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TESI DI LAUREA

Technological innovations suitable for nutrient recovery in Latin America

Modelling of implementation impacts for a case study city

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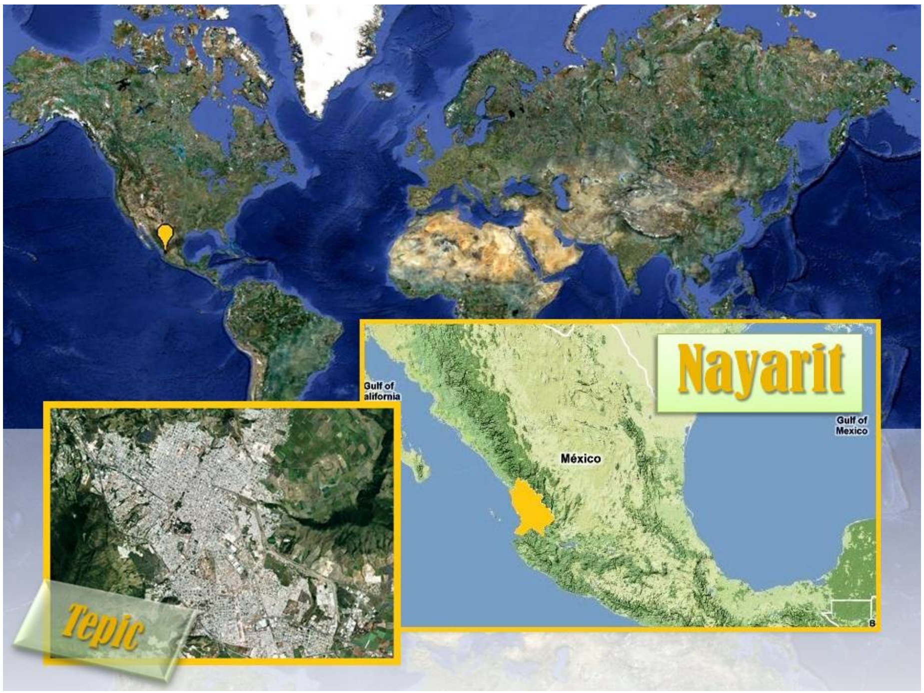
Abstract

This work deals with the design and evaluation of scenarios for improved waste water management in middle sized cities of México considering as case study the city of Tepic, Nayarit. While designing scenarios the first priority is reducing the environmental impact caused by the direct or indirect discharge of wastewater without proper previous treatment. However an important added value to the scenarios might be the recovery of valuable products such as nutrients.



State of Nayarit in Mexico and city of Tepic

The reduced availability of phosphorus generates increasing fertilizes prices. For nitrogen fertilizers, instead, the main production technology is based on the stripping air with a very high energy input. Therefore nowadays, reducing natural resource consumption is very important and nutrient recovery for agriculture is significant, in order to increase energy-efficiency and saving of natural resources. They can make a contribution to environment safeguard and protection.

Nutrient recovery can take place from urban wastewater systems.

By 2050, about 70% of the world's population will live in urban areas. With this increasing urbanization, the problem is to adapt the urban infrastructure to provide an adequate life quality. Sanitation and wastewater infrastructure has not been given high priority in many regions of the world.

In these last years, centralized systems have been built to serve the densely populated areas. Main problems about these systems are the large investment costs. For this reason, in rural areas, the decentralized systems are almost obligatory. The centralized systems transform resources into pollutants such as phosphorus and nitrogen. Another problem is that a small amount of human faeces pollutes a big amount of water. This is a big problem, especially where there is not enough drinking water.

On one side, the use of treated wastewater may be considered as a problem as it involves hygienic hazards, as well as containing organic matter and eutrophying substances in the form of nitrogen and phosphorus that, in high amounts, cause problems in seas, lakes and streams. On the other side, they would be valuable for agriculture purpose. Specially the macronutrients nitrogen, phosphorus and potassium in urine and faeces can be utilized instead of artificial fertilizer produced mostly by fossil resources, they cannot be considered in a long-term perspective.

Decentralisation leads to costs reductions in the waste and wastewater handling. The construction and maintenance of the sewer network, such as pumping stations can be avoided. In decentralized systems, it is possible to separate black and grey water from the households, or also urine and faeces. This is very important because urine contains the main fraction of the nutrients, little COD and hardly pathogens. The yearly per capita contribution to the wastewater is about 4 kg of Nitrogen, about 0,4 kg of Phosphorus and about 1,8 kg of Potassium.

The main steps of this Thesis are:

- Literature research: technological innovations for nutrient recovery in developing countries and newly industrialized countries, especially in mid-tech and low-tech sector;
- Registration of innovations in a catalogue (database);
- Detailed information collection for selected innovations in the catalogue (construction requirements, efficiencies, implementation barriers, investment and operation costs, etc);
- Creation of a matrix summarizing the distinctive features of each technological innovation researched, for later decision making. This decision matrix includes environmental, social and economic aspects;
- Pre-selection of technologies adequate for the case study city by means of the decision matrix;
- Application of one selected technology to the design of a scenario for the case study city and modeling of the impacts by means of Material Flow Analysis.

City of Tepic

Tepic is the capital city of the federal state of Nayarit. It is situated at 21° 31’ north latitude and 104° 54’ west longitude, in Western. It is one of the 203 urban settlements of Mexico and also one of the 117 cities of the country considered as “middle sized cities”, namely with a population number between 100.000 and 1.000.000 of inhabitants. Tepic's population in 2007 was 305.489 inhabitants. In 2030 about 475.411 inhabitants are expected to be living in the city.

The organism that operates the water and the wastewater facilities in the city is called "Sistema de Agua Potable y Alcantarillado de la ciudad de Tepic" (SIAPA Tepic). This organism divided the city in 7 sectors. The water supply is regulated from groundwater sources with 58 shafts (not all of them are active). They are all administered by the SIAPA.

A part of the total population of Tepic is not connected to the water supply service administered by SIAPA, but it receives water from other sources, such as private providers, or directly from the Mololoa river or from the neighbors. This part is the 2% of the total population, about 9508 inhabitants in 2007. Life conditions of people living close to the Mololoa river are shown below.

Conditions of the Mololoa river

Groundwater is the main source of drinking water for the city. The Industrial private water supply and *Other private water supply* represent instead industrial and non-industrial users that extract groundwater from their own wells for its processes.

Another flow of water to the city comes from rains. *Purified water* is a little part of supply and it is represented by the water provided by the water purifying companies, such as bottled water, soft drinks etc.

At the end, the water supply used from the population that is not connected to centralized water system is represented by the *Decentral Water Supply*. This supply is characterized by water of other source. They are used by two main users (processes): households and non-industrial uses, such as public services, restaurants, hotels, etc.

The natural evaporation of rainwater and the rain which infiltrates directly into the soil without being collected in any sewer. The drinking water supplied to the industry is considered in this system as an outflow because all industrial processes were left outside the system boundaries for this project.

Other outflows are the discharges from non-industrial users into the river or into the soil (such as the direct discharges of some hospitals and gas stations), the lost-water through wrong connections, cracked pipes, leakages, and the water dissipated by the human activities offices, commerce such as evaporated water, water lost in watering of gardens and plants and so on.

The wastewater generated from households and non-industrial uses such as restaurants, shops, cinemas, is connected to the *wastewater sewer*. This process collects also a part of the wastewater generated by the industries; the other part is directly discharged into the Mololoa river (unknow volumes). The wastewater sewer process has an outflow represented by the wastewater which goes out from the sewer system into the soil and groundwater bodies due to cracks on the pipes.

From this process, the wastewater goes into the four wastewater treatment plants: *El Punto*, *La Cantera*, *Delicias* and *Forum*, according to their capacities and the rest of the water is discharged to the river.Other direct discharges to the river come from either the rain sewer or illegal discharges. The water, from households not connected to the public service, is relted to the *decentral sanitation* process. The outflow from this process is related to the use of letrines, septic tanks without sludge disposal, uncontrolled discharges, open defecation, etc.

Following inputs were considered: wastewater, wastewater sludge and urine. Each wastewater treatment plant was studied individually choosing a potentially suitable nutrient recovery solution. Adsorption and precipitation are the processes considered for all four treatment plants; the direct application of urine was instead considered for the decentral sanitation.

In both discharge and sludge lines the total percent of nitrogen and phosphorus recovered were calculated, alternating adsorption and precipitation processes.

Scenarios

Three scenarios were studied for this city. In each scenario it was chosen the best technology which, at the same time, should recover the largest amounts for both, nitrogen and phosphorus. The *scenario 1* is characterized by adaption in all the wastewater treatment plants, *El Punto*, *Delicias*, *La Cantera* and *Forum*.

Scenario 1				
WWTP	*El Punto*	*Delicias*	*La Cantera*	*Forum*
$N_{tot\ removal}$ [t/year]	1254.31	167.24	167.24	167.24
$P_{tot\ removal}$ [t/year]	320.53	42.74	42.74	42.74

Nutrient recovery *Scenario 1*

The *scenario 2* is characterized by changes only in the *Decentral sanitation*. In this case the used technology was the direct application of urine.

Scenario 2	
Decentral sanitation	Direct application of urine
$N_{tot\ removal}$ [t/year]	32.00
$P_{tot\ removal}$ [t/year]	3.60

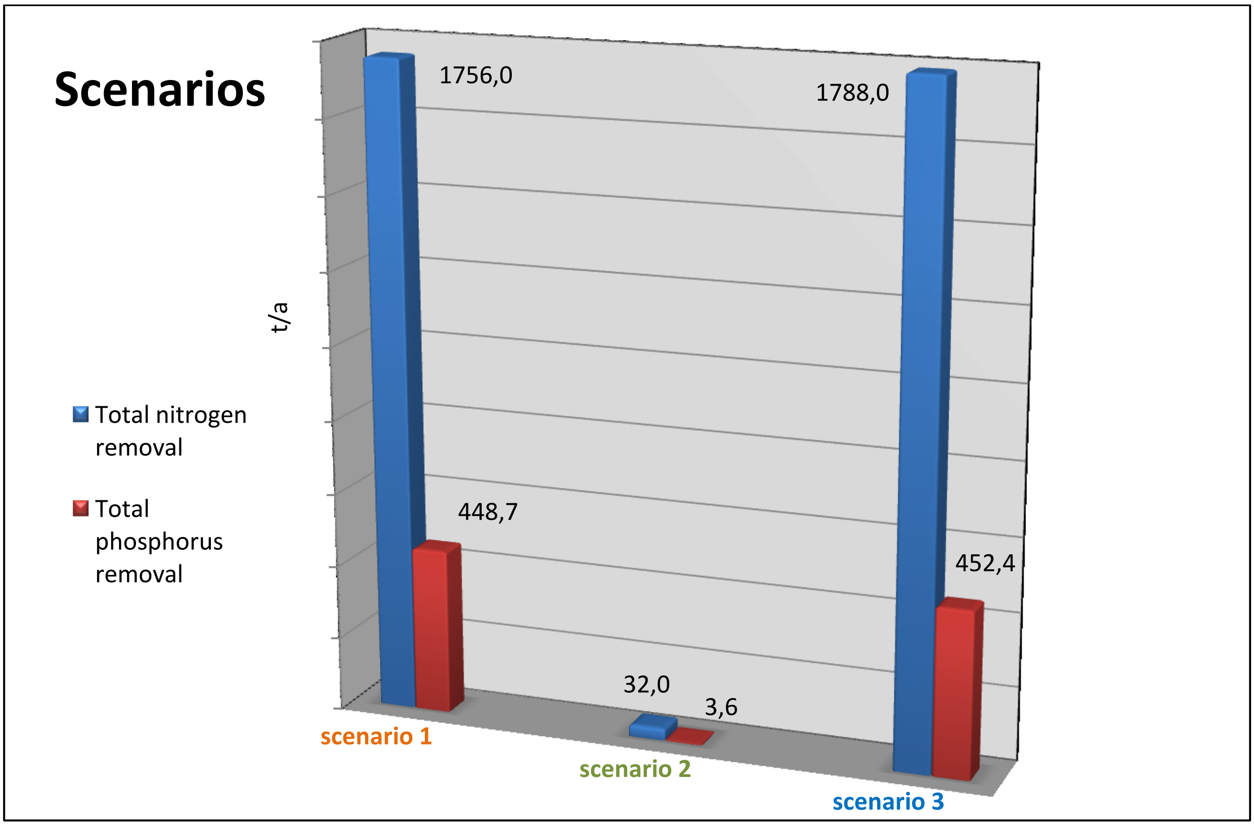
Nutrient recovery *Scenario 2*

The *scenario 3* is characterized by all the wastewater treatment plants, *El Punto*, *Delicias*, *La Cantera* and *Forum* plus the changes in the decentral sanitation. In particular, *Scenario 1* and *Scenario 2* were summed added together.

Scenario 3					
WWTP + Decentral sanitation	*El Punto*	*Delicias*	*La Cantera*	*Forum*	Direct application of urine
$N_{\text{tot removal}}$ [t/year]	1254.31	167.24	167.24	167.24	32.00
$P_{\text{tot removal}}$ [t/year]	320.53	42.74	42.74	42.74	3.60

Nutrient recovery *Scenario 3*

Utilizing the adsorption and precipitation processes in sewage and discharge lines in all four the wastewater treatment plants of the city, and the collection and the direct application of urine in agriculture for the 2% of the population which are not connected to the sewer of the city, it was possible to know the total nutrient recovery in the city of Tepic.



Comparison between Scenarios

Conclusions

The choice of the best configuration depends on many factors. Besides the market value of the fertilizer recovered and its use, an important aspect is the cost factor, such as the costs of construction and operation of the nutrient recovery facilities. For example, precipitation process can be set in tanks which are already present in the treatment plants, such as in the aeration tanks. This is very important because this process does not need other facilities. It is different for the adsorption process which needs, for example, of charged columns for the adsorption and so, larger costs are generated.

Other factors about the best configuration choice can be acceptance problems concerning the use of urine as fertilizer especially if treated (or untreated) wastewater is already being used in agriculture, when there are cultivated fields (as is already happening in many areas of the city) close the treatment plants. This reuse can seem a positive aspect, but it is related to disease transmission, hormone, medicine residues, etc. It can be a dangerous practice for the human health. Furthermore, there are other substances (subproducts) generated during the recovery processes, such as organic and inorganic pollutants. Consequently, these substances have to be treated or disposed. This is another important decisional factor on the processes choice.

Further evaluations can affect the decisions about the best recovery scenario for the city of Tepic. Besides an accurate costs evaluation, as mentioned before, another consideration can concern an assessment on the geographical location of the treatment plants (for example, if there are cultivated fields or industrial areas close to plants), as well as an analysis on the possible economic and demographic development of the city, can be considered as next steps of this research. In fact, with this evaluations, it would be possible to understand which areas will expand, with a consequently increase of wastewater production.

Another assessment could concern a research for local demand for N and P and also a market research on selling price and purchasing of nitrogen and phosphorus recovered around Tepic. Furthermore it would be advisable to interview the population, trying to know what they think about the direct application of urine as fertilizer.