

Water, Wastewater, and Environmental Security Problems: A Case Study of Mexico City and the Mezquital Valley

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ABSTRACT

Increasing social tensions and conflicts can now be observed due to growing water scarcities and higher wastewater discharges in many parts of the world. These conflicts can be analyzed in two ways. First, a social conflict can be responsible for creating water scarcity by reducing accessibility, destroying water systems, and reducing water availability. Second, water resources scarcity, both in terms of quantity and quality, can often be the cause of conflicts in a society. The article focuses on the second type of conflict by analyzing several examples from Mexico: especially conflicts that have been generated by the use of the wastewaters of Mexico City for irrigation in the Mezquital Valley since 1912.

INTRODUCTION

The complex relationships between the environment and the potential conflicts it can cause can be approached in two ways. Traditional analysis views the environmental destructions as direct causes that could generate conflicts. Some authors, especially during the post-1970 period, have explored this possibility. However, during recent years, several investigators have been analyzing the reverse process, i.e., the environmental destructions could be the results of conflicts.

Since water is a major constituent of the natural environment, the interrelations between water scarcity and social conflicts can be analyzed in at least two dimensions. Firstly, a social conflict could be a response to water scarcity, real or perceived, by the very fact that the security of a reliable water availability can no longer be assured for a growing population. This could contribute to a large-scale migration from a water-deficient to a water-surplus area.

The present article focuses on the second dimension of the environment and the security issue, i.e., the scarcity of water resources (both in terms of quality and quantity) could contribute to conflicts in a society. The focus will be on Mexico. There are several examples of such conflicts, only one of which would be discussed herein: irrigation

in the Mezquital Valley using the wastewaters from Mexico City.

Wastewater irrigation has generated a conflict between the farmers who cultivate the croplands and the inhabitants of the towns of the area, whose health could be affected by the resulting contamination. An additional contributory cause, which has accelerated the conflict, is the fact that the population of this region has increased significantly in recent years due to economic growth and urban migration, and thus people had to move much closer to the irrigated areas and the dams that store the wastewaters of Mexico City.

DESCRIPTION OF STUDY AREAS AND PROBLEMS

The study area includes two specific zones, each having certain specific characteristics. The first is the metropolitan zone of Mexico City (MZMC), an area where large quantities of wastewater are generated. The second is the agricultural zone of the Mezquital Valley (MV), which is the largest area in the world irrigated with wastewater.

Conceptually, big cities can be compared to a living organism, since to live and function they require certain "nutrients" such as water, raw materials, food, and energy. After these resources are used, processed, and assimilated,

waste products are generated. The whole process could be considered to be "urban metabolism," and includes supply, production, and consumption of inputs, as well as outputs in terms of solid, liquid, and gaseous wastes, and the effects of the disposal practices on the environment. For example, water supplied to the city, after use, ends up in the sewer.

Within this overall context, the problems of water, which is one of the main resources to satisfy the basic needs of a metropolis such as the MZMC, and their impacts on the environment, will be examined here. Important aspects to note are both the pollution caused and increasing water scarcity. It is estimated that water pollution has increased by some 150 per cent during the past ten years [1].

Urban Zone

The Distrito Federal (Federal District, DF) area of Mexico City is located at the southwest of the Mexico Valley Basin, at the southern end of the Mesa Central (Central Plateau). This basin has an area of 9,600 km². At the beginning of the present century, this area had approximately 350,000 inhabitants: 50 years later, it has increased some 8.5-fold, reaching some three million people. This exponential growth has expanded the urban zone of the DF and its neighboring areas, creating a very big urban conurbation called MZMC. Currently this zone has almost 20 million people. How to sustainably satisfy the increasing needs for infrastructures and various services to support such a large urban agglomeration is one of the biggest challenges facing the country at present.

With respect to the territorial expansion of this conurbation, the MZMC has expanded considerably and now exceeds the limits of the DF. In 1950, the urban area of the metropolitan zone reached 257 km². By 1994, this extension was integrated by 16 delegations of the DF, in addition to 27 municipalities of the neighboring State of Mexico, for a total of 1,273 km². This is almost a 5-fold increase in some 44 years.

The DF is located within the MZMC, and the problem is further complicated by its average altitude of 2,240 m above mean sea level (msl). Its highest point is the hill of the Ajusco, which is 3,950 m above msl.

Among the natural constraints to the urban growth of the MZMC are its irregular topography, soils having high agricultural productivity, aquifer recharge, ecologically sensitive areas that should not be urbanized, presence of national parks, zones prone to disasters, and an insufficient water availability to satisfy continually increasing requirements.

Agricultural Zones

Here, the focus is on a zone that is an irrigation district (DR063) located in the MV, at the southern part of the State of Hidalgo, which is irrigated with the wastewaters from the MZMC. The valley is located some 100 km to

the north of Mexico City, and includes interconnected valleys, drained naturally by the Tula River and its tributaries, which are part of the Pánuco River system.

Natural vegetation can currently be observed only on the mountains, since most of the lower lands are covered by the irrigated crops. Only two crops, alfalfa and maize, cover between 60-80 per cent of the whole area. The production of vegetables that could be eaten raw is prohibited by law [2] because of potential health problems. However, the law is seldom enforced [3].

CURRENT STATE OF WATER RESOURCES

Potable Water, Sewage, and Sanitation

In Mexico, as in other Latin American countries, the intense and unbalanced urban growths have become major concerns during recent decades. According to the available analyses and official diagnosis, MZMC can be considered to have already dangerously exceeded the optimum size that can be efficiently managed.

One of the most important constraints facing MZMC is the limited water availability of the Mexico Valley

Intense and unbalance urban growths have become major concerns

Basin. Indeed, the metropolitan zone, located in a practically closed basin surrounded by hills, with topographic difficulties for economically importing water to a height of more than 2,000 m above msl, having a land surface that is becoming increasingly impermeable due to the use of asphalt and concrete, is facing a serious water problem. Continuing increase in population and steady expansion of economic activities are accelerating water requirements, thus further aggravating water scarcity. Until now, the main source has been ground water. However, steady aquifer overexploitation has already contributed to very serious land subsidence in many parts of the city. Unquestionably, expanding water demands of an increasing population, and the resulting acceleration of economic activities, have far exceeded the safe yield of the basin. The need for importing water from outside the basin is obvious, since the total extraction rate of ground water from the Mexico Valley is around 35 m³/s, compared to an estimated recharge rate of only 20-25 m³/s [4]. The new sources of water are at least 150 km away, and at 1,500 m below its level.

With respect to the DF, water demand has increased from five m³/s in 1930, to 30.3 m³/s in 1960, and 38.2 m³/s in 1986. Furthermore, the price for each additional m³ of water increases proportionally more than the pop-

ulation increase [1]. Although the water demand in the DF was 38.2 m³/s in 1986, based on a supply of 340 liters per inhabitant per day, the supply was 36.8 m³/s, which is equivalent to 312 liters per person per day. This means there was a deficit of 1.4 m³/s, which worsened during dry seasons [4].

Some 75 per cent of the water supplied to the city is extracted from 1,365 wells and 60 springs located to the southwest of the capital. Another 23.5 per cent and 5 per cent come from the Lerma and Cutzamala rivers, respectively. This requires 443 km of pipelines, which supply 202 storage tanks, with a joint capacity of 1.5 million m³ [1]. There are 102 plants to pump the water to the upper zones at the west and south of the DF. For its distribution, there are 560 km of primary pipeline network and 12,044 km of secondary network. Water quality is controlled by 244 chlorinating plants, four potabilization plants with a total capacity of 1.1 m³/s, and other processes [4].

Overall, the high rates of demographic growth and the continued intensification of socioeconomic activities, makes provision, operation, and maintenance of water supply and drainage networks, and associated facilities and activities a complex, difficult, and expensive task. In the western zone, urban growth has already exceeded the capacities of the storage tanks, thus making it necessary to use pumps to supply water to the towns, some of which are at an elevation of 2,550 m.

Several factors contribute to worsen the problem. First, high industrial concentration contributes to higher water demands. Second, the efficiency of the water supply system leaves much to be desired. It is estimated that leaks in the distribution systems contribute to a loss of around 40 per cent of the supplied volume for the MZMC. This does not include inefficient use in households. Third, the wealthier population in the MZMC consumes up to 40 times more than the volume used by the poorer sector, and only 9 per cent of the users utilize 75 per cent of the total water supply, while more than two million people do not have access to clean water in their households [1].

The water supply in the metropolitan zone is provided by a complex series of infrastructures, which are not easy to operate and maintain since different sections were constructed over various decades or even centuries, requiring very significant cumulative investment.

At present, only 1.6 m³/s of treated wastewater is generated, although industrial and commercial users jointly use 8.6 m³/s of potable water that is not essential to their operation and functions [4]. In addition to the problem of obtaining an adequate quantity of water, the drainage and disposal requirements of wastewater need to be solved. It has been necessary to construct extensive and expensive works, such as deep drainage. In the DF, the drainage system has a primary network of 1,217 km and a secondary network of 12,299 km. There are also 64 pumping plants and storm-water storage tanks, and 90 km of deep drainage.

At the western side of the city, there are some regulatory dams that control floods before they enter rivers used for

drainage. These floodwaters are intercepted and transported to the north of the city by pipes [4].

The central part of the urban zone has subsided due to soil characteristics and pumping of ground water. It is now necessary to pump a significant part of the sewage water to the Texcoco Lake and the Grand Canal, including runoffs that are not drained by gravity [4]. The Texcoco Lake also receives water pumped from the west from the Churubusco River, as well as the flows from the south and the rivers located to the west of Texcoco, which discharge to the De la Compañía River [4].

At present, the drainage service covers 76 per cent of the population. The balance of 24 per cent is mostly located around the city limits, where wastewaters are discharged into the rivers and the gorges. In the plains, they are discharged on lands or even streets, and consequently contaminate the aquifers [4].

A major problem in the MZMC is the health problems created by wastewater generated by the multiple users in the urban zone. Efforts have been made to clean the MZMC, which contains one of the largest urban populations in the world, but these have resulted in only limited success.

The treatment and reuse system consists of nine plants, having a total capacity of 4.8 m³/s, and 419 km of networks for the distribution of the treated effluent. Only 37 per cent of the installed capacity is utilized at present because of lack of storage. Treated effluent produced is 1.6 m³/s, which is used for irrigating parks and filling lakes [4]. It is impossible to analyze the problems associated with potable water, drainage, and sanitation individually in the MZMC, since they generate a set of interrelated, complex problems. The magnitude and the characteristics of the problems will be discussed next.

Within the MZMC, besides the desiccation of the lakes over the years, urban growth has meant that the lands and the hills that have historically served as aquifer recharge areas can no longer do so. Reduction in recharge areas and overexploitation of ground water have contributed to the steady lowering of groundwater tables.

The situation is further worsened by deforestation, expansion of areas under asphalt and concrete, and the subsequent reduction in the infiltration capacity; these factors have contributed to the intensification of the dust circulation phenomenon due to squalls and dry tornadoes, land subsidence, and other environmental damages. Thus, the MZMC not only requires large quantities of water but also produces equally high quantities of wastewater. Together, they have negative social impacts in the MZMC as well as the neighboring areas.

The insecurity that can be noted in Mexico City is not only because of lack of clean water, but also due to other related problems, such as land subsidence, which ruptures pipelines and thus further increases water losses, which in turn require more water. This by itself may not be a potential cause of conflict, but the transportation of water to and from the basin is, especially as the volumes are steadily increasing with time. There is also a historical

background of conflicts between the states concerned in terms of environmentally-safe disposal of wastewaters, i.e., between Mexico City and the States of Mexico and Hidalgo.

The total drainage generated within the MZMC area is 1,700 million m³/year, of which 1,350 million m³/year correspond to urban drainage and the balance, 350 million m³/year to rainfall. Of this total volume, 150 million m³/year is destined for urban reuse. In Texcoco, 100 million m³/year are accounted for by lake evaporation and grass irrigation. In Tula, Chiconautla, and Zumpango, 120 million m³ are used annually for direct irrigation. Two hundred and fifty million m³/year reach the Endhó reservoir, which is also used for irrigation. This volume represents the average annual figure, but during the rainy season, it increases substantially. There are 32 treatment plants, with a total capacity of 8.7 m³/s, and the average amount treated is 4.8 m³/s (150 million m³/year).

The mean annual volumes of raw wastewater and urban drainage that reach the MV are 55 m³/s and 16 m³/s, respectively. Urban drainage can reach a total of 90-200 m³/s after some extraordinarily heavy rainfalls [4]. Wastewater comprises 55-67 per cent domestic sewage, 11-17 per cent industrial wastewater, and 16-34 per cent discharges originating from commercial facilities and services [5].

A mixture of wastewater, urban drainage, and surface water is used to irrigate the MV, and is controlled by some dams, the most important of which are Taxhimay and Requena; these dams store significant volumes generated during the rainy season [6].

With reference to the characteristics of the wastewater used for irrigation, it is estimated that the lands receive annually 468 kg/ha of heavy metals, 712 kg/ha of boron, and 2,340 kg/ha of methylene blue active substances, mainly detergents [1].

The industrial discharges to the municipal sewerage system have been controlled since 1973 by the "regulation for prevention and control of polluted waters." This law was reinforced by 33 regulations, which were developed by the Instituto Nacional de Ecología (INE) and published between 1988-1991 [7]. However, effective implementation of these regulations by the governmental agencies, municipalities, and the private sector leaves much to be desired.

Characteristics of the Agricultural Areas

The wastewaters from the MZMC have been used since 1912 to irrigate the MV, which at present is the largest area that is irrigated with wastewater. Over the years, the quality of wastewater has varied considerably because of extensive industrial developments in the urban zone. A number of studies on the region are available at present, mainly related to the heavy metal contents in water, soil, and crops.

The main use of wastewater is for irrigating 90,000 ha of agricultural land in the MV. The unused wastewater,

especially during the rainy season, is stored at the Endhó reservoir, located on the Tula River, a tributary of the Pánuco River. Wastewater also has other uses in its place of origin, such as reutilization within the city, for example, to supply lakes Xochimilco, Chapultepec, and San Juan de Aragón. It is also used as a source of cooling water for thermal power plants in the Mexico Valley.

The use of wastewater for irrigation in the MV has been an important option that has been extensively used since it improves drainage conditions and satisfies the increasing demand for water in the agricultural sector. Wastewater irrigation could have beneficial effects, especially as it contains many nutrients essential for plant growth. It also improves soil structure and enhances fertility due to the addition of organic matter. Other benefits reported are removals of bacteria and residues of detergents from the effluents.

While wastewater could contribute to aquifer recharge in some cases, it could also cause accumulation of pathogens, salts, and heavy metals, which could be detrimental to the crops, soils, groundwater quality, and finally human and animal health [6].

The development and operational costs of the drainage

Use of wastewater for irrigation ... improves drainage conditions and satisfies the increasing demand for water in the agricultural sector

system in the crop lands are generally lower than for conventional treatment systems [6]. Since many hazardous substances present in the wastewater end up in the sludge, proper sludge disposal would be an important requirement [6].

Considering Mexico's economic and social conditions, the reuse of wastewater for irrigation could be a practical option. The following factors are worth noting:

- A flow of 184 m³/s of wastewater is generated in the whole country, of which 105 m³/s come from domestic sources and 79 m³/s from industry. It is expected that this will increase to 207 m³/s by the year 2,000 [6].
- The Mexican municipal authorities face increasing restrictions on how to dispose of sewage effluents, especially in terms of direct discharges into natural water bodies without any treatment. The costs of construction, operation, and maintenance of conventional treatment plants could be very high for certain municipalities. Approximately half of the 361 plants, with a mean capacity of 20 m³/s, are not operating regularly at present [6].
- Current agricultural potential is limited due to production methods that require plain surfaces, and climatic

and topographical conditions. Some 1,072,320 km² of the country are in arid or semiarid zones [6]. More than half of the country receives annual rainfall of less than 600 mm. The usable agricultural area is now approximately 270,000 km², of which only 58,000 km² are irrigated, and only 1,565 km² are irrigated with wastewater.

- The cost of fertilizers is increasing, and technical support to the farmers to use them efficiently is limited. Wastewaters contain nutrients, though not all, and not in quantities required for optimal plant growth.

Wastewater used in the MV has improved certain agricultural conditions. Analogous results with respect to nutrients in fodder have been detected by Gutiérrez [8] and Siebe [9]. Both studies indicate a statistically significant enrichment of phosphorous and sodium, and a slight enrichment of potassium and copper in tissues of alfalfa. Moreover, low levels of calcium and magnesium absorption were observed in alfalfa irrigated with wastewater. Gutiérrez reports a significant increment of nitrogen in plant tissue due to wastewater irrigation [8].

This, however, does not mean that wastewater irrigation can be recommended in general. If effluents do not receive any pretreatment, the potential for bacteriological contamination and accumulation of toxic substances from industrial discharges need to be carefully monitored. Soil structures, health implications, and sociocultural conditions need to be adequately reviewed before wastewater irrigation can be practiced.

ENVIRONMENTAL SECURITY AND ITS RELATIONSHIP TO THE ENVIRONMENT

The notion of environmental security is of comparatively recent origin, and its possible use as a policy is even more recent. The concept of environmental security itself has been the subject of numerous debates in academia and government ministries.

The relationship between security and environment is now generally accepted as an important and necessary condition for development. The concept was incorporated in some of the publications of the United Nations Environment Programme and was referred to during the Earth Summit in Rio in 1992. This increase in popularity, and the end of the Cold War, have tended to replace the notion of military security with environmental security, even though the two concepts are very different.

Concepts on Environmental Security

The notion of security has always been present in human history. Security has been an essential requirement for global and regional peace, but traditionally security considerations have been directly related to the issues of war and peace. Since environmental security is a comparatively new concept, two factors should be considered

simultaneously: insecurity created by external conditions, and a set of measures that could be taken to change the overall status. Consequently, the concept of environmental security is somewhat ambiguous. Indeed, this concept takes us simultaneously to the environmental conditions that could create insecurity, and to the policies whose objective is to control those conditions that contribute to insecurity. Thus, environmental security and insecurity should be discussed simultaneously.

Nevertheless, the notion of insecurity is often misunderstood. It is often mistaken with environmental insecurity. But environment is different from security, and it is often not easy to comprehend the notion of insecurity. Therefore, it should be viewed in terms of the actors defining their insecurity situations in relation to their own environment. In other words, only the social actors could be considered as major players in environmental insecurity. This is a function of their perceptions of the environmental reality, and these perceptions depend on factors such as ideology, culture, and the level of knowledge of the actors. Accordingly, "objective" environmental insecurity does not exist. The only possible way of measuring environmental insecurity is by the analysis of behaviors (when a policy of environmental security makes sense), which of course does not exclude a diagnosis of the environmental conditions that are the origin of the perceptions.

Environmental insecurity is a complex social process, which can be viewed through two concepts: risk and threat.

Finally, the last category in this brief nomenclature of environmental insecurity is catastrophe, conscious or not, natural or technological. Here, insecurity transforms into a "loss." The importance of this loss could be defined as a function of the dominant system of values, or by the distance to the catastrophe.

The difference between an environmental threat and an environmental problem is also important. Here again, the measure could be established by the actor. From this point of view, a modification to the environment may be considered by one country as fundamental, but by another merely as a simple problem.

The concept of environmental insecurity cannot only be applied to international relationships and to countries, but also to all the social actors, whether they are individuals, groups, political communities, or the set of the international community. In other terms, the environmental threats can be analyzed at each of these levels. The challenge of the analysis will be the determination, on an empirical plain, of how the insecurity in one level changes to another with time.

Such an analysis, however, is difficult because of two additional reasons. First, environmental threats can be defined as a function of the values or the interests. An environmental threat can have social, cultural, physical, strategic, and even political consequences, because they may compromise government stability or its external relations with other governments. Therefore, there is no

“pure” environmental insecurity: it only exists as social, economic, or other forms of insecurity, generated by an environmental modification or perception of an environmental threat.

It is rare that an environmental threat can be treated alone. Often it could create other forms of insecurity. There is also a phenomenon that could be termed as insecurity chaining or aggregation, which creates various problems at the gestation level, and which cannot be ignored in the analysis.

Wastewater Irrigation

Problems related to the environment can be analyzed through the concept of environmental security. Irrigated agricultural development with wastewater in the MV will be used to indicate the concepts of environmental insecurity.

In general, Mexico can be considered to be a country having the fundamental characteristic of a predominantly centralized administration. Indeed, the state has often made unilateral decisions in the past, which had to be followed, and one of the sectors most affected by this approach has been the water sector. Historically, the state has managed, through a number of organizations, the water policy. This fact has turned the state into an important agent and “modifier” of the environment. This also has directly affected the population.

With such developments, environmental modifications have produced various reactions of insecurity in the population, which have resulted in migrations toward urban communities with different characteristics from their places of origin. In these places, people can survive, but they have to modify their earlier lifestyles. In Mexico, millions of people emigrate continuously toward urban centers, where they expect to find employment opportunities and thus better lifestyles.

The above problematic is a reflection of major population concentrations, of which the cities of Mexico, Guadalajara, Monterrey, Tijuana, and Puebla, are important examples. Besides the inherent problems of the large urban centers, the watersheds within which such agglomerations are located mostly do not have the capacity to satisfy their water needs. The state, which has the responsibility of providing water, has to import large volumes of water from the neighboring basins to supply these communities, thus causing social conflicts between both populations.

Indeed, many conflicts over water have already occurred in Mexico. Examples can be seen in the Alto Lerma

Basin, from which water is transferred to Mexico City, or the problem in Huejotzingo, where a group of peasants “confiscated” a series of wells that supplied water to the city of Puebla. Such actions reduce irrigation water availability, which created conflicts between the various water users, which in turn resulted in a confrontation between the peasants and the state armed forces. Even now, several years later, the wells remain “confiscated.” These two examples vividly illustrate the problem of environmental security due to increasing water scarcity, which threatens the existing equilibrium among the users.

Another example of environmental conflict is the agricultural sector, where farmers use wastewater for irrigating their crops. The inhabitants have become victims of diseases that were not so frequent in the past. This phenomenon can be noted along the Pánuco Basin, where wastewaters from Mexico City and other communities are causing contamination of soils, surface runoffs and aquifers. Consequently, severe pollution problems exist in the Zumpango Dam area, located at the limits of the Hidalgo and Querétaro States, where high levels of heavy metals in fish had resulted in a ban on fishing.

The supply of potable water to Mexico City, as well as the drainage of its wastewaters, have produced a sense of insecurity in its population. This can also be noted in the State of Mexico, from which ground water is abstracted for use in Mexico City. High abstraction rates are causing land subsidence, which directly affect the population in terms of damages to buildings and other urban infrastructures.

Similarly, wastewater disposal practices in Mexico City are contributing to environmental insecurity, which is most manifested in the MV, where the wastewater is used for irrigation. Extra water and the organic matters present in wastewaters may contribute to better agricultural yields, which increases the incomes of the farmers. Simultaneously, however, it could also result in significant pollution and health problems.

Another problem worth noting is the disposal of pollutants in the Pánuco basin, which reaches the mouth of the Gulf of Mexico. In a few more years, it could create a serious pollution problem to the marine environment, and thus become an international problem instead of a purely national one, as it is at present.

As far as the MV is concerned, two factors further increase environmental insecurity and perception of risk by the local population. Increasing human activities are not only worsening the quality of wastewaters produced but also continuous migration is rapidly forcing more and more people to settle closer and closer to the irrigated zones, thus increasing their potential health problems.

Another factor further aggravates the problem. It is its distance from Mexico City. Since water is managed at the federal level, and the federal authorities are located in Mexico City, the centralized bureaucracy is under no political or media pressure to solve the problem some 120 km away. Environmental changes are considered important and fundamental by many of the inhabitants

Various reactions of insecurity in the population . . . have resulted in migrations toward urban communities

of the MV, while the authorities think it is only one of the many problems that have to be solved all over the country. Thus, the priorities accorded to this issue by the inhabitants of the area and the central government are different, which further increases the environmental insecurity of the local populace. In the absence of an effective dialogue between the two parties, the problem could further worsen in the future.

FUTURE SCENARIOS

Some current studies estimate that if the current trends that define the problematic of the MZMC continue, the Federal District and its associated urban zone could account for 50 to 60 per cent of total federal public investment by the year 2010 [1]. This urban agglomeration is likely to account for more than one-third of the national population and nearly 40 per cent of the economically active population. It could have a pronounced predominance on national employment opportunities, and thus, a very substantive increase in productive occupations. Approximately half of the workforce is likely to be underemployed or unemployed. The service sector will increase significantly compared to the manufacturing and industrial sectors. The steady increase in demand for all the urban necessities and price rises would ensure the economic dependence of the city on the rest of the country. This would lead to higher federal investments in the city, which could have a negative impact on the balanced development of the various regions. This could further increase core-periphery tensions from a national perspective.

With regard to the metropolis, if the current trends continue, the inadequacy of the urban infrastructure and life support system would deteriorate, and other new distorting elements may surface, which could further complicate the situation. Attempts to resolve such complicated and interrelated conditions have the potential to further distort the socioeconomic differences among the population of the metropolitan area, as well as between the metropolitan area and the other regions of Mexico.

By the year 2010 the urban area of the DF would cover 75 per cent of its total surface and the resulting ecological imbalance would in all probability be irreversible. For example, the lacustrine area could disappear, all the aquifer recharge areas could be eliminated, 85 per cent of forest cover could be lost, and 90 per cent of soils could be degraded. These factors, in addition to the fact that increased human activities would generate much higher levels of air, water, and soil pollution, in all likelihood would make the overall environmental situation far worse than it is at present.

Only two examples of the impacts of uncontrolled pollution growth and increased human activities will be briefly discussed here. By the year 2010, it would be necessary to more than double the amount of water needed for the city, compared to 1990. Equally, wastewater generated is likely to double during the same period, thus

making it even more difficult to find economic alternatives for its safe disposal.

The acute internal problematic of Mexico City and its associated co-urban zone in the areas of water supply, safe wastewater disposal, and appropriate environmental conditions may mean that the evolution of future problems is likely to impose a major challenge to the country in terms of their solution, as well as ensuring the improvement of the quality of life of the majority of its inhabitants. The problems are likely to be somewhat similar in other expanding urban centers. This, thus, has to be a priority issue in the future sustainable development plan of the country.

The current growth rate (3.6 per cent per annum) of the metropolitan zone indicates that by the year 2010, there would be some 21 million inhabitants. Considering the current supplies, and to reach a 99 per cent coverage, the total water requirements would be of 58.1 m³/s, which represents an increase of 12.5 m³/s. The total availability would be, in general terms, slightly above the requirements [1].

However, if the current practices and trends on supply, distribution, and operation of water supply and sanitation services continue, the net result is likely to be enhanced aquifer exploitation, increased land subsidence in many parts of the city, and deterioration in the quality of the extracted water. The water distribution is likely to become worse, which will further accentuate the present inequalities. In addition, the costs of operation and maintenance, and the subsidy needed to maintain the service, will rise, as will the waste of the resource by the users. All these will have adverse impacts on total coverages, reliability of supply, and overall water quality.

If the above scenario is correct, the volume and quality of wastewater discharges will also be seriously affected. Equally, investments needed to construct, operate, and maintain water supply and sewerage systems would be very high. Trained manpower needed to operate and maintain the systems would be a major constraint. Thus, capacity building from the highest levels of management to the lowest levels would be necessary.

SOLUTIONS

For the case analyzed, even if it is considered that wastewater irrigation can be used in the MV (fortunately soil characteristics prevent the heavy metals present from having significant impacts on crops), it is important to note that the problem is very complex in terms of the overall environmental security of the people concerned. This is because the farmers benefiting from the present practice of wastewater irrigation would not welcome any changes that could reduce their income. However, non-farmers who live in the zone feel that the wastewaters should be properly treated and used so as not to have adverse impacts on their health and the environment. With respect to pollution of the River Moctezuma, it is already very serious because the quality of the water that

reaches the Zumpango Dam is very poor. For example, fish have very high levels of lead. This has contributed to an additional conflict with the fishermen of the nearby towns, because fishing is now strictly restricted and regulated. However, in spite of such restrictions, contaminated fish from the reservoir are regularly sold in the nearby markets, including Mexico City [10].

There are no simple "win-win" solutions to such complex problems because of the differing nature of the beneficiaries and their personal interests. Enforcement of the restricted fishing regulation will undeniably reduce the income of the fishermen. Since unemployment and underemployment in the region are already high, and the fishermen are mostly uneducated and unskilled, the chances of them obtaining alternate sources of income are relatively low. If unrestricted fishing is to be allowed, it would clearly have long-term health implications to consumers. Thus, no matter what solution is adopted, many people are going to be losers. National socioeconomic conditions make it highly improbable that the losers of any solution implemented would ever be properly compensated.

The ideal solution would be to treat the wastewater of Mexico City properly so that it could be used without reducing the environmental security of the people downstream. This would require very considerable investments, which do not appear to be a realistic alternative in the near future. Even if this becomes a feasible alternative, the problem will not disappear overnight because of the contaminants present in the bottom sediments of the water bodies. Even the very discussion of these complex social-economic-technical-political issues in public could contribute to the generation of social tensions between the various groups, at least in the near term. In addition, the political will to tackle such complex problems requiring large investments is basically missing at present.

CONCLUSIONS

This article is the first of a series of papers on environmental conflicts, real, apparent, or imaginary, that have been generated, or are likely to be generated, between various users, between various states, and between federal and state interests due to water- and wastewater-related problems in Mexico. This is an area of policy analysis that has been basically ignored by both the government and academia so far. Considering the problems that have already surfaced, and that are likely to surface in the future, they need immediate analysis and attention.

Concern for environmental conservation has not been a tradition in Mexico [11]. It is a comparatively new concept. At present, like any other new concept, one can see more rhetoric than action. However, the issue of environmental security due to water scarcities and wastewater management can no longer be ignored. Already social tensions between the various water users are apparent, and these can only escalate in the future, unless

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the problems concerned are properly diagnosed and analyzed, and appropriate solutions are implemented. If the problems remain unchecked and unresolved, social tensions could lead to political tensions. Possibilities of violent conflicts due to water scarcities between various user groups and actors are no longer in the realm of possibilities or conjectures, since some have already occurred, not only in Mexico but also in other countries. Unless these conflicts are resolved in their early stages, the positions and views of the diverse parties are likely to harden in the future, as are the intensities and extent of the problems. If nonviolent solutions are not tried at this manageable stage, violence cannot be ruled out in the future.

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