



Assessment of the adverse environmental effects of the Zimapán Dam, Mexico

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Abstract

The Zimapán dam is an hydroelectrical project with an area of 23 km². It is located between the Hidalgo and Querétaro states. The dam receives more than 22 m³/s of untreated wastewater coming from Mexico City and other two industrial cities, Tula and San Juan del Rio. The reservoir is placed over fractured cretaceous limestones and volcanic rocks. There are evidences of water-rock interactions. Some springs below the dam were reactivated. Induced microseismicity is observed in the area. Earthquakes, 2-3° Richter are reported.

Tilapia fish was introduced in this reservoir. The quality of water could provoke the presence of pathogen microorganism and metals in the fish. More than 6,000 ton/year are fished out and distributed to Mexico City markets. Inhabitants of small settlements located around the dam are the group most at risk because they consume the fish during long periods of time. Even though the establishment of wastewater treatment plants is the solution, there are technical, economical and social problems that complicate their implementation.

1 Introduction

The Zimapán Dam is located between the States of Hidalgo and Querétaro, in central Mexico. The dam is located 130 km away from Mexico City. The artificial lake has an area of 23 km². The maximum estimated capacity is 1,360 x 10⁶ m³. The estimated power capacity is 1,292 GW/year. The dam is located in the Infiernillo Canyon (fig 1). The arch dam is 207 m high, 122 m in length along the top arch and 46 m in length at the bottom arch. The reservoir is placed



over fractured cretaceous limestones and volcanic rocks. These rocks are affected by two big falls, Cajon and Tula falls. 50-cm karst cavities were found into the canyon walls.

The main dam tributaries are the Tula and San Juan rivers. The Tula River receives the excess of the untreated urban wastewater generated in Mexico City that is not used for irrigation in the Mezquital Valley. Mexico City contributes with more than $25 \text{ m}^3/\text{s}$ wastewater to the Tula River. San Juan river drains the wastewater from two industrial cities, Tula and San Juan del Rio. In Tula is located one of the main petrochemical plants. San Juan del Rio is one the main industrial centers of the State of Queretaro. In this industrial site there are chemical, metal, textile and wine industries. The Tula River contributes with $20 \text{ m}^3/\text{s}$ to the dam, whereas the San Juan River provides only $2 \text{ m}^3/\text{s}$.

After the dam, the Tula River changes the name to Moctezuma River. This one continues to the Gulf of Mexico as Pánuco River.

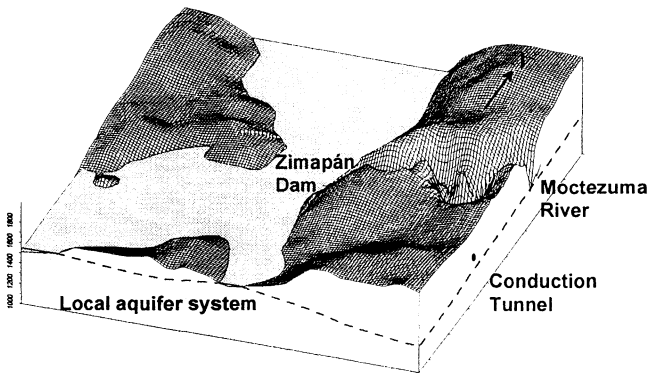


Figure 1 Zimapán Dam

2 Potential environmental affectations

A dam always represents environmental changes, specially when receives urban and industrial wastewaters. The dam water quality increases its nutrient concentration, mainly in phosphates and nitrogen compounds, which could produces eutrofication. Chemical analyses of the San Juan and Tula rivers reveal the presences of lead, mercury and cadmium in their waters (Palacio *et al*¹). The total dissolved solids and oxygen demands are also highs.



The recreational use of the reservoir is restricted. Acute consumptions of water with high contents of pathogen microorganisms can provoke gastrointestinal diseases. There are not analytical evidences of hydrocarbons neither organic compounds as solvents in the dam water, but in September 98, 500 m³ of gasoline were detected floating over the Tula River (ACQUIM²).

Tilapia fish was introduced in this reservoir, even though in Mexico fishing is forbidden in this type of artificial lakes. The quality of the water could provoke the presence of pathogen microorganism and metals in tilapia (Allen³). More than 6,000 fish tons of fish a year are distributed to Mexico City markets (Rodriguez *et al*⁴). Inhabitants of small settlements located around the lake are the group most at risk because they have been consuming this fish during long periods of time.

There are also evidences of water-rock interactions. Fractured limestones presented conditions to be attacked by the CO₂ originated by the organic matter decomposition. Karstification process enlarges fracture and cavities in carbonate rocks. In the dam nearness, Foyo and collaborators⁵ detected more than 2,000 fractures and 200 karst fractures. After the dam filled, infiltrations over the canyon walls, very close to the dam, are appearing. Some springs below the dam were also reactivated. These phenomena were expected due to the load of organic matter in the water and to the increase in hydraulic load. Induced micro seismicity is observed in the area. Small earthquakes, 2-3° Richter, are often reported. Earthquakes of greater magnitude were reported to the north of the dam.

A conduction tunnel 26 km length was drilled into the carbonate rocks from the dam to the power generation installations (fig 1). This tunnel drained a perched aquifer located over it. The aquifer was the only one water supply source of the La Ortega inhabitants. After the tunnel building, a spring associated to the aquifer disappeared. La Ortega is pumping water from a mining area located 700m down from the village. The water quality corresponds, as expected, to mining water. The Federal Commission of Electricity, CFE, financed these works.

3 Remediation alternatives

Even though the establishment of wastewater treatment plants is the solution, there are technical, economical, political and social problems that complicate their implementation. This remediation program implies changes in the water management policies. Most of settlements conduct their wastewaters without any treatment to small streams and non-impearmebilized channels. They will need new sewage pipelines and landfills for the final disposal of the treatment plants muds.

Municipalities need strong federal support for such works. They can not be self-sufficient, the price of water in Mexico is symbolic, in small localities the price is not more than .20 US dolls. *per* m³. It will be very complicated to increase the water price. People believe that wastewater treatment is included in their taxes.



In some cases the re-use of treated wastewater in agriculture and industry could reduce aquifer overexploitation. In Mexico City reductions in groundwater abstraction means less subsidence.

Mexico City, the main contributor, must increase its wastewater treatment capacity. The treatment of more than 20 m³/s require large spaces and funds, both of them not available. It will be also necessary to built separate pipelines for sewage and rainwater. The mixture of both kind of water complicates its treatment.

Small reservoirs along the rivers can reduce the contaminant and sediments load of the rivers. Its function is not only to retain sediments, but part of the dissolved nutrients are transformed to suspend matter, and under anoxic conditions denitrification could occur.

Even in the case that all the water conducted to the dam be treated, the 1,360 x 10⁶ m³ of the reservoir will require dozen of years to be renewed. If physical and chemical conditions change, desorption processes can occur in the river and dam sediments. All these works must guarantee the water supply for the Dam operation.

Tilapia fishing must be forbidden meanwhile an assessment of the potential risks associated to its consumption is done. Maybe metals in fish meat are not the problem, but the pathogen microorganism can produce acute diseases. Poor people living around the lake must have other options for work and food.

4 Discussion and conclusions

The adverse environmental affectations related to the Zimapán Dam are consequence of economical, political, environmental, and social complex factors. The management of water in Mexico City illustrates the situation. 60 m³/s are supplied to Mexico City. 15 m³/s correspond to external sources. Pipeline leakages are estimated in 20-40 %. Same percentage is calculated for sewage. Then, the wastewater generation is estimated in 29 m³/s, from which, only 5 m³/s are treated. The rest is conducted out of the Valley, although Mexican water regulations restricted the use of wastewater for irrigation, this water is used for irrigation along the river.

The establishment of treatment plants represent a serious inconvenient for farmers. Wastewater for agriculture is free whereas treated wastewater will have a price. Regional water authorities must discuss with farmers the possible changes in water use policies. Besides, the organic material content reduces also the fertilizer application. Some crops irrigated with this water are polluted with pathogens, representing another health problem.

The main problem, which can be detected, is the tilapia consumption. Restrictions in fishing and information campaigns over the health affectations could stop the consumption and the associated risks.

There are not studies related to biota affectations. Perhaps some endemic species are or were endangered. The adverse effects downstream are unknown. The type and intensity of water-rocks interactions must be know to prevent infrastructure damage. It is necessary to carry out specific studies.



5 References

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