

WATER AND SUSTAINABILITY IN MEXICO CITY

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Keywords: Mexico City, sustainability, water management, springs, ground water, land subsidence, basins, drainage, flooding, potable water, leaks, water treatment.

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Summary

The population of Mexico City has always relied on important transformations of the natural environment to satisfy their basic needs. The main processes underlying the peopling of the City's basin geography, the hydraulic works built to give room to a flourishing society and the radical transformations infringed to the ecosystem after the Spanish conquest are discussed in this article. The goal is to emphasize the interrelated nature of the availability of natural resources, especially water, and population dynamics.

1. Introduction

The environmental problems of Mexico City are usually associated with the poor quality of the air, especially since the decade of the 1980s in which the population was exposed to dangerously high levels of contaminants and a series of measures was

implemented to control this situation, with the support of important financial resources from abroad.

In spite of the importance given to the dimension of air in Mexico City during the last years of the twentieth century, many other aspects that are related to the environmental crisis of the city also demand urgent solutions. Among them the management of water is important; throughout history this has caused radical transformations to the natural environment, and in present times it imposes serious risks to the subsistence of one of the planet's most populated cities.

In this article the importance of water for the sustenance of Mexico City will be covered. A brief reference to the ecological characteristics of the city is followed by a description of the main transformations it has undergone throughout time that modified the natural ecosystem which was dominated by water. Mexico City's development into an urban "blob" dominated by asphalt, makes it more dependent on extraction of groundwater and from external basins for the supply of this vital liquid. It is emphasized that the environmental crisis Mexico City is experiencing at the end of the twentieth century has its origins not only in the accelerated demographic growth that led to an unseen expansion of and speculation in urban land, but principally in an insufficient knowledge of the functioning of the natural ecosystem, and the water cycle in particular, which jeopardizes satisfying the basic needs of the present and future population.

The solution to the crisis cannot be limited to a growing exploitation of the aquifer or to importing water from distant sources; what is required is a combination of social, economic, political, and cultural solutions that will promote more efficient and sustainable management of this resource. These include, among many other elements, a strict respect for the hydrological cycles, avoidance of wastage caused by leakage which at present represents about 40 percent of the available supply, the utilization of rain water, encouraging the recycling of drain water, avoidance of further growth of the urban area especially in the water replenishment areas, distribution of the water supply with equity among the various social groups, and promotion of the payment of water at realistic prices. In order to guarantee the permanence of the city, given the complexity and interdependence of the solutions to the water situation in Mexico City, a determined effort is required from various sectors of society including government, the private sector, academia, and civil society as a whole.

2. Natural Environment

Mexico City is located at 2240 meters above sea level, in the southern part of the basin of Mexico, and covers a surface of approximately 1400 square kilometers. The basin, which was originally closed, occupies an area of approximately 9600 square kilometers, and is located in the southern part of the Central Volcanic Axis, between meridians 98.15°S and 99.30°S and between parallels 19.00°W and 20.15°W . Its greatest longitude measures 110 kilometers and the shortest 80 kilometers. The mountain chains that surround it are of volcanic origin; to the north of the valley are the sierras of Tepetzotlan, Tezontlapa, and Pachuca, to the east are the plains of Apan and the Sierra Nevada, to the south, the Sierras Chichinautzin and the Ajusco, and to the west, the Sierra Las Cruces, Monte Alto and Monte Bajo. The highest peaks are located towards

the south-east, the Popocateptl and the Iztaccihuatl, with altitudes of 5465 and 5230 meters above sea level, respectively.

The basin of Mexico, in turn, is surrounded by other basins: to the north by the valley of the river Tula and the Meztitlan lagoon, to the east by the Tecolutla river, to the west by the Lerma river, to the southeast by the Atoyac and Mixteco rivers, and to the south by the Amacuzac river. At the bottom of the basin, which is where Mexico City lies now, was a system of lakes which covered a surface of 1500 square meters, five of them being the largest: the Texcoco, Zumpango, Chalco, Xochimilco, and Xaltocan lakes. The lake of Texcoco, the shallowest of these, used to receive all of the flow of the basin, before it evaporated. Only about 50 square kilometers of lakes still exist, which include the remnants of Xochimilco, Texcoco, Chalco, and Zumpango.

The climate of the Mexico City can be considered as high altitude subtropical, temperate, and semi-dry. The median temperature is 20 degrees centigrade and the rainy season is concentrated between the months of May and October. The annual rainfall is 700 millimeters and the average volume is of approximately 210 cubic meters per second.

Regarding the natural setting, nine original environmental zones have been identified within the basin: lake system, saline lakeshore, deep-soil alluvium, thin-soil alluvium, upland alluvium, lower piedmont, middle piedmont, upper piedmont, and sierras. This environmental diversity sustained a great variety of flora and fauna, which in turn provided the inhabitants of the basin with a sufficient food supply, although the growth in population even in pre-Hispanic times caused a scarcity of animal protein which came mainly from hunting. This led the indigenous cultures to develop farming techniques, which included the domestication of plants, principally maize, and to diversify their diet with the important components of vegetables, aquatic organisms, and birds. However, since early times, the population of the basin also imported diverse products for its sustenance, mainly maize, beans, natural gum, and cocoa. The most abundant resource, water, which dominated the environment, represented the fundamental element of their economy and culture.

In administrative terms, parts of different federate entities are located within the basin: the State of Mexico (48.1% of the total area), Hidalgo (26.5%), Tlaxcala (8.8%), Puebla (1%) and the Federal District (15.7%). The latter, the headquarters of the federal government, is the federate entity of which the Mexico City is a part, but its accelerated growth, especially during the decade of the 1960s, spread beyond the administrative limits and now hosts 37 municipalities of the neighboring State of Mexico, a situation which frequently complicates the necessary administrative co-ordination required to attend to the diverse problems of the city.

3. Population

Some scholars estimate that the presence of humans in the basin of Mexico goes back to about 25 000 years B.C. The first small human settlements were registered in the year 5000 B.C., and larger settlements were recorded around 1700 B.C.; it is calculated that by the year 100 B.C. the total population reached 215 000 inhabitants, grouped in

various villages. In the year 100 A.D. Teotihuacan, located towards the north east of the lake of Texcoco, housed 30 000 inhabitants, a population that reached 100 000 inhabitants in the year 650 and that, by 750, had diminished to only 10 000. Some hypotheses around this demographic collapse point to the principal cause as the ecological decay of the region, resulting from an over-exploitation of the natural resources.

Diverse communities started settling in the basin and on the lake shores; around 1220 the Aztecs arrived in the basin, and in 1325 they occupied the island of Tenochtitlan, where they founded their religious, political, and economic center. Aztecs were able to adapt themselves to the lake environment through hydraulic works such as aqueducts, dikes, small islands, canals, and the *chinampas* farming system, one of the most productive systems ever developed. This system consists of extensions of land formed by a succession of elevated fields within a network of channels dredged over the bed of a lake. At present there are still some vestiges of *chinampas* in what is left of Lake Xochimilco. The flanks of the mountains surrounding the basin were also used for farming, by implementing a system of terraces, some of which had irrigation systems, others using the natural run off.

Descriptions of the Great Tenochtitlan according to Spanish chronologists and other historians, show the great magnitude of the hydraulic works which surrounded what was in the sixteenth century one of the largest cities in the world. It occupied a surface of 13.5 square kilometers and had a population estimated at 300 000 inhabitants in the central zone, and more than one million in neighboring towns.

After the conquest in 1521, the population decreased radically and a century later added up to only 10% of what it had been before contact with the Europeans: less than 100 000 inhabitants in all the basin, and less than 30 000 in what was the Great Tenochtitlan. This was the consequence of wars and slavery and the arrival of new diseases with which the indigenous population could not cope. Additionally, the religious, political, economic, and cultural collapse resulting from the conquest played an important role, as did also the destruction of the urban infrastructure and the environmental deterioration induced by new forms of appropriation of natural resources, including the introduction of new species, foreign to the natural environment.

It was not until the beginning of the twentieth century (four hundred years later) that the population of the city grew to the level it was before contact with the Europeans. After the revolution of 1910 which ended in 1921, the city regained its dynamism and, starting in the 1940s, in which decade the industrialization process begins by import substitution, it experienced very high rates of demographic growth, turning, as it did 500 years before, into one of the largest cities in the world. It is estimated that by 2000 the population of the city had reached about 18.2 million people inhabiting a surface of about 1400 square kilometers; this means that about 18.5% of the total population of the country, which is near 100 million, is concentrated in an area of less than 1% of the national territory of about 2 million square kilometers.

The impressive population growth of this city in the twentieth century was due to multiple causes. In the first place, the concentration of economic activities in the capital

of the country attracted important flows of population, mainly people of rural origin, who were incorporated into the newly born and pungent or intense industrial activity which offered attractive salaries, together with urban services appropriate for a city in expansion. In fact, the education, medical, and health services which were offered to the growing number of inhabitants, together with the access to better quality food and housing, all contributed to reduce the incidence of infectious diseases, which until a few decades previously were the main cause of death, thus diminishing the high death rates, especially among children.

Both phenomena, high immigration and higher life expectancy, together with the high fertility rate, gave place to one of the highest rates of demographic growth ever registered in the history of a population. This situation of demographic boom changed in a relatively short time, and a lower annual rate of growth has been subsequently registered; from nearly 7% in the 1960s, to around 1.5% in the 1990s. This has been due in part to a lower fertility rate, a higher standard of education enjoyed by city women, and greater participation in the labor market than for the rest of Mexican women. The total fertility rate, which during 1970–1975 was 5.4 children per woman, decreased to 2.5 per woman over the period 1990–1995.

On the other hand, the city has experienced lower immigration from other parts of the country. Starting in the 1980s, a reversal in the internal migration flows is apparent; these were previously oriented in great part to Mexico City, and are now directed principally more to medium sized cities in the north and center of the country. The lower population attraction registered in the 1980s, was a response to economic slow down, to decentralization of the economic activity, and to environmental problems that tended to drive out the population. It is of note that, in 1975, 45% of the industrial employment of the country was concentrated in Mexico City and by 1994 only 24 % of the national total was generated in this city.

As for migratory flows, immigration to the city went from 825 000 people between 1965–1970, to nearly 1 million in 1975–1980, then diminished to 559 000 in 1985–1990. On the other hand, the number of out-migrants from the city in the same periods went from 381 000, to 697 000 and 1 million, respectively. The net migration was positive, 444 000 in 1965–1970 and 301 000 in 1975–1980, and then, for the period between 1985–1990 the balance was negative by 440 000. In other words, for the first time in recent history the city lost more population than it received.

According to the official projections on behalf of the National Population Council, it is estimated that the population of Mexico City will reach a total of 20 million inhabitants, by the year 2010. Previous estimates had projected that figure for 1995, indicating that Mexico City was on course to be the largest city on the planet; the decrease in fertility, but above all the diminished immigration, caused these figures to decline during the last decades of the twentieth century.

Year	Inhabitants
1521	300 000
1742	101 000
1803	138 000

1900	347 721
1910	471 066
1921	615 367
1930	1 029 068
1940	1 644 921
1950	2 982 199
1960	5 155 327
1970	8 656 851
1980	13 734 654
1990	15 047 685
1995	16 898 316
2000	18 202 274
2010	20 462 242

Sources: Partida, V. “La ciudad de México. Nuevo derrotero en su ritmo de crecimiento”, in *Demos. Carta demográfica sobre México, 1994, No. 7*. UNAM, México., pp.13-14.
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Table 1. Mexico City Population 1521–2010

4. Expansion of the City

Population growth from the beginning of the settlement in the basin of Mexico made it necessary for humans to take up more of the space, which was originally dominated by water. By constructing islands with aquatic plants and mud the conquest of lakes was initiated, taking land away to make room for a flourishing society. The city the Spaniards found in 1519 had been achieved due to the construction of an important hydraulic infrastructure. Predominant in it were elevated streets surrounded by water from the lake that regulated its level, preventing floods and the consequent combination of fresh and salt water between the various lakes that formed the ecosystem. In order to provide enough potable water to the growing population, two clay aqueducts had been built to convey the springs of Chapultepec to the west and those of Coyoacan to the southeast. After the Spanish conquest utilization of the natural resources was transformed and territorial expansion acquired new modalities which, as in the pre-Hispanic period, sought to reclaim land from the lakes, although in a more radical manner, drying them out completely. This process took several centuries and was a key factor in the development of the city. Population growth in Mexico City, especially in the twentieth century, has been accompanied by a process of territorial expansion which entailed the utilization of the dried out lake beds for urban use, and this has extended to the mountains that surrounded them and to transition zones, with an irreversible impact. The impact this pattern of human settlement has had on the level and quality of the aquifer are especially fundamental for the subject of this article.

The mountainous and transition zones, given their permeability, filter not only the water from run off but also domestic and industrial contaminants, which seriously jeopardizes the quality of groundwater. The occupation of transition and replenishment areas has been common practice during the last decades and has encouraged the use of septic

tanks in planned developments. In the squatter, illegal settlements, which urban expansion has been based on in the last years, there is nearly a complete lack of any drainage system at all. Another common practice of the twentieth century has been to channel the flow of the rivers into pipes, as also has been the combination of rain and river waters with waste waters, which are subsequently directed into the urban drainage systems. It is of note that more than a third of the metropolitan area is built on a lakebed, and the dwellings with septic tanks dispose of their waste and drain water in the areas nearest to where the aquifers are replenished. According to data from the last census of population and housing in 1990, 17.6% of the houses in the metropolitan area of Mexico City had no drains connected to the main city system.

At present, Mexico City occupies an area nearly one hundred times larger than when contact was first made with the Europeans. The evolution of the urban area has been as shown in Table 2.

1.1.1 Year	1.1.2 Square kilometers
1521	13.5
1920	46.0
1940	117.5
1950	260.6
1960	416.9
1970	722.5
1980	891.1
1990	1295.5
1995	1370.0

Source: Consejo Nacional de Población (1997) *Escenarios demográficos y urbanos de la Zona Metropolitana de la Ciudad de México, 1990-2010. Síntesis*. México, CONAPO.

Table 2. Mexico City Urban Area 1521-1995

5. Transformation of the Ecosystem

In order to host the growing population of Mexico City, a series of infrastructure works have been carried out which have been related to the hydraulic system of the basin from historic times. Important to mention are the efforts to win back land from the lakes by means of constructing islands, which is the way the pre-Hispanic societies achieved settling the valley; after contact with the Europeans, this was done by opening the basin and consequently the draining of the lakes. The transformation of the ecosystem as a result is governed by a curious contradiction: how to do away with the basin's natural water, on one hand, that imposes natural limits to the growth of the city, and on the other hand, how to supply enough water for the growing population.

5.1 The Pre-Hispanic Period

The Aztecs achieved management of their water resources, with great mastery, by the construction of canals, aqueducts, dams, directed streams, drains, and terraces which prevented constant floods, and at the same time supplied spring water for the population and agricultural purposes, as the lake water was not fit for human consumption. As the population grew, the local springs became insufficient, and in 1416 the first clay aqueduct was built from Chapultepec at the west of the city; which conducted water to the Templo Mayor, which is nowadays the center of the city. This aqueduct was seriously damaged by a great flood in 1449 and then reconstructed with more resistant materials by order of the emperor Nezahualcoytl, and it continued to provide good service until well after the Spanish conquest.

By 1499, given the continued demographic growth, it was necessary to complement the water supply, and new facilities were built to extract the water from the springs of Coyoacan, much to the local villagers' opposition. The following year, a new flood resulting from 40 days of rainfall provoked its destruction. Among the most important works that were developed to extend the habitable space are those developed to extend the original island in which the Aztecs settled. Given the scarcity of firm land in the lake system, *chinampas* were built which consisted of the accumulation of beds of aquatic plants and mud extracted from the bottom of the lake, keeping them rigid with willow stakes. Initially they were used to build houses on, but later they were used for agriculture, representing one of the most productive systems ever achieved. It is estimated that at the beginning of the sixteenth century there were over 100 000 *chinampas*, with three to four dwellers each, that supplied most of the needs of the local population. It is calculated that those located in the area of Xochimilco produced enough to feed up to 100 000 persons.

On the other hand, and with the purpose of preventing floods and the mixing of soiled waters from the lake of Texcoco with the fresh water from the rest of the lakes, the Aztecs built a system whereby they could control the flow and rising of the waters, which consisted of dykes that were also utilized as paths to link the islands. When the Spaniards arrived there were 8 dikes whose length varied from 2.5 to 16 kilometers. Within this type of construction, the great dike of Nezahualcoytl built in 1450 is notorious, with a length of 16 kilometers that regulated the flow of water between lakes. As a closed basin, the evaporation of water led to the minerals that originated from mountain streams being concentrated in the lowest lake, Texcoco. The Aztecs knew how to take advantage of this situation and exploited the salt fields; they were therefore able to have this precious product in spite of being so far from the sea.

Waterway traffic, principally of merchandise, was very important in pre-Hispanic Mexico. It is estimated that there were more than 200 000 canoes, four large ports, and multiple docks. At the beginning of the twentieth century transportation through existing canals and lakes was still common, particularly small steam vessels between Chalco and Xochimilco. The efforts to live with water in an apparently harmonious way were defeated together with the indigenous population after contact was made with the Europeans. The latter saw this resource rather than as a potential for growth, as an

obstacle for the reproduction of their culture, in which animal traction, ploughs, and the cultivation of wheat, played a fundamental role.

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Biographical Sketch

Dr. Haydea Izazola is a professor and researcher with tenure in the Department of Methods and Systems, Sciences and Arts for Design, at the Universidad Autónoma Metropolitana's (UNAM) Xochimilco campus in Mexico. Dr. Izazola obtained a degree in economics from UNAM, a Master's degree in Demography, and a Ph.D. in Social Sciences with a major in Population Studies from El Colegio de México. Her research interests include the relationship between quality of life and quality of urban environment, and in particular the relationship between migration and the deterioration of the environment. Dr. Izazola has been a member of the Mexican LEAD-Program (Leadership for Environment and Sustainable Development) since 1995. She has also been a member of the Mexican Society of Demography (SOMEDE) since 1984, where she has coordinated the working group on Population and Environment from 1991 to 1997, and at present acts as the Secretary of International Affairs. Dr. Izazola has written numerous scientific articles and has edited several books on the relationship between population and environment, including: *Población y ambiente ¿nuevas interrogantes a viejos problemas?* in 1993, *Desarrollo sustentable, medio ambiente y población a cinco años de Río* and *Población y medio ambiente, descifrando el rompecabezas*, both in 1999.