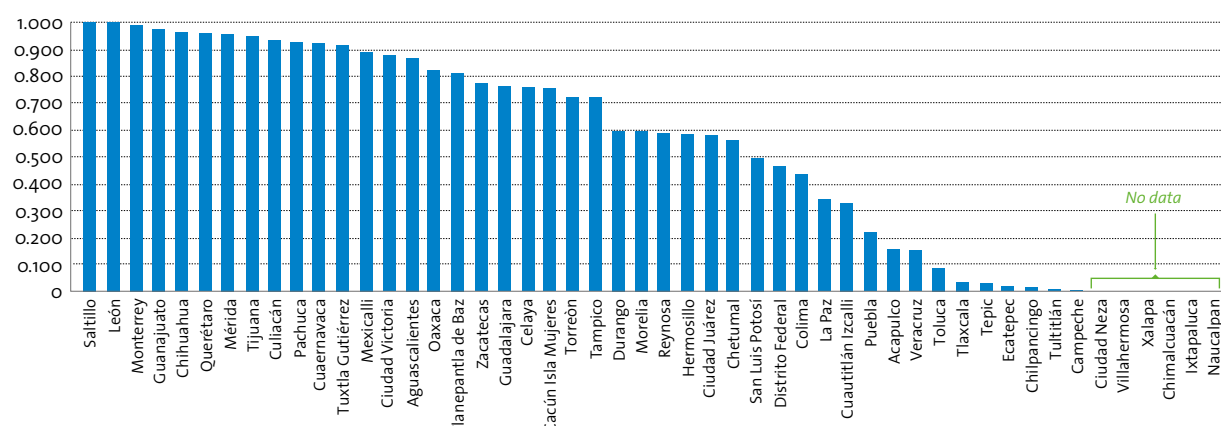
Graph 2. Distribution of continuity factor in 50 Mexican cities



Source: CCA, 2011.

Graph 3. Distribution of productivity factor among 50 Mexican cities

Source: CCA, 2011.

Graph 4. Distribution of percentage of connections with household meters in 50 Mexican cities

Source: CCA, 2011.

the states of Chiapas, Guerrero, Oaxaca and Puebla have the worst service, with several dwellings having sporadic water service provided once or twice a week, despite being the states with the greatest water availability in the country.

Graph 2 shows the distribution of a continuity factor (Sandoval, 2012), in other words, the percentage of connections that receive water 24 hours a day, 7 days a week, according to information from the utility companies.

Graph 3 shows the distribution of a “productivity factor” that takes into account the number of connections per operator of the piped water system. Nearly half the sample falls below acceptable levels. In this case, although the topographical context

of each city and the complexity of the networks may play a role, this indicator is mainly due to the existence of powerful unions in certain regions of the country that prevent the optimization of the workforce (Sandoval, 2012).

In Graph 4 shows the percentage of metered connections. Nearly two-thirds of cities have under 80 percent of metered connections. On the basis of the above information, Sandoval (2012) notes that:

- National service coverage statistics, measured in terms of household connections that enable the supply of drinking water and wastewater discharge, indicate high coverage, but when continuity of service is analyzed, numbers vary widely.
- There are significant differences in labor

productivity and commercial efficiency. Cities in the north of the country have the best indicators.

4.3 Water source management and administration

4.3.1 The water service structure

In recent years, Mexico has undergone profound changes in its water policy. These changes begin in the 1980s, when the Mexican state expressed its determination to decentralize public drinking water provision. The first step occurred in 1980, when the federal government ceded the operation of water and sewerage systems to state governments, which in some cases was in turn transferred by the states to municipalities (Castro et al., 2004).

Drinking water service was subsequently municipalized in 1983 through the passage on February 3 of a constitutional amendment to Article 115, stipulating that drinking water services were the responsibility of municipalities. This resulted in the devolution and decentralization of drinking water administration, infrastructure and investment, from the federal government to state and municipal governments.

On January 16, 1989, President Salinas created the National Water Commission (CNA) as a decentralized agency. Towards the end of that year, he proposed the decentralization, autonomy and promotion of private participation in the operation of water services, with citizen participation. In 1992 a new National Water Law was passed, designed, among other things, to strengthen the concession of rights of use and encourage private water management. Two new agencies were created: the Watershed Councils, understood as a new field of water management involving the various sectors and local authorities, and the Public Water Rights Register, designed to stimulate a commodity circulation of the water rights licensed by CONAGUA. The Law also explicitly stated the authorities' interest in having society participate in various fields: by paying more for services, creating a new water culture or investing in capitals (Aboites, 2004).

The 1992 legal reforms reinforced the decentralization and private participation policies in the sector, radically reorienting the role of public institutions in resource administration and management.

Likewise, irrigation districts were transferred to the users thereof. Districts were divided into irrigation modules according to the secondary network, networks and roads, and an Association of Users was created in each of them, to which the CNA granted a Water Concession and Infrastructure Use Title (Castro et al., 2004).

State programs generally reflect federal policies marked by frequent statewide negligence as regards assuming a larger role in regulating water and sanitation, and a lack of capacity. However, some states have established investment programs with support from the federal government to contribute to the expansion of service coverage on the one hand, and encourage the streamlining of water and energy use and business development on the other (Sandoval, 2012).

4.3.2 Organizational mechanisms and/or innovative technologies for providing services for urban areas

CONAGUA allocates federal funds through a set of investment programs, each with individual operating rules that tend to vary slightly from year to year and in addition have to conform to the rules also set by state authorities. In recent years, the main programs have been:

- a. APAZU (Drinking Water, Sewerage and Sanitation in Urban Areas Program), created in 1990 to support state and municipal projects for the expansion and improvement of water services.
- b. PAL (Clean Water Program), implemented since 1991, designed to increase and maintain, through chlorination, disinfection levels of the water supplied to the population, in order for it to meet the criteria for human use and consumption.
- c. Prossapys (Program of Sustainability of Drinking Water and Sanitation Services in Rural Areas), implemented in 1999, designed to expand coverage of services in localities with under 2,000,500 inhabitants.
- d. PROMAGUA (Program for the Modernization of Water Operating Organizations), implemented in 2001 to support public services in cities with more than 50,000 inhabitants, where private participation schemes are promoted.
- e. PRODDER (Devolution of Rights Program), which seeks to contribute to the implementation of measures to improve the efficiency and

- infrastructure of drinking water, sewerage and wastewater treatment in municipalities, by assigning federal income obtained from the collection of dues for the exploitation, use or exploitation of national waters to drinking water and sewerage providers.
- f. Support program for the Valley of Mexico for water and sanitation projects, recently named “Water Sustainability Program for the Valley of Mexico.” This program is assigned federal funds, in addition to the funds obtained from the public services that receive water supplied by the CONAGUA infrastructure (Cutzamala, Lerma and wells operated by the federal organization). Funds are managed by a trust originally established for the implementation of an international credit.
 - g. PROTAR (Wastewater Treatment Program), the forerunner of which was created to support public utility companies’ investment programs in construction, improvement and expansion.
 - h. PROSANEAR (Federal Wastewater Treatment Program), in which a tax incentive is created through the cancellation or exemption from payment of water discharge rights by municipal authorities. Funds have been allocated to offset the operating costs of sewerage treatment for public services demonstrating full compliance with discharge standards.
 - i. PROME (Program for Streamlining Public Water Services) under a technical assistance program signed with the World Bank (called “PATME”), with the aim of reinforcing the technical development and financial self-sufficiency of a

Table 6. Strategic Urban Infrastructure Projects for Water, Sewerage and Cleaning

Category	Project	Metropolitan area or city	Investment (approx. figure in million USD).	Status Nov. 2012
Valle de México	New sources	Mexico	353	Studies
	Cutzamala System	Mexico	547	Under construction
	Atononilco Wastewater Treatment Plant	Mexico	794	Under construction
	El Caracol Wastewater Treatment Plant	Mexico	61	Under construction
	East (TEO)	Mexico	1574	Under construction
	Sewerage works	Mexico	246	Under construction
	River Company Tunnel	Mexico	150	Completed
	Rio de los Remedios Tunnel	Mexico	62	Completed
	Main Canal Pipeline	Mexico	38	Completed
Dams and aqueducts	El Zapotillo Dam	León - Guadalajara	349	Under construction
	El Zapotillo Aqueduct	León	666	Under construction
	El Purgatorio	Guadalajara	449	In bidding process
	El Realito Dam	San Luis Potosí–Celaya	82	Completed
	El Realito Aqueduct	San Luis Potosí	191	Under construction
	Improvement of integral water management	San Luis Potosí	71	Under construction
	Paso Ancho Reservoir	Oaxaca	73	Under preparation
	Paso Ancho Aqueduct	Oaxaca	132	Under preparation
Wastewater treatment	Sewerage works	Guadalajara	286	Under construction
	Agua Prieta Wastewater Treatment Plant	Guadalajara	202	Under construction
	El Ahogado Wastewater Treatment Plant	Guadalajara	67	Completed
	Cleaning up of Atoyac River	Puebla and Tlaxcala	66	Under construction
	Cleaning Apatlaco up of Río	Morelos (Cuernavaca)	130	Under construction
	Total Acapulco Sanitation	Acapulco	57	Under construction
Desalination projects	Ensenada	Ensenada	40	Under construction
	Other projects	Seven cities	251	Under preparation
Total			9112	

Source: (CONAGUA, 2012e) – In millions of pesos, November 2012.

selected group of public services. It has a component to enhance CONAGUA's capacity to collect information, assess the development of the sector and "modernize" public utility companies' services, by providing assistance and technical evaluation as well as a "classic" investment program based on assessment and diagnosis, with certain actions implemented within the framework of a results-based spending plan.

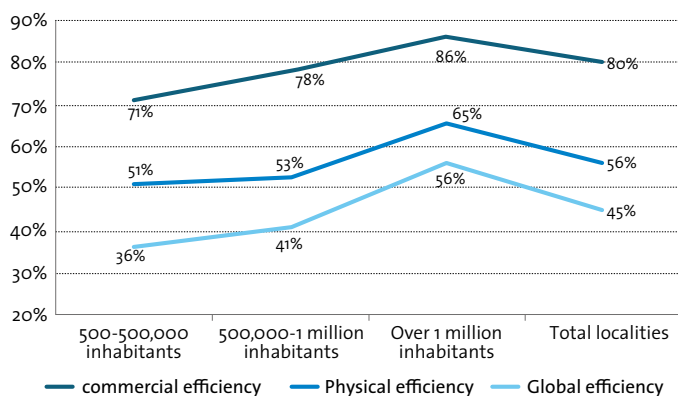
Most of the funds are allocated by transferring resources to the state or municipal authorities, under a coordination agreement whereby the executors agree to follow federal rules.

Increases in water demand in metropolitan areas pose an enormous challenge for local and federal authorities, as a result of which strategic projects have been developed. Table 6 shows the most important ones, where the amount of investment exceeds \$9 million USD. Most projects have been implemented in conjunction with capacity building programs to improve the performance of public services and to make projects financially viable.

4.3.3 Efficiency indicators of operating companies

Graph 5 shows the physical and commercial efficiency of the operating companies by size of the locality. As one can see, the larger the urban population, the greater the commercial and physical efficiencies. The highest efficiencies are found in cities with over one million inhabitants.

Graph 5. Physical and commercial efficiencies by size of locality



Source: CONAGUA, 2012c.

Investments for 2011 totaled \$2,911,300 USD (37,474.9 million pesos), of which 83.1% were assigned for urban areas and the remainder for rural areas (CONAGUA, 2012b).

In urban areas, resources were spent on drinking water (19.3%), sewerage (37.5%), sanitation (22.3%), improving efficiency (14.7%) and other items (6.2%). The State of Mexico, Mexico City and its metropolitan area alone absorbed 9.7 billion pesos. Of these 37.47 billion pesos, 31 billion were spent on the construction and rehabilitation of drinking water works, sewerage and sanitation; 15,688.4 million were provided by the federal government; 5,907.2 million by state governments; 3,456.7 by municipal governments and 6,076.7 million by other entities. These areas are home to approximately 30% of the country's total population.

4.3.4 Water financing and management in Mexico

In Mexico, water infrastructure is funded by the following:

- Tariffs, with a limited ability to generate resources for capital investment.
- Taxes, transferred from chapters to municipal spending and federal or state transfers, since local taxes such as property taxes are rarely applied to capital investments for water in cities, partly as a result of the existence of the aforementioned transfers.
- Transfers, directly as specific chapters in federal taxes, are assigned on a regular basis, as well as in the form of state and federal programs, usually associated with a set of operating rules stipulating the technical, administrative and financial commitments expected from the utility company or municipality.
- Credit, which is only directly available to the few utility companies operating with sound financial structures and reasonable stability. Recently, however, there have significant efforts to support certain private participation schemes, together with venture capital and subsidies where the federal or state government usually assumes financial commitments, rather than the municipality or utility company.
- Direct private investment, which, with the exception of "Aguas de Saltillo" is unusual (Sandoval, 2012).

The rates charged for drinking water collection for domestic use are shown in Table 7, for major cities of the country in the years 2011 and 2012. The table shows that in eight cities, rates remained unchanged for the water collection service, while the remaining 24 increased. Within this group of 24 cities, the most striking cases involve Aguascalientes, León, Xalapa and municipalities in the Mexico City Metropolitan Zone such as Naucalpan and Atizapán, where increases of between 7% and 15% were recorded, even though their rates per cubic meter were already among the highest in the group of cities presented.

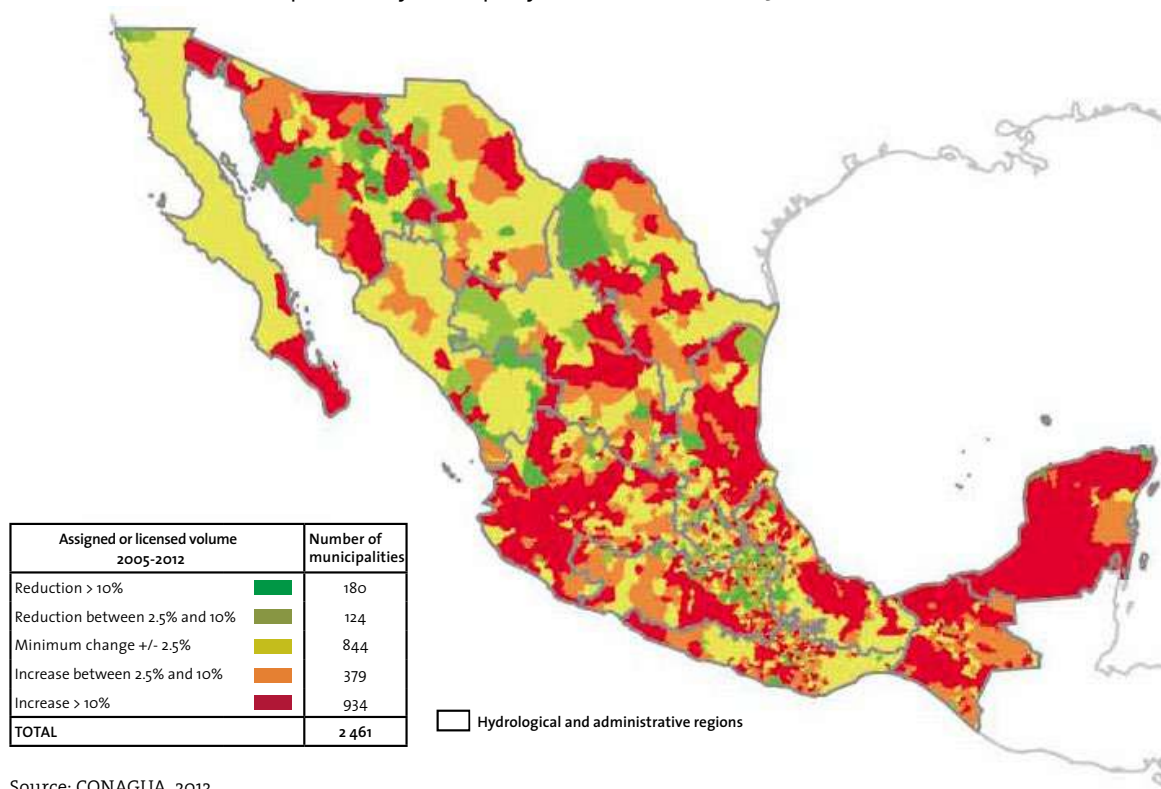
4.4 Water saving in cities, efficient water use and new designs for low water consumption

Map 8 shows that very few municipalities experienced a reduction in consumptive uses of water between 2005 and 2009. Conversely, several municipalities saw increases of over 10%. Unfortunately, this data includes all consumptive uses not just urban public use, which would be more helpful for determining trends in cities.

Table 7. Percentage change in water rates for domestic consumption in the main cities in Mexico (2011-2012)

City	2011	2012	Variation in rates (\$)	% to/
Acapulco	9.3	10.4	1.1	12
Aguascalientes	17.8	19.2	1.4	7.7
Atizapán	13.5	15.2	1.7	12.9
Campeche	1.8	1.8	0	0
Cancún	9.9	9.9	0	0
Chetumal	9.9	9.9	0	0
Colima	4.2	4.3	0.2	4.1
Culiacán	4.5	4.9	0.4	9.1
Delicias	5.4	5.4	0	0
Mexico City	15.6	16.2	0.6	3.6
Ensenada	13.8	14.2	0.5	3.5
Gómez Palacio	7.1	7.4	0.3	4.1
Guadalajara	5.6	5.8	0.2	4
Hermosillo	4.7	4.7	0	0
Juárez	5.8	5.8	0	0
La Paz	7.6	8.3	0.7	9.3
León	15.5	16.8	1.4	8.7
Mérida	3.9	3.9	0	0
Mexicali	4.5	4.6	0.1	2.9
Monterrey	8.2	10.2	2	23.8
Morelia	18.3	18.3	0	0
Naucalpan	13.5	15.4	2	14.6
Oaxaca b/	1.6	4.4	2.8	172.8
Puebla	10.1	10.5	0.3	3.5
San Juan del Río	5.3	5.5	0.2	4.2
San Luis Potosí	7	7.7	0.8	10.8
Tijuana	17.3	18	0.6	3.5
Tlaxcala	4.9	5.1	0.2	4.3
Toluca	8.7	9.5	0.7	8.4
Torreón	7.7	8	0.4	4.7
Tula de Allende	3.8	4.6	0.9	22.8
Xalapa	9.4	10.1	0.7	7

This information is based on monthly consumption of 30 m³, a volume regarded as sufficient for a family to cover its basic needs.
Source: CONAGUA, 2013b.

Map 8. Evolution of Consumptive Use by Municipality in the Period from 2005 to 2012

Source: CONAGUA, 2013.

5. Wastewater treatment

Up to December 31, 2012, national drinking water coverage of 90.5% was recorded, when 1.5 million inhabitants were incorporated into the service for the first time (CONAGUA, 2013b). However, the population without this service still stands at 10.9 million, 200,000 less than in 2011 (Table 8). At the state level, 17 states in Mexico recorded coverage above the national average, such as the Federal District and Colima, with coverage of over 98% while Yucatan, Guerrero and Oaxaca registered coverage of below 80%.

Mexico has 2,342 municipal wastewater treatment plants formally operating with a total installed capacity of 140.1 m³/s and a treated flow of 99.7 m³/s. It is estimated that treatment coverage of 47.5% of all the wastewater collected has been achieved. Between 2000 and 2011, wastewater treatment coverage doubled. At the top end, Aguascalientes, Baja California, Nuevo León, Tamaulipas and Guerrero have treatment coverage

of over 75% of treated water, while Yucatán, Hidalgo, Campeche, Tabasco and Chiapas have the lowest wastewater treatment rates. Table 9 lists the ten urban areas with the highest installed capacity and treated flow, led by Monterrey, Mexico City, Chihuahua and Juárez.

States that experienced a significant increase in coverage in the period from 2003 to 2011 include Baja California, Chiapas, Chihuahua, Querétaro, San Luis Potosí, Tamaulipas and Veracruz (CONAGUA, 2012c).

5.1 Treatment Systems

The most commonly used method in terms of the number of plants in the country is stabilization ponds, utilized in 732 plants, equivalent to 31.2% of the total number. This is followed by activated sludge, employed in 698 plants, 29.8% of the total, and in third place by the URA (Up-flow Anaerobic Reactor) process, utilized in 188 plants equivalent

to 8% of the total. These figures contrast when the treated flow is analyzed. In this case, the most important systems are activated sludge, which treats 46% of the wastewater collected, ponds, which account for 16% and advanced primary treatment, which processes 11% (CNA, 2012c).

5.2 Reuse and recycling

The Mexican government has a program to promote wastewater reuse through CONAGUA. Known as the CONAGUA Wastewater Reuse and Exchange Program, it is designed to “achieve integrated, sustainable water management, stipulated in the National Development Plan 2007-2012, regarding the management and preservation of water to achieve social well-being, economic development and the preservation of the ecological wealth of our country.”

The government is currently in the process of consolidating actions to promote treated wastewater reuse in the country and its exchange for first-use water in those activities in which this option is viable and feasible. The government has also encouraged the participation of both the public and the private sectors in the treatment and reuse of wastewater from various productive activities for agricultural uses, watering green areas, industrial cooling processes, cleaning and secondary municipal services. As regards the exchange of treated wastewater for first-use water, it would be used in agriculture and industry, among other uses, to stop exploiting ground and/or surface water. The surface water saved would be used to serve growing cities and industries.

Another incentive measure implemented by CONAGUA has been to persuade the operators of water systems for domestic use which decide to

Table 8. Evolution of Sewerage Coverage in Urban Zones, 1990 to 2012

Year	Total population in private dwellings	Inhabitants (millions)		Beneficiaries	Percent Coverage
		With service	Without service		
1990	57.3	45.3	12		79
1995	66	58.5	8.1	13.3	87.8
2000	71.1	63.8	7.4	5.2	89.6
2005	76.1	71.9	4.2	8.1	94.5
2010	84.7	81.6	3.2	9.7	96.3
2010*	85.4	82.2	3.2	9.7	96.3
2011*	86.8	83.6	3.1	1.4	96.4
2012*	87.9	84.8	3.1	1.3	96.5

Note: Percentages and sums may not coincide due to the rounding of figures. * Information up to December determined by CONAGUA. Source: CONAGUA, 2013b on the basis of information from the Censos de Población y Vivienda 1990, 2000 and 2010; Conteos y Vivienda 1995 and 2005.

Table 9. Treated flow in the main localities of over 50,000 inhabitants

State	Locality	Population	Number of treatment plants	Installed Capacity (l/s)	Treated flow (l/s)
Nuevo León	Monterrey	3,702,161	13	10,030	8,728
Federal District	Mexico City	8,609,001	25	6,685	3,148
Chihuahua	Chihuahua	831,211	3	3,705	2,222
Chihuahua	Juárez	1,360,865	4	3,551	2,551
Baja California	Tijuana	1,619,270	14	3,095	2,796
Veracruz	Veracruz	576,437	28	2,986	1,620
Baja California	Mexicali	777,404	5	2,797	1,946
Puebla	Puebla de Zaragoza	1,830,376	5	2,620	2,060
Guerrero	Acapulco de Juárez	685,336	15	2,240	1,937
Coahuila	Torreón	621,541	5	2,125	1,561

Source: CONAGUA, 2012c.

obtain the benefit of federal programs, to include in their construction, expansion, rehabilitation, projects and studies actions the reuse and exchange of treated wastewater, as typified in the Operating Rules for Hydro-Agricultural Infrastructure and Drinking Water, Drainage and Sanitation Programs, applicable as of 2012.

As for water reuse, since 2007, achievements have exceeded the goals set, particularly in 2011 when 2,700 m³/s more were reused than the amount set (Table 10).

During the first two years of the program, the goal for exchanging treated wastewater was slightly exceeded. This did not happen in 2009 or 2010, but in 2011 the target was once again exceeded by 600 l/s, due to the increase in the use of treated water in industrial activities, with first-use water no longer being employed in activities other than domestic consumption.

While gray or rainwater is rarely treated in Mexico, water from stormwater collectors is normally mixed with that from sanitary collectors and treated together in treatment plants as sewage.

5.2.1 Examples of the reintegration of water into ecosystems. Reuse and Recycling in Mexico City

A study by Jiménez (2013) reports that in order to cope with the challenge of meeting the growing demand for water in Mexico City, local water services that also manage wastewater have implemented various projects for utilizing reuse water for municipal and industrial purposes, some of which have been in operation since 1956. Moreover, the federal government has been responsible for a water reuse program in Mexico City and a second basin for agricultural irrigation since 1920.

At present, at least 260 l/s of water is reused to supply various industries in Mexico City. The main constraint on increasing reuse is cost, since treated wastewater is more expensive than first-use water and there are no regulations requiring companies to use reclaimed water. It is estimated that a proper legal framework for industrial reuse could increase the volume treated by an additional 1,000 l/s.

In addition, 1,300 l/s of reuse water are supplied to production power plants for cooling. Nearly 2,000 l/s are used for the irrigation of green areas and recharging recreational lakes and agriculture. Within the city, 1,200 l/s are used for recharging groundwater and 175 l/s for car washing.

New car wash centers are obliged to use reclaimed water. In addition, a treatment plant produces 600 l/s for ecological purposes, consisting of recharging what was formerly Lake Texcoco, which was drained by the Spaniards during the colonial era.

The last major public projects for planned reuse began operating in late 1980. The amount of reused water from public plants accounts for 10% of the total supply. Moreover, even though they are not officially registered, several dozen private treatment plants reuse water in sports clubs, golf courses and schools for watering the lawn or flushing toilets. Private reuse is not controlled by the government.

The rest of the wastewater produced in Mexico City, approximately 60,000 l/s, is used in its entirety, without any treatment to irrigate 90,000 hectares in the Valley of Tula, located 100 km north of Mexico City. This form of irrigation has been conducted for more than 110 years and, as a result of its use, over 25,000 l/s of wastewater filters into the aquifer. This aquifer provides water from various springs that are

Table 10. Goals 2007-2012 regarding the reuse of treated wastewater (l/s)

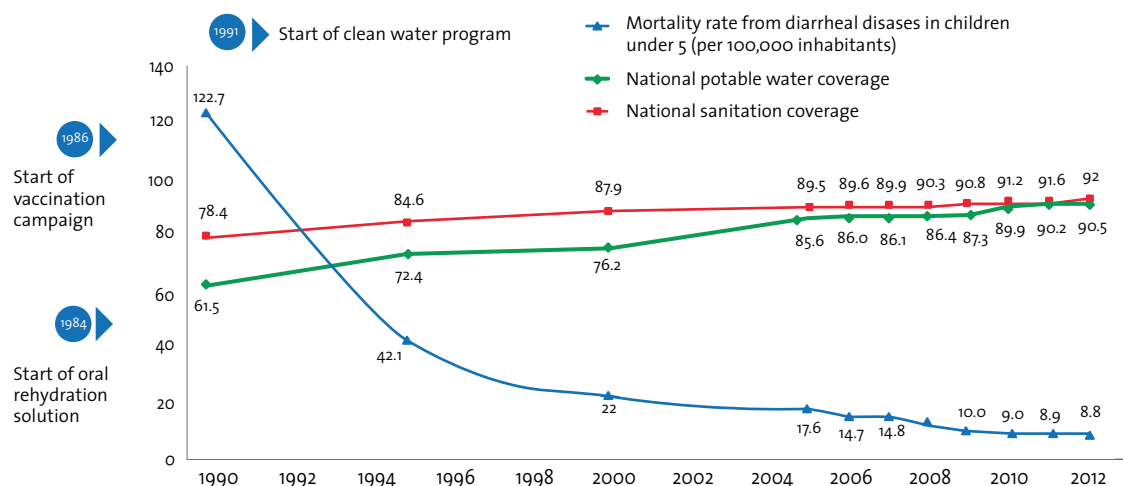
Year	Goals	
	Set:	Actual
2007	20,000	20,100
2008	21,000	21,500
2009	21,500	21,700
2010	22,000	22,400
2011	22,500	25,200
2012	23,000	25,200

Source: CONAGUA, 2013b.

Table 11. Goals for 2007 to 2012: exchange of treated wastewater (m³/s)

Year	Goals	
	Set:	Actual
2007	5	5.3
2008	5.5	5.7
2009	6	5.7
2010	6.5	6.2
2011	7	7.6
2012	7.5	7.8

Source: CONAGUA, 2013b.

Graph 6. Drinking water and sewerage coverage and mortality from diarrheal diseases in children under five, 1990-2012

Source: CONAGUA, 2013a.

used to supply the 500,000 people living in the valley of Tula. Despite its origin, the water has proved to be of acceptable quality (Jiménez and Chávez, 2004) due to various treatment mechanisms of natural origin that occur during its transport, storage and infiltration into the soil. In fact, it has been shown that some pollutants such as heavy metals and emerging contaminants remain in agricultural soils for several years or even decades (Siebe, 1995, Gibson, 2007 and Durán, 2009 in Jiménez, 2013).

5.2.1.1 “WQ” Standards and Treatment Technology

With regard to standards, Jiménez (2013) explains that wastewater reuse for agriculture has been regulated since the 1980s. These standards were amended in 1986 (NOM-001- SEMARNAT 1986) to adjust the characteristics of the quality of treated wastewater discharged into the atmosphere. In the case of use for agricultural irrigation, in order to control health risks, fecal coliform content was limited to 10^3 MPN/100 ml and helminth egg content to 1/l for all types of irrigation and 5 helminth eggs/l for the irrigation of crops that are not consumed raw or processed. Moreover, a higher BOD was allowed in order to improve the quality of agricultural soils, whereas the use of the amount of heavy metals was limited to the values established by the 2004 Standards of the US EPA for reuse water. As in most countries around the world, in Mexico, there is no

government standard for water reuse for industrial purposes. For water reuse in public uses, the NOM-003- SEMARNAT-1997 water standard is employed, which only covers restrictions for biological contaminants. In order to regulate the infiltration of reuse water into groundwater, the NOM-014-CNA-2003 standard has been adopted.

Planned wastewater reuse for industrial and municipal purposes has always been carried out after at least one secondary treatment together with filtration. The effluent produced has proved adequate for most uses, except for recharging recreational lakes, particularly Lake Xochimilco, which currently suffers from eutrophication and therefore require advanced treatment.

All investments in public projects have been through public funding. Plants are also operated by the government in general.

Public reuse projects are managed by Mexico City and municipal water services, while water reuse in agricultural fields outside the Mexico City basin is operated by the federal government.

6. Water and health in cities

The provision of safe water and sanitation is a key factor in the population's health, especially that of children. These services contribute to the control of

the incidence of waterborne diseases such as viral hepatitis, typhoid fever, cholera, dysentery and other causes of diarrhea as well as possible effects resulting from consumption of water with toxic chemicals, such as arsenic or fluoride.

In Mexico, infant mortality from diarrheic diseases was reduced to 8.8 per 100,000 by 2012 (Graph 6), as a result of various public health actions and interventions, among which the distribution of oral serum (as of 1984), vaccination campaigns (as of 1986), the Clean Water Program (since 1991) and increased drinking water and wastewater, sewerage and sanitation coverage. Despite these results, there are states such as Chiapas, Oaxaca and Guerrero with high mortality rates in the order of 41.6, 29.2 and 21.1 respectively (CONAGUA, 2011).

Graph 6 shows the incremental behavior of drinking water and sewerage coverage shown in comparison with the reduction in mortality rates from diarrheal diseases in children under five.

In 2012, more than 6 million cases of intestinal infectious diseases were reported, equivalent to a rate of 5,275 cases per 100,000 inhabitants (considering the INEGI Census 2010 and applying the CONAPO projection for December of that year), indicating a growth rate in relation to 2010 due to the increase in the population and number of cases (CONAGUA, 2013b) (Table 12).

5.1 Certain issues related to health problems and water in Mexico

To understand more about the problems of water-related diseases, it is important to explore the purification and disinfection processes undergone by drinking water. There are 699 water purification plants in operation nationwide (with an installed capacity of 135.1 m³/s, CNA 2013b). Of the 329.8 m³/s of water supplied nationwide, it is estimated that 205 m³/s, equivalent to 62%, comes from groundwater sources, the remaining 124.5 m³/s being obtained from surface sources, of which 88.8 m³/s (71%) are processed for potabilization. Conventional clarification is the most commonly used process in terms of the number of plants, since it is employed by 206, followed by reverse osmosis treatment, utilized in 193 plants and, thirdly, the clarification patent used at 158 facilities.

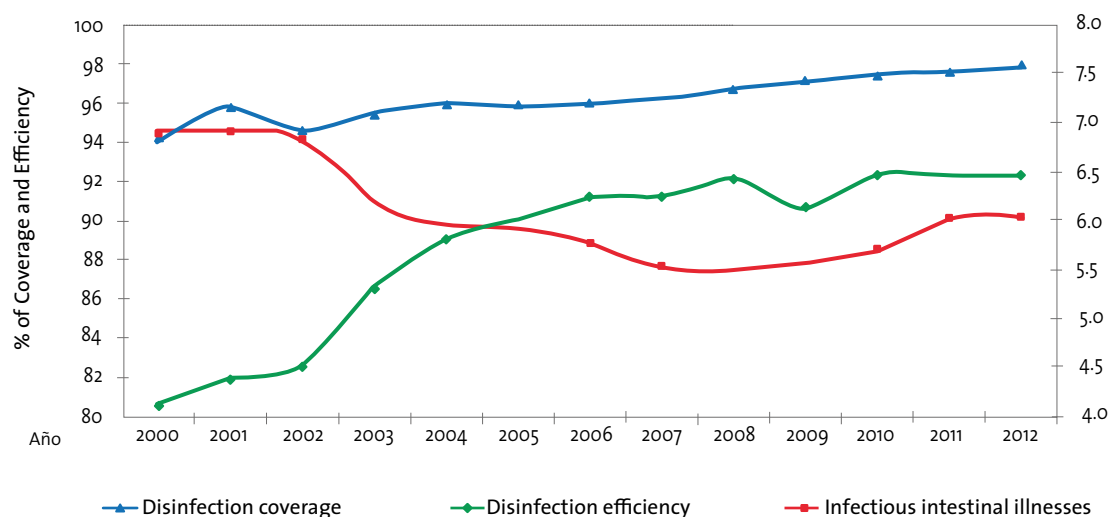
The service provider, usually the municipality and occasionally the state, is responsible for performing chlorination. The effectiveness of the procedure for disinfecting the water supplied to the population through formal supply systems is evaluated through the determination of residual free chlorine, a key indicator, whose presence in the domestic outlet indicates the efficiency of disinfection. The latest available data (CNA, 2013b)

Table 12. Registered cases of infectious diseases of the digestive tract, 2002-2012

Disease	Number of cases per year										
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011 ^{a/-}	2012
Intestinal infectious diseases	6,831,630	6,191,011	5,351,869	5,912,952	5,765,081	5,533,670	5,500,546	5,564,841	5,705,412	6,025,664	6,045,506
Shigellosis	31,473	27,704	22,321	19,441	16,483	14,799	12,885	13,136	11,378	9,975	8,181
Cholera								0	0	1	2
Typhoid Fever	7,889	20,020	25,952	31,790	37,012	44,076	44,199	46,174	44,757	48,055	54,147
Paratyphoid fever and salmonellosis	80,494	102,754	109,444	109,536	115,014	122,956	120,986	139,143	120,414	122,345	128,434
Intestinal virus infection, other agencies and ill-defined	5,374,980	4,823,611	4,778,135	4,765,567	4,716,011	4,616,080	4,645,091	4,715,783	4,923,459	5,283,896	5,345,173
Bacterial food poisoning	21,659	36,057	39,947	40,559	37,987	36,121	35,887	38,555	40,903	44,467	47,165

a / The number of cases by type of illness does NOT coincide with those reported in the CONAGUA 2012c edition, because the Secretariat of Health adjusted its information. SOURCE: Secretariat of Health, *Boletín Epidemiológico*, Published by the Single Information System for Epidemiological Surveillance of the Secretariat of Health (week 52, 2012, Preliminary Information).

Source: CONAGUA, 2013b.

Graph 7. Disinfection coverage and efficiency vs. Incidence of intestinal infectious diseases, 2000 to 2012

Source: CONAGUA, 2013.

show that in 2012, disinfected water coverage of 97.9% was achieved (Graph 7).

Since supply sources receive increasing amounts of contamination, they have deteriorated and when they are subjected to a conventional disinfection process such as the addition of chlorine, they produce disinfection by-products known generically as organochlorinates (Aboites et al., 2008), there being a relationship between these compounds and various forms of cancer.

7. Climate Change and Variability and the Resulting Impact on Water Resources in Cities

Although Mexico produces about 1.5% of greenhouse gases, it is one of the countries most at risk of climate change. In urban areas, the effects of climate change will be increased and intensified by other processes that will make them more dangerous, meaning that a prospective view of the vulnerability of cities in Mexico must be integral.

One might assume that the most vulnerable areas are rural areas, due to their historical conditions of poverty and marginalization. However, some

of the most vulnerable regions are in fact certain major cities, mainly due to factors that increase their vulnerability, such as population growth, urban concentration and the location of cities in areas with scant or overexploited water resources, or which increase settlements in high risk areas due to climate change impacts, which increase their degree of exposure. Climate and hydrometeorological disasters include the following: droughts, food insecurity due to lack of irrigation water or drought, extreme temperatures, floods, forest fires, insect infestations, earth movements associated with situations of a hydrological origin and windstorms. These events account for a significant portion of the estimated damage caused by disasters, which in 2009 caused \$35,409 billion USD in damages, 85% of the total caused by all types of disasters.

The urbanization process, which has stabilized in developed countries, will continue in the following decades in developing countries, as foreseen by the United Nations Population Division (UN, 2012). Thus, the urban population will increase by 72% between 2011 and 2050, from 3.6 billion to 6.3 billion, respectively. Virtually all of the new urban population will be concentrated in cities in less developed countries. These urbanization processes will pose enormous regional challenges to water management, since with very few exceptions,

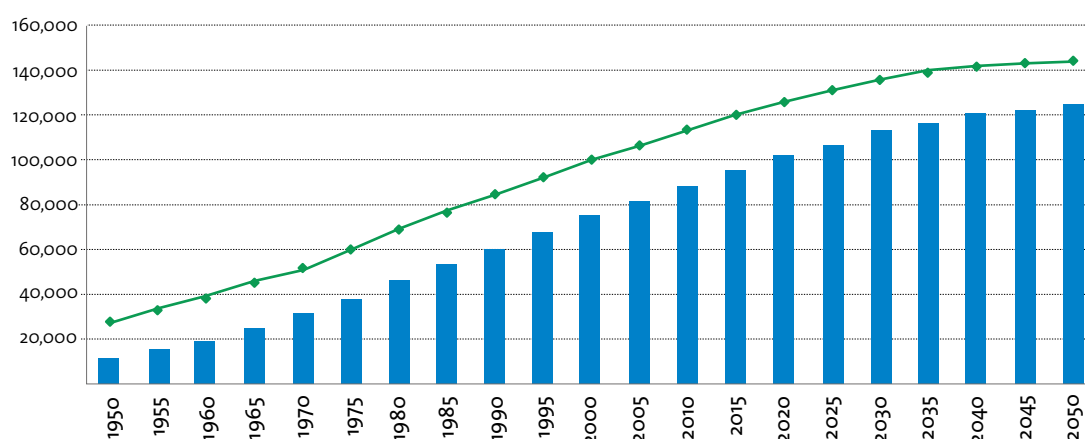
nature does not provide the water necessary to supply human concentrations of this magnitude locally, not to mention the difficulties of the resulting wastewater treatment and disposal, as well as the by-products of processing, particularly sewage sludge.

As noted earlier, in Mexico this urbanization process began rapidly in the 1950s and will continue into 2050, as shown in Graph 8. According to these estimates, in 2030, the country will achieve an urban population of nearly 112 million (82.6% of the total) and of nearly 124 million by 2050 (86% of the total). Mexico's urban population will increase by

35.7 million in 2050 compared to the 2010 data, which is greater than the sum of the current metropolitan areas of Mexico City, Guadalajara, Monterrey and Puebla population, the four largest in the country. The challenges associated with supply and sanitation will be enormous and require extremely efficient urban water management, together with wastewater treatment and environmental conservation measures, required to preserve supply sources.

Urban concentration in mega-cities poses special problems. According to United Nations estimates (UN, 2012), the population in cities with

Graph 8. Total (line) and urban (bars) population in Mexico for the period from 1950 to 2050



Source: Prepared by Polioptro Martinez using data from the United Nations Population Division.

Table 13. Observed effects and possible impacts on water services as an effect of climate change

Observed effect	Observed or potential impacts
Increase in ambient temperature	Reduced availability in basins fed by shrinking glaciers, as observed in certain cities in the Andes in South America.
Increased water temperature	Reduction of dissolved oxygen, mixed patterns and capacity for self-purification. Increased eutrophication
Rising Sea Level	Salinization of coastal aquifers.
Changes in rainfall patterns	Changes in availability due to changes in rainfall and other related phenomena (i.e. aquifer recharge, evapotranspiration)
Increased variability of annual precipitation	Greater difficulty in controlling avenues and using storage in rainy season.
Increased evapotranspiration	Reduced availability Salinization of water resources Lower groundwater levels
More frequent and intense extreme events	Avenues affecting water quality and the integrity of the hydraulic infrastructure, further erosion of channels that introduce different types of pollutants into water resources. Drought affecting water availability and quality.

Source: Bates et al., 2008.

over 10 million people will reach more than 10 million, compared with the 148 million residing in cities that size in 1970. In Mexico, in approximately 2030, about 50% of the population will live in just 31 cities with over 500,000 inhabitants, with high concentrations in the mega-cities of Mexico City, Guadalajara, Monterrey and Puebla (Box 1 shows a case related to climate change and its effects on cities). Many of these Mexican cities, as mentioned earlier, are located in regions where almost all the water resources have been used up or are being overexploited.

Without even considering the effects of global climate change, by 2030 some of Mexico's major basins will record high water stress conditions. In approximately 2030, in the Valle de Mexico, the absolute shortage it already suffers will be exacerbated. The Rio Grande and Baja California Peninsula regions will experience extreme scarcity while the Lerma-Chapala basin will be under conditions of water scarcity (less than 1,700). The Balsas and North Central Basin hydrological-administrative regions will encounter conditions of virtual scarcity, which they will probably experience if the effects of climate change are added.

The above mentioned scenario, which basically takes changes in water demand into account, will be compounded by the effects of changes in water supply and hydro-meteorological risks, caused by alterations in the water cycle due to climate change.

According to the International Panel on Climate Change (IPCC) (Bates et al., 2008) certain effects of changes in temperature and precipitation on water services can already be observed. Some of the major changes observed or expected are shown in Table 13. With regard to annual average water availability, recent studies on Mexico (Martínez Austria and Patiño Gómez, editors, 2011) estimate that by the end of this century, precipitation will be reduced by about 15.2%, as shown in Table 14.

This reduction in rainfall will produce even greater decreases in runoff and groundwater recharge, which ultimately determine availability. This is because, with drier soil and increased evapotranspiration of natural vegetation, caused by higher temperatures, more rainfall will be retained and evaporated in soil and vegetation, without reaching rivers or other surface or ground water bodies. Examples of this ratio include estimates for

Table 14. Percentage decrease of precipitation due to climate change

State	Projected decline in the period from 2060 to 2090 as a percentage		
	Winter	Summer	Annual
Aguascalientes	22.20	6.53	13.00
Baja California	28.70	13.80	21.28
Baja California Sur	28.73	18.10	18.01
Campeche	13.83	28.09	17.61
Coahuila	12.64	19.90	12.92
Colima	24.68	7.07	14.43
Chiapas	16.40	7.91	12.45
Chihuahua	20.48	15.25	14.24
Federal District	20.14	12.82	12.86
Durango	28.06	8.69	15.59
Guanajuato	21.12	7.04	12.30
Guerrero	18.54	12.65	11.86
Hidalgo	18.22	13.05	13.25
Jalisco	22.73	12.48	14.45
Mexico	21.49	12.68	13.05
Michoacán	20.70	11.68	12.84
Morelos	20.69	13.76	12.84
Nayarit	28.37	10.82	16.28
Nuevo León	13.28	11.02	12.72
Oaxaca	17.57	19.01	13.67
Puebla	15.96	16.38	13.18
Querétaro	19.40	10.04	12.45
Quintana Roo	13.11	29.26	17.65
San Luis Potosí	16.81	6.80	11.30
Sinaloa	31.58	9.55	17.05
Sonora	28.47	20.15	21.26
Tabasco	10.95	27.04	16.18
Tamaulipas	14.06	18.05	14.88
Tlaxcala	16.78	15.62	12.37
Veracruz	12.82	19.96	13.93
Yucatán	16.65	26.81	18.87
Zacatecas	23.07	6.33	13.13
National	20.00	15.76	15.15

Source: Montero et al., 2010.

the Río Conchos basin, a sub-basin of the Río Grande, which shows that while rainfall will decrease by an average of 20% by the end of the century, runoff will be reduced by 27% (Rivas et al., 2010).

As for the reduction of dissolved oxygen in water bodies as a result of a higher temperatures, this seems to be the cause, combined with lower available volumes, of cyanophytes algae blooms in the Valle de Bravo dam, which feeds the Cutzamala sys-

tem available, which requires additional treatment through large amounts of activated carbon before sending the water to the metropolitan area of Mexico City (CONAGUA, 2012D).

The increased risk associated with climate change for Mexican cities, from the point of view of water, is the occurrence of extreme hydrometeorological events, especially droughts and floods.

With respect to flooding, in 2010, the cost of damage caused by extreme weather phenomena alone amounted to \$6,412,270,000 USD. Damage caused by the tropical storms of 2013 has yet to be quantified, but considering previous data from the Secretariat of Finance and Public Credit and insurance companies, it could easily reach a similar figure.

In Table 15 shows the damage caused by these phenomena between 1999 and 2010 in terms of loss of life and property damage. As can be seen, the cost of damage due to hydrometeorological disasters tends to increase. The period from 2005 to 2010 saw the five most costly disasters of the eleven analyzed during this period.

The value of this damage is mainly associated with its impact on cities. Thus, for example, the record figure for 2010 is largely due to the amount of damages in the metropolitan area of Monterrey, Nuevo León. That year, in that state, damage from Hurricane Alex accounted for 2.45% of the state's GDP (CENAPRED, 2012).

Table 15. Damage caused by hydrometeorological disasters in Mexico

Year	Deaths	Damage Millions USD*
1999	480	901
2000	100	157
2001	163	188
2002	120	836
2003	138	331
2004	104	55
2005	203	3,503
2006	220	340
2007	187	3,839
2008	148	1,079
2009	100	1,090
2010	199	6,412

Source: CENAPRED. * Rate exchange 12.87 pesos by dollar.

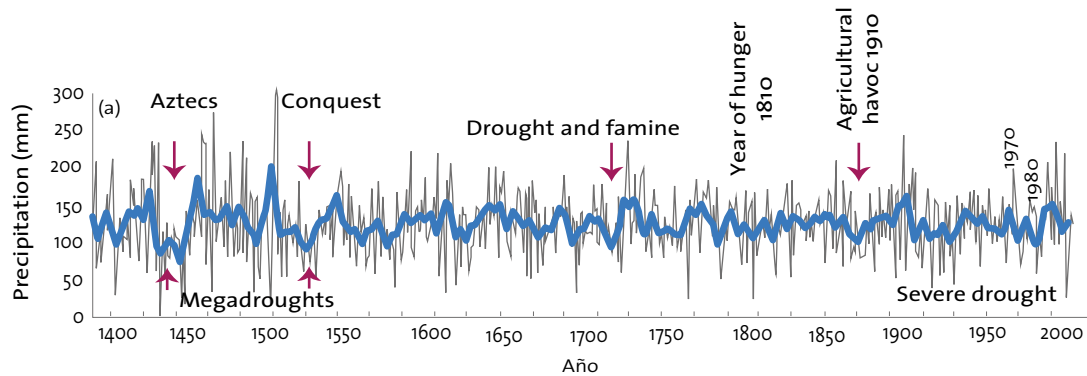
Drought is one of the natural phenomena that produce the greatest loss of life, economic damage, delays in the process of social development and environmental damage. However, as noted in the UN risk report in 2011, one of the main problems of drought management is that their impacts are not registered or properly measured. To estimate the effects of drought, sufficient information is only available in a few cases in developed countries. According to the FAO (2013), "since 1900, over 11 million people have died as a result of drought, and more than 2,000 million have been affected, more than by any other physical risk." Moreover, according to many researchers, the duration and intensity of droughts has increased, particularly since 1940. In Mexico, studies on droughts reconstructed for the past 600 years show that the country, in addition to short regional droughts, has recorded mega-droughts at intervals of approximately 50 to 100 years (Cerano Paredes et al., 2011), as shown in Graph 9.

The most recent droughts that have affected Mexico –the first between 2003 and 2006 and the second between 2010 and 2013– have been particularly intense. Graph 10 shows the percentage of national territory under drought conditions from 2003 to August 2013, the month when this phenomenon was interrupted by heavy rains, the other weather extreme, which has produced unprecedented damage throughout the country.

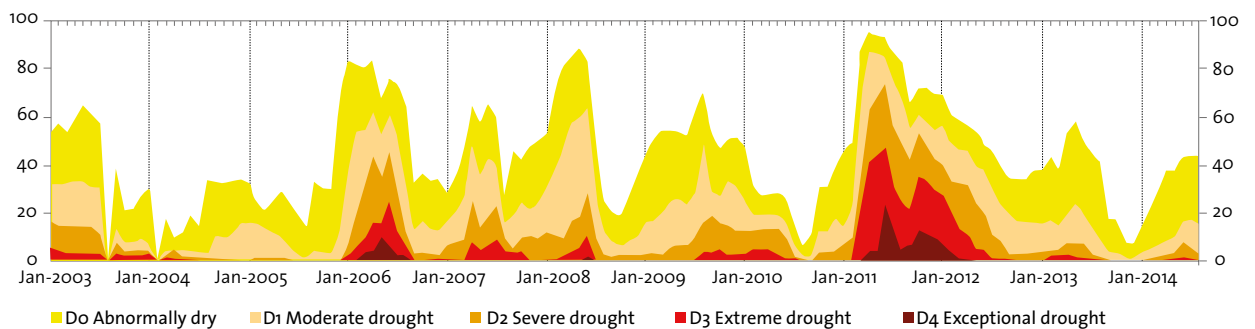
As one can see, 2011 saw a rain deficit in 90% of the country, with over 40% under severe drought. Throughout the decade, an average of over 30% of the country has been under rainfall deficit conditions.

Since many of the effects of climate change are present in the water problems affecting cities, many of the recommended adaptation measures will be useful in any case. The emphasis on adaptation focuses on building resilience, understood as the ability of a city to anticipate, cope with and recover from catastrophic events. In cities, however, risk is not distributed evenly, and mostly affects the poor, who have less capacity for risk prevention and disaster recovery; settle in high-risk areas and under conditions of high demographic concentration. The urban poor should therefore be in the front line of efforts to increase urban resilience (Baker, 2012).

There are numerous technical measures to increase resilience (see, for example, Martínez Austria and Patiño Gómez, 2012). However, the

Graph 9. Variability of precipitation in northwest Mexico in the past 600 years

Source: Cerano Paredes et al., 2011.

Graph 10. Percentage of Mexican territory affected by droughts between January 2003 and August 2013

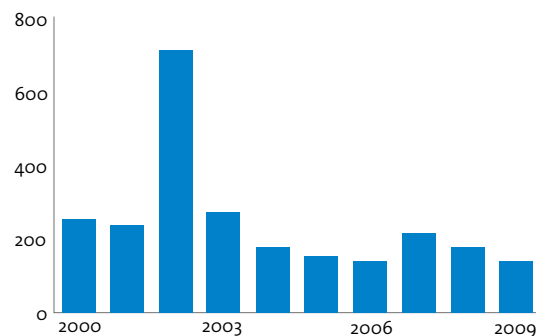
Source: SMN, 2013.

crucial actions are those designed to increase the social resilience of urban communities. During the latest congress on “Resilient Cities” (Balbo et al., 2013), the following key messages for achieving the desired result were reported:

- The participatory approach facilitates the exchange of knowledge and the most successful interventions.
- Resilience requires community construction.
- Actions based on community action create opportunities for innovative, cost-effective solutions.
- The urban poor are active, resourceful agents, yet still the most vulnerable.
- Development planning should be integrated with adaptation.

Adaptation is a process. There are no single, universal or eternal measures. Most cities are unaware of the effects and expected magnitude of events in a changing climate. However, the construction of urban resilience cannot afford to wait.

Regarding the number of people affected by climatic and hydrometeorological disasters during the period from 1999 to 2009, Graph 11 shows that annual variability in the occurrence of major disasters is exacerbated by hydrometeorological phenomena.

Graph 11. Number of those affected by climatic and hydrometeorological disasters (millions of inhabitants)

Source: CONAGUA, 2011.

Resilience and Adaptation to Extreme Weather Events: The case of the floods (Hurricane Alex) in the Metropolitan Area of Monterrey

Located in northeastern Mexico, the Metropolitan Area of Monterrey (MAM) is one of the main urban centers in Latin America. With a population of approximately four million inhabitants and a dynamic, diversified economy, Monterrey has become one of the principal industrial regions in Mexico and a leading destination for foreign direct investment, particularly in the manufacturing sector.

The city's water supply and extreme weather phenomena are closely related. Hurricanes Alex (July, 2010) and Ingrid (September, 2013) caused significant damage to the metropolis. For example, Hurricane Alex harmed pipelines and collectors, adversely affecting water service delivery. Fifty-four kilometers of water pipes and 45 kilometers of collectors were destroyed, which required the reconstruction and rehabilitation of seven pumping stations and approximately 10,000 household connections. Treatment plants were also affected. The event left large sectors of the population without a water supply. Although most services were restored within 72 hours, there were areas where the damage due to this natural phenomenon could not be repaired as quickly. In the MAM alone 50,000 people were left without drinking water for days and in some neighborhoods, service was interrupted for several weeks. Four years after the hurricane, the devastation it caused to the city's road structure is still visible yet water services were fully restored shortly after the hurricane.

The same month that hurricane Alex occurred, the state government established the State Board for the Reconstruction of Nuevo León (CERNL). Although a full evaluation of the latter is still pending, the scheme itself warrants examining. It should be stressed that estimates of the damage were not without difficulties or friction between the different spheres. The Council was formed of representatives of all three levels of government and civil society actors, predominantly from the business community. The Council was divided into ten committees. Each committee liaised with federal and state agencies. It is not difficult to imagine the complex operation of a Council with so many committees. This was exacerbated by the rotation of those responsible for federal and state agencies due to changes in administration, with adverse effects on the development of the corresponding work. Three years after Alex, the CERNL formally concluded its work. Regarding financial aspects, contributions to the reconstruction process were estimated at over 17 billion pesos. However, almost all the resources were allocated to road, urban mobility and water infrastructure, ignoring the social agenda of reconstruction. It is also fair to say that while the CERNL contributed to the city's reconstruction after the occurrence of Alex, it lacked the structure to address underlying issues and structural matters associated with urbanization and the presence of climatic events. The complexity of these issues and their understanding go beyond actions designed in times of emergency.

The lessons and experiences drawn from the case of Monterrey may also be of interest to other Latin American cities. The greatest challenges are associated with rapid population and economic growth, which complicate the design of coherent policy responses, rather than with natural phenomena resulting from climate change. Alex and Ingrid, and the storms and hurricanes that preceded them, revealed the existence of a dysfunctional, fractured institutional architecture, unable to fully addressing this phenomenon. In fact, there was a double dysfunction: One relates to the water sector framework in which institutions, programs and laws from different levels of government came together, not always in the direction of sound resource management but often running in opposite directions. This is crudely exemplified by the operation of the National Fund for Natural Disasters. The other concerns the dysfunctionality of the metropolitan area itself, which is reflected in a pattern of urbanization that magnified the damage. Thus, what has proved to be natural has been the unsatisfactory response to the flash floods that from time to time impact the Metropolitan Area of Monterrey.

8. Conclusions

Mexico is a country with unequal access to water and sanitation, as shown by some of the facts that have been presented. The outlook may worsen, especially because it is estimated that the urban population will continue to grow, placing increasing pressure on urban development and water service delivery, particularly in parts of the country where water is already scarce.

A key finding for achieving better decision-making about urban water management is the need to have appropriate information for this use. This requires a change in the way databases are constructed, rather than new or different ways of obtaining data.

In Mexico, efforts should be made to ensure that the human right to water is fulfilled as regards access, coverage, quality and affordability. However, in certain areas where access is precarious, it has been observed that this is only possible through the creation of new forms of water supply, such as commercialization through water trucks or community arrangements for the construction, maintenance and operation of the local system, usually based on high investment by the settlers themselves and self-management regulations that include monitoring, surveillance of the system and the implementation of sanctions.

Given the above scenario, water governance becomes important in achieving an equitable distribution of water based on access to water as a human right. And despite the fact that in recent years, water policy has undergone profound changes through the decentralization of the provision of public drinking water, the growth of water demand in metropolitan areas and the incorporation of the population's participation into problem solving poses an enormous challenge to local and federal authorities. Therefore, efforts to sort out the governance framework of urban water services and implement demand management mechanisms should be at least as great as those still devoted to major projects for transporting the water flow between basins.

As mentioned earlier, although Mexico produces about 1.5% of greenhouse gases, it is one of the countries most at risk of climate change. In urban areas, the effects of climate change will be

increased and exacerbated by other processes that will make them more dangerous, meaning that a prospective view of the vulnerability of cities in Mexico must be integral. One might assume that the most vulnerable areas are rural areas, due to their historical conditions of poverty and marginalization. However, some of the most vulnerable regions are in fact some of the major cities, which is mainly due to constant population growth, urban concentration and the location of cities in areas with scant or overexploited water resources, which increase settlements in high risk areas due to climate change impacts and in turn increases their degree of exposure. The three levels of government should therefore improve their coordinated action to optimize and manage land use practices, and implement new urban planning models that incorporate the impacts of climate variability and enable stormwater runoff to be more effectively managed.

In regard to water and health, although progress has been observed in the declining rates of intestinal infectious diseases, much remains to be done since other diseases such as typhoid or salmonella cases have increased. Certain programs such as the Clean Water Program should be reinforced while new programs that promote increased drinking water coverage should be implemented.

On the other hand, as we have seen, not all cities can bear the financial burden of large pressure aqueducts. These also create social and environmental damage in the basins of origin and during the route of the aqueducts, in many cases increasing the use of energy for pumping and treating water. The design of such projects on the grounds of "substituting sources" must not be interpreted as abandoning the mandate to control groundwater extraction and discharges into surface bodies.

The financial area must be reformed to help give operators stability and incentives for increasing their efficiency. Nowadays, a system that has been damaged due to poor decisions in the past, can always aspire to be rescued through federal funds, if the city has the political and financial negotiating capacity to do so. Subsidy programs should gradually be implemented in conjunction with performance enhancements that promote the professionalization of municipalities and agencies

in the administration of the systems. Likewise, although the Mexican government has made enormous efforts to increase coverage and improve the performance of municipal systems, huge challenges remain to ensuring sustainable, quality services. There is an urgent need to implement an effective system for the custody, restoration and preservation of national waters that will reverse the imbalance of numerous hydrological basins and aquifers. It will be of little benefit to seek greater energy efficiency in extraction if groundwater levels continue to decline and quality, reliable sources are increasingly distant and vulnerable. There will be never be enough water if we lose clean water sources.

Likewise, a radical institutional reform should be promoted in municipalities and states to clarify the responsibilities of each organ or order of government for citizens. Operating organizations should have operational clarity and independence, sufficient resources and budgetary support tied to their performance, while municipal and state authorities should focus on regulating rates and the performance itself, but without continually interfering with operational decisions and the administration of systems. Users should be entitled to learn about and understand the situation of their water and sanitation systems, participate in decisions and demand that they provide quality services at a fair price, and that they also undertake to comply with the payment and proper use of services.

A key point is agency boards of directors, which should be integrated into medium-sized cities with citizens who can really professionally support the proper running of systems, using good corporate governance practices and establishing mechanisms to ensure that councils are fully held to account, particularly if they are citizens. Local political authorities should be fully responsible for the state of the assets and flows of operating organizations, and accountable for the delivery thereof to the following municipal administration. Better communication mechanisms, such as citizens' water observatories, can help construct a mature, informed dialogue between authorities, operators and citizens.

Among the challenges derived from the physical aspects of water is the lack of criteria for determining appropriate volumes for efficient use, and utilizing them to establish programs in cities to ensure efficient water use. This would not only save water but also the energy used for transporting, purifying and treating it. On the other hand, and as yet barely acknowledged nationwide, there is the importance of water reuse in Mexican cities. In comparison with many other countries (Jiménez and Asano, 1998), Mexican cities, particularly the largest ones, are characterized by much higher reuse levels than many cities in various countries including those in the developed world. This advantage is one that Mexico should not only preserve but further increase, making it a country that exports knowledge and technology in this field.

As one can see, the current situation and prospects for water supply in Mexican cities is undoubtedly critical. It will require an enormous effort of organization and coordination to stop the dramatic decline in the quality and availability of water, land use and the lack of accountability mechanisms that would lead to professional management of the systems involved. The lack of reliable information in certain areas such as the number of illegal connections or the amount of water supplied through water trucks qualifies the coverage figures mentioned in the official data. Access to information, its analysis and communication to decision makers and citizens can be an important lever in this change and is a task in which the academic community must play a central role.

A view from Villahermosa, Tabasco. Image courtesy of Jordi Vera



9. References

- Aboites, L., Cifuentes, E., Jiménez, B., and Torregrosa, M. (2008). *Agenda del agua*. México, Academia Mexicana de Ciencias - Red del Agua.
- Aboites (2004). "De Bastión a Amenaza. Agua, Políticas Públicas y Cambio Institucional en México, 1947-2001", Boris Graizbord (ed.), *El futuro del agua en México*, México, Universidad de Guadalajara/ Centro Universitario Económico Administrativas, pp. 87-114
- Aguilar Barajas, I. (2013). Gestión de Riesgos Hidrometeorológicos Extremos para el Área Metropolitana de Monterrey y su Adaptación al Cambio Climático, Documento de Reporte Final, Proyecto Fortalecimiento de la Gobernanza Hídrica en Contextos de Cambio Climático: El Caso de la Zona Metropolitana de Monterrey, produced for the UN-Habitat program.
- Baker L. Judy, editor (2012). *Climate Change, disaster risk and the urban poor. Cities building resilience for a changing world*. The World Bank. Washington, D. C.
- Balbo A., Dowing-Smith E., Kavanaugh L. (2013). *Resilient cities 2013: Congress Report. CLEI-Local Governments for Sustainability*. Bonn, Germany. 20 pages.
- Bates B.C., Z. W. Kundzewics, S. Wu and J. P. Palutokpf Eds. (2008). *Climate Change and Water*. Technical Paper VI of the IPCC. Secretariat, 210 pp.
- Capello, R, and P. Nijkamp (2011). "Regional Growth and Development Theories Revisited", pp. 301-324, in R. Stimson, R. R. Stough and P. Nijkamp (eds.), *Endogenous Regional Development.- Perspectives, Measurement and Empirical Investigation*, Cheltenham, U.K. and Northampton, USA, Edward Elgar.
- Castro, José, Karina Kloster and María Luisa Torregrosa (2004). "Ciudadanía y gobernabilidad en México: el caso de la conflictividad y la participación social en torno a la gestión del agua" in Blanca Jiménez and Luis Marín (editors) *El agua en México vista desde la Academia*. Mexico, Academia Mexicana de Ciencias, pp. 339-370.
- CCA (2011). *Gestión del Agua en las Ciudades de México*. Mexico: Consejo Consultivo del Agua.
- CENAPRED (2012). Características e impacto socioeconómico de los principales desastres ocurridos en la república mexicana en el año 2010. Centro Nacional de Prevención de Desastres Secretaría de Gobernación. Mexico. 157 pp.
- Cerano Paredes J., Villanueva Díaz J., Valdez Cepeda R. D., Méndez González J., Constante García V. (2011). "Sequías reconstruidas en los últimos 600 años para el noreste de México". *Revista Mexicana de Ciencias Agrícolas*. No. 2, pp. 235- 249.
- CONAGUA (2011). Estadísticas del agua en México. 2011 Edition, 185 pp.
- _____ (2012a). Estadísticas del agua en México. 2012 Edition. 141 pp.
- _____ (2012b). Atlas del agua en México 2012. 142 pp.
- _____ (2012c). Situación del Subsector Agua Potable, Alcantarillado y Saneamiento. Edición 2012. 280 pp.
- _____ (2012d). Conferencia de prensa sobre problemática de calidad del agua de la presa Valle de Bravo, Mexico. Available at <http://www.conagua.gob.mx/CONAGUA07/Conferencias/VE-Conferencia%20de%20Prensa-Calidad%20del%20Agua%20en%20la%20presa%20Valle%20de%20Bravo.pdf>
- _____ (2012e). Proyectos estratégicos de agua potable, drenaje y saneamiento. Conagua, Gerencia de Estudios y Proyectos. Mexico, Conagua.
- _____ (2013a). Estadísticas del agua en México, 2013 edition. 176 pp.
- _____ (2013b). Situación del Subsector Agua Potable, Alcantarillado y Saneamiento. 2013 edition. 337 pp.
- Durán-Álvarez, J.C., Becerril E., Castro V., Jiménez B., and Gibson R. (2009). "The analysis of a group of acidic pharmaceuticals, carbamazepine, and potential endocrine disrupting compounds wastewater irrigated soils by gas chromatography-mass spectrometry". *Talanta* 78 (3):1159-66.
- ECLAC (1991). *El desarrollo sustentable: transformación productiva, equidad y medio ambiente*. Santiago de Chile: UNO-ECLAC.

- FAO (2013). DROUGHT FAO Land and Water Division <http://www.fao.org/docrep/017/aq191e/aq191e.pdf> Consulted September 19th, 2013.
- Figuerola Vega, G. (1984). Case History No. 9.8. Mexico., D. F. In J. Poland, Guidebook to studies of land subsidence due to groundwater withdrawal, Paris: UNESCO.p.p. 217-232
- Garza, et al. (1995). *Dinámica macroeconómica de las ciudades en México*. Vol. I. México, Instituto Nacional de Estadística, Geografía e Informática.
- _____. (1990). El carácter metropolitano de la urbanización en México, 1900-1988.
- _____. Estudios demográficos y urbanos, 37-59.
- Gobierno Constitucional del Estado de Nuevo León (2010). Atlas de Riesgo para el Estado de Nuevo León (Primera Etapa) (Documento de Consulta Pública), Monterrey, N.L., Gobierno del Estado, Secretaría de Desarrollo Sustentable.
- IMCO-Instituto Mexicano para la Competitividad (2013). Índice de Competitividad Urbana. 178 pp. Anexo Estadístico.
- Instituto Nacional de Estadística y Geografía (INEGI) (2010). Tabulados básicos y muestra censal del Censo de Población y Vivienda 2010. <http://www.inegi.org.mx/est/contenidos/proyectos/ccpv/cpv2010/Default.aspx>
- Jiménez, Blanca (2013). *Case Study: The planned and unplanned reuse of Mexico City's wastewater*.
- _____. & Asano T. (Ed.) (2008). *Water Reuse: An International Survey of Current Practice, Issues and Needs*. IWA Publishing, 628 pp.
- _____. and Chávez, A. (2004). "Quality assessment of an aquifer recharged with wastewater for its potential use as drinking source: "El Mezquital Valley" case". *Water Science and Technology*, 50 (2): 269-273.
- Magaña, V. (2013). Clima en Monterrey: Escenarios de Cambio Climático, Documento de Reporte Final, Proyecto Fortalecimiento de la Gobernanza Hídrica en Contextos de Cambio Climático: El Caso de la Zona Metropolitana de Monterrey, produced for the UN-Habitat Program,
- Martínez-Austria P. and Patiño-Gómez C. Eds. (2012). *Adaptación al cambio climático*. Instituto Mexicano de Tecnología del Agua. 123 pp.
- _____. (2011). *Atlas de vulnerabilidad hídrica de México ante el cambio climático*. Instituto Mexicano de Tecnología del Agua.
- Palerm, J., T. Martínez Saldaña (eds.) (2013). *Antología sobre Riego. Instituciones para la gestión del agua: vernáculos, legales e informales*. Biblioteca Básica de Agricultura. Mexico, Colegio de Postgraduados.
- Pineda et al., (2010). "Para dar de beber a las ciudades mexicanas: el reto de la gestión eficiente del agua ante el crecimiento urbano". In Blanca Jiménez, Torregrosa and Aboites (ed.). *El agua en México: Cauces y encauces*. pp. 117-140.
- Ramírez, A. (2013). "Modelación de Eventos Hidrometeorológicos Extremos y su Impacto sobre el Comportamiento del Sistema Hidrológico de la Ciudad de Monterrey", Documento de Reporte Final, Proyecto Fortalecimiento de la Gobernanza Hídrica en Contextos de Cambio Climático: El Caso de la Zona Metropolitana de Monterrey, produced for the UN-Habitat Program.
- Rivas Acosta I., Güitrón de los Reyes A., Ballinas González, H. A. (2010). "Vulnerabilidad hídrica global: aguas superficiales". En Martínez-Austria P., Patiño-Gómez C. Eds. *Atlas de vulnerabilidad hídrica de México ante el cambio climático*. Mexico, Instituto Mexicano de Tecnología del Agua. pp. 81-113.

- Saltiel, G. (2008). "Problemática del sector agua potable mexicano - análisis, ejemplos y propuestas". En R. Sandoval, & R. Olivares, *El agua potable en México - historia reciente, actores, procesos y propuestas*, Mexico, ANEAS, pp. 229-237
- Sandoval, Ricardo (2012). *Urban water management in Mexico*. IANAS report.
- Schmidt, S. y Hatch Kuri, G. (2012), "El agua en México. Una cuestión de seguridad nacional", *Foreign Affairs Latinoamérica*, Vol. 12, No. 4, pp. 89-96
- SEGOB (2010). MEXICO. Informe Nacional del Progreso en la Implementación del Marco de Acción de Hyogo (2009-2011). Intermediario, México, D.F., Secretaría de Gobernación, Dirección General de Protección Civil (www.preventionweb.net/english/countries/americas/mex) (Last accessed: May 30, 2011).
- Sisto, N. (2013). Análisis de las Vulnerabilidades y Modelación de los Impactos Socio- Económicos, Documento de Reporte Final, Proyecto Fortalecimiento de la Gobernanza Hídrica en Contextos de Cambio Climático: El Caso de la Zona Metropolitana de Monterrey, produced for the UN-Habitat Program,
- SMN (2013). Climatología. Servicio Meteorológico Nacional. Comisión Nacional del Agua. http://smn.cna.gob.mx/index.php?option=com_content&view=article&id=236&Itemid=74
- UN (2012). World Urbanization Prospects. The 2011 Revision. Highlights. United Nations Department of economic and Social Affairs. Population Division. New York, p.p. 50
- Torregrosa, M.L. K. Kloster, C. Arteaga, (2006). "Gestión, solidaridad y conflicto en torno al agua. El caso de Milpa Alta en Vázquez, V., D. Soares, A. de la Rosa and A. Serrano. *Gestión y cultura del agua*, T. II. Mexico, IMTA-Colegio de Postgraduados en Ciencias Agrícolas.
- UN (2013). GAR.- Global Assessment Report on Disaster Risk Reduction 2013, New York, United Nations Office for Disaster Risk Reduction.
- UNESCO (2012). Managing Water under Uncertainty and Risk. The United Nations World Water Development Report. Executive Summary, Paris, United Nations Educational, Scientific and Cultural Organization.
- WEF (2014). Global Risks 2014.- Ninth Edition, Geneva, World Economic Forum
- WMO (2009). Integrated Flood Management Concept Paper, Geneva, World Meteorological Organization, WMO- No. 1047
- World Bank (2014). World Development Report 2014 – Risk and Opportunity.- Managing Risk for Development, Washington, D.C., International Bank for Reconstruction and Development.