VII.1 Introduction

Mexico is a federal republic composed of 31 states and a federal district. The country has a surface area of nearly $2 \times 10^6$ km$^2$ and an annual rainfall of 777 mm, which is equivalent to $1,522 \times 10^8$ m$^3$ a$^{-1}$ of water. This volume of water should be sufficient for all the needs of its population but the poor geographical and temporal distribution of the water resources result in a shortage of water for 75 per cent of the country. These areas are classified as arid or semi-arid (SEMARNAP, 1996).

The national population of 89 million has an annual growth rate of 1.9 per cent and 70 per cent of the population reside in urban areas. The metropolitan area of Mexico City, with 18 million inhabitants, contrasts greatly with the highly dispersed rural population of 20 million living in 149,000 communities of less than 1,000 inhabitants. The general level of education is low and there are more than 56 ethnic groups speaking indigenous languages. Life expectancy is 69-72 years. The prevalence of infectious disease and parasitism is superimposed on that of chronic degenerative illnesses. The infant mortality rate continues to be high.

The gross national product was US$ 3,750 per capita in 1993 (INEGI, 1994) and Mexico is currently facing a severe economic crisis. This aggravates the poverty experienced by 50 per cent of the population living in rural areas and the marginal zones of large cities. This situation is generally considered to be only temporary and it is expected that economic development will begin again in Mexico as it has done in the past. In 1994, Mexico signed the North American Free Trade Agreement with the USA and Canada. Mexico is also a member of the Organisation for Economic Co-operation and Development (OECD).
VII.2 The Mezquital Valley

The Mezquital Valley is within the bounds of the state of Hidalgo. It is situated in the Mexican high plateau, 60 km north of Mexico City (Figure VII.1), with an altitude between 1,700 m and 2,100 m above sea level. The 495,000 inhabitants of the valley are principally involved in agricultural activities, complemented by livestock breeding. Their standard of living is higher than that of the population without access to wastewater for use in irrigation (Romero, 1994).

Irrigation districts 03-Tula and 100-Alfajayucan use raw wastewater from the metropolitan area of Mexico City (Figure VII.2). This wastewater has received no conventional treatment. Due to the immense size of the cultivated area (83,000 ha in 1993-94) and its antiquity (91 years in continual operation), the region represents a unique example of wastewater irrigation (Table VII.1). The wastewater, whether raw, partially treated or mixed with rainfall, is highly valued by the farmers because of its ability to improve soil quality and because of its nutrient load that allows increased productivity (Table VII.2) (SARH, 1994; CNA, 1995). In 1990, the maize-alfalfa crop covered a surface 10-times bigger than the vegetable crop, but the productivity was six-times lower.
Table VII.1 Irrigation data for the Mezquital Valley, 1993-94

<table>
<thead>
<tr>
<th>Irrigation systems</th>
<th>Area (ha) covered(^1)</th>
<th>Cultivated(^2)</th>
<th>No. of users</th>
<th>Water volume (10(^6) m(^3) a(^{-1}))</th>
<th>Production value (10(^6) N$)(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>District 03 (Tula)</td>
<td>45,214</td>
<td>55,258</td>
<td>27,894</td>
<td>1,148</td>
<td>255</td>
</tr>
<tr>
<td>District 100 (Alfajayucan)</td>
<td>32,118</td>
<td>22,380</td>
<td>17,018</td>
<td>651</td>
<td>85</td>
</tr>
<tr>
<td>Private units</td>
<td>5,375</td>
<td>5,450</td>
<td>4,000</td>
<td>96</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>82,707</td>
<td>83,088</td>
<td>48,912</td>
<td>1,895</td>
<td>340</td>
</tr>
</tbody>
</table>

\(^1\) Covered area refers to irrigable land with irrigation infrastructure

\(^2\) Cultivated area includes some areas with more than one crop per year

\(^3\) Average exchange rate for that period was N\$ 3.5 per US\$ 1
Table VII.2 Agricultural productivity in the Mezquital Valley, 1990-92 (t ha\(^{-1}\) a\(^{-1}\))

<table>
<thead>
<tr>
<th>Crops</th>
<th>National mean</th>
<th>Mezquital mean</th>
<th>Hidalgo State irrigation area</th>
<th>Rainfed area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet corn</td>
<td>3.7</td>
<td>5.1</td>
<td>3.6</td>
<td>1.1</td>
</tr>
<tr>
<td>Kidney bean</td>
<td>1.4</td>
<td>1.8</td>
<td>1.3</td>
<td>0.49</td>
</tr>
<tr>
<td>Oat</td>
<td>4.7</td>
<td>3.7</td>
<td>3.6</td>
<td>1.7</td>
</tr>
<tr>
<td>Barley (fodder)</td>
<td>10.8</td>
<td>22.0</td>
<td>15.5</td>
<td>13.5</td>
</tr>
<tr>
<td>Lucerne</td>
<td>66.3</td>
<td>95.5</td>
<td>78.8</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Sources: Agricultural and Hydraulic Resources Secretary (SARH), Mexico 1994 (National values)

The wastewater is contaminated with pathogenic organisms and toxic chemicals that constitute a health risk for both farmers and consumers of agricultural products. The principal crops grown are alfalfa, maize, wheat, oats, beans, tomatoes, chillies and beetroot. There is a small but valuable production of restricted crops in the lower section of the Valley (District 100), including lettuce, cabbage, coriander, radish, carrot, spinach and parsley. This crop restriction is part of the management policy for reuse of wastewater with adequate health safeguards.

During its use in the Mezquital Valley irrigation districts, the Mexico City wastewater (a mixture of domestic and industrial waste) receives natural "land" treatment which is equivalent or superior to conventional secondary wastewater treatment. The environmental effects that could be experienced due to the water pollution that would result if this irrigation scheme was not available are:

- The raw wastewater would lead to gross environmental pollution estimated at 1,150 t d\(^{-1}\) organic matter, expressed in terms of their biochemical oxygen demand (BOD), which would affect the land and water resources downstream in the Panuco River basin, including several coastal lagoons and the Gulf of Mexico.
- Municipal and rural water supplies, hydroelectric plants, fishery developments, aquatic ecosystems and a rich biodiversity would be affected.
- Nutrient rich wastewater flowing downstream to the river basin would cause excess aquatic weed and vector infestation as a result of eutrophication.
- The aesthetic value of the natural environment and the landscape would be affected by foaming and other effects, such as odour.
- Without this huge, natural land treatment process it would be almost impossible to accomplish and to integrate sustainable development of land and water resources in a very important region of Mexico.
VII.3 Pre-intervention situation

At present, there are legal and institutional guidelines that ensure sustainable agricultural development in the Mezquital Valley. The National Water Law, in force since 1993, has one section dedicated specifically to the prevention and control of water contamination. In addition, Ecological Technical Standards 32 and 33 (now Official Mexican Standards) set down the requirements for wastewater use in agricultural irrigation (Diario Oficial de la Federacion, 1993). The National Water Commission (Comisión Nacional del Agua; CNA) was officially created in 1989 as a federal government entity responsible for promoting construction of the hydro-agricultural infrastructure, as well as for its operation, and for ensuring that the laws and standards relating to efficient use of water and control of its quality are upheld.

The Federal Government, specifically CNA, has been in charge of the irrigation districts since 1949. Each district is under the administration of a chief engineer appointed by CNA, and being under the control of a single authority greatly facilitates management of the irrigation scheme. There is also a management board composed of representatives of central and state governments, water users associations and local credit banks. Some farmers work in co-operatives managed by themselves, although most are individual workers who own very small parcels of land (an average of 1.5 ha per user).

Farmers lodge their water demands with the local District Office, specifying where and when the water is required. The District Manager then prepares a first draft of the irrigation schedule, analysing the different factors involved, such as the amount of water available, water demand timetables, the crop preferences of the farmers, agricultural authority policies, crop restrictions and resources available. The resultant irrigation programme (plan de riego) is implemented following discussion with, and approval by, the farmers who will take part in it.

A fee is charged to the users (farmers) by CNA to recover some of the operational costs, although government subsidies remain high. Efforts are being made to eliminate these subsidies. The real operational and maintenance costs are around N$ 4.42 (4.42 new pesos) per thousand cubic meters and the farmers are paying only N$ 1.46 (33 per cent), plus N$ 0.75 (17 per cent) estimated as labour costs for small maintenance works (the average exchange rate for the 1993-94 agricultural cycle was N$ 3.5 per US$ 1). Therefore only 50 per cent of the operational costs are covered by the farmers using the wastewater. Every year since the beginning of this century, the government has provided funding for continuous extension of the irrigation infrastructure. It is rather difficult to estimate these construction costs as a component of the wastewater economic value because insufficient information is available. However, the farmers profits are often about 60 per cent from marketed crops and some salad vegetables can be more profitable (70 per cent and even 80 per cent).

In the last four years, due to the spread of cholera, CNA has enforced restriction on crops irrigated with wastewater and whose products are consumed uncooked, such as salad crops. This decision, taken as a preventative measure, caused social conflict with farmers who saw their income severely reduced by the restriction of their cash crops without other viable alternatives being proposed.
The volume of wastewater generated has increased over time. It is distributed in the Mezquital Valley by a complex system of tunnels, reservoirs and canals, which themselves have a purifying effect on the wastewater. The result is that different areas are irrigated with water of different quality. For example, at the entrance to the Valley, the wastewater has a maximum of $6 \times 10^8$ faecal coliforms per 100 ml, whereas at the outflow from the Vicente Aguirre reservoir the count is reduced to a minimum of $2 \times 10^1$ (Table VII.3). The same reduction occurs with helminths; the concentration of *Ascaris* eggs is reduced from 135 per litre at the Valley entrance to less than one per litre at the outflow of the lowest reservoir (Cortés, 1989; Cifuentes *et al*., 1994). This situation has stimulated the interest of academic institutions, which carry out epidemiological studies in the Mezquital Valley. Their first results (Figure VII.3) demonstrated that there is a higher risk of *Ascaris lumbricoides* infection in the infants of farm workers using raw wastewater than for those using partially treated wastewater from storage reservoirs, and that the risks for both groups were considerably higher than for those in the rain-fed control area. By contrast, the risk to children and adults in the reservoirs group was similar to that observed in the controls (rain-fed area). As expected, the age group 5-14 years, especially males, had the highest intensity of *Ascaris* infections when exposed to raw wastewater (Cifuentes *et al*., 1995; Blumenthal *et al*., 1996). In addition, these studies suggested an association between the prevalence of diarrhoeal disease and the exposure of the farmers’ children to wastewater of different quality; children from households exposed to raw wastewater had a small but significantly increased risk. The higher rates of diarrhoeal diseases found in infants (1-4 years old), who mostly depend on their mothers, could be explained by crowded households, deficient hygiene practices and unsanitary conditions in the farmers’ domestic environment (Figure VII.4) (Ordóñez, 1995). These results support the view that parasite infection is more effective as an indicator of the effects of wastewater use on the health of an exposed population.

**Table VII.3** Faecal coliform concentrations in the Mezquital Valley reservoirs (MPN$^1$ per 100 ml)

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Geographic mean$^2$</th>
<th>Maximum$^2$</th>
<th>Minimum$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Endho</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflow</td>
<td>$2.6 \times 10^7$</td>
<td>$6 \times 10^8$</td>
<td>$3 \times 10^4$</td>
</tr>
<tr>
<td>Effluent</td>
<td>$6.1 \times 10^4$</td>
<td>$3 \times 10^5$</td>
<td>$4 \times 10^4$</td>
</tr>
<tr>
<td><strong>Rojo Gomez</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflow</td>
<td>$5.3 \times 10^5$</td>
<td>$3 \times 10^4$</td>
<td>$5 \times 10^3$</td>
</tr>
<tr>
<td>Effluent</td>
<td>$1.4 \times 10^4$</td>
<td>$2 \times 10^5$</td>
<td>$1 \times 10^1$</td>
</tr>
<tr>
<td><strong>V. Aguirre</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflow</td>
<td>$5.9 \times 10^3$</td>
<td>$1 \times 10^4$</td>
<td>$1 \times 10^2$</td>
</tr>
<tr>
<td>Effluent</td>
<td>$3.3 \times 10^2$</td>
<td>$3 \times 10^4$</td>
<td>$2 \times 10^1$</td>
</tr>
</tbody>
</table>

$^1$ Most probable number  
$^2$ Source: Cortés, 1989  
$^3$ Source: Cifuentes *et al*., 1995
**VII.4 Intervention scenario**

In 1993, Mexico hosted a regional workshop to analyse the issues surrounding agricultural wastewater use and to propose appropriate interventions to ensure public and occupational health and safety. The workshop was organised by the Mexican Institute for Water Technology (IMTA), with the assistance of the World Health Organization (WHO), the Pan-American Health Organization (PAHO), the Food and
Agriculture Organization of the United Nations (FAO), the United Nations Environment Programme (UNEP) and the United Nations Centre for Human Settlements (UNCHS/HABITAT). Representatives from 12 countries in Latin America and the Caribbean participated. The workshop recommended the creation of a study and reference centre in the Mezquital Valley with the aim of promoting, co-ordinating and integrating investigative studies carried out in the favourable conditions found in that area.

With regard to wastewater treatment as a measure for the protection of health and the environment, CNA is conducting detailed engineering studies in relation to the possible construction of conventional treatment plants in the Great Drainage Canal, in the metropolitan area of Mexico City, and in the discharge point from the Central Deep Outfall (Emisor Central) in the Mezquital Valley. In this respect, CNA has existing experience with treatment plants, both large and small, currently operating in the metropolitan area and whose effluents are used to irrigate green areas and to fill recreational lakes in the urban area.

On a smaller scale, it may be possible to convince farmers to invest in treatment plants at the plot level to ensure safe production of salad vegetables and other high risk crops. At present, CNA is concentrating on assisting the farmers who use wastewater to build their own stabilisation ponds, to adapt the quality of the wastewater to the requirements for cropping restrictions and to demonstrate that the practices being used are safe. To ensure that these safe practices are used correctly, a strict wastewater quality certification programme is needed.

Two events in the politics and administration of the country have facilitated more direct intervention in the future to improve the conditions under which wastewater is used in the Mezquital Valley. First, recent changes in the organisation of federal public administration, have placed the overall management of water (i.e. through CNA) under the newly created Ministry of Environment, Natural Resources and Fisheries. This will allow more emphasis to be given to environmental problems, which are precisely the central issue in the Mezquital Valley and which could affect downstream water resources in the Panuco River basin (as mentioned above). The second important event was the proposal to create the regional study centre in the Mezquital Valley. The specific objective of this centre is to enhance technical and scientific understanding in order to enable rational and safe use of waste-water and thereby to assist the development of sustainable agriculture. In order to assist the many and varied investigations in the Mezquital Valley, the reference centre should provide two basic facilities:

- An information system including data generated by the field studies and environmental monitoring network.
- Various demonstration units of an experimental and educational nature, to facilitate training and technology transfer.

**VII.5 Lessons learned, constraints and opportunities**

The project to create a study centre in the Mezquital Valley faces obstacles commonly found in developing countries. These are:
• High levels of poverty and unemployment which are aggravated by excessive demographic growth, and a currency (the peso) weighed down by external debt and a shortage of financial resources.

• Persistent conditions of environmental deterioration. Above all, the need for basic domestic sanitation in rural areas demands attention and competes for scarce funds.

• Strong market pressure to adopt developed country solutions which are inappropriate (technically, economically and financially) for developing countries. The treatment of wastewater is a good example of this.

• The process of administrative decentralisation. In its initial phase this results in serious difficulties with co-ordination, usually because there are few well-prepared professional and technical personnel available at the local level.

Nevertheless, there are factors that favour the implementation of the project, such as:
• Many institutions and researchers, both national and international, are interested in carrying out appropriate studies.

• There is political will to halt environmental deterioration and to revert present trends in order to ensure sustainable development.

• The basic institutional infrastructure exists to implement interventions for improving agricultural production and water sanitation in the irrigation districts.

• Some international co-operation agencies are interested in giving technical and financial assistance to the proposed study centre, because of its regional relevance for countries in Latin America and the Caribbean. The InterAmerican Development Bank, for example, has indicated its interest in the project. The Bank, together with the Japanese government has approved a US$ 800 million credit for large-scale wastewater treatment plants in the metropolitan area of Mexico City, as well as for the necessary hydraulic infrastructure.

VII.6 Conclusions and recommendations

• The rational use of wastewater for irrigation in agriculture and forestry, or in aquaculture, is a highly useful and productive practice that contributes to sustainable development which is the central objective of Agenda 21 as approved at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992.

• The interventions necessary to improve the efficiency of wastewater use, in order to protect health and safeguard the environment, require a full understanding of local socio-cultural and economic conditions. Such understanding must result in action, which should be translated into guidelines and applied promptly.

• In the Mezquital Valley, irrigation conditions are ideal for carrying out field research. The results of this research could be used at the national level and eventually in other developing countries.
Taking the above points into account, it is proposed:
• To support the creation of a Regional Study and Reference Centre for the rational and safe use of wastewater in the Mezquital Valley.

• To enforce crop restrictions and other wastewater use regulations, based on recent epidemiological findings.

• To introduce simultaneously a pilot intervention programme of basic housing sanitation in the irrigation area.

VII.7 References


INEGI 1994 Sistemas de Cuentas Nacionales de México. Instituto Nacional de Estadística, Geografía e Informática (INEGA), Mexico.

Ordoñez, B.R. 1995 Personal communication, Mexico.

