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Tenorio project: a case of sustainable development in Mexico

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ABSTRACT

The project Tenorio–Villa de Reyes main objective was to increase the coverage of treatment in the metropolitan area of San Luis Potosí and to recycle the treated for agriculture and industry. The project consisted of the construction of one municipal wastewater treatment facility with a total capacity of 90,720 m^3/day, five main sewage collectors, one irrigation system with a reservoir called Tenorio that receives most of the treated water, and one distribution system (38-km pipe) that allows reusing the tertiary effluent in the cooling towers of the Power Villa de Reyes. The project has been in operation for almost 5 years, and so far it has reached almost 90% of the plant capacity with significant impact over the restoration of the Tenorio ecosystem due to the improvement of the water quality, and although only 50% of the flow is received in power plant, it has served to the purpose of saving 40 Mm^3 of potable water. Before the beginning of the operation, "Tenorio" reservoir had been receiving raw wastewater and wildlife became scarce. Currently, the return of wildlife is very substantial, and the site has become a nesting site for several migratory birds' species. The Project Tenorio is the first on its type in Mexico that combines industrial water reuse, agricultural reuse, aquifer recovery, and the recovery of and the development of ecosystem that could be considered as an artificial wetland. It is well known that wetlands provide habitat for plants and animals and also absorb excess nutrients, sediments, and other pollutants before they reach rivers, lakes, and other water bodies or in our case before part of the water is used for irrigation of crops. In the case of the Tenorio reservoir, once the artificial internal walls were completed and it was filled with the effluent of the Tenorio Plant, the native plants were restored and the natural depuration process was established to complete the treatment of the water improving significantly its quality. In the spring or 2010, the presence of Daphnia, which are well know for being used as indicator organisms for toxicity test, was definitely consider as indicator of the lack of toxic substances that had been successfully removed by the treatment plant and by the natural depuration process that occurs in the reservoir. During the last 3 years, the number of migrating birds has increased and there are several species of birds that have been observed to rest, feed, and nest during their cross-continental journeys. The quality of the water has been monitored during the last 3 years (BOD, COD, TSS, nitrogen, and coliforms), and it has been found that even though the rate of improvement is low, the effects are notorious over the ecosystem. The power plant management is very satisfied with the use or recycled water since they have proven the reliability of the system in terms of both quality and quantity.

Keywords: Water recycling; Wastewater reuse; Sustainable development; Ecological benefits

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1. Context of problem

San Luis Potosí is the 11th most populated metropolitan area in México with more than 1.3 million people. San Luis Potosí was founded on a semi-arid region with less than 400 mm of the annual rainfall. Its industrial and economic development has been always related to water availability and water conservation efforts.

Until 2005, the waste water treatment coverage of the city was 32% [1] and the raw waste water discharge replenished some storm basins and degraded wetlands or was used in the crop irrigation without further treatment.

As many places in México, and most developing economies, unplanned raw waste water reuse causes many problems, especially in seriously hydric stressed regions with low water availability vs. an important demand for economic growth.

During the 1980s and 1990s, the industrial and services sectors developed rapidly in the city. This growth increased not only the drinking water demand but also the need for energy that aggravated the water availability problem. The aquifer was then the main source to meet the demand with extractions near to 127 Mm^3 (Million cubic meters) per year. The overdrafting reached 43 Mm^3 in the year 2000 (approximately 50% above the natural recharge rate). Groundwater provided 76 Mm^3/year of potable water and 35 Mm^3/year for irrigation, and the industrial water requirements were near to 16 Mm^3 with a very high conflict rate and competition between uses.

Before Degremont's project began operations, the "Tenorio" reservoir received raw wastewater from the sewage system of the San Luis Potosí capital city, where mostly agricultural users battled for it and its nutrients. These situations were aggravated by a growing demand of water for industrial use and the environmental degradation on site.

2. Project scope

The main objectives of the "Tenorio" project were to increase the coverage of waste water treatment in the metropolitan area of San Luis Potosí up to 85% and that the reclaimed water would contribute also to augment water availability for potable supply, water quality for agriculture production, and the possibility to supply the industry with an alternative reused source.

The project scope included the following:

- Construction, operation, and transfer of a municipal wastewater treatment facility with a total capacity of 90,720 m^3/day,
- five main sewage collectors (18.9 km) (Fig. 1),
- bringing into water quality compliance more than 400 hectares of irrigation systems,
- 38 km of purple distribution line and one 4000-m^3 regulation tank that allows the reuse of the tertiary effluent into the cooling towers of the power plant of Villa de Reyes, and
- the restoration of the one-million-square-meter reservoir called Tenorio turning it into a controlled artificial wetland. The Tenorio wetland would polish most of the treated water.

3. Description of innovation

The Tenorio Project is the first one of its type in Mexico making possible planned water reuse for industrial and agricultural purposes, ground water replenishment, and environmental restoration using a reservoir that functions as an engineered artificial wetland called Tenorio Tank.

The Tenorio wastewater treatment plant (WWTP) designed for a total capacity of 1,050 l/s (90,720 m^3/day) process design and construction include the following (Fig. 2):

(a) Pretreament and an advanced primary treatment enhanced with chemicals for the whole capacity.
(b) Natural engineered treatment and polishing for at least 600 l/s (51,840 m^3/day) to the Tenorio reservoir for agricultural reuse.
(c) Secondary treatment with activated sludge and nitrogen removal, and tertiary treatment with lime softening, filtration, and chlorine disinfection for a total capacity 450 l/s (38,880 m^3/day) for industrial reuse in cooling towers in the power plant of Villa de Reyes.

At present, the Tenorio WWTP (Picture 1) treats 950 l/s (82,080 m^3/day). In industry with an excess capacity for the power plant that can double its production rate as needed, 250 l/s (21,600 m^3/day) is reused and 700 l/s (60,480 m^3/day) is treated through the agricultural reuse facilities.

In the Tenorio wetland, once the artificial flow-control structures were completed and it received the effluent of the Tenorio Plant, the native plants population began its natural restitution process and the natural water treatment process was established improving its quality significantly.

The productivity of the wetland has reached approximately 20 Mm^3/year, and it provides more than one-third of the water supply for the irrigation,

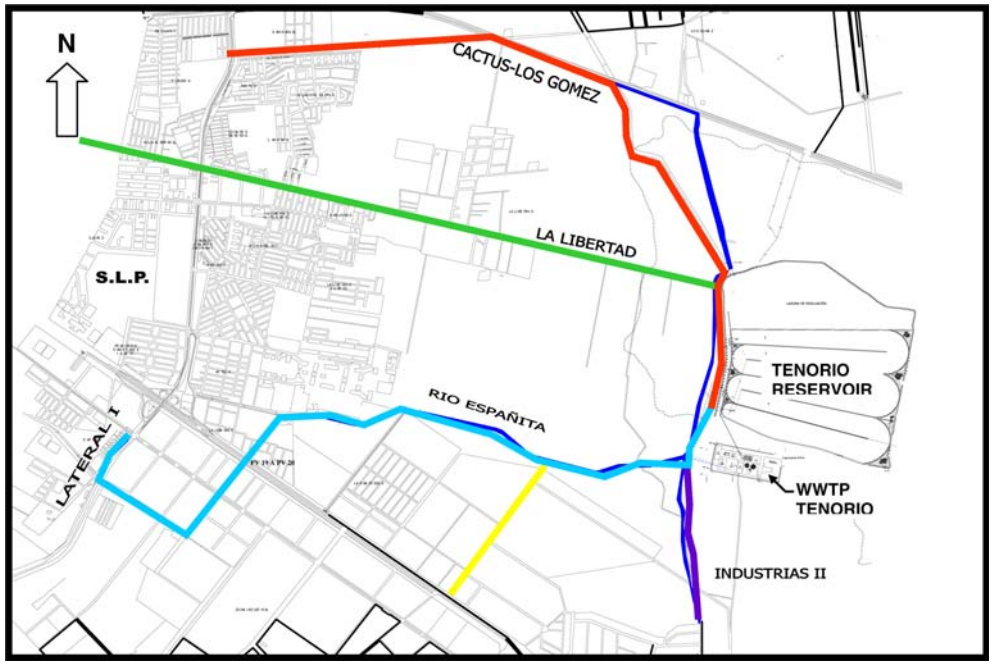

Fig. 1. WWTP and Tenorio reservoir [2,3].

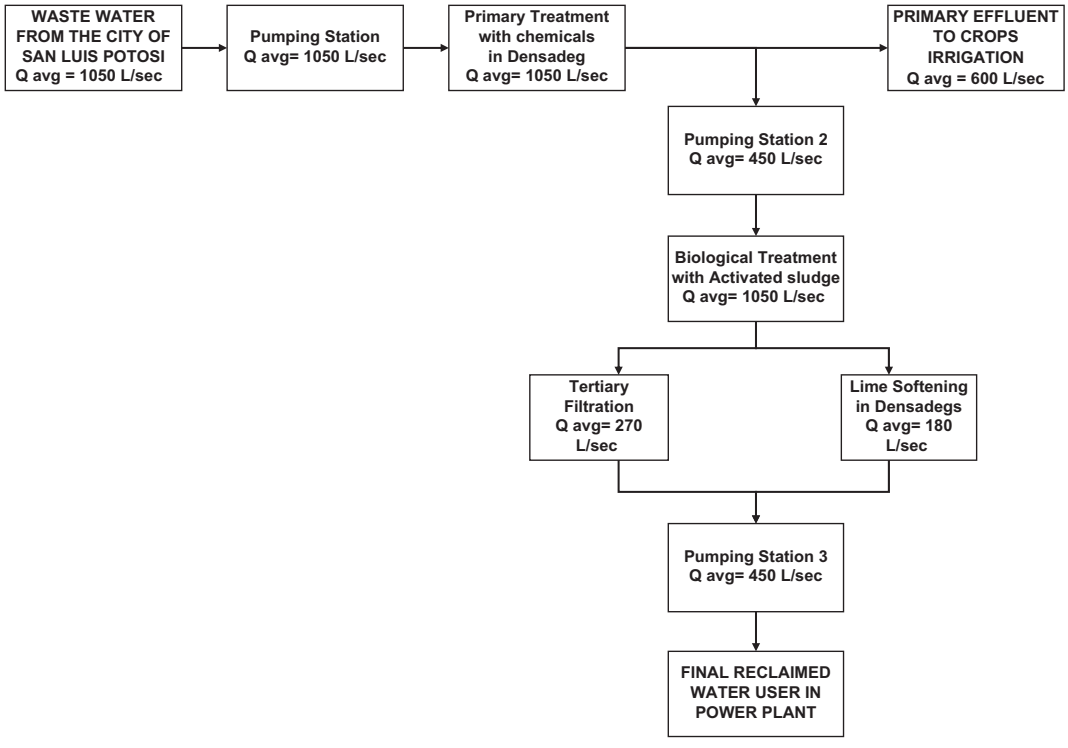

Fig. 2. Flow diagram of the treatment process [4].

enabling farmers to use advanced pressurized irrigation systems and growing more valuable crops and safety for their consumers. Also, the wetland enabled new and safe habitats for plants and animals to develop as the wetland absorbs excess nutrients, sediments, and other pollutants before reuse.

In the spring or 2010 (Picture 2), it was documented the presence of *Daphnia*, organism com-

Picture 1. Tenorio municipal waste water treatment plant.

monly used as a bio-indicator for toxicity tests in sensible environments. These findings confirmed the absence of toxic substances and the successful removal of them by the treatment systems put in place.

During the last 3 years, the number of migrating birds using the wetland as a natural reserve has increased, and several species of birds have been observed to rest, feed, and nest during their cross-continental journeys. Currently, wildlife is sound and present year-round, and wetland aquatic ecosystems have been restored making el Tenorio one of the most important nesting sites in the region for several migratory bird species (Picture 3).

4. Results proven

The project has been in operation for 5 years, and so far, it has reached almost 90% of the plant capacity in terms of municipal wastewater treatment.

At present, the power plant only uses 55% of the installed capacity for industrial reuse supply and the

Picture 2. Tenorio reservoir and the surrounding irrigated areas with reclaimed water.

Picture 3. Migration birds.

project has contributed with the augmentation of 7.8 Mm^3 per year for drinking water availability. It is expected that these figures may double as the power and water needs grow in the near future due to population and economic growth of the metropolitan area.

The industrial reuse has contributed to reduce in almost 40 Mm^3 ground water demand in 5 years of operation. Savings are equivalent to 33% of the potable water deficit in the metropolitan area of San Luis Potosí in the next 20-year planning horizon.

The main quality indicators of the reclaimed and produced water have been monitored during the last years, especially BOD, COD, TSS, nitrogen, and fecal coliforms behaviors. In the last 5 years, significant impacts over the restoration of the Tenorio wetland and regional ecosystems were evident.

Table 1 summarizes the water quality analysis done over the influent and effluent of the Tenorio reservoir.

Table 1
Water quality analysis in Tenorio reservoir

Monthly average 2009–2010			
Parameter	Primary effluent	Tenorio effluent	Units
TSS	66	23	mg/l
TP	5	6	mg/l
COD	157	81	mg/l
BOD	81	35	mg/l
NTK	25	22	mg/l
Fecal Coliforms	10,092	627	C/ 100 ml

Degremont has been working with local authorities to protect the wild life in the Tenorio Reservoir and it is expect that in collaboration with local universities and environmental agencies to launch in the near future different programs to continue promoting the preservation of the restored ecosystem.

In terms of reclamation of wastewater for industrial usages, considering that the WWTP can produce more high quality water, Degremont has been promoting with the local agencies the utilization of the extra capacity in other industries located in the San Luis Potosí Metropolitan Area. Table 2 summarizes some of the main parameters of the treated water sent to the power plant of Villa de Reyes.

Table 2
Quality analysis of the reclaimed water sent to the power plant for cooling towers

Monthly average 2007–2010			
Parameter	Municipal influent	Reclaimed effluent	Units
TSS	188	3.8	mg/l
TP	8.5	1.3	mg/l
COD	514	15.9	mg/l
BOD	268	2.9	mg/l
NTK	32.6	1.5	mg/l
Fecal Coliforms	1.49E+10	22.7	C/100 ml
Total hardness	108	104	mg/l as $CaCO_3$
Silica	102	64.8	mg/l

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