Water, society and environment in the history of one Mexican city

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ABSTRACT This paper reviews the problems in the city of Morelia over a period of four centuries in providing and financing provision for water, sanitation and wastewater management. It documents when and how innovations were introduced to improve and extend supplies, to draw water from new sources and manage wastewater. It also explains who took responsibility for this, how it was funded and who benefited. Although provision improved greatly throughout this period, the financial difficulties in addressing these problems and also the differential access to water related to deficient infrastructure and to social and political inequalities still remain today. Problems of water scarcity and water pollution have also become more serious. This review shows how historical studies can contribute to a better understanding of the influence of different social actors on changes in water use and management. It also helps identify those processes and social relationships that lead to conflict and environmental deterioration. The paper notes that such problems must be addressed not only by the State directly but also through a greater degree of participation and involvement by the wider society in decision-making and problem-solving related to water.

KEYWORDS pollution / sanitation / urban history / water / water scarcity

I. GENERAL INTRODUCTION

The objective in this paper is to analyze the changes in the relationship between water and society in the history of one Mexican city, Morelia, capital of the state of Michoacán. This relationship is examined within four historical periods:

Colonial period[1] (16th–19th centuries): Several cities were founded to extend Spain's economic and political domination over what was then western New Spain; Valladolid (now Morelia) was one of these. Built in the Guayangareo Valley, it grew slowly, and only gradually introduced public works to supply water, access to which depended on concessions (*mercedes*) issued by the Crown, and which tended to favour local and regional power groups. Technological and financial difficulties contributed to the city's inadequate water supply.

Porfiriato period[2] (ca. 1874–1910): Morelia entered a period of economic recovery and demographic growth that increased demand for water after years of political instability. The nascent State introduced public works for potable water and hygiene, while new legislation and technology for water use and management brought about the installation

1. Period dominated by the Spanish, who colonized and governed New Spain (later Mexico) and its indigenous population for four centuries.

2. Period after Mexico's War of Independence from Spain, characterized by the political stability of President Porfirio Díaz' 40 years in office.

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of distribution networks carrying running water to homes, sewers for wastewater, purification systems and the draining of marshes to prevent outbreaks of malaria.

Post-revolutionary period[3] (1921–1979): the city experienced marked economic and demographic growth spurred by policies of development and urban–regional transformation. The State took control of water and authorized and built irrigation works, potable water systems and sewers. New legal and technological dispositions modified access to water and its control, use, distribution and management. Many projects begun during the Porfiriato period were completed, including hydraulic works for draining the marshes and changing the course of rivers. Flush toilets (known as "English toilets"), running water and sewers were also introduced, and measures were taken to improve water exploitation, namely the Cointzio dam, irrigation district and purification plant.

Modern period[4] (1980–late 1990s): urban growth continued and important changes led to water scarcity and pollution. The use and exploitation of underground water was encouraged with the drilling of wells, although wastewater was still disposed of untreated into natural waterways.

3. Period following the Mexican Revolution that featured efforts at national reconstruction and the development of a model of urban–industrial development.

4. Period characterized by a profound economic crisis in the country, accompanied by greater social and environmental deterioration.

II. THE ORIGINS OF VALLADOLID AND WATER SUPPLIES IN THE SIXTEENTH CENTURY

Early in the sixteenth century, a group of Spaniards interested in colonizing the Guayangareo Valley founded the city of Valladolid. This became both a regional political–administrative seat for western New Spain and a religious centre, whose authority stretched beyond the province of Michoacán. It was an important educational centre, a meeting place, a market for products from other regions and home to elite groups, including *hacendados*[5] merchants and high-ranking politicians, army officers and clergy.[6]

At first, the population drew water directly from the Chiquito River, although some hydraulic works were soon constructed. In 1549, work began on a wooden aqueduct that functioned for several years. Later, stone drains and channels were introduced, although technical and architectural flaws limited their utility and durability. By the late sixteenth century, the Viceroy had received many petitions to help resolve the city's problematic water supply. Thus, in 1590, a tax was imposed on wine sellers,[7] to collect revenue to construct and rehabilitate the water system and aqueduct.[8]

5. *Hacendados* are major landowners with a productive, economic and social system with feudal characteristics.

6. González y González, Luis (1980), "Ciudades y villas del Bajío Colonial", *Relaciones*, No 4, Autumn.

7. During the colonial period, the Viceroyalty authorities established that the rights to selling wine and meat, and taxes on imported (European) wine should finance diverse water projects in the New Spain.

8. Juárez, Carlos (1982), *Morelia y su Acueducto: Sociedad y Arte*, Universidad Michoacana de San Nicolás de Hidalgo, Mexico, pages 23–25.

III. THE SEVENTEENTH CENTURY: UNEQUAL ACCESS AND DISTRIBUTION

The scarcity of labour caused the Spaniards to petition the Viceroy to implement a policy of "congregating" towns. This stimulated population growth and the development of productive activities in Valladolid,[9] but also increased the townspeople's demand for water for domestic use and for irrigating orchards, gardens and fields (for wheat cultivation) around the city.

9. See reference 8, pages 28–29; also Alonso, Ramón (1991), "Cronología histórica de Michoacán y Valladolid/Morelia", Revista *Morelia 450 Aniversario* No 2, Epoca Unica, Mexico, page 33.

Tax revenues financed the rehabilitation of the aqueduct, but these works were later suspended due to technical, administrative and financial problems. Although the *ayuntamiento* (municipal council) was directly responsible for these projects, it depended on the Crown and the interests of local power groups more concerned with their own well-being than the collective good.[10] Mired in difficulties caused by insufficient funding, bureaucratic inefficiency and the misappropriation of wine tax revenues, the *ayuntamiento*'s aqueduct project also had technical and architectural problems typical of the period, including structural design flaws and weak construction materials. Often, when one section of the aqueduct was completed, it was necessary to go back and repair the previous one. Thus, the city's water supply remained deficient and irregular.

10. Juárez, Carlos (1988), *El Clero en Morelia durante el Siglo XVII*, IMC–INAH, Mexico, page 79.

Along with the aqueduct, the city introduced a distribution system that carried water in canals directly to individual homes, gardens, convents and public buildings, with outdoor taps provided for the general population.[11] Both systems reflected the unequal distribution of water and the city's characteristic sociospatial segregation; while an elite sector received running water at home, most people had to walk long distances and line up at public fountains (or public taps) to obtain small quantities of water.

11. See reference 10, page 40.

These differences arose because those who received water in their homes had been granted permits (*mercedes*) by the Crown to exploit water resources, thus assuring them control of water and hindering its use by the general population. This system benefited mainly *hacendados*, landowners, large-scale merchants, public officials, high-ranking military officers and the religious orders, including the Augustinians and the Jesuits.[12] Indians, *mestizos* and blacks, on the other hand, were ineligible to receive permits, so their only access to water was at public fountains or at the few springs and waterholes around the city that were not already controlled by elite groups (Spanish, Creoles). If they were found using water they "had no right to", they were severely punished with public whippings or steep fines.[13]

12. See reference 10.

13. See reference 10.

Clearly, unequal water distribution in Valladolid, based on legal dispositions and permits issued by the Crown and the *ayuntamiento*, adversely affected large sections of the population. Moreover, it allowed dominant groups to benefit from waterworks to which they made only minimal financial contributions, in contrast to the onerous contributions in labour and kind made by surrounding towns and many of the city's Indian and *mestizo* inhabitants.

Due to meagre financial resources, the ayuntamiento suspended public hydraulic works for several years, and it was not until 1677 that the Viceroy sent funds to rehabilitate the aqueduct. Although this improved supply for a few years, demand continued to increase; by 1681 there were 2,000 inhabitants, 800 Spaniards and 1,200 members from different castes, in the city.[14]

14. See reference 9, Alonso (1991), page 34.

IV. WATERWORKS IN THE EIGHTEENTH CENTURY

A bequest by a bishop of Michoacán in 1705 provided funds for an ambitious project to supply water to the city that included erecting a stone aqueduct and an underground distribution system (Photo 1). In this way, the clergy displaced the local government (*ayuntamiento*) from the

PHOTO 1
The aqueduct of Morelia in the early years of the twentieth century

area of water management and increased its own economic and political power and influence in the city.(15)

Despite persistent technical problems, the need to reconstruct many sections of the aqueduct and constant maintenance, by 1731 – almost three decades later – construction was complete. However, this new system made water distribution in Valladolid even more unequal than before; more permits were issued to privileged sectors of the population, while most people continued to rely on public fountains. By 1785, the aqueduct had deteriorated severely and needed urgent repairs; many arches had collapsed, causing severe problems and frequent interruptions of water flow to the public fountains (located in the downtown area, where the aqueduct ended).

By then, Valladolid and the whole Viceroyalty were suffering from a deep economic crisis, which spurred the clergy and the civil authorities to institute measures designed to avert social upheavals. Large sums were authorized for public works, including reconditioning the aqueduct, a project that provided jobs for many families.(16) The man in charge, Friar Antonio de San Miguel, had difficulties obtaining the funds needed to carry out the reconstruction project,(17) but work was concluded four years later, in 1789, bringing benefits to the city's 17,000 inhabitants. With the completion or rehabilitation of several sections of the aqueduct

15. See reference 10, pages 79–80.

16. See reference 8, pages 62–65.

17. González de Cosío, Francisco (1973), *Historia de las Obras Públicas en México Vol II*, Secretaría Obras Públicas (editor), México, page 341; also De la Torre, Juan (1971), *Bosquejo Histórico de Morelia*, Gobierno de Michoacán, Mexico, page 184.

in the late eighteenth century, a very difficult chapter in Morelia's history – the introduction of water – came to a close.

V. WATER SUPPLIES AND TREATMENT: NINETEENTH AND TWENTIETH CENTURIES

After Mexico achieved independence from Spain, Valladolid changed its name to Morelia. The city grew from 11,890 inhabitants in 1820 to 40,042 in 1910, and became the tenth largest city in Mexico (Table 1). Obviously, the urban area expanded and urban and industrial demand and competition for water intensified. The *ayuntamiento* took charge of operating and maintaining the infrastructure for capturing, transporting and distributing water, and extended the supply network to new areas of the city. From 1857 to 1890, it built 12 public fountains, restored many sections of the distribution system and reconstructed parts of the aqueduct and the curtain of a dam.[18] However, despite these efforts, supply problems persisted. The water available in most public fountains was insufficient as demand outstripped supply. Moreover, the system's operations were marred by frequent technical failures and clandestine[19] diversions of water away from human use to irrigation.

During this period, local, state and federal governments became particularly concerned with improving the environmental conditions of cities, and proposed many measures dealing with water use and management that were based on European technological innovations. These included water purification systems, running water in homes, flush toilets (which were known as "English toilets") and sewers. These technologies generated changes in water culture, including increased consumption as a result of the availability of running water in homes and the use of toilets; increases in the volume of wastewater; and the necessity to build sewers to carry this wastewater and dispose of it into the city's rivers.

a. Water purification projects

Morelia's problems with poor water quality stemmed from the high sediment load and high organic material content of the Chiquito River (the main supply source), and from contaminants in the infrastructure itself.[20] This made it necessary to treat the water and construct new piped supply networks. Large water-holding tanks were built that eliminated organic and inorganic sediments from the water drawn from the Chiquito River, and a chemical agent (alum) was added to kill pathogenic organisms. These public works were installed in 1903–04, and were apparently the first of their kind in Mexico. The system began to function in 1906, but health problems as a result of treating the water with alum soon emerged and, by 1910, its use was discontinued and the city's problem of poor water quality returned.

b. Running water

In 1910, construction began on a distribution system designed to carry running water to homes through iron pipes, replacing the old aqueduct/canal network that had supplied the city since the seventeenth

18. Tavera, Xavier (1988), *Morelia en la Época de la República Restaurada (1867–1876) Vol I*, Instituto Michoacano de Cultura–El Colegio de Michoacán, Mexico; also Peña, Patricia (1987), *Obras Hidráulicas en México. Abastecimiento de Agua Hasta el Porfiriato*, UNAM, Mexico; and Michoacán government archives (1889), *Archivo Poder Ejecutivo, Informe de Gobierno*.

19. These were clandestine because that water source was meant to be exclusively for human use. The local authorities allowed the connection of private taps for irrigation without legal support – which can be regarded as a form of corruption.

20. Mendoza, Justo (1968), *Morelia en 1873: Su Historia, Su Topografía, Su Estadística*, Ed. Fimax, Mexico, page 12.

TABLE 1
Growth in Morelia's population, 1793–2000

Year	Population	Population growth rate	Period
1793	17,093	n/a	n/a
1803	18,000	0.5%	1793–1803
1822	11,890	–2.4%	1803–1822
1828	19,174	8.3%	1822–1828
1852	25,000	1.1%	1828–1852
1856	22,000	–3.1%	1852–1856
1869	25,000	1.0%	1856–1869
1872	23,643	–1.8%	1869–1872
1882	25,000	0.6%	1872–1882
1890	26,974	1.0%	1882–1890
1895	33,890	4.7%	1890–1895
1900	37,278	1.9%	1895–1900
1910	40,042	0.7%	1900–1910
1921	31,148	–2.3%	1910–1921
1930	39,916	2.8%	1921–1930
1940	44,304	1.0%	1930–1940
1950	63,245	3.%	1940–1950
1960	100,828	4.8%	1950–1960
1970	161,040	4.%	1960–1970
1980	297,544	6.3%	1970–1980
1990	428,486	3.7%	1980–1990
2000	549,996	2.5%	1990–2000

SOURCE: Information from 1793 to 1970 in Arreola, Raul (1978), "Morelia: monografías municipales", Government of Michoacán, Mexico; also INEGI (1980), *X Mexico: Population and Housing Census 1980*, Instituto Nacional de Geografía e Informática, Mexico; INEGI (1990), *XI Mexico: Population and Housing Census 1990*, Instituto Nacional de Geografía e Informática, Mexico; and INEGI (2000), *XII Mexico: Population and Housing Census 2000*, Instituto Nacional de Geografía e Informática, Mexico.

century.[21] This brought important changes in water use and management, as household taps gradually replaced public fountains. This change also modified consumption patterns and increased demand for water, in accordance with the health and hygiene standards associated with the new European technology.

21. See reference 8; also see reference 18, Peña (1987).

c. English toilets and sewers

Problems associated with disposing of wastewater and human waste became worse with the introduction of running water. These included smells emanating from sewers, and public health problems arising from standing water in the streets and water contamination from domestic latrines. Although some documents from this period mention the unsanitary conditions in the city, there are no records of morbidity rates among the population. From 1910 to 1920, the local government (*ayuntamiento*)

took two approaches: expanding the sewer system to increase the outflow of wastewater and other wastes from the city; and forcing inhabitants to install English toilets connected to the sewers. Sewer construction was one of the government's most significant actions in the area of waste disposal. In addition, decrees in 1910 established guidelines for disposing of urban discharges, and attempts were made to regulate the use of wastewater for irrigating vegetables and other agricultural products in an effort to prevent health risks to the population. However, no one foresaw the future consequences of increasing discharges of contaminated water outside the city.

d. Draining marshes and flood control

Although Morelia's marshes and wetlands were of considerable ecological and productive value to the local Indian population, the Spanish considered them "inconvenient" because they contributed to outbreaks of disease and epidemics such as malaria. Some historians[22] have described how the city suffered from malarial epidemics in the nineteenth century. The urban area was surrounded by wetlands and rivers, the natural habitat of mosquitoes such as the *Anopheles*,[23] and hundreds of people died from malaria.

Wetlands formed around Morelia in the rainy season, when rivers often breached their banks and flooded nearby fields. The Rio Grande was Morelia's most problematic river; some sections were so full of sediment that its natural course actually disappeared. Municipal and state authorities initiated several projects to "rehabilitate" this river, re-channelling its course, strengthening and reforesting its banks, and cleaning, deepening and widening a pool near one of its bridges.

Some wetlands were drained by pumping out water and were then filled with solid waste to create new arable fields. This also fostered the construction of "country homes" on the outskirts of the city.[24] One proposal suggested diverting the entire river – from its source to its mouth in Lake Cuitzeo – to control the floods that affected crops and to prevent the formation of wetlands that constituted a public health risk.

VI. THE POST-REVOLUTIONARY STATE AND WATER PROJECTS: MORELIA 1921–1979

After the revolution (1910–1921), legal and institutional changes in Mexico strengthened the State's role as a central actor in water management. Water became public property and part of the nation's patrimony, while supply and irrigation systems became the responsibility of individual states. In the 1920s and early 1930s, the State took only limited action regarding potable water but had no formal plan or sufficient resources to satisfy demand, although some legislative advances were made.[25]

During the Cardenista period (1934–40),[26] the State developed a water policy based on introducing technology to guarantee urban supplies and irrigation water for agricultural areas. Morelia especially benefited when it was included in a federal potable water programme in 1935 that financed the installation of a household supply system and sewers. Around 1940, the Cointzio dam was inaugurated, and this controlled the flow of the Rio Grande and irrigated more than 20,000

22. See reference 18, Tavera (1988); also see reference 20.

23. According to World Health Organization, pools of standing or slow-flowing water provide a breeding ground for many insects, including mosquitoes that can transmit diseases. All malaria-transmitting mosquitoes belong to the genus *Anopheles*, which breeds exclusively in fresh, clean water, with the exception of *Anopheles sundaicus*, which breeds in brackish water. See http://www.who.int/water_sanitation_health/tsunami_qa/en/index1.html.

24. See reference 18, Tavera (1988) and Michoacán government archives (1889).

25. Bribiesca, José Luis (1958), *Ingeniería Hidráulica en México: El Agua Potable en la República Mexicana*, Mexico.

26. During this period, Lazaro Cardenas was president of Mexico and undertook important reforms. Large landholdings were broken up and distributed to small farmers according to the *ejido* system (social property), and many foreign-owned properties, especially oil fields, were expropriated. Cardenas, who was determined to make Mexico a modern democracy, was strongly opposed by large landowners, industrialists and foreign investors, but (himself a *mestizo*) he became a hero to native peoples and the Mexican working classes.

hectares of farmland. Rehabilitation of the river also began, while the course of the Chiquito River was modified to prevent floods and the formation of wetlands.

Meanwhile, Morelia's population had doubled in just 30 years – from 31,148 inhabitants in 1921[27] to 63,245 in 1950 – although the volume of water available had not increased. The city still depended on its traditional source, the Chiquito River, and its flow of just 82 litres per second (equivalent to 112 litres per person per day). To increase supplies, in the late 1940s some water from the Cointzio dam was diverted to the city, providing an additional flow of 300 litres per second. But this angered farmers because the dam was originally designed to irrigate their fields. Although these modifications increased water volume, the high levels of sediment and suspended solids meant that it required purification. In 1948, construction began on a water treatment plant that required a very large financial outlay.

27. Between 1910 and 1921, during the Mexican Revolution, many people died and Morelia´s population decreased in this period.

By the early 1970s, Morelia's population had nearly tripled, to 161,040. Again, it became necessary to find alternative water supplies. The technical solution was to exploit groundwater by drilling wells and, by the mid-1970s, the first wells were ready. In addition to the problem of supplying water to the city's growing neighbourhoods, in the 1960s competition between industrial and urban demand for water from the dam increased. Morelia needed more water but farmers opposed reductions in the volume of irrigation water.

In the 1970s, industrial output grew as new companies – including a cellulose/paper-processing plant – were established in the city or on its outskirts. Also, in the late 1970s, Morelia created an industrial corridor to regulate the location of new factories. The impact of new plants (and older ones) was more environmental than economic. Some companies, such as the cellulose/paper-processing plant, required large amounts of water and obtained permits to exploit springs, drill wells and extend lines from the urban supply system. Another effect of industrial growth was an increase in the volume of pollutants. Wastewater was still discharged directly into rivers without treatment, a practice that led to serious conflicts in the 1980s as urban, industrial and agricultural stakeholders all vied to control sources, and pollution worsened.

VII. SCARCITY AND SOCIOENVIRONMENTAL DETERIORATION: MORELIA 1980–2000

Since the 1980s, urban growth in Morelia has been characterized by the establishment of many squatter settlements.[28] During this period, urbanization increased the demand for lots, housing and urban services, as the population almost doubled in just 20 years, from 297,544 to 549,996 inhabitants between 1980 and 2000.

28. Vargas, Guillermo (1997), *Proceso de Urbanización y la Configuración Territorial del Espacio Urbano-Rural de la Región Morelia*, MA thesis, El Colegio de Michoacán, Mexico.

a. Water scarcity

During the 1970s, around a dozen wells were drilled to supply the city; by the late 1980s, there were nearly 50 wells, after a municipal ban on exploiting groundwater was lifted. Most of the new settlements established in and around Morelia during the 1980s and 1990s had no alternative but to drill wells because surface sources had long been used to supply

older areas of the city. Flows from wells varied from 1 to 58 litres per second and most operated 24 hours a day. However, some were over-pumped (water being extracted beyond the recharge rate) and fell into disuse or provided less water.

In the 1980s, the authorities tried to reverse the trend of overexploiting groundwater by drawing water from the La Mintzita spring, which has a flow of 1,100 litres per second. However, they only succeeded in obtaining 400 litres per second because of conflicts over water control between the municipality and a nearby cellulose/paper-processing plant.

In the 1990s, total water availability from all sources was 1,969 litres per second, with 61 per cent coming from surface sources and 39 per cent from groundwater:

- Cointzio dam: 630 litres/second (32 per cent)
- Mintzita spring: 400 litres/second (20 per cent)
- San Miguel del Monte spring: 120 litres/second (6 per cent)
- Salto/La Quemada springs: 60 litres/second (3 per cent)
- wells: 759 litres/second (39 per cent)

However, 40 per cent of this supply was lost through leaks and illegal connections that draw water from the distribution network and canals leading to the city. Thus, net availability was only 1,181 litres per second, 91 per cent of which was destined for human consumption and 9 per cent for industrial/commercial use in the city.[29] By 1995, the estimated demand for water in Morelia was 1,586 litres per second, calculated on the basis of 548,200 inhabitants[30] and a daily use index of 250 litres per person per day.[31] This meant a deficit of more than 400 litres per second, a figure that coincides with estimates from the city's Potable Water System (SAPA).

According to the XII Population and Housing Census, 89 per cent of dwellings in Morelia have running water in 2000, 2 per cent obtain water from public taps and 9 per cent lack access to water.[32] These data, however, said nothing about the quality or reliability of the service – including the regularity of the supply and the volume available per inhabitant. For example, only 139 of the city's 230 neighbourhoods (60 per cent) enjoyed regular service; 44 (19 per cent) received water two or three times a week; and 47 others (21 per cent) were irregular settlements that depended on one public outlet or on tanker trucks.[33]

Even in the central city, distribution was unequal, as residential areas got more than 300 litres per person per day while popular neighbourhoods got less than 100 litres per person per day, and many received water only two or three times per week and then for only two hours at a time. In irregular settlements with little or no service, flows from public outlets that functioned only a few hours a week could mean as little as 50 litres per person per day.[34]

More recently, the situation hasn't changed much, with continued social segregation and unequal water access, particularly in the squatter settlements. Poor people live daily with water scarcity. A factor that exacerbates unequal distribution is households' differing capacity to store water. Homes equipped with cisterns can better regulate supplies, while those with no cisterns have to rely on the city's daily and hourly water distribution schedule. Given that most houses in low-income areas do not have cisterns – because of the cost – they can only store water in buckets and drums. Thus, their consumption levels are well below those of other

29. SARH–CNA (1993), *Plan Maestro para el Mejoramiento de los Servicios de Agua Potable, Alcantarillado y Saneamiento de Morelia, Michoacán*, SIHASA, Mexico.

30. INEGI (1995), *Conteo de Población y Vivienda*, Mexico.

31. SSA–Dirección de Ingeniería Sanitaria (1976), *Manual de Saneamiento: Vivienda, Agua y Desechos*, Ed. Limusa, Mexico.

32. INEGI (2001), *XII Censo de Población y Vivienda: Estado de Michoacán*, Mexico.

33. Avila, Patricia (2001), "Urbanizacion popular y conflictos por el agua en Morelia", PhD Thesis, CIESAS, Mexico.

34. See reference 33.

sectors. Although consumption charges are indexed according to a system of high-, middle- and low-income neighbourhoods to compensate for inequalities in income level and water distribution, this does nothing to resolve problems of access. Despite the deficient service characteristic of low-income areas, people there still have to pay quotas. One response to these conditions emerged in the 1980s, as entrepreneurs with tanker trucks began to transport small quantities of water to popular neighbourhoods and irregular settlements where they could sell it at high prices. Unfortunately, this has only accentuated sociospatial differentiation in Morelia, as the poor end up paying a higher price for water than other inhabitants (Photo 2).

b. Water pollution in Morelia and its hinterland

The problem of pollution in Morelia and its hinterland emerged as discharges of untreated urban and industrial wastewater into the city's rivers increased. According to information from the municipality, in the 1990s, the volume of wastewater reached 2,142 litres per second: 1,674 from the city and 468 from industry. Pollution levels (from faecal

PHOTO 2
Typical house in a squatter settlement of Morelia, where water is available for a few hours per week and low-income groups only have small containers to store water

coliforms to heavy metals) in wastewater severely damaged the Rio Grande, the main source of irrigation water for the Morelia–Querendaro district. In the 1980s, environmental regulations were introduced to control discharges from the paper industry, which was considered one of the most serious polluters. Although the Urban Development and Ecology Department established general and specific limits for pH, colour, suspended particles and Sodium Absorption Ratio (SAR),[35] the cellulose/paper-processing plant (the most polluting industry in the Morelia area) installed only a primary treatment system – oxidation pools – that does not eliminate toxic substances or heavy metals. This did not satisfy the minimal conditions for discharges, as SAR indices continued to exceed permitted levels.

As a result, problems of salinity and deteriorating water quality in the region became worse as farmers irrigated fields with water contaminated with urban and industrial discharges.[36] This affected not only agricultural productivity but also farmers' working and sanitary conditions, and gastrointestinal illnesses, skin diseases and fungal infections became common. Also, animals that drank the water or washed in the region's canals and drains began to show higher morbidity and mortality rates, while aquatic life disappeared from the river and was much reduced in Lake Cuitzeo.

The 1990s brought important changes in water legislation that modified the State's traditional functions in this area. New legal dispositions on water exploitation and pollution control were established, and the use of residual waters in agriculture was restricted due to the risk of cholera. Despite these initiatives, the local press recorded several cases of cholera brought on by the ingestion of contaminated water and foods. However, the federal government – through its Department of Health (Secretaría de Salud) – handled those statistics with great discretion so as not to alarm the people and to avoid the imposition of commercial sanctions on its agricultural and fishing products (as had happened in Peru, due to the cholera outbreak there, which had very serious economic consequences).

But problems persisted, in large part because these measures did not address the root causes of pollution. Water legislation did not oblige the municipal government to build a water treatment plant and failed to force the paper industry to clean up its operations, although it did affect 5,447 agricultural users in the irrigation district and 2,000 fishermen in Lake Cuitzeo by limiting their croplands and fishing activities.

In the last few years, this overview has not changed; urban and industrial discharges are still not treated, the Chiquito and Grande rivers are more polluted and the Cuitzeo continues to deteriorate. The project to build a treatment plant for urban discharges has been a political promise since 1985; and the environmental regulations for industries are very flexible.

VIII. FINAL COMMENTS

This review of the urbanization process in Morelia allows us to identify the changes that have occurred in the relationship between water and society, and the social conflicts that have emerged over time. In the Colonial era, the relationship was marked by unequal access and

35. The Sodium Absorption Ratio (SAR), which describes the amount of excess sodium in relation to calcium and magnesium, is an indicator of salinity (total amount of salt in the water). When the salt levels are too high, a salinity hazard may exist. Salts in soil and/or water can reduce water availability to a crop to such an extent that yield can be affected.

36. SARH (1988), *Agua y Sociedad: Una Historia de las Obras Hidráulicas en México*, Mexico.

distribution due to sociospatial segregation and the control of water by local power groups. Technical and financial problems in introducing water into the city were a source of dispute as the elite groups refused to assume responsibility for such projects, and this affected water availability and led to conflicts over its use.

In the Porfiriato period, greater competition between urban and productive uses, changing social perceptions of environmental hygiene (water purification, sewers, waste management), and the creation of a juridical–institutional framework for water use and management all worked to modify this relationship. Social conflicts continued to emerge as a result of disputes over the control of water, and changing values and social regulations.

In the post-revolutionary period, a new relationship emerged as the State began to assert greater control over water use and management, the juridical–institutional framework was modified and new technologies for water exploitation were introduced, including large-scale irrigation works, running water in homes, sewers, drainage of wetlands and water purification. Also, government became responsible for financing the construction of waterworks to satisfy urban, industrial and agricultural demand, although this led to higher public debt and weakened the financial capacity of states and municipalities to confront urban water problems. As a result, conflicts increased, especially in squatter settlements, due to deficient services.

In the late twentieth century, new problems related to scarcity and pollution emerged and spread beyond Morelia's city limits to affect surrounding rural areas. Water problems became more complex as various factors contributed to environmental problems inside and outside the city: rising domestic and industrial demand; unequal distribution related to economic standing and place of residence (squatter settlements vs. residential areas); overexploitation of certain sources (deep wells); and pollution of the Chiquito and Grande rivers by urban and industrial discharges.

Three elements were common to all four periods: financial difficulties in solving problems of urban supplies; differential access to water due to sociospatial segregation and deficient infrastructure; and control of water by the State and local power groups. Other important factors include changing social perceptions concerning the value of water (agricultural, urban and industrial uses, environmental hygiene), new technological forms of water exploitation (aqueducts, public outlets, running water, latrines, English toilets, sewers, water purification, wells), and changes in water legislation that modified the relationship between State and society.

This review of water use over a period of four centuries in the city of Morelia shows how historical studies can contribute to a better understanding of how changes in water use and management were influenced by different social actors. Such studies help identify those processes and social relationships that lead to situations of greater conflict and environmental deterioration. To arrest these trends, the State will have to apply public policies that focus on guaranteeing more equitable access to water for the population, improving the conditions of environmental hygiene, and protecting rivers and other water bodies close to cities. However, not even this will be enough. A greater degree of participation and involvement by the wider society in decision-making and problem-solving related to water is also necessary.