“A Demand-side Management Approach for Mexico City”

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Abstract

The City of Mexico, one of the largest and most crowded megalopolis in the World, is struggling to provide enough water to an ever-increasing population. Although cuts have been common for a number of years, the crisis has lately extended, affecting well over 5 million inhabitants.
The problem is only expected to get worse, compounded by the following factors:

a) Main supply relies on over-exploited aquifers and distant external sources.
a) Since the ancient city was constructed on top of a lake, parts of the metropolis are gradually sinking. In consequence, wastewater discharges have to be pumped out.
b) About 40% of all the incoming liquid is lost in leaks, due to old piping system and seismic activity.

In light of this complex crisis, the Authorities have failed to find an adequate solution, since the approach has traditionally been to find new external sources, i.e. a supply-side strategy. The paper analyzes a different approach, focused on demand-side management, and discusses alternatives from a quantitative and qualitative point of view, using the retrofitting of sanitary facilities as an example. Successful experiences in other cities are presented, along with a discussion of the main obstacles to overcome. It is concluded that the potential for such strategies are considerable in Mexico City, but adequate financial stimulus for conservation are urgently needed, along with a change of perspective on behalf of Government Authorities, to focus on demand reduction rather than on costly, and in most cases impractical, augmentation of supply.

“As long as the last leak has not been repaired, every sanitary facility upgraded as far as technology permits, rainwater collected from every roof, and 100% of all wastewaters recycled, there is not the ethical nor moral right to go to other regions in demand for water”
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Domestic water demand management: implications for Mexico City

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(1) Main supply relies on overexploited aquifers and distant external sources.
(2) As the ancient city was constructed on top of a lake, parts of the metropolis are gradually sinking. In consequence, wastewater discharges have to be pumped out.
(3) About 40% of all the incoming liquid is lost in leaks, due to an old piping system and seismic activity.

In light of this complex crisis, the authorities have failed to find an adequate solution, since the aim has traditionally been to find new external sources, that is, a supply-side strategy. This article analyses a different approach, focused on demand-side management, and discusses alternatives from a quantitative and qualitative point of view, using the retrofitting of sanitary facilities as an example. Successful experiences in other cities are presented, along with a discussion of the main obstacles to overcome. It is concluded that the potential for such strategies are considerable in Mexico City, but adequate financial stimulus for conservation are urgently needed, along with a change of perspective on behalf of government authorities, to focus on demand reduction rather than on costly, and in most cases impractical, augmentation of supply.

Keywords: water; demand management; Mexico City; urban development; sustainability

1. Introduction

Availability and equitable access to quality freshwater supplies is rapidly becoming a major problem worldwide, climbing to the top of the agenda for many a politician or urban planner. The continuity of large cities in both developing and more developed countries alike is undoubtedly linked to guaranteeing an adequate supply of this most vital resource to its inhabitants. History proves that water scarcity alone or poor water management can be the cause of the demise of great urban centres, if not entire civilizations (Diamond 1999; De Villiers 2000). Mexico City, one of the largest and most overpopulated megalopolises in the world, is a paradoxical example, worth regarding as a beacon call of troubles to come for other growing cities, should a 'business as usual' type of resource management continue its course unchallenged.

This article focuses on evaluating the magnitude of the problem, comparing current supply-side management approaches to what a true demand-based approach would look like. Although agriculture is by far the largest water consumer in Mexico

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as a country, with well over 70% of total abstractions (CONAGUA 2010), this is not the case in the densely populated urban centres, where domestic use takes the lead. Although proposed solutions to reduce the impact of agriculture and industry from a demand point of view abound, the emphasis of this article is on domestic consumption, which requires the participation of individual citizens as a collective, and is thus more challenging to local planners and policymakers.

2. Current assessment of the water situation in Mexico City

Built on top of five ancient lakes, with an average annual precipitation exceeding 750 mm, this megalopolis of over 20 million inhabitants struggles with an excess of water in the rainy season, causing floods and related disasters, while *at the same time* suffering from a severe and highly inequitable water scarcity (Perlo *et al*. 2005). 2010 was a classic example of the paradox: in February, unexpected heavy rains collapsed the walls of a major channel known as *Canal de la Compañía*, that normally carries wastewater effluents and precipitation overflows out of the highland Valley of Mexico (Fernandez 2010). The disaster displaced thousands of inhabitants, costing the government millions of dollars to repair. Fears of epidemic outbreaks were rampant, with entire neighbourhoods flooded with stagnant, mosquito-breeding, wastewater. On the other hand, the period between 2009 and 2010 was one of the worst and most worrisome for local authorities in terms of water scarcity. In one month alone over 5 million people were left without water, a situation that repeated itself and still continues to be a problem in many areas of the city (Romero 2010).

2.1 Historical background

It is unclear today exactly when the ancient city of Tenochtitlan was erected, or why the original inhabitants decided to build a settlement on top of the highland lake of Texcoco. According to researchers like Angel Palerm (1973), who devoted many years to studying agricultural practices in pre-Hispanic Mexico, the tradition of growing food on floating baskets over the waters of the lake, a technique known as *Chinampas*, was well established even before the Aztecs came to the region. This practice was followed by filling in small portions of the lakes with dirt and mud, to create an artificial island of sorts, where the constant humidity and abundance of nutrients provided an ideal medium for a variety of crops.

It could have been that watching this conversion of water to land for agriculture inspired the Aztecs when they started building their city in the Valley of Mexico (c. 1325 according to accounts), or it could well have been a defence strategy, akin to the canals in Venice, as was testified by the small band of *conquistadores* that first reached the capital of the then flourishing empire in 1519. The men led by Hernan Cortes were ‘shocked and awed’ at the sight of a beautiful yet at the same time terrifying city surrounded by water (Legorreta 2006).

After the invasion and subsequent conquest took place, the Spaniards gradually installed a European-style city, with plazas and churches, replacing canals for paved roads wherever possible. This went hand in hand with an altogether different approach to water. Whereas the Aztecs were surrounded by it, and seemed to feel quite comfortable dwelling in the middle of a lagoon, the Spaniards saw it as a nuisance, an attitude aggravated by a sequence of catastrophic floods. Thus, in 1607 the first hydraulic works were inaugurated by Enrico Martinez, a Spanish engineer assigned to the task of draining the closed lake system. A large tunnel was dug in an area known as *Nochistongo*, sending the effluents downhill towards the lowlands and eventually to the sea (Legorreta 2006). After a few pioneering unsuccessful attempts, better channels were established, thus draining a continuous flow and gradually drying out the ancient interconnected system of lakes. This process continues to this day, in a more modern version.

2.2 Conventional management approach

The great lake of Texcoco, the ‘inland ocean’ as Cortes called it, where waves were so mighty that even before the Spanish arrival, the Aztecs had built a large protective barrier in 1449, has now been reduced to nothing more than an enhanced pond, basically a polluted wetland. The other lakes and natural water channels of the interconnected system, once navigable, have likewise been depleted (Ezcurra 1990). Highways and famous streets of the modern city bear the names of old waterways, as a grim remembrance of an aquatic ecosystem that has been irreparably lost.

A greater problem, however, loomed up in the centuries after the 'drainage' of the basin was started. Much greater than living in an endorheic, flood-prone, basin was the spectre of population growth. Expansion of Latin American cities, like in most of the world, reached its peak in the second half of the twentieth century (INEGI 2010). By the 1950s, Mexico City supplied potable water to a burgeoning population of 2 million entirely from underground sources. It was in that decade that the government was forced to do the first hydraulic project to bring in water from external sources to the capital (Legorreta 1997), partly due to overexploitation of the local aquifers, yet in great measure due to the gradual sinking of several urban areas, a process that had in fact begun at the turn of the century. This had already been linked to excessive water extraction, and related to the type of soil that a drained lakebed will leave behind (Ezcurra 1990).

Throughout the 1960s this first project was deemed insufficient, and a new, more ambitious scheme was put in place, known as the Lerma-Cutzmala project, a series of interconnected lakes, reservoirs, canals and pumping stations to bring water to the city. Inaugurated in 1982, it still provides 28% of the current total supply (Legorreta 2006). Although it provided a certain degree of relief after its inauguration, it was only temporary. Population has kept on growing and municipal authorities admit to a deficit in supply of over 5 m^3/second. This results in over 1 million residents not having any access to tapped, potable water in their homes, and another 7–8 million with irregular access (Martinez 2004). The term 'irregular' has been expanded to include cut-outs in service of over 30 days in some neighbourhoods!

In summary, with local aquifers and deep wells already overexploited and the supply from external sources not being enough, the situation looks complicated for the local authorities and water commissions, who are debating now on what to do. Multimillion dollar investments have been placed on the table, similar in dimension and scope to the 1980s Cutzamala project, but have largely failed to materialize. A series of protests along the basin of the Temascaltepec River (Legorreta 2006) in the western part of the country, conducted mainly by local farmers against a proposal to divert part of the river into the Cutzamala system, led to an eventual cancellation of the project, bearing witness to the fact that social unrest can also be a leading cause for discouraging massive hydraulic works. In a developing country with an expanding population, such as Mexico, it becomes increasingly difficult for a particular city or province to try and solve its lack of vital resources at the expense of neighbouring regions, especially when those same resources are badly needed elsewhere.

3. Alternative approaches to water management

Traditionally, urban planners, hydraulic engineers and the like have strived to supply their target populations with water using a classic supply–demand economic model. Users are perceived to have a need, which varies according to a large number of parameters, such as population size, consumption patterns, habits, socio-economic group and so on (Mitchell *et al.* 2004; Butler and Memon 2006). Projections into future population growth and expansion are usually considered. Governments or private companies, whatever the case may be, will then seek out sources that are most readily available first, in terms of cost–benefit, and then continue with external sources when this is deemed insufficient, as in the scenario described above.

Until recently, little attention has been paid to analysing the needs themselves (demand-side approach) or ways to mitigate them, which in itself requires a major paradigm shift (Wolfe 2009a). Politically, this can be perceived as inconvenient because it implies tampering with people's habits or way of life. However, increases in costs, population expansion and a growing lack of adequate freshwater supplies have created a need to focus on reducing demand (Gleick 2001; Green 2003).

3.1 Challenges to demand-management strategies

Despite the fact that 'economic and financial gain has been reported as considerable', when it comes to demand-reduction projects such as the extensive implementation of water-saving appliances (Butler and Memon 2006), a tenacious resistance persists among municipal governments and authorities to seriously tackle the issue of water supply from a demand-based approach. Even in cases where such a strategy would clearly be cheaper, more efficient and environmentally benign, while at the same time providing (or 'freeing up' in this case) the same amount of water than a large-scale project, such as the building of a dam or reservoir, there is still a tendency to favour the latter, particularly in developing countries. In light of the recent economic crisis and the fact that 'new' water sources are becoming ever more difficult to find, an honest exploration into this reluctance to change becomes all the more pressing. Researchers such as Corral-Verdugo *et al*. (2003) and Wolfe (2009a) have set out to study the sociological implications and public perceptions of water demand-management strategies. In general terms, perceived water scarcity or a 'crisis' will trigger the success of these policies, but there are other key factors involved, such as existing knowledge of available options and the institutional framework of water authorities (Toteng 2008; Wolfe 2009b).

Besides the political aspects mentioned above – trying to change habits and established tendencies amongst civilians is not usually a popular measure – there is also a perception that any technology or initiative that places the management and provision of a resource in the hands of the user implies a loss of control to the authority in charge of supplying it. After all, water has been used as a tool for political and military power ever since the early days of human civilization (Gleick 2001). Thus, in this context a greater 'empowerment' for the community could be perceived as a diminishing of power to the centralized supplying entity.

The *status quo* in most cases nowadays implies that water, electricity or any of a number of vital resources are supplied by 'someone else' (i.e. an external source), usually a large powerful structure, in exchange for a payment or government subsidy. Thus this causes a 'detachment' between the users and the provision of the supply. This detachment in turn provokes a lack of concern when it comes to maintenance and quality issues, in a sense, the essence of a centralized economy (Rifkin 2003).

The loss of control that comes from any measure that encourages users to participate in this manner also stirs fears of a potential loss of quality control. Officers from water authorities may not be keen on promoting individual rainwater harvesting for drinking water provision, for example, due to the daunting challenge that would be posed by having to control quality in millions of households. However, in a city like Mexico (or so many others in developing countries), where there is simply not enough water to supply everyone at current levels of demand, or the water supplied by the mains tends to be of a poor quality in general (most people in the city refuse to drink water straight from the tap), even harvested rainwater with a dubious quality tends to be more acceptable.

3.2 Successful experiences

The concept of tackling demand, generally seen as innovative and alternative compared with the traditional vision of engineering schools and policy-planners, has been successfully tried in a few countries on a large scale. This is quite apparent in the energy sector. One such example is South Korea, where an intensive nationwide campaign by the government in the past decades to reduce electric consumption has saved the government a considerable expense in infrastructure (Cunningham and Saigo 1999). The state of California has also made hefty investments in efficiency and resource conservation, amounting to important long-term savings (Vine *et al*. 2006). According to studies made at energy utilities in California and Washington, DC, conservation investments were estimated at USD $350/KW, compared with $1000 USD/KW for a new coal plant or from $3000–$8000 USD/KW for a nuclear power plant (Cunningham and Saigo 1999). This only includes capital costs, and not maintenance and operation. The concept of 'Nega-watts' in electric jargon illustrates the point nicely, referring to all those watts that do not have to be generated (thus saving the planet from the associated emissions and impact) thanks to efficiency or conservation measures. The term 'Nega-litres' is also currently used in Mexico, as a corresponding analogy to water, thanks to the entrepreneurial work of architect Cesar Añorve, a local expert in sustainability and ecological sanitation (Blanco 2007).

The principle of demand-side management can apply even in health care and water quality aspects. A recent study, covering several developing countries in Africa and Southeast Asia, showed that it may be more cost-effective to implement several individual household-based water disinfection systems, compared to a centralized source treatment. Techniques that can be replicated with ease in thousands of households, such as chlorination and solar disinfection, proved to be not only less costly in the long run but also more effective as a means of controlling diseases caused by poor water quality (Clasen *et al*. 2007).

The equivalent of this for water conservation would be to tackle the problem at a user level, for instance by replacing micro-components such as toilets, taps and urinals by more efficient versions (Butler and Memon 2006), or by implementing rainwater harvesting and localized grey-water reuse. A good example of such an intervention on a large scale is Mexico City itself, with the toilet replacement programme described below.

3.2.1 The case of Mexico

In 1989 the municipal government of Mexico City decided to implement a water efficiency programme whereby old toilets, using an average of 16 L/flush, would be replaced by newer more efficient models (6 L/flush), considered to be the *best available technology* at the time (Beekman 1998). By 1991, 350,000 units had been replaced achieving an estimated savings of 28 million m^3/year, enough to satisfy the annual domestic needs of 250,000 residents. This, followed by a significant increase in water tariffs a year later has had a significant impact on alleviating water scarcity (Hinrichsen *et al*. 1998).

In 2009, faced with what was possibly the worst water crisis in history, government authorities announced a plan,[1] officially launched in August of that year, with the aim of replacing '4.7 million showers and 1.7 million toilets' for low flow, efficient versions, over a period of at least 3 years. The project, supported by incentives, would save approximately 7000 L/second of water compared with current consumption rates.

Related initiatives include the certification of low-flow showerheads (less than 3.8 L/min) and toilets with flush volumes of 5 L or less, as well as the launching of a 'green seal' in 2009 that certifies manufacturers of these water-saving products, giving them greater recognition and market access (CONAGUA 2010). Some local government districts, known in Mexico City as *delegaciones*, have launched independent water conservation programmes in coordination with the National Water Commission (CONAGUA). Miguel Hidalgo, for instance, an influential borough located at the heart of a commercial district near the city centre, has been providing free water-saving showerheads to its residents since 2009, in exchange for their old ones, which are then duly dismantled and recycled. At the initial phase, the target is to replace 3000 showers, conserving an estimate 4.5 million litres of water per year by these substitutions alone. The programme is scheduled to continue throughout 2011 (Miguel Hidalgo 2010).

In the meantime, local water authorities have been forced to implement cuts, affecting over 5 million inhabitants of the city, to preserve the external supply of the city, already reduced to 40% of its capacity. Although the rainy season that year allowed most of the catchment basins to partly recover, severe supply cuts are foreseen in the near future, if drastic conservation measures are not implemented (Ecoportal 2009).

4. Analysis of a sustainable strategy for Mexico City

Outlined below are certain areas where, based on past experiences, an important potential for savings can be considered. Although agriculture and industry are also major water consumers in Mexico, the focus here is on domestic and commercial demand. Replacement of urinals and toilets in this regard is seen as paramount because they account for a large portion of urban water consumption (Grant 2006).

4.1 Metering

Analysis of demand with regards to water is extremely complex and dependent upon a number of factors, not least among them geographical location, cultural practices or habits, age and profile of users, available technology and income. From an economics point of view, water has been commonly regarded as a low-unit-cost bulk product (Green 2003), thus investment in individual measurement or metering tends to be low, compared with other products, where unit cost is perceived as high. This naturally changes in a situation of scarcity, because it is also deemed a vital or essential commodity.

Overall, the very fact of metering has been shown to have a favourable impact on reducing consumption (Roaf 2006), even though most mechanical meters are not completely reliable or accurate (Butler and Memon 2006). In Latin America, metering coverage was esteemed to be slightly over 60% by the World Health Organization (2000). This has been consistently increasing, especially in Mexico where older meters are gradually being replaced by automated, digital ones.

It must be noted, however, that metering in and of itself does not necessarily induce citizens to retrofit or use the best available technology, as water savings *per se* are usually not enough to justify the investment. This has been better achieved by implementing adequate building codes and equipment standards (Green 2003), or by incentive programmes, as we shall discuss below.

4.2 Replacement of sanitary facilities

Of all the micro-components in a modern, average household (washing machine, kitchen sink, shower, etc.), the toilet is the single largest water guzzler. In the United Kingdom, studies done by Anglian Water estimate a consumption rate of 31%, followed by the washing machine, with 20% (Butler and Memon 2006). Similar studies in the United States also place the toilet at the top of the list with a 27.6% average (American Water Works Association 1999). In Mexican households it can represent up to 40% of total consumption (Reyes *et al*. 2002). Even higher percentages can be placed on toilets and urinals for offices and businesses, where other consumptive uses such as showering or washing are generally minimal. Thus, it would seem that any serious programme to reduce demand would have to tackle this most personal issue of sanitation.

The frequency of toilet flushing depends on a variety of parameters, including age group (older people tend to urinate more often and spend more time at home), and cultural habits (Butler and Memon 2006). For instance, the United States overall seems to have more flushes per day, than the United Kingdom, although why this occurs remains unclear. A comparison between low-income and high-income homes in Karachi, Pakistan, reveals that even though total consumption is strikingly different (55 L/day vs. 250 L/day in the latter case), the amount of water actually used for WC flushing remains quite similar (Green 2003).

Notwithstanding, calls for 'voluntary constraint' in times of drought in the state of California have temporarily brought demand down by 25% (Green 2003). The slogan 'it's yellow, let it mellow' is well remembered among older Californians. In a similar light, a recent campaign in Brazil, promoted by an NGO and endorsed by ex-President Lula, calls for people to urinate in the shower to save water used for flushing. Widely disseminated

TV advertisements and videos claim that by just flushing one time less per day, a single household could save over 4100 L of water per year (Morgan 2010). In conclusion, these frequency patterns of usage are highly susceptible to changes in public perception and education campaigns.

Thanks to the replacement programme launched in 1989 (described above), and succeeding regulations for new buildings that require modern, efficient appliances to be installed, most toilets in Mexico City today have a 6 L tank. Previous models of 10 L or more are obsolete and rarely seen. Urinals consume a standard of 1 gallon/flush (3.7 L), based on North American models. However, it has been observed that a number of units with user-operated manual flush valves tend to be left open or not closed properly, allowing for leaks and higher consumption. In addition, those that have automatic sensors tend to flush more times than what is required, sometimes two or three times in a single use (Grant 2006).

4.3 A demand-side approach scenario

Since the invention of the first 'water closet' with its continuous flushing, at a time when water was perceived to be unlimited, there have been substantial improvements in these contraptions. Already the conventional, widely used, 6 L tank is becoming obsolete and no longer the state of the art. Dual-flush models, for instance, use an average of 4 L for liquids and 6 L for solids, although these volumes could be slightly higher in practice (Grant 2006). Other low-flush models abound, and more are rapidly coming onto the market. Countries such as Singapore and Australia, for instance, have maximum limits of 4.5 and 4 L/flush, respectively, whereas the Netherlands has dual-flush requirements in most of its new constructions (Baynes 2002; Green 2003).

The techniques for dry or waterless sanitation (also known as ecological sanitation or composting toilets) have also evolved considerably (Sawyer *et al*. 2000), although public acceptance in urban centres is still low (Grant 2006). Successful experiences have been recorded, however, in rural areas, slums or poor suburban areas of cities not normally having tapped water service. Although there are issues related to maintenance, they can be gradually resolved by technological innovation. These systems can thus be seen as a promising alternative for the future.

Urinals have also seen considerable improvements in terms of efficiency, with waterless models now widely available in Mexico and elsewhere. Some manufacturers claim savings as high as 250,000 L/year, although more adequate scientific research is needed, particularly due to the high variabilities discussed above. Initial designs required the use of chemicals to avoid odours, this has been overcome by newer inventions that do not require any such inputs, and can in fact be used with very small amounts of water if desired (Koeller 2005).

An extensive analysis by Butler and Memon (2006) concludes that installing low-flush toilets in place of high-flush units provides scope for significant water savings. A feasibility study done for a Mexican university of 15,000 students by Adler (2005) estimated savings of approximately 31 million L/year by the replacement of all urinals and all existing toilets to dual-flush. This is enough water to supply the needs of 160 average Mexican families for an entire year. A pilot study endorsed by the state of Oregon (SWEEP 2001) monitored the replacement of 100 toilets in selected households for efficient dual-flush models, revealing a striking reduction of 67% in average water use compared with the baseline scenario. The study also covered other water- and energy-efficient appliances (washing machines, showers, etc.) with similarly encouraging results.

Given this context, the legal requirement for a 6 L tank in Mexico City can be deemed as insufficient, with the spectre of a potential crisis affecting many millions of inhabitants in densely populated areas looming in the horizon. Official pamphlets distributed freely motivate people to replace their toilets, and to do simple things like turning off faucets or reporting leaks, but there is little mention of more advanced approaches such as waterless urinals or dual-flush toilets.

5. Financial aspects and feasibility

Despite whatever technical or political drawbacks there may be, demand-side approaches for water savings have been overall highly successful in financial terms, as well as achieving objectives with less social impact or environmental disruption (as in the case of building large dams, reservoirs, etc.). In the United States, retrofitting programmes in the past decade achieved demand reductions of up to 23% in some cases (Green 2003), although caution must be taken in studies older than a few years, given the rapid advance of new technologies.

An ambitious retrofitting programme in Phoenix, Arizona, cost $15 million USD to implement (Dziegielewski and Baumann 1992) and yielded $88 million. Similar experiences in New York, Texas, Florida and California report highly favourable benefit–cost ratios. During the 1990s, 2.3 million low-flow toilets were given out in selected cities of these states through rebate programmes or entirely for free, with total water savings exceeding 400 million L/day, which amounts to 140 billion L/year (USGAO 2000).

Another advantage of demand-based programmes is that they allow water authorities to inspect the final user or end-points of the system more closely (where water is actually consumed), something which is rarely done in traditional, large-scale, water-supply projects. A number of studies identified leakage from toilet valves as a major source of waste (Borisova *et al*. 2009). In the case of Tampa and San Francisco, in fact, the fixing of these leaks accounted for more savings than the retrofits themselves. In Mexico, leaks along the entire water-supply system are estimated at 40% (Gleick 2001; Legorreta 2006), amounting to approximately 25,000 L/second, including the many losses incurred in millions of valves and leaky taps across the city.

5.1 Pricing

An adequate price structure along with proper metering can also go a long way to increase water savings (Gleick 2001). A tripling of water prices in Bogor, Indonesia, brought about a 30% reduction in domestic consumption. Although this may seem drastic, and inapplicable to many socially sensitive regions such as Mexico, it allowed the local water authority to connect more households to the existing system, and to avoid altogether the construction of a new supply system, with all its associated social and environmental impacts (Postel 1997; Hinrichsen *et al.* 1998).

The idea of payment for environmental services has been getting increasing attention from policymakers, as a means of linking higher tariffs directly to the conservation of areas from where water supplies are obtained, such as watersheds and upstream rivers. In Costa Rica, for example, the concept of 'environmentally adjusted water tariffs' is used to finance conservation while at the same time providing an incentive for demand reduction (Pagiola *et al*. 2005). Other countries, such as Colombia and Ecuador, are implementing similar schemes at a regional level. The success of these plans relies on informing, and at times involving, users on the destiny of the extra fees paid to water companies or authorities. A study in Zaragoza shows, furthermore, that consumers will respond better to hikes in water prices (in terms of reducing demand), if there is a clear correlation between the rates and the actual amount consumed (Arbues and Villanua 2006).

It is, however, difficult to impose high tariffs where an important portion of the population lives in marginalized conditions. The publicly owned Water Utilities Corporation of Botswana, for instance, was forced to increase prices during severe droughts. As a consequence, poor urban residents, in a country that boasted 100% piped potable water coverage in most towns, are now struggling to afford an adequate supply (Toteng 2008). As a way of compromise, Mexico City has implemented a tiered tariff, where low consumers will keep on getting a heavy subsidy from the government whereas high-end users (such as businesses, large homes with gardens, hotels, etc.), will pay the full fee. Prices range from roughly $0.20 USD/m^3 in the lower tier, to $3.00/m^3 in the high end of the spectrum (SACM 2010). Industry, agriculture and other key economic enterprises are subject to special tariffs, similar to what happens in the electric supply service, depending on the type of activity.

These fees, regardless, do not reflect the reality of what most people pay, because during water scarcity periods, which abound in the city, individual consumers and small businesses are forced to buy water from trucks (called *pipas* in Spanish), which can reach, at times of peak demand, the outrageous figure of \$8.50 USD/m^3, that is, almost triple the highest tiered, unsubsidized, tariff (Planeta Azul 2009b).

5.2 *Incentives*

Other than giving away or installing retrofits for free, which is not always practical given the high upfront costs, well-structured incentive programmes can work towards making the necessary changes. The solar and renewable energy industry has greatly benefited in many countries of the world from varying schemes of tax breaks and rebates (SEI 2007). New technologies can be difficult to gain acceptance on a massive scale, especially when involving households with myriads of individual decisions to be made.

It took a legal battle of several years, waged by a company with top investment behind it, for Plumbers' Unions in the United States to accept the inclusion of waterless urinals in the International Plumbing Code and the Uniform Plumbing Code, two important standards for hydraulic installations in the country. The arguments ranged from the possibility of foul smells, to blocked sewers and exposure to health risks (Davis 2010). None of these arguments were ever scientifically validated, with the result that waterless urinals, in their many forms and versions, are gaining wider acceptance in the United States and all over the world, Mexico included.

The city of Toronto, for instance, has put in place an effective incentive programme stimulating residents to change their toilets for more efficient ones (ICLEI 2004). Depending on the model, whether high efficiency or dual-flush, there is a rebate offered. The city also provides a catalogue of brands that have been approved and tested. The procedure for reclaiming the rebate, as well as helpful information for choosing a model and installation, is quite clear for users on the website (www.toronto.ca/watereff/flush/index.htm). Similar schemes can be adapted to the replacement of urinals for waterless or low-flush versions.

Clarity and accessibility to information is key to the success of such programmes. As mentioned previously, Mexico City officials have made very concise promises to replace fixtures for more efficient models, but it remains completely unclear to the average user how this is going to take place, or what specific benefits or incentives are offered.

5.3 *Predicting demand*

Evidently, any strategy to achieve a long-term reduction in consumption requires predictions of future demand. This is an extremely complex subject, involving a large number of variables, particularly in rapidly growing and expanding megacities such as Mexico (Mitchell 1999). It is important to note that any savings obtained by lowering demand are not only related to a reduction in supply costs. Dealing with the wastewater generated can at times be more costly than the actual supply network. In the United Kingdom, for instance, the infrastructure of the sewage network has a considerably higher asset value than that of the supply network (Green 2003). The same can be said for operation and maintenance costs. In Mexico City this is even more pronounced because all wastewater (about 30,000 L/second without taking rain into account) must actually be *pumped* out of the city, with a very high energy and electricity cost (Breceda 2003), due to the fact that the valley is sinking. Where water used to flow out by gravity at the turn of the twentieth century, it now has to be lifted several metres, otherwise risking stagnation and floods (Ezcurra 1990).

6. Conclusion

The recently completed census of 2010 yielded a population count for what is known as the 'Metropolitan Zone of the Valley of Mexico', well above the 22 million accounted for in 2005 (INEGI 2010). It is projected that by 2040, with current estimates for growth, several surrounding cities could be absorbed as has occurred in the past to form a megalopolis of over 40 million inhabitants (Legorreta 2006).

The City of Mexico as a whole consumes today 72,000 L/second of water, but this is still insufficient. Government authorities estimate that a volume of at least 5 m^3/second is required to alleviate current scarcity. With increasing population, this will need to be much more in the near future. Where such a gigantic supply will come from remains a dilemma to the authorities involved.

In light of this situation, technical advisors for the National Water Commission have recently suggested reattempting the expansion of the external supply system, by bringing water from the Temascaltepec River in the western part of the country (the project was abandoned during the 1990s due to firm local opposition). The cost of the project in the beginning, 20 years ago, was over $300 million USD, and would have brought approximately 5000 L/second to the city. Another major project that has been indefinitely suspended is the tapping of water from the Tecolutla basin, to the east of the city. Attempts to bring water from the south and other areas have also been cancelled (Legorreta 2006).

With opposition likely to rise, rather than recede (population and demand for resources tends to increase in these other areas of well!), the city is stuck in a quagmire. If a project was faced by fierce and unwavering resistance 20 years ago, there is no indication that it will be easier today, quite the opposite, not to mention the costs, which would be considerably higher as well. As Manuel Perlo, head of the University Programme for City Studies (PUEC) brilliantly framed it: 'If we compare the costs of storing 1,000 litres of rainwater, recovering 1,000 litres from leaks, and bringing 1,000 litres from Temascaltepec, the latter will by far be the most expensive option'.[2]

There seems to be little option left, then, but to look within. It was already done in 1989, with the toilet replacement programme, so cherished by Mexico City dwellers as one of those rare successes in contemporary water management. Further opportunities for water savings are now available, with the new technological advances of waterless urinals, widely tested and accepted in many buildings already, modern low-flush or dual-flush toilets, and a host of other innovative water-saving devices.

Although the census bureau (INEGI) counts the number of houses 'connected to drainage' or 'with tapped water', there is not to date an official census of sanitary facilities per household, nor at a citywide level, even though they could be inferred by statistical methods, made all the more complex by widely varying socio-economic conditions. Investment in research and detailed calculations of this sort are of paramount importance, in order to make a precise assessment of the true impact of demand-side approaches.

Even assuming conservative estimates, the potential gain of replacing sanitary facilities and other demand-management approaches is enormous. If this is complemented by measures such as rainwater harvesting and wastewater reuse, which is currently under 10% of the total effluent (Martinez *et al*. 2004), considerable progress can be made. It is important to note that every litre of water not used from the main supply is a litre that becomes available to people that may more desperately need it. In a city where some people barely live on 14 L/day whereas others consume over 800 L/day (Legorreta 2006), the issue becomes not only one of humanitarianism or satisfaction of basic needs but also one of mitigating potential social conflict.

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Notes

1. The reference to a 'historic crisis', as well as an announcement of the water savings plan, was made by Ramon Ardavin, Sub-Director of the

National Water Commission (Conagua), to the media (Ecoportal 2009; Planeta Azul 2009a)
2. Newspaper interview: Reforma, 16/4/2009, published in http://www.cicm.org.mx/noticias.php?id_noticia=3588, consulted on 8/8/10. Translation by author.

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