Wastewater: From Waste to Resource

The Case of Atotonilco de Tula, Mexico

Reuse of Treated Wastewater for Agriculture, Energy Generation, and Transfer of Value to Stakeholders in the Valley of Mexico

Context

The Valley of Mexico metropolitan area (Zona Metropolitana del Valle de México [ZMVM]) is the country's financial, political, and cultural epicenter. The ZMVM is the OECD's third largest metro area and the world's largest metro area outside Asia (OECD, 2015). It is composed of over 50 municipalities and is home to the federal government in Mexico City. Nearly 20 million people live in this area and in the last decade the population has grown at an average of 1.2 percent per year.

Currently, only about 6 percent of wastewater generated in the area is treated. For the past 80 years, most of the wastewater produced in the ZMVM has been sent to the Tula Valley (also known as Mezquital Valley)—a region located in the state of Hidalgo—without treatment, and has been used by farmers for irrigation. Given the large amounts of wastewater and storm water available, what used to be an arid landscape transformed into a highly productive irrigation district of more than 80,000 hectares and a source of reliable income for about 60,000 families. Local farmers value wastewater (whether raw, partially treated, or mixed with rainfall) for its ability to improve soil quality. However, the wastewater contains pathogenic organisms and toxic chemicals constituting a health risk for farmers and consumers of agricultural products. To manage the health risks, there is a crop restriction policy for reuse of the untreated wastewater: the wastewater can be used only for certain crops that will not be

PHOTO 1. Aerial View of Atotonilco Waste Water Treatment Plant

Source: Acciona.

eaten uncooked. Crops grown in the valley are predominantly alfalfa and maize, and there is a small production of restricted crops in the lower section of the valley including lettuce, cabbage, and coriander. Crop restriction policies can be difficult to enforce, and the policy limits the potential to grow higher value vegetable crops. In addition, untreated wastewater negatively affects the ecosystems of the nearby El Salto River and the Salto Tlamaco irrigation canal.

Through the national water commission (CONAGUA), the federal government developed the Atotonilco Wastewater Treatment Plant (WWTP) project to benefit more than 10.5 million people (CONAGUA 2010) in the ZMVM, and more directly, 700,000 people living in the Mezquital Valley and 300,000 who live in, or in close proximity to, the irrigation areas. The Atotonilco WWTP is part of the national program of sustainable water use in the basin of the Valley of Mexico (Programa de Sustentabilidad Hídrica de la Cuenca del Valle de México [PSHCVM]), initiated in 2007. The Atotonilco WWTP is the program's biggest project; it includes the construction of a plant that aims to treat 60 percent of the residual waters from the Valley of Mexico, solve the flooding issues during the rainy season, improve water quality for irrigation, and use the emission of methane from sludge digestion to generate electricity.

CHALLENGE
Urban growth has led to increased wastewater flow, untreated irrigation water, and threats to public health
OBJECTIVE
• Improve the quality of life of the 700,000 inhabitants of the Mezquital Valley
• Provide high-quality water for farmland irrigation
• Decrease water consumption
• Achieve high energy efficiency in the plant
• Improve the quality of water feeding into natural systems
• Generate direct employment during the plant's construction and operation
• Use market-based instruments for financing

Solution

The Mexican federal government included the Atotonilco WWTP project in the PSHCVM program to ensure municipal and local government compliance with federal laws for wastewater treatment. The Atotonilco WWTP, the largest wastewater treatment plant in Latin America and one of the largest in the world, is located within the municipality of Atotonilco de Tula in the state of Hidalgo. It occupies 160 hectares with a capacity of 35,000 liters per second and a maximum capacity of 50,000 liters per second—to be able to absorb storm water during the wet season. The plant has an estimated lifespan of 50 years and was built in a strategic location at the end point of the central sewage pipeline and the beginning of the canals for irrigation and the future east sewage pipeline (under construction through the PSHCVM).

An innovation of the Atotonilco WWTP is that it uses a combination of wastewater treatment processes depending of the origin and end use of the wastewater. The Atotonilco WWTP was designed to operate with two treatment processes: (a) a physical-chemical process train, based on chemically enhanced primary treatment (CEPT) to clean up storm water flow discharged to the river; and (b) a high-rate activated sludge (biological) treatment for wastewater flow to be reused in irrigation (Acciona Agua 2017). This treatment scheme optimizes the plant resources and reduces significantly the operational costs. The wastewater treated for irrigation purposes meets the quality standards (NOM 003-SEMARNAT) to be used to irrigate up to 90,000 hectares in the Mezquital Valley, which is the largest agricultural district in Mexico (and probably in Latin America) irrigated with wastewater.

In the process of sludge stabilization in the anaerobic digesters, biogas is generated, which is used for the production of electricity for self-consumption and for heating the digesters (combined heat and power system). The installed capacity of 32.4 megawatts provides about 60 percent of the plant's electricity requirements. The gas engines also have a heat

recovery system that supplies thermal energy to the digestion process. Therefore, the project can supply most of its own energy needs, greatly minimizing energy costs and improving energy efficiency (Bello, Contreras, and Rodriguez 2016). Furthermore, in capturing methane and using it to generate energy, the plant will reduce greenhouse gas (GHG) emissions by about 145,000 tons of carbon dioxide (CO_2) per year, allowing the Atotonilco WWTP to get and monetize carbon credits. Moreover, the biosolid (stabilized sludge) produced meets the quality standards to be type C sludge, which, according to the NOM-004-SEMARNAT-2002 standard (SEMARNAT 2002), is suitable for application in forests, soil enhancement, and agriculture, and therefore could be reused. Finally, the plant uses recycled or treated water for the operation of plant, reducing the use of potable water by 93 percent (Bello, Contreras, and Rodriguez 2016).

All these processes make the Atotonilco WWTP a very innovative project that uses wastewater as a resource, giving value to all its byproducts: reusing wastewater for irrigation, producing electricity and thermal energy from its sludge, and providing suitable quality biosolids for beneficial use. From an environmental point of view, the project will enhance the water quality flowing to the nearby water bodies (El Salto River and the Salto Tlamaco Canal), improving existing habitats.

Financial and Contract Agreements

The project was planned as a private-public partnership (PPP) under a design-build, operate and transfer contract, needing an initial investment of around US$686 million, which the Mexican government could not cover on its own. In 2009, CONAGUA launched a tender for a wastewater plant to treat 60 percent of the Valley of Mexico's wastewater. In 2010, the contract for the construction, operation, and maintenance was awarded to the consortium Aguas Tratadas del Valle de México (ATVM), comprised of the following organizations and businesses: Promotora del Desarrollo de América Latina, Atlatec, Acciona Agua, Controladora de Operaciones de Infraestructura, Desarrollo y Construcciones Urbanas, and Green Gas Pioneer Crossing Energy.

Total investment: Mex$9,389 mdp (US$686 million)	
FONADIN (%)	49
Consortium of partners (%)	20
Commercial banks (%)	31

The contract between ATVM and CONAGUA was established as a 25-year concession project financed by Fondadin, the infrastructure national fund of Mexico (Fondo Nacional de Infraestructura in spanish), and private investors. Despite the investment cost, this project was funded without the support of any multilateral financial institution. CONAGUA relied on Fonadin, which normally subsidizes projects up to 40 percent of the costs of PPPs. In this case, however, the threshold was raised to 49 percent because of the project size and the relatively low tariffs charged to water users. The project allowed for low tariffs due to the project's economies of scale, the optimized use of biogas (generation of electricity and thermal energy), and the combination of treatment technologies for different end uses of wastewater. Much of capital remained in the form of debt and equity, with Banobras (Mexico's development bank) leading the debt financing and attracting commercial banks, so that most funding was still dependent on the sponsors successfully completing the project. With the subsidy fixed at 49 percent during the tender process, the winning bid was chosen on the basis of the lowest tariffs requested. Construction has been underway since 2011 and the first phase became operational in 2014 (Kenny, Lavanchy, and Kjorstad 2012).

Existing Regulation

NOM 003-SEMARNAT is a regulation that establishes the minimum water quality requirements to be used for agriculture. However, it does not differentiate by crop or type of soil. It also establishes that it is not

permitted to irrigate vegetables that are consumed raw with untreated wastewater. The regulation should be improved and include directives to regulate the use of treated wastewater for irrigation purposes, therefore fostering this sustainable practice in a safe way.

*NOM-004-SEMARNAT i*s a regulation that establishes the minimum quality of sludge (biosolids) to be used for fertilizing purposes in agriculture. However, this regulation does not include any directive related to the amount (dose) or the management of the sludge.

Benefits

Economic

- Energy efficiency and operational costs reduced: reduction of energy consumption from external suppliers
- Potential extra revenue from carbon credits of up to US$2 million
- Low water tariffs given the economies of scale and the plant's efficiency
- Generation of around 4,000 new employments during construction, and will provide 150 permanent jobs during operation (20 years)
- Better quality of irrigation water, allowing farmers to diversify or switch to up to 10 times higher value crops; Crop restrictions in the region will be lifted given the improved water quality.
- Possibility to use drip irrigation given the improved quality of the water, increasing water efficiency
- Potential new economic activities such as fish farming and ecotourism
- Beneficial use of sludge (biosolids)

Environmental and Social

- Cleaner water is expected to improve the health and living standard of 700,000 people in the Mezquital Valley and 300,000 inhabitants who live and work directly within the irrigation zone
- ATVM estimated a reduction of 145,000 tons of CO_2 carbon dioxide in average per year
- Better water quality flowing back into the natural ecosystem, recharging aquifers
- Environmental remediation: the project has invested in reforestation using native plant species, with the aim of recovering and improving the quality of environmental services in the site
- Mexico's overall water treatment rate is expected to rise from 36 percent to 60 percent
- Health improvement: decrease of gastrointestinal and skin diseases rate in the area previously irrigated with raw wastewater
- Reference case of wastewater reuse for irrigation

Lessons Learned

Innovative institutional arrangements and agreements for the management and execution of the project (PPP). The Atotonilco WWTP project was built on a PPP scheme with an approximate total investment of US$900 million. The project incentivized private parties to participate, given that the successful bidder would design, build, and operate the plant for 25 years. Moreover, of the initial investment, the Government of Mexico through FONADIN financed 49 percent instead of the usual 40 percent, reducing the perceived risks by the investors and making it desirable.

Multiquality of wastewater tailored for the different uses (fit to purpose). The treatment technology has been customized for the project, depending on the origin and end use of the wastewater. An important objective was to preserve most of the nutrients to provide added value for the farmers. The treatment capacity of the plant has been adapted to current flows, taking into account the seasonal climate differences that characterize a region with a dry period of seven months followed by a rainy season of five months.

Holistic approach and sustainability focus. Since the project's inception, sustainability has played an important role. The holistic approach resulted in the use of outputs that would otherwise go unused or used in less valuable ways: methane is used for biogas energy generation, and treated wastewater is used to improve and expand crop irrigation in the area. Moreover, the project focused on energy and water efficiency.

The WWTP has won the Infraestructuras 360° award from the Inter-American Development Bank (IDB) in recognition of the comprehensive implementation of a sustainability strategy.

Clear regulations. Given the potential innovative uses for treated wastewater, clear regulations have helped to promote the use of all the resources in a safe and sustainable manner.

Stakeholder engagement. The farmers valued the untreated wastewater and saw it as a right that they had gained more than 50 years ago. The access to untreated wastewater had allowed them to grow marketable crops at low production costs. Moreover, some believed that the untreated wastewater and its nutrients led to higher than average yields. Many are still (as of 2017) unsure about the benefits of treated wastewater and fear that the utility will make them pay high prices for the treated wastewater and that their crop productivity will decrease. Therefore, CONAGUA put in place several stakeholder engagement programs to (a) clarify the issue; (b) explain the new opportunities that will arise from using treated wastewater (such as switching to higher vale crops); and (c) enable the farmers to use drip irrigation to optimize water use. A *fideicomiso* (trust) was created (Fideicomiso de Infraestructura Ambiental de los Valles de Hidalgo) to enable proposals on integrated management of water resources, advanced irrigation, and agricultural industrialization, among others.

The Atotonilco WWTP adds considerable social and financial value to its stakeholders through the intelligent resource recovery from wastewater. Irrigation with clean, treated wastewater will no longer pose a health risk to the farmers or consumers, and crop diversity and agricultural profits can grow without the need for crop restrictions. By including additional elements such as energy generation and beneficial use of biosolids, the project maximized the ability to turn waste into a resource.

PROFILE

NAME

Atotonilco WWTP

LOCATION

Atotonilco de Tula, Hidalgo (México)

SIZE

Nominal average treatment capacity of 35 m^3/second and a maximum treatment capacity of 50 m^3/second (approx. 10 million people equivalent)

MAIN INNOVATIONS

Wastewater reuse for irrigation: 80,000 hectares of land will be irrigated using treated effluent

Energy efficiency: biogas is used to generate thermal energy and electricity for self-supply (combined heat and power)

Multi-quality recycled water

Transferred value to stakeholders

TECHNOLOGY

Co-generation

Anaerobic digesters

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