Energy and environmental costs related to water supply in Mexico City
R. Salazar, A. Rojano and I. López

ABSTRACT

Water and energy are critical resources that are essential and interdependent. Satisfying consumers’ water needs requires energy for supply, purification, distribution, and treatment of water and wastewater. This energy consumption to provide water is linked with negative environmental externalities. This paper provides an overview of the energy and environmental costs related to water supply services in Mexico City, one of the largest cities in the world; this city is heading towards a major water crisis, more than 30% of its water supply comes from external sources. The internal groundwater sources are overexploited between 9 and 12 m$^3$/s generating 6–28 cm of sinking every year. The current water availability is 130 lt/person/day, which is below the minimum requirements. Also, half of Mexico City’s water supply is lost through poor infrastructure alone and mismanagement of water resources. The external and internal sources of water supply are analyzed in terms of the energy consumption and costs as well as the generation of contaminants in the atmosphere such as CO$_2$, SO$_2$, N$_2$O. Finally, some opportunity areas are provided to reduce energy use and contamination of the non-sustainable water consumption pattern of Mexico City.

Key words | aquifer overexploitation, CO$_2$, energy consumption, water availability

INTRODUCTION

From 1950 to 2000, the urban population growing rates in almost all countries were higher than the rural population, this rapid urbanization bring about a megacity, which is an urban area having more than 10 million people (Biswas 2006).

In 1950, only New York was a megacity. By 1975, the number of megacities had increased to five, and, by 2000, to 16. It is estimated that by 2015, this number will increase to 21. One of these major urban centers is Mexico City with a population of 20–22 million people (Tortajada 2008).

The phenomenal growth rate of the city between 1950 and 2005 – from 2.9 million to more than 22 million at present has made it almost impossible for institutions to respond to the rapidly increasing needs of the population in terms of water supply, drainage and sanitation, with the consequent economic, social and environmental problems.

The main problem in megacities, is the lack of appropriate management, adequate institutions and sustainable planning, to address these challenges beyond short-term approaches requires large investments to cover the needs of all sectors of the population in terms of water supply, drainage and sanitation. On the other hand, megacities require massive quantities of power. Megacity residents consume about five to ten times the energy of the national average.

Besides the specific problem with megacities, the climate change problem add an additional constraint, water availability can decrease between 10 and 20% during the following decades, and water availability in Mexico is expected to decrease from 4,500 m$^3$/s/day to less than 3,500 m$^3$/s/day due to this phenomenon (IMTA 2010).

It is not possible to discuss water problems without mentioning the energy used to provide water supply, both resources have high impact in the economic development of countries (Kenway et al. 2010); however this strong link between water and energy is not fully considered in the water management and distribution as well as in the electricity generation.
Energy is required to lift water from depth in aquifers, pump water through canals and pipes, control water flow and treat wastewater, and desalinate brackish or sea water. Globally, commercial energy consumed for delivering water is more than 26 quads, 7% of total world consumption (Easton 2008). Latin America spends between 1,000 and 1,500 million dollars every year to pump water that never reaches the final user due to leakage and losses in the system (Hoffman 2010).

According to the American Energy Information Administration (EIA) and to the International Energy Agency (IEA), the world-wide energy consumption will continue to increase by 2% per year on average unless action is taken. Particularly in the United States, about 4% of power generation is used for water supply and treatment, according to a report from Sandia National Laboratories to Congress; domestic hot water heating accounts for some 9% of domestic energy use. In addition, some 20% of the world’s electricity comes from large-scale hydroelectric dams – dams that require steady, large flows of water.

The use and management of water and energy has huge environmental implications; the management of these two resources is, undoubtedly, the main environmental challenge that mankind will face during the following decades in order to achieve sustainable development in this field, particularly in relation to climate change.

The first priority in most of the countries is the efficient use of energy and water supplies available. Currently, attention must be focused on new energy and water supplies that meet sustainability and environmental requirements.

**A CASE STUDY IN MEXICO CITY**

**Water supply and demand**

Mexico City has the largest urban population in the world living in an enclosed basin with no natural outflow to the sea (Weiner 2000). The water supply is a non-sustainable scheme which is dependent on external sources facing a serious water deficit, as well as social conflicts. As a result of increased demand from consumers and industry, and the rapid deforestation in the surrounding hills that have served as aquifer recharge areas, more water is now leaving the system than entering it. It is estimated that 65 m³/s of water is needed to support the potable and agricultural irrigation needs of Mexico City’s population (Bojórquez et al. 2000). The main aquifer is being pumped at a rate of 55.5 m³/s, but is only being replaced at 28 m³/s, or about half of the extraction rate, leaving a shortfall of 27.5 m³/s (Lead 2004). The Magdalena River provides 2% of this shortfall, but this river is increasingly contaminated by urban pollution (Ezcurra & Mazari 1996).

The combined Lerma-Cutzamala requires 443 km of pipelines, which supply 202 storage tanks, with a joint capacity of 1.5 million m³. There are 102 plants to pump the water to the upper zones of the west and south of the Federal District. For its distribution, there are 560 km of primary pipeline network and 12,044 km of secondary network. It also requires a tremendous amount of energy – equivalent to an 800 MW reactor running permanently – because water must be conducted uphill over 1 km (Morgan 1996). An estimated 40% of the total water supplied to the MCMZ (Mexico City and Metropolitan Zone) is lost through leaks in the aging municipal systems. These two supplementary sources contribute 6 m³/s of groundwater and 13 m³/s of surface waters respectively, amounting to 30% of the total supply to Mexico City (Tortajada 2008). Table 1 presents a summary of the water balance for Mexico City.

The average water demand in Mexico City is 300 lt/hab/day while in Europe water consumption is between 100 and 150 lt/day.

**Energy related to water supply**

Water supply and distribution for Mexico City needs a huge amount of energy to reach the final user. Water needs to be pumped to a height of more than 1,000 m. Because of the increasing soil subsidence, wastewater also has to be pumped up to discharge from the city. The above has made water supply and sewerage very energy-intensive and expensive. In 2000, for example, energy used in the MCMZ on pumping clean water, treating water for drinking purposes and collecting wastewater and rainwater was 2.436 Peta Joules.

Specifically, water volume from Cutzamala River travels 160 km and it has to be pumped 1,100 m, the energy...
consumption is 2.85 (kWh/m³) and the costs related is $0.99/kWh. The construction of its fourth stage of this water transfer scheme from Cutzamala River would have an initial investment of $502 million to increase the volume of water only by 5 m³/s, from 19 at present to 24 m³/s which means that each cubic meter of water from the Cutzamala River is estimated to require an investment of $23 million (Tortajada 2008).

Table 1 shows energy consumption for water supply and disposal from 2000 to 2005 to supply clean water to the users of Mexico City, as well as to transport wastewater out of the city.

Almost 40% of the total volume of water distributed is lost due to leakages in the distribution systems. Therefore before thinking about expensive projects, water policy should be focused first on repairing the distribution networks, water pricing and other water conservation practices.

### Table 1: Water supply and demand for Mexico City

<table>
<thead>
<tr>
<th>Water supply</th>
<th>Water demand</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>External sources</strong></td>
<td></td>
</tr>
<tr>
<td>Cutzamala</td>
<td>9.72</td>
</tr>
<tr>
<td>Lerma</td>
<td>4.0</td>
</tr>
<tr>
<td>Caldera</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>15.12 m³/sec</strong></td>
</tr>
<tr>
<td><strong>Internal sources</strong></td>
<td></td>
</tr>
<tr>
<td>Groundwater and lakes</td>
<td>17</td>
</tr>
<tr>
<td>Risco (Magdalena River)</td>
<td>1</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>18 m³/sec</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>33 m³/sec</strong></td>
</tr>
</tbody>
</table>


ENVIRONMENTAL EFFECTS ON WATER-ENERGY CONSUMPTION IN MEXICO CITY

### Subsidence in Mexico City

According to official figures, the water extracted from the aquifer to supply water for residential use in Mexico City is between 45 and 54 m³/s, but the natural recharge rate is only about half of this figure. This fact has resulted in very serious overexploitation, the groundwater table is falling at an alarming rate of more than 2 m/year. The central area of the MCMZ has subsided approximately 10 m during the 1900s, varying from 10 cm/year in the central area to 20–25 cm in the area of the International Airport of Mexico City. Increasing subsidence has resulted in extensive damage to the water supply and sewerage infrastructure, as well as degradation of the quality of the groundwater on which its own survival depends (Tortajada 2008).

Non-revenue waters are one of the main challenges facing megacities both in developed and developing countries. Lack of investment tends to be the most frequently mentioned reason for high, non-revenue water.

### CO₂ emissions

There is a correspondence between water supply, energy use and CO₂ emissions. Three percent of energy use for water would result in the unit energy use of 2.26 kW-hr/m³
attributed to water and the corresponding carbon emission of 1.37 kg CO₂/m³ (Novotny 2010).

Taking into account the information provided in Table 3, the annual electricity consumption, as well as oil consumption (3 kg CO₂ for each kg of burn oil), it was estimated that each car traveling 12 hours per day produces 20 CO₂ tons. Therefore, the CO₂ emissions related to water supply are equivalent to 52,000 cars. Moreover, water loss in Mexico City is about 13 m³/sec; if we reduce these amounts by 50%, we can reduce the cost of water supply by 580 million pesos yearly and CO₂ reductions by more than 380 thousand tons.

Every saving in water use can be related not only with energy savings but also with carbon dioxide bonus. In the last years, there are some actions that the Mexico City government is implementing to cope with the water problem. In 2001, the Environmental Administration System was instituted, which is the application of the environmental strategies to public administration to reduce the environmental impacts associated with water and energy, such as decreasing water and energy consumption, responsible consumption of paper and refuse separation. These actions were implemented in 30 buildings with reductions of CO₂ emissions. So far the savings are 165 thousand m³ of water and 2,237 megawatts of energy (SMA 2006).

### REFERENCES


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