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Water Stress, Peri-Urbanization, and Community-Based Water Systems: A Reflective Commentary on the Metropolitan Area of Mexico City

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With a population of over 22 million, Mexico City's metropolitan area is facing enormous water security challenges. Its supply heavily relies on overdraft of groundwater and import from neighboring basins, leading to problems such as subsidence and raising concern over its sustainability. The impacts of the water stress in Mexico City are highly unequal across the metropolitan area and particularly severe in low-income peri-urban neighborhoods. This paper will first review the current water stress in Mexico City, its impacts on vulnerable communities, as well as some existing technical and institutional approaches aiming to tackle these challenges. We will then focus on the community-based water management systems in Mexico City's peri-urban areas, based on the case of Tecámac, one of the 59 municipalities that form the conurbation area. We will discuss the local water politics in the municipality, the historical evolution of the community-based water system, SAPTEMAC, as well as its current agenda. This essay highlights the importance of incorporating the community-based water systems in the development toward a solution to the water crisis in megacities like Mexico City: not only do they serve as provider of potable water to a considerable number of households, but they also represent a collective resistance against the speculation-driven (peri) urbanization and can make substantial contribution to the promotion of a comprehensive water reform in the country.

Keywords: water sustainability, peri-urbanization, community-based water management system, water governance, Mexico City

INTRODUCTION

The Metropolitan Area of Mexico City (officially Zona Metropolitana del Valle de México) is formed by Mexico City (the former Federal District, including 16 municipalities), 59 municipalities from the State of Mexico, and 1 municipality from the State of Hidalgo[1]. It is the largest metropolitan area in North America and one of the largest megacities in the world. By 2020 the

[1]In this paper, "Mexico City" refers to Mexico's capital or the former Federal District (In 2016, Mexico City ceased to be the Federal District, and is officially known as Mexico City and enjoys greater autonomy). The terms "Greater Mexico City" or "Metropolitan Area of Mexico City" refer to the metropolitan area. The term "conurbation area" refers to the municipalities outside Mexico City that are part of the metropolitan area. The former Federal District is divided into 16 boroughs.

Metropolitan Area of Mexico City had a population of 22.8 million, 9.2 million living in the former Federal District (Instituto Nacional de Estadística y Geografía, 2020).

The Valley of Mexico has a territorial extension of 9,739 sq. km., which is predominantly occupied by the Metropolitan Area of Mexico City (7,854 sq. km). The basin is an endorheic one with 7 aquifers (World Bank (Banco Mundial) 2013, p. 11). Annual precipitation varies from 600 to 1,500 mm (González Reynoso et al., 2010). While the Valley concentrates almost one fifth of the country's population and one fourth of the GDP, it only shares 0.7% of the country's renewable water resources (Torregrosa et al. 2015, p. 402) and has the country's lowest per-capita water availability (101.29 m^3/person/year, see Sosa-Rodríguez, 2019).

Due to its geographic and hydrological conditions, Mexico City suffers serious water stress but meanwhile is prone to periodic flooding. Since late nineteenth century and early twentieth century, a state-led, centralized water management system was developed and consolidated in Mexico City as part of the nation's modernization project. By developing engineered hydraulic infrastructures, the authorities sought to tackle water deficit and flooding by modifying the basin's hydrological cycle and creating intra- and inter-basin connections. Riverbeds were replaced by tunnels and converted to paved roads. In the twentieth century, two inter-basin transfer systems were built to bring water from outside the Mexico Valley basin: the Lerma system (1951) and the Cutzamala system (1970s) to meet the growing demand for water. The Cutzamala system is one of the largest engineered water systems in the world, with 7 reservoirs, 322 km of tunnels and canals, 1 large treatment plant, and 6 pumping stations to raise water 1,100 m in elevation difference (World Bank, 2015), consuming 0.56% of the electricity generated in the country (World Bank (Banco Mundial) 2013, p. 13, 14).

This article aims to review Mexico City's water sustainability challenges and particularly, how water stress and conflicts in the peri-urban area are related to speculation-driven urbanization, and how local communities mobilize through community-based water systems to reclaim the community control over (and autonomous management of) water. The article is based on literature review, archive research, as well as the authors' participation in the public events organized by community-based water systems in 2020 and 2021, including organizations such as Sistema de Agua Potable de Tecámac, Escuelita del Agua, Agua para Todos Agua para la Vida, etc.

As discussed in Section Water Sustainability Challenges in Mexico City, the city's water supply heavily relies on overdraft of groundwater and importing water from the neighboring basins, leading to problems such as subsidence and raising concerns over its long-term sustainability. The problem is compounded by decaying infrastructure and deficiencies in water governance. Section Qualitative Deficit of Water Service and Unequal Impacts of the Water Stress across the City will discuss the quantitative and qualitative deficits of water service in the city, and how the city's water stress is disproportionately affecting its large extensions of low-income neighborhoods in the periphery. Section Approaches to Tackle Mexico City's Water Stress will provide an overview on several technical and institutional approaches that have been proposed or taken to tackle the city's water challenge. Finally, in Section Neoliberal Urbanization, Community-Based Water Management, and Environmental Justice, we will discuss the water politics and conflicts in Tecámac, a peri-urban municipality in the Metropolitan Area of Mexico City and how community-based water management systems there can potentially provide an alternative solution to the metropolis's water crisis.

WATER SUSTAINABILITY CHALLENGES IN MEXICO CITY

Mexico City's water stress is worsened by the rapid urbanization in the twentieth century and the increasing intensity and frequency of extreme meteorological events. The expansion of urban infrastructure and human settlements has significantly altered the Valley's water cycle and hydrogeological condition. Water supply in the Valley of Mexico continues heavily relying on overdraft of ground water and import from external sources. According to Sistema de Agua de la Ciudad de México (2018, p. 51), the water supply to Mexico City (former Federal District) between 2005 to 2017 is on average 31.4 m^3/s. Fifty-eight percent of the water is from local aquifers, and 42% is imported from adjacent basins.

The World Bank (Banco Mundial) (2013) projected that by 2030, the urban water use in the Valley of Mexico will ascend from the current 66.8 m^3/s to 91.8 m^3/s, raising the overexploitation of groundwater from the current 21.1 m^3/s to 46.2 m^3/s. The overdraft of groundwater in the Valley of Mexico leads to subsidence of 5–36 cm per annum (Sistema de Agua de la Ciudad de México 2018, p. 56, 58), damaging foundation of buildings and urban infrastructure including the water pipeline and the drainage system. Groundwater pollution is also associated with groundwater overdraft and the infiltration of wastewater from the sewage. Currently, 12% of the groundwater extracted in Mexico City (former Federal District) presents some physical or chemical deficiencies (Sistema de Agua de la Ciudad de México 2018, p. 63; Ocampo-Astudillo et al. 2020, p. 88).

Meanwhile, the external sources where Mexico City imports water cannot be taken for granted either. Climate change in the region leads to a combination of decreasing precipitation and increasing evaporation, which is translated into a reduction of the water that the Cutzamala system can supply (Sistema de Agua de la Ciudad de México 2018, p. 88). For example, a severe drought in 2008 in the basin where the Cutzamala system extracts and imports water from led to a notable decline in Mexico City's water supply in 2009, from 32.0 m^3/s in the previous year to 29.3 m^3/s (Sistema de Agua de la Ciudad de México 2018, p. 51). This type of event may become more frequent in the future due to climate change[2].

Mexico City's water stress is exacerbated by the infrastructure deterioration. Leakage is a key challenge to water security in

[2]The maintenance of the inter-transfer system may also cause major disruptions to water supply in Mexico City. For example, during the 4-day maintenance work of the Cutzamala system, 72% of the population in the former Federal District went through water rationing to different extent (Diario de México, 2018).

Mexico City. Between 2009 and 2017 the network of water distribution in Mexico City suffered a loss of 38–42% due to leakage (Sistema de Agua de la Ciudad de México 2018, p. 62). Wastewater treatment and reuse has also been a sensitive issue to Mexico City. According to World Bank's report in 2013, the Valley of Mexico produces 52 m^3/s of residual water, of which only 6.1 m^3/s is treated. The rest of residual water, untreated, is drained out of the Basin (World Bank (Banco Mundial) 2013, p. 14), bulk of which was sent to the Mezquital Valley in the State of Hidalgo for irrigation purpose. Although some organic matters in the wastewater may serve as nutrients for the crops, chemical contaminants associated with the untreated wastewater were reported in the local agricultural system, raising concerns over the bio-accumulative processes and food safety (Ponce-Lira et al., 2020). Considerable progress has been made since the Atotonilco Wastewater Treatment Plant—which is one of the world's largest wastewater treatment plants- started operating in 2017. Located 75 km north of Mexico City, the plant is designed to treat 60% of Mexico City's wastewater and improve the sanitary and agricultural condition of the Mezquital Valley area (Alemán et al., 2019).

Natural water bodies are often used as damp areas for wastewater in Mexico City, which introduces another source of pollution. Traditional forms of agriculture (such as *chinampa*) are in decline in tandem with the environmental decay. Although the Conservation Land Act of 1987 prohibited the establishment of human settlements in ecological conservation zones, informal settlements continue expanding in protected areas, generating negative impacts on hydro-morphological quality and biodiversity (Caro-Borrero et al., 2021)[3].

Since 1983, as part of Mexico's decentralization reform, water supply and drainage became responsibility of municipal authorities[4]. However, municipal water operators are often reported to have problems such as lack of autonomy, financial resources, long-term planning, transparency, and institutional capacities. According to a World Bank (Banco Mundial) (2013) sample survey, in the Valley of Mexico operate 23 municipal water agencies; Mexico City (former Federal District)'s water supply is run by the Mexico City Water System, instead of being operated by each borough/municipality. Less than 40% of the water service agencies in Valley of Mexico was evaluated as "good" or "normal"; only 16% of the agencies could be considered efficient and only 51% of the service cost is covered by fees. IMCO (2014) ranked the performance of the water agencies of 50 municipalities/metropolitan areas. Among the 10 agencies with the worst rankings, 5 were from the Metropolitan Area of Mexico City: Ecatepec, Nezahualcóyotl, Tultitlán, Chimalhuacán, and Ixtapaluca, all in the conurbation area.

QUALITATIVE DEFICIT OF WATER SERVICE AND UNEQUAL IMPACTS OF THE WATER STRESS ACROSS THE CITY

In quantitative terms, access to piped water is almost universal in the Metropolitan Area of Mexico City (98% according to the 2015 Intercensal Survey). However, a closer look at various dimensions of the water provision and service presents a different picture. Qualitative deficits and inequality within the metropolitan area remain high. For example, 18.31% of the population do not have access to piped water inside their dwelling (González Flores (2017, p. 22).

In terms of service frequency, the 2018 National Survey of Household Incomes and Expenditures (Instituto Nacional de Estadística y Geografía, 2018) found that about 23% of the households in Mexico City (former Federal District) do not have 24-h supply of running water[5]. This situation is worse in the neighboring State of Mexico. Overall, 43% of population in the Valley of Mexico do not have access to all day long water supply (Sosa-Rodríguez, 2019, p. 91). Currently, 358 neighborhoods in 10 municipalities of the former Federal District are subject to water rationing, affecting about 1.8 million people (Sistema de Agua de la Ciudad de México 2018, p. 66). Not surprisingly, in the 2014 National Survey of the Characteristics of Localities and Urban Environment (Instituto Nacional de Estadística y Geografía, 2014), 148 of the 529 surveyed localities of Mexico City reported water as their worst problem.

The impacts of the water stress in Mexico City are highly unequal across the metropolitan area. Areas with severe water shortage largely overlap with areas with high level of social marginalization. The phenomenon of no access to water inside dwelling is essentially a peri-urban phenomenon: whereas in the central city, only 3.42% of the dwellings do not have access to piped water inside dwelling, this number is 29.22% for the 3rd ring, and 34.93% for the 4th ring (González Flores 2017, p. 29). Within the former Federal District, the 358 neighborhoods affected by the water rationing are mainly located in three municipalities: Tlalpan, Iztapalapa, and Magdalena Contreras (Sistema de Agua de la Ciudad de México 2018, p. 66). In terms of water quality, problems related to the hardness of water, excessive total dissolved solids, and excessive iron, manganese, and sodium are most likely to be found in the east part of the city (Sistema de Agua de la Ciudad de México 2018, p. 63, 64).

SACMEX has a mechanism for subsidizing residential water use. In theory, the subsidy is supposed to cover domestic water use for all residents in Mexico City. Each neighborhood is assigned to a level of subsidy according to its socioeconomic condition (i.e., residents' income level and land value, see Morales-Novelo et al., 2018). Although this scheme is designed to favor low-income communities, in reality, the subsidy disproportionately benefits higher-income households and often

[3]According to Mexico City's Environment and Land Zoning Office, out of the city's 87,000 hectares of conservation land, 2,819 has been occupied by informal settlements, which is home to 57,000 families (Roa Márquez, 2016).

[4]Currently, 90% of the country's water agencies operate at municipal level, although municipal governments can also opt for coordinating with other municipal governments or the State government on water and sanitation service, and in some municipalities water supply has been privatized (IMCO, 2014).

[5]12.5% of the households have running water every third day, and 10% of the households receive running water only twice a week, once a week, or only occasionally (INEGI, 2018). SACMEX (2018, p. 43) calculates that 17% of its coverage is under daily rationing (only 8 h of regular service) and 9% only receives water once, twice, or three times a week.

does not reach low-income families and communities. It is estimated that the top 20% of households received 45% of the total subsidy, while the bottom 20% of households received only 12% (Revollo-Fernández et al., 2019). This is mainly because many low-income communities are simply not covered by the urban public water system[6] or are more susceptible to water cuts. Their daily per capita water consumption is also much lower than that of high-income communities (Morales-Novelo et al., 2018)[7].

The vulnerabilities related to water and sanitation faced by the low-income peri-urban communities have to do with the exclusionary way in which the megacity is made. First, as a result of the segmentation of the urban land and housing markets, many low-income neighborhoods were built in places that are not suitable for human settlements but were the only affordable options for the low-income population. Developers and landowners sold those lots with false claims or promises on infrastructure and service, taking advantage the information asymmetry and absence of government regulation. Second, the fact that many informal settlements were developed with no proper planning makes it very costly to provide adequate infrastructure in an *ad hoc* manner—particularly in the case of a centralized water system. Although over years residents of many informal settlements have improved the condition of their neighborhoods through clientelist politics or collective actions, government investment in informal settlements in general is highly inadequate. Third, the peri-urban fringe of the metropolitan area and the rural hinterland are actually "subsidizing" the city center by providing additional carrying capacity. Extraction of groundwater in the central part of Mexico City was halted since 1950s to prevent further subsidence. But since the dependency on overexploitation of groundwater persists and water has to be extracted from somewhere else anyway, it means that the risk of subsidence is relocated to the periphery (Sistema de Agua de la Ciudad de México 2018, p. 56). For example, despite its relatively abundant natural water resources, many settlements in the Xochimilco lack water. Part of the reason is that a considerable part of the municipality's water is extracted to supply the central parts of the city, and it is estimated that only 1/3 remains for local use (Sánchez, 2018).

Most people with no access to piped water at home resort to water truck delivery, or to less extent, water is brought from a different dwelling, a community faucet, a well, etc. (González Flores 2017, p. 23). As De Alba (2017) pointed out, water rationing and water truck delivery somehow have become de-facto official policy to respond to water stress in Mexico City. Between 2007 and 2017, water truck delivery varied between 34,000 and 42,000 vehicles each year (Sistema de Agua de la Ciudad de México 2018, p. 66.)

The lack of reliable access to clean water generates a number of negative consequences for low-income households and communities. The suboptimal water quality leads to detrimental health consequences and higher risk of waterborne diseases. Having to carry water from outside the dwelling is a highly time-consuming and exhaustive task for many families (particularly female-headed households). Low-income households in Mexico City often have to rely on water trucks and bottled water for a considerable part of their domestic water consumption. However, water truck delivery is much more expensive than regular water service from the public distribution network. Whereas, water price set by the urban public water system is highly subsidized, private water truck service and bottled water are priced based on the supply-demand relationship. The population relying on water truck delivery for domestic water supply- who are likely to live in marginalized communities without access to public network of water distribution- pay a price 14 times as high as the price of the water from the public water distribution network (Sosa-Rodríguez, 2019, p. 91)[8]. For many of these households, potable water poses an enormous economic burden (Salazar Vargas, 2014).

APPROACHES TO TACKLE MEXICO CITY'S WATER STRESS

Various initiatives have been proposed or implemented to mitigate water shortage and tackle water sustainability challenges of water in Mexico City. The first approach seeks alternative and additional water sources, which often involves ambitious engineered projects. It has been proposed to extract water from deeper aquifers; several wells as deep as over 2,000 meters have been drilled to study the potential existence of deep aquifers in the basin (Sistema de Agua de la Ciudad de México, 2018). Efforts have been made to explore additional external sources to bring water to Mexico City. Three strategic projects were planned or implemented during the Peña Nieto Administration (2012–2018), which were expected to add an additional external supply of 22.2 m^3/s to the Valley of Mexico[9]. It has also been proposed to artificially refill the local aquifers (Sistema de Agua de la Ciudad de México, 2018).

The second approach focuses on increasing wastewater treatment and reducing leakage in the water distribution network. This means investing in the maintenance and expansion of the existing network and facilities, such as repairing pipeline leakage and constructing new treatment plants.

The third approach seeks to improve the hydrological condition of the city by rehabilitating existing natural water bodies (including Magdalena River, Lake Texcoco, Lake Xochimilco, etc.) and developing green infrastructure. The idea of urban hydraulic parks is especially appealing as it tackles the water paradox in Mexico City- the coexistence of water shortage

[6]In 2012, in Iztapalapa (former Federal District), the average daily income of households using the urban public water system was 817.7 pesos, while it was only 301.5 pesos for households relying on water trucks (Salazar Vargas 2014, p. 162).

[7]Domestic users in Chalco consume between 20 and 80 L per capita daily, while some users in wealthy zones of Las Lomas get on average around 600 L per person per day (Romero Lankao, 2010).

[8]For example, in Iztapalapa, in 2014, the average water price from the public water distribution network was 6.91 pesos/m^3 (13.67 pesos for tier-1 neighborhoods, 12.6 pesos for tier-2 neighborhoods, 7.1 pesos for tier-3 neighborhoods, and 5.15 pesos for tier-4 neighborhoods). The water from legal private water trucks is sold at between 62.5 and 150 pesos/m^3 (Salazar Vargas 2014, p. 157).

[9]6 m^3/s from reservoir El Tule; 4.2 m^3/s from two wells in the area of Mezquital; and 12 m^3/s from the North Sierra region of Puebla, see Comisión Nacional del Agua (2017).

and periodic flooding. In addition, these parks can create vibrant public spaces. One example of this "hydropuncture" approach is the award-winning project, La Quebradora Hydraulic Park (Novakovic, 2019; Perló Cohen, 2019).

The fourth approach consists of ecotechnological initiatives and the promotion of a more efficient use of water[10]. An important policy initiative in Mexico City is the promotion of rainwater harvesting, particularly in marginalized communities with difficult access to clean water. The Government of Mexico City made a Master Plan, established guidelines, and offered fiscal incentives/subsidies for the installation of rainwater harvesting systems in neighborhoods with water shortage. Between 2007 and 2018, rainwater harvesting system has been authorized in 8,396 new constructions (Sistema de Agua de la Ciudad de México 2018, p. 70, 71). In 2019 and 2020, a total of 20,010 systems have been installed in households in 5 boroughs of the former Federal District (Secretaría del Medio Ambiente, 2020). The NGO Isla Urbana, specialized in rainwater harvesting for over a decade, plays a key role in the development of the ecotechnology, its installation, and community engagement.

A fifth group of policy recommendations urge to implement comprehensive institutional reforms in the water sector (Organisation for Economic Co-operation and Development, 2013). They focus on a variety of institutional and structural issues, including the impact and outcomes of privatization (Pierce, 2012), water pricing and subsidies (Organisation for Economic Co-operation and Development, 2013; Revollo-Fernández et al., 2019; Sandoval-Minero, 2019; Secretaría del Medio Ambiente, 2020), coordination and collaboration across jurisdictions and agencies (IMCO, 2014; Martínez et al., 2015), personnel training, information collection and water management strategies (Val-Segura and Arriaga-Medina, 2015), citizen participation in water governance (Castro, 2017; Torregrosa, 2017; Salgado López, 2019). It is important to highlight here activists' and social organizations' struggles against neoliberal water policies that pursue water commodification and privatization. Their approach to water sustainability is built upon the frame of social/human rights and community autonomy, which will be discussed in the following section.

NEOLIBERAL URBANIZATION, COMMUNITY-BASED WATER MANAGEMENT, AND ENVIRONMENTAL JUSTICE

Origin of Water Stress and Conflicts in the Peri-Urban Fringe

The various technical approaches mentioned in the previous section certainly have their merits. With that said, when discussing Mexico City's water sustainability challenge and public policy, it is important to consider its metropolitan context. The central city and the peri-urban interface are characterized by contrasting socioeconomic condition and political and cultural landscapes in water management. For example, in 2010, GDP per capita was USD 26,550 in the former Federal District, but was only USD 7,140 in the conurbation municipalities (Organisation for Economic Co-operation Development 2015, p. 46). While a single entity, SACMEX, manages most of the water supply and distribution in the former Federal District, in the conurbation area, each municipality has its own water operating agency, resulting in a more fragmented institutional landscape.

Water stress in Mexico City, particularly in its northern peri-urban fringe, cannot be reduced to the deficit on the water balance sheet. There, water-related conflicts arise essentially as the result of the recent wave of speculation-driven urbanization. The aggressive expansion of the central city not only physically and functionally integrates the previous rural hinterland through real estate projects, commercial plazas, freeways, or other megaprojects, but also creates enormous negative ecological and social consequences (Oropeza and Gamboa, 2020). This peri-urbanization disrupts local livelihoods and approaches to natural resources management (such as water and land). Without addressing the way in which cities are made, it is unlikely that existing technical and institutional approaches can achieve water sustainability goals. This section will discuss this based on the case study of Tecámac.

Tecámac is a municipality in the State of Mexico and within Mexico City's metropolitan area. Before the 1980s, Tecámac was a rural agrarian municipality (Correa Ortiz, 2010). As the natural water bodies (including Lake Xaltocan) were drained around the mid-twentieth century, artificial wells had to be drilled to extract groundwater instead. In this context, community-based water systems were created in the 12 towns that formed the municipality to manage local potable water supply and distribution, including the "System of Potable Water of Tecámac" (Sistema de Agua Potable de Tecámac, SAPTEMAC) that serves the municipal seat (the town of Tecámac). These systems are not run by the municipal government, but by an autonomous board/committee whose members are elected from local families. For decades, this system worked well in Tecámac. Neighbors contributed money and voluntary work in water infrastructure projects, preserving the organization's autonomy. By 1993, SAPTEMAC served a total of 2,534 households; its pumping system had been fully computerized; its operation met the State norms and offered an uninterrupted service throughout the year, which was recognized by the Water Commission of the State of Mexico (Correa Ortiz, 2010).

Intense conflicts around water management in Tecámac began in late 1990s and early 2000s. This occurred against the backdrop in which a real estate boom swept Mexican cities. As the result of the State promotion of home mortgages targeting low and lower-middle income working class and a deregulation of urban and housing development, large extensions of social-interest housing projects quickly proliferated in peri-urban areas, taking advantage of cheap land there and absence of government planning and regulation. This real estate

[10] Mexico's urban households have been using various approaches to save water. For example, 51% of the urban households in the country would reuse water from washing vegetables/fruits/clothes. Note that 9.6% of the urban households also reuse rainwater, although this percentage is lower than rural households (18.8%, see Instituto Nacional de Estadística y Geografía, 2017).

boom has generated severe ecological and social consequences. Numerous studies have documented the precarious conditions and infrastructure deficits in these "social" housing projects (Fausto Brito and Munguía Huato, 2010; Marosi, 2017; Salinas Arreortua, 2019).

Tecámac became a perfect target for real estate interest due to its location and the municipal authorities' interest in turning the municipality into a dormitory city of Mexico City. Social-interest housing projects mushroomed in Tecámac, including Los Héroes Tecámac, one of the largest of its kind in Latin America, constructed on the land of the District of Irrigation No. 88 (Sistema de Agua Potable de Tecamac, Estado de México A.C. 2019, p. 9). In the period 2000–2010, about one fifth of the new dwellings constructed in the State of Mexico were located in the municipality (García Ibarra, 2017). Tecámac's population grew from <173,000 in 2000 to more than 547,000 in 2020 (Instituto Nacional de Estadística y Geografía 2014)—an annual population growth rate of 5.9% during this period, placing it as one of the fastest growing municipalities in the entire country. As happened elsewhere, the uncontrolled expansion of housing projects—bulk of which happened without proper planning and evaluation of hydrological conditions—threatened the water security in Tecámac and the functioning of the existing water management system. Activists argue that the unprecedented population and housing growth in the municipality, as well as the land use change, would alter the local water cycle and reduce the groundwater recharge capacity.

Struggle to Preserve Autonomy and Resist Speculation-Drive Urbanization

In December 2003, as the municipal government continued giving green light to new real estate developments by modifying the urban development plan without respecting the proper procedure of public consultation, SAPTEMAC pursued legal actions and led a protest that successfully blocked the municipal government's action. In the following years, conflicts between SAPTEMAC and the municipal authorities escalated. The municipal government made aggressive moves to dissolve community-based water systems and control the entire water administration in the municipality ("municipalization"). SAPTEMAC questioned the motives for municipalization and struggled to maintain its operation and autonomy and to curb the speculation-driven urbanization. On several occasions, the municipal government attempted to evict SAPTEMAC from its office space or sabotage its infrastructure and operation. These attempts met strong backlash from the civil society (Sistema de Agua Potable de Tecamac, Estado de México A.C., 2019).

In February 2005, the municipal government evicted the organization from its office, an act of retaliation for the protest that the organization led in 2004. SAPTEMAC filed a complaint before the Administrative Dispute Court of the State of Mexico, and supporters of the organization set up tents outside municipal palace for a lapse of 100 days. In September 2005, the Court reached a decision in favor of SAPTEMAC, which the municipal government refused to accept. The municipal police even arrested SAPTEMAC's personnel who intended to resume the organization's operation, which triggered yet another protest and violent confrontation. It was not until after the municipal election in 2006, with the transfer of power to the opposition party, that SAPTEMAC recovered its properties. With that said, tensions between SAPTEMAC and the municipal government continued until recently. Recent administrations disrupted SAPTEMAC's board election in 2016 and sabotaged its operation and infrastructure in 2017.

The conflicts between SAPTEMAC and the municipal authorities are embedded in the local political context. Local political caciques make alliance with external actors (commercial developers) and have deep vested interest in the real estate boom in the municipality. They aggressively seek to control strategic resource like land and water, and view community-based organizations like SAPTEMAC as obstacles that must be removed. The political leadership in Tecámac had also developed powerful clientelistic networks to maintain power, to secure key political posts for its followers, and to attack social movements or activism (For a more detailed discussion, see Castro Maravilla, 2019). SAPTEMAC did not succeed in stopping Tecámac's transformation into a dormitory town of Mexico City, and the organization finds itself under constant besiege and harassment. Today, 4 of the 12 original community-based water systems in the municipality have been municipalized, the rest 8 are still operating (Sistema de Agua Potable de Tecamac, Estado de México A.C., 2019). These independent systems serve ∼16% of the municipality's population (most of them in the old towns). The rest 84% (most of them in recent housing developments) is covered by the municipal government through the newly created Decentralized Organism of Potable Water and Sanitation (Organismo Descentralizado de Agua Potable y Saneamiento, ODAPAS, see Municipal Government of Tecámac 2019, p. 251).

On the other hand, SAPTEMAC has been able to preserve its autonomy and integrated itself into various nationwide social movements against neoliberal policies, human right abuses, and megaprojects. Currently SAPTEMAC operates 6 wells, serving some 4,300 registered users in the municipal seat of Tecámac (Sistema de Agua Potable de Tecamac, Estado de México A.C., 2019). Its resistance to municipalization, to large extent, has been made possible thanks to its alliance with a wide range of civil organizations and activists. After the incident of eviction in 2005, numerous organizations, activists, scholars joined the 100-day protest outside the municipal palace, including nearby campesinos opposing the Texcoco airport project, representatives from the Zapatista Front of National Liberation, Comité del'68, etc. In 2015, the Zeferino Ladrillero Centre for Human Rights and other legal aid activists helped SAPTEMAC to secure the recognition from the State government on its authority over water management in the municipal seat (Sistema de Agua Potable de Tecamac, Estado de México A.C. 2019, p. 30).

Tecamac's water politics and SAPTEMAC are not isolated case in Mexico City's metropolitan area. According to Correa Ortiz, by 2010 there were still 358 "original towns" (*pueblos originarios*, many remain as agrarian communities with its own customs and communitarian institutions) in the Metropolitan Area of Mexico City, 234 of which are located in the conurbation area. By the end of the twentieth century, what sustains the claims of social and political rights in the rural hinterland of the metropolitan area had transformed from one of "revolutionary agrarianism" (*agrarismo revolucionario*), which centers around state-led land distribution, to one of "original towns," which emphasizes on cultural diversity, ethnopolitics, and communitarian institutions. In response to the aggressive urban expansion of the megacity since the 1980s, former agrarian communities like Tecámac reinforce their community-based organizations to make collective claims of rights and reclaim control over local resources and livelihoods (Correa Ortiz, 2010).

Community-Based Water Systems as Agent Tackling Water Sustainability Challenges

Community-based water systems are quite common in Mexico's rural and peri-urban areas, serving communities where public water systems are absent. They are often led by locally elected governing boards and rely on collective community service in the development and maintenance of local water infrastructure. According to the National Institute of Statistics and Geography (INEGI), among Mexico's 3,670 agencies of water service, about 1,200 can be classified as "community-based" (Peña García and López Mera, 2020). These community water systems are heterogeneous in terms of their legal status, internal organization, relationship with government agencies, funding sources, as well as their technical capacity and performance (Silva Rodríguez de San Miguel, 2015). Many of them are also committed to preserving ancestral knowledge, rehabilitating local ecosystems, etc. (Moctezuma Barragán, 2018). They view water as an ancestral heritage for the community and its access as a collective right. They energetically oppose neoliberal policies that frame water as a commodity, and megaprojects that prioritize corporate interests but threaten local bio-cultural diversity (Acosta, 2020). Mexico City's vast peri-urban fringe, as reflected in the case of Tecámac and the SAPTEMAC, is part of the national and regional struggle over water access, rights, and policies.

The fragmented institutional landscape of water governance has often been blamed to be responsible for the deficiencies in water and sanitation management in Mexico[11]. The proposal of creating a single municipal (or metropolitan) water authority may sound attractive. However, without mechanisms to ensure accountability and citizen participation, such authority would be appropriated by corporate interests and work against sustainability agenda. This article does not intend to deny the importance of coordination across jurisdictions and agencies. However, we argue that community-based water management organizations need to be recognized as important changemaker in the solution of Mexico City's water crisis for three reasons: First, these organizations' efforts to defend territory and local livelihoods consist in a significant counterbalance to the speculation-driven urbanization, which is largely responsible for the water stress and conflicts in the megacity. Second, beyond defending their own operation and autonomy, organizations like SAPTEMAC are dedicated to consolidating a narrative against water privatization and commodification, raising awareness of water as human and social rights[12], and promoting more democratic and progressive national water laws. This struggle is an integral part of a broader national and regional movement against neoliberal policies and neo-extractivism. Third, as a potential alternative to conventional state-led, centralized infrastructure, community-based water management systems are venues for developing and implementing innovative ecotechnologies and democratic water governance practices to tackle both climate change and environmental injustice.

That being said, community-based water systems in Mexico also face tremendous challenges. Water management is embedded in power relationships and social-political processes (Acosta, 2020). Not all of the community water systems reach the same level of internal governance. Lack of transparency can lead to a decline in community participation and cohesion (e.g., users stop paying bills). Beyond that, community-based water systems are not formally recognized by the current national water law- therefore many of them have to operate as civil organizations (such as SAPTEMAC), rural agrarian committee, etc. As a result of this institutional void, community-based water systems are often neglected in policymaking and are excluded from government programs. Lacking technical capacity and funding, some community-based water systems suffer infrastructure deficits or are heavily indebted on utility bills. It is against this backdrop that in recent years activists and social organizations such as "Agua para Todos Agua para la Vida" proposed a new national water law to replace the current one. A key component in this citizen initiative is to recognize and guarantee the legal status of community water systems, and to include them in national water policies and programs (Barragán, 2020).

CONCLUSIONS

As one of world's largest megacities, the Metropolitan Area of Mexico City faces several major water sustainability challenges, including (1) hydrological disequilibrium (overexploitation of local aquifers, increasing dependency on importing water from further remote locations, subsidence, lack of mechanism to tackle climate change, etc.); (2) decaying infrastructure; (3) deficiency in service provision in terms of water quality and service frequency; and (4) institutional inefficiency (also see Sistema de Agua de la Ciudad de México, 2018). These challenges disproportionately affect the vulnerable communities in the peri-urban area. In this context, a wide

[11] Whereas the international standard is each water distribution serving 750,000–1 million people, in Mexico this number is 44,000, which raises concern over economy of scale (IMCO, 2014).

[12] Following the Colombian organization "Escuela del Agua" ("Water School"), SAPTEMAC and other independent water systems created an initiative called "Escuelita del Agua" ("Little Water School"). The initiative offers training sessions to community leaders and activists on water management and promotes activism and solidarity (SAPTEMAC, 2019, also see https://transformativecities.org/atlas/atlas-26/).

range of policy proposals have been made or implemented. Drawing on technical and institutional approaches, these policies seek to improve the hydrological condition of the city, restore its water balance, and elevate the efficiency of its water governance.

This article argues that it is important to analyze Mexico City's water stress in its metropolitan context, recognizing the disruptive impacts of its rapid peri-urbanization and the diversity in economic, cultural, political, and institutional terms within the megacity. Peri-urban municipalities like Tecámac used to be Mexico City's rural hinterland and were only loosely connected with the central city. The neoliberal urbanization since 1990s integrate these former agrarian communities to the central city, in tandem with the influx of real estate projects, commercial plazas, and megaprojects causing severe ecological and social consequences. Tecámac, like many other peri-urban municipalities, was to large extent transformed into Mexico City's dormitory town. In this context, water conflicts intensified in Tecámac: on one hand, local political caciques, in alliance with external actors (developers), seek to expand control over key resources such as water through a policy of municipalization, in order to execute their urban agenda and make profits. On the other hand, facing the disruptive force of the speculation-driven urbanization, local communities also mobilize through organizations such as SAPTEMAC to reclaim the community control over (and autonomous management of) local resources and livelihoods.

This article highlights the merits and potential of these struggles. Despite the sabotages from the local political cacique, today SAPTEMAC continues operating autonomously and providing water service to the municipal seat. More importantly, SAPTEMAC's struggle tackles one of the key causes of the water crisis in Mexico City, the speculation-driven urbanization. It has also been integrated into broader national and regional social movements against neoliberal policies and environmental injustice.

AUTHOR CONTRIBUTIONS

YC is responsible for conceptualization, methodology, investigation, and writing. AB is responsible for conceptualization, resources, review and supervision. The corresponding author is responsible for ensuring that the descriptions are accurate and agreed by all authors.

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