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SUSTAINABILITY, BENEFITS AND SAVINGS IN THE REUSE OF WASTEWATER TO PRESERVE THE REGION'S WATER RESOURCES AND PROTECT THE ENVIRONMENT FOR INDUSTRIAL PURPOSES

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Abstract: In Mexico, much of the wastewater is discharged without treatment, aggravating the situation. This research proposes the reuse of treated wastewater as a viable and sustainable solution. However, several challenges are identified, such as lack of adequate infrastructure, financing and public awareness about this practice. However, a comprehensive approach is proposed that includes:
• Development of Sustainable technologies and Ecotechnologies for a green future: Research and develop more efficient and economical treatment technologies.
• Strengthening governance: Create clear regulatory frameworks and financing mechanisms.
Through a descriptive and analytical analysis, a review of the current situation of water management in Mexico is presented, the main challenges are identified and solutions based on the reuse of wastewater for various uses are proposed, and technologies and technologies are mentioned. Sustainable Ecotechnologies as efficient alternatives. Reusing wastewater can have multiple benefits, such as reducing pressure on water resources, promoting more sustainable development and generating economic savings. In addition, advanced technologies are mentioned as a promising alternative for wastewater treatment. The reuse of treated wastewater is a key strategy to address the water crisis in Mexico. However, a coordinated effort from various actors is required to overcome existing challenges and achieve more sustainable water management. The ``*Tecnológico de Estudios Superiores de Coacalco*`` (TESCo) is positioned as a key player in the search for innovative solutions in this area.
Keywords: water scarcity, reuse, wastewater, Sustainable technologies and ecotechnologies, sustainable management, Mexico.

INTRODUCTION

> "The planet's thirst cries out for radical change."

SCARCITY OF FRESH WATER AND GLOBAL SANITATION AND IN MEXICO REQUIRE INNOVATIVE SOLUTIONS

Wastewater Treatment: Centralized Systems vs Alternative Systems

The Water Crisis and Wastewater Reuse

Freshwater scarcity is a global crisis. Despite its vital importance, this resource is often managed in an unsustainable manner. In Mexico, as in many other countries, a large part of the wastewater is discharged without treatment into bodies of water, aggravating the situation.

The reuse of treated wastewater emerges as an innovative solution to address this problem. By harnessing a resource that is traditionally thrown away, pressures on water resources can be reduced and more sustainable development promoted. However, in Mexico, reuse has not yet been exploited to its full potential.

The Challenge of Reuse in Mexico: Globally, 2.4 billion people lack access to basic sanitation services, which causes more than 80% of wastewater to be discharged into rivers or go directly to the sea without any type of treatment. Latin America invests more in drinking water than in sanitation. They treat only 30-40% of wastewater, with a negative impact on health and the environment (World Bank, 2020).

In Mexico, wastewater is received in treatment plants for the removal of its contaminants, prior to its discharge into bodies of water. Within the hydraulic infrastructure that the country has to provide wastewater treatment by 2015 are the following: 2,477 municipal wastewater treatment plants in operation and 2,832 industrial wastewater treatment plants in operation (CONAGUA, 2016).

Despite the increase in the construction of wastewater treatment plants in the last decade, the demand for their treatment is still not satisfied; In 2016, only 57.02% of the municipal wastewater collected was treated and only 32.85% of the industrial wastewater generated was treated. These percentages are alarming if we think that the rest are discharged into the different bodies of water that supply the city. population for various activities

A New Vision for Water Management: To address these challenges, it is necessary to adopt a more comprehensive and sustainable approach to water management. This implies:

- **Wastewater reuse as a sustainable solution**: Reuse of treated wastewater emerges as a promising strategy to address water scarcity and promote sustainability. However, its implementation in many countries, including Mexico, is still limited.

- **Promote reuse:** Promote the reuse of treated wastewater in various sectors, such as agriculture, industry and municipal services.

- **Develop appropriate technologies:** Research and develop more efficient and economical wastewater treatment technologies, adapted to local conditions.

- **Strengthen water governance:** Establish clear regulatory frameworks and financing mechanisms to promote investment in sanitation and reuse infrastructure.

- **Raise awareness among the population:** Educate the population about the importance of water and the need to use it efficiently and responsibly.

The Role of Natural Technologies, such as constructed wetlands, offer a promising alternative for wastewater treatment in low-income communities. These systems are cheaper to build and operate, require less energy, and can provide additional benefits such as improving water quality and creating habitats for wildlife.

A Sustainable Future: The water crisis requires urgent and coordinated action. By taking a holistic and sustainable approach to water management, we can ensure water security for future generations and promote more equitable economic and social development.

The role of TESCo is positioned as a leader in the search for innovative solutions for water management. Through research, education and collaboration with various stakeholders, TESCo seeks to develop and promote sustainable technologies and practices for water management.

In conclusion, the reuse of treated wastewater is a key strategy to address water scarcity and promote sustainable development. By taking a comprehensive and collaborative approach, we can transform water management in Mexico and ensure a more prosperous future for all.

JUSTIFICATION

FOCUSING ON WATER SCARCITY AND SUSTAINABILITY IN THE STATE OF MEXICO THROUGH THE REUSE OF INDUSTRIAL WASTEWATER

This research contributes directly to the fulfillment of Sustainable Development Goal 6, by promoting the sustainable management of water resources and guaranteeing access to drinking water and sanitation for all. Furthermore, by reducing the water footprint of industries, we contribute to other SDGs such as responsible production and consumption (SDG 12) and climate action (SDG 13).

The growing water scarcity in the State of Mexico, exacerbated by climate change and the increase in industrial demand, requires the adoption of innovative and sustainable solutions. The reuse of wastewater is positioned as a key strategy to mitigate environmental impacts, guarantee the continuity of production processes and contribute to the Sustainable Development Goals (SDGs).

This research focuses on evaluating the technical, economic and environmental feasibility of wastewater reuse in the automotive, aerospace, pharmaceutical, electronics, chemical, textile and food industries of the State of Mexico. These industries, fundamental pillars of the state economy, present a high potential for the implementation of water treatment and reuse technologies.

By promoting the reuse of wastewater, we seek to:

- **Reduce pressure on water resources:** Increasing the availability of water for other uses and preserving aquatic ecosystems.
- **Minimize waste generation:** Reducing the amount of wastewater discharged and the costs associated with its treatment.
- **Improve water use efficiency:** Optimizing production processes and reducing drinking water consumption.
- **Contribute to the circular economy:** Closing water cycles and promoting environmental sustainability.

The results of this research will allow the development of strategies and public policies that promote the implementation of wastewater treatment and reuse technologies in the industries of the State of Mexico, thus contributing to a more sustainable and resilient future.

PROBLEM

Fresh water is scarce on the planet and, yet, sufficient for everyone, the problem is that it is unevenly distributed for geographical, territorial and social reasons. International reports show that the main water governance problem is the lack of wastewater management systems.

Both the availability and use of water are changing.

Concern about the Earth's water resources can be summarized in three key areas:

WATER AVAILABILITY

Water scarcity already affects four out of 10 people (WHO)

2.1 billion people lack access to safely managed drinking water services (WHO/UNICEF 2017)

A total of 4.5 billion people lack safely managed sanitation services

WATER QUALITY

Regarding water quality, the most frequent sources of pollution are human waste, with 2 million tons per day dumped into rivers. Since the 1990s, water pollution has only gotten worse in almost all rivers. from Latin America, Africa and Asia. Water quality is expected to deteriorate further in the coming decades, increasing threats to human health, the environment and sustainable development. Globally, the most common challenge facing water quality is nutrient loading, which depending on the region is often associated with pathogen loading. Hundreds of chemicals also affect water quality. Trends in water availability and quality are accompanied by projected changes in flood and drought risks.

Global water cycle is intensifying due to climate change resulting in related disasters: wetter regions are becoming wetter and dry regions are becoming even drier. The population currently affected by land degradation/desertification and drought is estimated at 1.8 billion people, making it the most significant category of "natural disaster" based on mortality and socioeconomic impact in relation to gross domestic product.

GOALS

GENERAL GOALS

Evaluate the effectiveness of the implementation of eco-technologies and sustainable technologies in the treatment and reuse of wastewater to optimize the use of water resources, minimize environmental impact and promote sustainability in industrial processes in the region.

SPECIFIC GOALS

- Establish the main characteristics of the community under study
- Analyze the legal framework established for wastewater treatment (TAR).
- Carry out the physical, chemical and biological characterization of the wastewater (AR) generated by the community.
- Determine the final uses of water: Possibility of reuse in agriculture, industry or aquifer recharge, and the specific requirements of each application.
- **Determine the benefits:** Qualify the environmental, social and economic benefits of reusing treated **AR**, including reduction of freshwater consumption, protection of aquatic ecosystems and savings in treatment costs.

Case Study:

- Determine the selection criteria for the WWTP proposal.
- Select the wastewater treatment train, which allows the reuse of treated water in the irrigation of green areas, complying with NOM 001-002 and 003-SEMARNAT
- Develop process flow diagrams for wastewater treatment (TAR) in Santa Ma. Cuevas, Zumpango, as well as the material balance.

LEGAL FRAMEWORK

RULES APPLICABLE TO THE PROJECT

It is true that there are companies that carry out wastewater treatment before discharging it into the drain, however it is important to know under what standards the composition of the treated water is regulated in order to conserve ecosystems and care for human health. These standards are found in the **NOM's: NOM-001-SEMARNAT-1996**, which establishes the maximum permissible limits of contaminants in wastewater discharges into national waters and assets; **NOM- 002- SEMARNAT-1996** which establishes the maximum permissible limits of contaminants in wastewater discharges to urban or municipal sewage systems; **NOM-003-SEMARNAT-1997** which establishes the maximum permissible limits of contaminants for treated wastewater that is reused in public services. In the case of treatment plants, there is the following standard: **NOM-004-SEMARNAT-2002** which mentions the specifications and maximum permissible limits for the use and final disposal of sludge and biosolids.

It was based on the **NMX-AA-3-1980** standard for carrying out residual water sampling to determine the physical and chemical characteristics of the problem water.

TREATMENT TRAIN SELECTION

Once the results of the analyzes carried out on the problem AR were obtained, they were compared with NOM-001, 002, 003 and 004-SEMARNAT in order to identify those contaminants present in the AR that exceed the LMP and which must be removed to be able to obtain treated water with optimal conditions for irrigation, as well as the possibility of obtaining biofertilizer for the improvement of green areas and the agricultural sector (Luna, 2017).

STATE OF THE ART

According to the search and presentation of references used for the research, the most important ones are highlighted below.

There are some articles that highlight the importance of the implementation of sustainable technologies for WWTPs, as well as the need for further research and new projects in the biogas utilization sector for the production of electrical and thermal energy.

Below is a table with the 3 basic methodologies for planning water reuse projects that can be used to develop the topic in depth:

METHODOLOGY	PURPOSE
Takashi Asano	It is based on an engineering perspective and visualized to be applied in developed countries.
World Bank	It has a multidisciplinary and interdisciplinary vision, basically aimed at developing countries.
Standish-lee Dog	It continues with the Takashi Asano school, but giving greater importance to social, legal and market aspects.

Table 2: Methodologies for planning and implementing water reuse projects.

Elaborated by Ana Karen Rodríguez, 2020. (Source: Mora C, 2008)

To carry out a conceptual model, it is necessary to visualize what degree of regeneration you want to reach, which is why seven categories have been identified for the reuse of regenerated RA (treated water). These categories are shown below in Table 3.

OPERATIONALIZATION OF VARIABLES

Below, the parameters identified in the AR generated in the domestic sector are listed (CONAGUA, 2016), which constitute the first independent variables in this research, because the concentrations obtained from each parameter will be compared with the maximum permissible limits. of the NOM (001, 002, 003) SEMARNAT; 1996 and this will allow the selection of the corresponding treatment train.

Once the independent variables have been monitored, the RA treatment train proposal will be carried out according to the case study.

ARTICLE	*WASTEWATER REUSE: IMPACT ON THE CHEMICAL AND MACRONUTRITIONAL ATTRIBUTES OF AN INCEPTISOL IRRIGATED WITH TREATED DOMESTIC WASTEWATER*	*SUSTAINABLE INFRASTRUCTURE: WASTEWATER TREATMENT PLANTS*	*THE GOALS OF SUSTAINABLE EVELOPMENT AND THE ACADEMY*
AUTHOR	WOOD C. ET AL.	LAHERA V.	COSME J.
YEAR	2015	2010	2018
MAGAZINE	ENGINEERING AND COMPETITIVENESS	QUIVERA ISSN: 1405-8626	MEDISAN ISSN: 1029-3019
INPUT	According to the cane irrigation tests in an Inceptisol soil, which were carried out by replicas with; Treated Water from a WWTP; Water from an underground well and water with fertilizers, it was shown that groundwater and treated water present similar properties that provide Macronutrients in Sugarcane.	The WWTPs in Mexico Use Polluting Technologies, Because Apart From Having High Energy Consumption, They Produce Toxic Waste. An alternative technology is required that does not generate pollutants and does not intensively use the Energy And Becoming A Sustainable Process.	Importance of Research Needs to Take into Account Sustainable Development Goals in Its Different Careers to Strengthen Knowledge, Awareness and Internationality.

Table 1: Main bibliographical references related to research methodology.

Prepared by Ana Karen Rodríguez, 2020. (Source: Mora C, 2008)

CATEGORIES OF MUNICIPAL WASTEWATER REUSE	REUSE PLACE	POTENTIAL RESTRICTIONS
Agricultural irrigation	Crops Commercial nurseries	Effects due to salts, solids and cultures. Crop commercialization and public acceptance.
Gardening irrigation	Parks school gardens Gardens in streets and public roads golf courses Cemeteries Green areas Residential gardens	Health effects due to pathogenic microorganisms (bacteria, viruses, parasites).
Industrial reuse	Cooling Boilers Water for the industrial process Construction	Corrosive properties of reclaimed water, biological and waste growth. Transmission of pathogenic microorganisms in water due to the aerosol used.
Aquifer recharge	Aquifer recharge Salt intrusion Sinking control	Residues of organic compounds in treated water and their toxic effects. Total dissolved solids, metals and pathogenic microorganisms in the treated water.
Recreational and/or environmental uses	Lakes and lagoons Wetland improvement Increase in ecological flow Aquaculture artificial snow	Risks to public health due to bacteria and viruses. Eutrophication by nitrogen and phosphorus. Bad smell.
Non-potable urban uses	Fire protection Air-conditioning Water for toilets	Possible repercussions on public health caused by the transmission of pathogenic microorganisms by aerosols. Effects on water quality from corrosion, biological growth and waste. Possible blockages in water system pipes.
Potable reuse	Mixing in the water supply Direct connection to the water supply line.	Residues of organic compounds in treated water. Transmission of pathogens including viruses.

Table 3: Categories of wastewater reuse according to Takashi Asano and collaborators.

Elaboration: Ana Karen Rodríguez, 2019 (Source: Mora C., 2008)

INDEPENDENT VARIABLES	DIMENSION	INDICATOR
Total nitrogen	Comply with the LMP established by the NOM (001, 002 and 003- SEMARNAT) at the exit of the TAR system.	NMX-AA-026-SCFI-2010 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
Smell	Identify the characteristic odor of the problem RA	NMX-AA-083-SCFI-2005 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-199
pH	NMX-AA-3-1980	NMX-AA-3-1980 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
Temperature	NMX-AA-3-1980	NMX-AA-3-1980
BOD	Comply with the LMP established by the NOM (001, 002 and 003- SEMARNAT) at the exit of the TAR system.	NMX-AA-028-SCFI-2001 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
COD	Comply with the LMP established by the NOM (001, 002 and 003- SEMARNAT) at the exit of the TAR system.	HANNA Instruments HI 839800 (reactor) and H 83099 (multiparameter) NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
Suspended solids	Comply with the LMP established by the NOM (001, 002 and 003- SEMARNAT) at the exit of the TAR system.	NMX-AA-004-SCFI-2000 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
Settleable solids	Comply with the LMP established by the NOM (001, 002 and 003- SEMARNAT) at the exit of the TAR system.	NMX-AA-004-SCFI-2000 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
Dissolved solids	Comply with the LMP established by the NOM (001, 002 and 003- SEMARNAT) at the exit of the TAR system.	NMX-AA-004-SCFI-2000 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
Fecal coliforms	Comply with the LMP established by the NOM (003- SEMARNAT) at the exit of the TAR system.	NMX-AA-42-1987 NOM-003- SEMARNAT-1996
Mud Production	Obtain residual sludge from problem wastewater.	Obtaining a representative sample
Sludge fermentation and biogas measurement	Quantify the amount of biogas generated by the anaerobic digester at scale.	Volumetric difference

Table 4: Project independent variables

Elaboration: Ana Karen Rodríguez, 2019 (Source: Mora C., 2008)

DEPENDENT VARIABLES	DIMENSION	INDICATOR
Effluent quality	Wastewater treatment system maintenance	LMP-NOM-001-SEMARNAT-1996 NOM-003-SEMARNAT-1996
Treatment train selection	Provide a feasible proposal for the community, which allows the treatment of AR and its reuse in activities with direct contact.	LMP-NOM-001-SEMARNAT-1996 NOM-003-SEMARNAT-1996

Table 5: Project dependent variables

Elaboration: Ana Karen Rodríguez, 2019 (Source: Mora C., 2008)

The objective of this work is aimed at updating the knowledge of researchers in this area about the variables in research and their operationalization. Bibliographic sources were consulted. As a result, the following No's tables have been obtained, which contain, in summary, updated information on the conceptualization of the variable construct, its classification and operationalization process in research on new wastewater treatment proposals.

The material that is made available is characterized by the topicality of its contents, which corresponds to some of the contributions given by the scientific community that studies the topic in question.

The variables intervene as cause or effect in the research process. The variables to be investigated are identified from the moment the problem is defined.

The hypothesis, the scientific questions or questions, or the idea to be defended, establish that aspect that characterizes the relationship of the object and the problem.

Variables are factors that intervene either as a cause or as a result within the process or phenomenon of reality, forming an essential part of the research structure.

This section summarizes theoretical aspects that support the importance of determining the variables that will intervene in an investigation of this type.

For Chcón (2017), a variable is operationalized in order to convert an abstract concept into an empirical one, capable of being measured through the application of an instrument. This process is important in the possibility that a less experienced researcher can be sure of not getting lost or making errors that are frequent in a research process, when there is no relationship between the variable and the way in which it was decided to measure it, thus losing the validity (degree to which empirical measurement represents conceptual measurement). Precision in defining terms has the advantage of accurately communicating results.

Medina (2014), defines operationalization as the process by which a complex theoretical variable is transformed into empirical, directly observable variables, so that they can be measured. From a more technical point of view, operationalizing means identifying what the variable is, what its dimensions are and what the indicators and index are (or, what is the same, defining it theoretically, really and operationally), since all this will allow us translate the theoretical variable into observable and measurable properties, descending increasingly from the general to the singular.

According to what was expressed by the two cited authors, there is agreement in explaining and applying what it means to operationalize the variables. Below, the parameters identified in the AR generated (CONAGUA, 2016) are listed, which constitute the first independent variables in the present research, because the concentrations obtained for each parameter will be compared with the maximum permissible limits of the NOM (001, 002, 003) SEMARNAT- 1996 and this will allow the selection of the corresponding treatment train.

THEORETICAL FRAMEWORK

PHYSICAL CHARACTERISTICS

Wastewater has specific characteristics; table 3.2 below shows the physical properties that can be found in RA once the characterization has been carried out (Morán,2015).

As it can be seen in the table above, one of the main characteristics of wastewater is solid materials, from the smallest to the thickest. Larger solids are generally removed at the beginning of the treatment train.

Total solids (ST): It refers to the residues remaining after the sample has been evaporated and dried at a temperature ranging from 103 to 105 °C. Total **suspended solids (TSS):** are the TS that have been retained in a filter (specific diameter) half an hour after it has been dried at a specific temperature. **Settleable solids:** refers to suspended solids determined in millimeters per liter, which settle within a specific time range.

Total dissolved solids: They are the solids that pass through the filter, which are evaporated and dried at a specific temperature, the rest comprises colloids and SD. The colloidal fraction refers to particles whose diameter is between 10-3 and 1 micron. These particles cannot be eliminated through the sedimentation method, since they comprise

PARAMETERS	INDICATOR		DIMENSION	UNITS	OBSERVA-TIONS	ANALYTICAL METHOD
	LMP-NOM-00X	LMP NOM-00X				
x_1	[Inf1…	… sup1]	X_1	Corresponding to the Standard	Interpretation 1	NOM-00 x_1
x_2	[Inf2…	… sup2]	X_2	Corresponding to the Standard	Interpretation 2	NOM-00 x_2
x_3	[Inf3…	… sup3]	X_3	Corresponding to the Standard	Interpretation 3	NOM-00 x_3
…	[Inf… …	…sup…]	…	Corresponding to the Standard	Interpretation…	NOM-00…
…	[Inf……	…sup…]	…	Corresponding to the Standard	Interpretation…	NOM-00…
x_n	[Infn…	…supn]	X_n	Corresponding to the Standard	Interpretation n	NOM-00 x_n

Table 6: Operationalization of applicable theoretical variables

Own elaboration (2024)

PARAMETERS	INDICATOR		DIMENSION	UNITS	OBSERVA-TIONS	ANALYTICAL METHOD
	LMP-NOM-001-SEMARNAT-1996	LMP NOM-003-SEMARNAT-1996				
pH	[Inf1…	… sup1]	NMX-AA-3-1980	dimen-sionless	INSIDE/ OUT	NMX-AA-3-1980 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
Tempera-true	NA	NA	NMX-AA-3-1980	°C	INSIDE/ OUT	NMX-AA-3-1980
DBO	[Inf1…	… sup1]	Comply with the LMP established by the NOM (001, 002 and 003- SEMARNAT) at the exit of the TAR system.	ppm	INSIDE/ OUT	NMX-AA-028-SCFI-2001 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
DQO	[Inf1…	… sup1]	Comply with the LMP established by the NOM (001, 002 and 003- SEMARNAT) at the exit of the TAR system.	ppm	INSIDE/ OUT	HANNA Instruments HI 839800 (reactor) and H 83099 (multiparameter) NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
Total Phos-phorus	[Inf1…	… sup1]		ppm	INSIDE/ OUT	
Fats and Oils	[Inf1…	… sup1]		ppm	INSIDE/ OUT	
Total Nitrogen	[Inf1…	… sup1]	Comply with the LMP established by the NOM (001, 002 and 003- SEMARNAT) at the exit of the TAR system.	ppm	INSIDE/ OUT	NMX-AA-026-SCFI-2010 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
Sedi-mentable Solids	[Inf2…	… sup2]	Comply with the LMP established by the NOM (001, 002 and 003- SEMARNAT) at the exit of the TAR system.	ppm	INSIDE/ OUT	NMX-AA-004-SCFI-2000 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
Dissolved Solids	[Inf3…	… sup3]	Comply with the LMP established by the NOM (001, 002 and 003- SEMARNAT) at the exit of the TAR system.	ppm	INSIDE/ OUT	NMX-AA-004-SCFI-2000 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
Total Suspended Solids	[Inf… …	…sup…]	Comply with the LMP established by the NOM (001, 002 and 003- SEMARNAT) at the exit of the TAR system.	ppm	INSIDE/ OUT	NMX-AA-004-SCFI-2000 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
Fecal Coli-forms	[Inf……	…sup…]	Comply with the LMP established by the NOM (003- SEMARNAT) at the exit of the ART system.	(MPN/ 100ml)	INSIDE/ OUT	NMX-AA-42-1987 NOM-003- SEMARNAT-1996

Table 7: Operationalization of case study variables (Theoretical)

Own elaboration

PARAMETER	CHARACTERISTICS	IMPORTANCE
COLOR	The cause of wastewater having color is due to suspended solids, also called "apparent color" and dissolved substances and colloidal matter, which is called "true color".	The color of the water is used to estimate the general condition of the water.
SMELL	The odor presented by wastewater is generated by compounds that are released when biological degradation takes place under anaerobic conditions (without the presence of oxygen).	One of the main compounds that causes bad odor is hydrogen sulfide.
SOLIDS	Larger solids are generally removed at the beginning of the treatment train.	Total solids (ST) Total suspended solids (TSS) Settleable solids (SD) Total dissolved solids (TDS)
TEMPERATURE	Generally, the temperature of the waste water is higher than that of the supply water, since the water from domestic discharges is hot.	Temperature measurement is very important, because in treatment systems there are biological processes in which microorganisms require a specific temperature to be able to degrade organic matter correctly.
TURBIDITY	It relates to the suspended material and is generally used to determine at a glance the quality of both natural and wastewater.	The suspended material prevents the passage of light, the greatest turbidity is related to particles smaller than 3 µm, especially particles between 0.1 and 1.0 µm
CONDUCTIVITY	The conductivity value is commonly used for water analysis to obtain a quick estimate regarding the content of dissolved solids.	The importance of determining this parameter is to identify if the wastewater can be used for irrigation.

Table 8: Physical properties in wastewater.

Elaboration: Ana Karen Rodríguez, 2019 (Source: source: Morán, 2015).

CHEMICAL CHARACTERISTICS	DESCRIPTION
pH	The optimal pH value for life to develop is 5-9, wastewater that has a value less than 5 and greater than 9 requires more complicated treatment using biological agents. If the pH of the wastewater is not adjusted before being discharged back into a body of water, the pH of that body of water will be altered; hence the need for effluents from WWTPs to have a pH value between permissible values.
Dissolved oxygen	As it is well known, the main source that provides oxygen to wastewater is air, due to turbulence in water bodies and this causes air diffusion to occur. The oxygen values present in water vary from 7 to 9 mg/L. When the amount of oxygen dissolved in the AR is determined, an estimate can be obtained about the amount of oxidizable organic substances within it.
Fats and oils	Both fats and oils that come from plant or animal origin are similar, basically they are esters that are made up of fatty acids, alcohol and glycerin. Oils are those that are in a liquid state at room temperature.
Nitrogen	Nitrogen is an important element for protein synthesis. It is a parameter that is determined in order to know the treatment that can be given to RA through biological processes. Ammoniacal nitrogen, nitrites, nitrates and organic nitrogen can be found in water.
Phosphorus	Like sulfur and nitrogen, phosphorus is also found naturally, as it helps the growth and development of organisms found in a body of water. As mentioned above, excessive amounts of some elements can be harmful, and the same thing happens with phosphorus, because when greater than normal amounts are found, it causes the proliferation of algae. The most common ways in which phosphorus can be found in AR are; orthophosphates, polyphosphates and organic phosphorus.

Table 9: Chemical properties of RA.

Elaboration: Ana Karen Rodríguez, 2019 (Source: source: Morán, 2015).

inorganic and organic molecules and ions which are dissolved in the water. Generally, to eliminate this type of particles, the coagulation method is carried out and subsequently, once the clots (larger particles) have formed, they are eliminated with the corresponding secondary sedimentation equipment.

CHEMICAL CHARACTERISTICS

There are some other chemical characteristics that must be taken into account when characterizing the AR (Soto F., 2010).

BIOLOGICAL CHARACTERISTICS

These characteristics are extremely important in the treatment of RA, since there are pathogenic organisms from human activities, due to the proliferation or development of bacteria and other decomposing microorganisms that can cause diseases.

BIOLOGICAL CHARACTE-RISTICS	DESCRIPTION
BACTERIA	They are important in the process of decomposition and stabilization of organic matter.
CHEMICAL OXYGEN DEMAND (COD).	It refers to the amount of oxygen that water requires to chemically oxidize organic matter. Oxidation degrades biodegradable and non-biodegradable organic material.
BIOCHEMICAL OXYGEN DEMAND (BOD).	It is one of the most used parameters in wastewater as it determines the dissolved oxygen used by microorganisms for the biochemical oxidation of biodegradable organic matter, that is, it determines the approximate amount of oxygen required to biologically stabilize the organic matter.

Table 10: Biological Characteristics of RA.

Own elaboration (Source: Ramalho R, 2003).

SUSTAINABLE TECHNOLOGIES AND ECOTECHNOLOGIES FOR A GREEN FUTURE

The following table lists the most common treatment methods, as well as their removal percentages.

CASE STUDY

In the case study "Methodology for the Proposal of a Sustainable Wastewater Treatment Plant. SMR Cuevas, Zumpango, Edo. From Mex.", the following operationalization of variables was obtained.

The methodology presented is exploratory, descriptive, investigative and explanatory, since it is an area that has not been studied, the current situation of the place is described, investigative because a characterization of the problem water was carried out, it will be documentary (it consists of collect background and information about the object of study or the topic to be developed from books, magazines and other publications).

RESULTS AND DISCUSSIONS

CHARACTERIZATION OF WASTEWATER

After analyzing the problem waters, the results of each analyzed parameter were obtained and a comparison was made with the LMP (Maximum Permissible Limits) of the reference standards taken for the use of treated water (001 and 003 SEMARNAT).

As it can be seen in the previous table, some of the parameters are not considered in the maximum permissible limits (LMP), however, there are two parameters in which the LMP are exceeded; In the problem water it has a value of 534 mg/L and the LMP is 20 mg/L, the value of fats and oils is 49 mg/L when the LMP is 15 mg/L. Likewise, the value of settleable solids in the problem water is 4.9 mg/L, while the

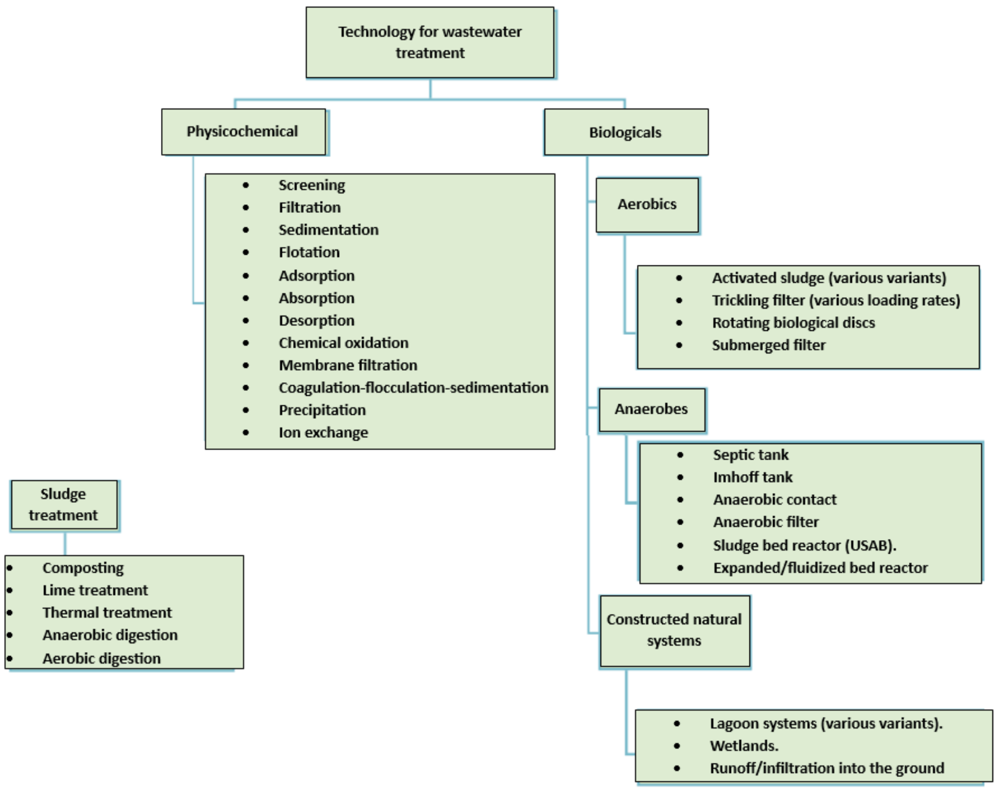

Figure 1: Technologies for wastewater treatment

(UNAM, 2013)

Process	Emotional Efficiency							
	SS	DBO	DQO	NH_3	Norg	NO_3	PO_4	STD
Chemical precipitation.	60-80	75-90	60-70	5-15	60-50		90-95	20
Chemical precipitation in activated sludge	80-95	90-95	85-90	30-40	30-40	30-40	30-40	10
Ionic exchange		40-60	30-50	85-98	80-95	80-90	85-98	
Electrochemical	80-90	50-60	40-50	80-85	80-85		80-85	
Electrodialysis				30-50		30-50	30-50	40
Chemical oxidation		80-90	65-70	50-80				
Reduction						NO3-NH3		
Bacterial assimilation	80-5	75-95	60-80	30-40	30-40	30-40	10-20	
Denitrification						60-95		
Lagoons		50-75	40-60	50-90	50-90	50-90	50	
Nitrification - denitrification						60-95		

Ammonia removal				85-98				
Filtration								
Multiple	80-90	50-70	40-60		20-40			
Diatom	95-99							
Microfilter	50-80	40-70	30-60		20-40			
Distillation	99	98-99	95-98		90-98	99	99	95-99
Flotation	60-80				20-30			
Freezing	95-98	95-99	90-99		90-99	99	99	95-99
Gas phase				50-70				
Soil expansion	95-98	90-98	80-90	60-80	80-95	5-15	60-90	
Reverse osmosis	95-98	95-99	90-95	95-99	95-99	95-99	95-99	95-99

Table 11: Approximate removal percentages, according to the treatment process used.
Source: Díaz R. 2013

PARAMETERS	INDICATOR		DIMENSION (RESULT OBTAINED ACCORDING TO THE ANALYSIS)	UNITS	OBSERVATIONS	ANALYTICAL METHOD
	LMP- NOM-001-SEMARNAT-1996	LMP NOM-003-SEMARNAT-1996				
pH			7.8	Adim.		NMX-AA-3-1980 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
Temperature			19.65	°C		NMX-AA-3-1980
DBO		20	534	ppm	OUT	NMX-AA-028-SCFI-2001 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
DQO			940	ppm		HANNA Instruments HI 839800 (reactor) and H 83099 (multiparameter) NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
Total Phosphorus	20		6.7	ppm	INSIDE	
Fats and Oils		15	49	ppm	OUT	
Total nitrogen			26	ppm		NMX-AA-026-SCFI-2010 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
Sedimentable Solids	1		4.9	ppm	OUT	NMX-AA-004-SCFI-2000 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
Dissolved Solids			1153	ppm	OUT	NMX-AA-004-SCFI-2000 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
Total Suspended Solids	150		6.49	ppm	INSIDE	NMX-AA-004-SCFI-2000 NOM-001- SEMARNAT-1996 NOM-003- SEMARNAT-1996
Fecal Coliforms		240	740	(MPN/100ml)	OUT	NMX-AA-42-1987 NOM-003- SEMARNAT-1996

Table 12: Operationalization of Variables applied to the case study.
Own elaboration (Source: Ana Karen Rodríguez, 2020)

LMP say it must be 1 mg/L. In the case of fecal coliforms, there is 740 NMP/100 ml when the LMP is 240 NMP/100 ml. Even when the value of dissolved solids is not above the maximum permissible limits, it is considered a problem to be solved because this amount of settleable solids can cause blockage in the pipes and since the treated water is intended to be used for irrigation of areas. greens, could even generate alkalinization of the soil.

PROPOSAL FOR SELECTED TREATMENT TRAIN

In the case study "Methodology for the Proposal of a Sustainable Wastewater Treatment Plant. SMR Cuevas, Zumpango, Edo. From Mex."; According to the composition of the AR and taking into account the LMP established in NOM-001-semarnat-1996, NOM-002-semarnat-1996 and NOM-003-semarnat-1996, the selection of the teams in the TAR was possible, with the purpose of reducing contaminants that are a problem for obtaining safe treated water (with the necessary quality for its use).

The pretreatment stage will be composed of a screen system and a horizontal flow sand trap. In the primary treatment there will be a rectangular settler. The secondary treatment will consist of an anaerobic reactor, a circular settler, a sludge desiccator and a composting system. Finally, in the tertiary treatment there will be a chlorination tank and storage tank.

The process block diagram is shown below, identifying the unit operations that are carried out throughout the treatment.

CONCLUSIONS

"This research arises as a result of the advice provided to a master's thesis project in environmental systems at TESCo. The close collaboration allowed us to develop a high-quality product, thanks to the importance given to the interaction between those involved. The results obtained are a valuable contribution that can be used by future generations."

ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OF REUSING WASTEWATER

Wastewater reuse is a practice that offers multiple benefits. Environmentally, it reduces pressure on water resources and reduces pollution, protecting aquatic biodiversity and promoting a circular economy. Economically, it generates savings in operating costs, creates new business opportunities and allows for the generation of energy. Socially, it improves the quality of life and encourages greater environmental awareness.

CHALLENGES AND RECOMMENDATIONS

Despite its advantages, wastewater reuse faces challenges. It is crucial to guarantee the quality of treated water for industrial uses, overcome negative perceptions and have a solid regulatory framework. Additionally, continued investment in research and development is required to improve treatment technologies.

In summary, wastewater reuse is a key strategy for sustainability, offering environmental, economic and social benefits. However, its successful implementation depends on overcoming certain challenges and proper management.

BLOCK DIAGRAM OF SELECTED TAR TRAIN SYSTEM

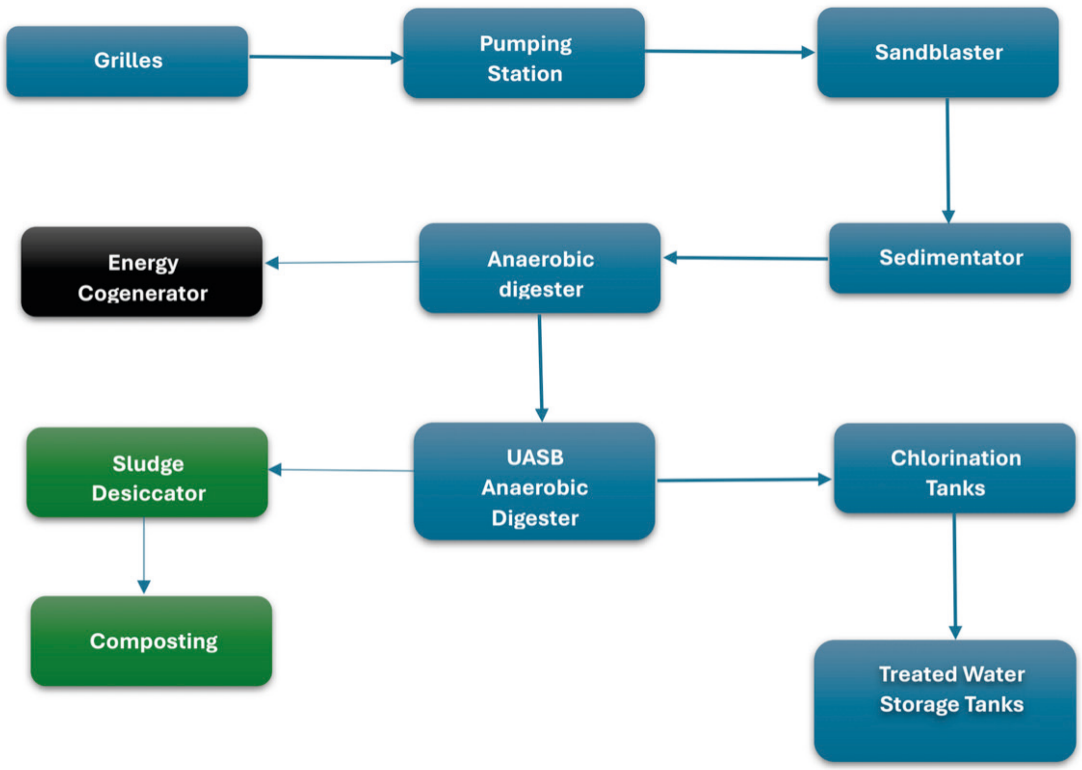

Figure 2: Proposal for the WWTP train system for the case study.

CONCLUSIONS CASE STUDY

According to the characterization of the wastewater, the following were identified as problem contaminants: BOD with a value of 534 ppm, the LMP being 20, and Fats and oils with a value of 49 ppm, the LMP being 15 ppm for the use of wastewater. with direct contact to humans, established by NOM-003-SEMARNAT. Likewise, it was identified that the settleable solids of the problem wastewater contained a value of 4.9 ppm, with the LMP being 1 ppm, specified in NOM-001-SEMARNAT.

The proposed treatment train initially consists of a screen system, which eliminates coarse floating solids, followed by a horizontal flow sand trap, for the removal of sand, subsequently, a primary settler with removal efficiency of 65% for suspended solids, 95% for settleable solids, 42% for BOD and 90% for fats and oils. The following equipment is an anaerobic system with a removal of 80% COD, 70% suspended solids, 80% BOD, 90% helminth eggs and 90% pathogens, it is a system that will allow the methane emitted to be used for the electricity generation. Subsequently, there is a secondary settler with the purpose of eliminating 70% of suspended solids and 38% of BOD. The last treatment equipment is the chlorination tank, which disinfects the water and eliminates up to 90% of fecal coliforms. The treated water will go to a storage tank for later use.

The waste obtained as a result of treatment will be biosolids (sludge), which will be taken to a sludge desiccator and subsequently to the composting system (one of the most economical treatments for biosolids), resulting in a biofertilizer, which will serve as a quality improver. soil of the green areas, both of the WWTP and the community.

REFERENCES

Ana Karen Rodríguez (2020), Metodología Para La Propuesta De Una Planta De Tratamiento De Aguas Residuales Sostenible. SMR Cuevas, Zumpango, Edo. De Mex. Tecnológico de Estudios Superiores de Coacalco.

Comisión Nacional del Agua (CONAGUA) (2016), Situación del subsector agua potable, alcantarillado y saneamiento. Edición 2009, México, SEMARNAT.

Díaz Rafael (2013). Causas y soluciones del problema de olores en las plantas de tratamiento de aguas residuales, UNAM, México.

Morán D. (2014) Diseño de una planta de tratamiento de aguas residuales para el municipio San Juan Chamelco, Alta Verapaz. Guatemala, México.

Norma Mexicana, NMX-AA-003-1983, Aguas residuales. Muestreo, Secretaria de comercio y Fomento industrial, 25 de marzo de 1980.

Norma Oficial Mexicana, NOM.003-SEMARNAT-1997. Que establece los límites máximos permisibles de contaminantes para las aguas residuales tratadas que se reúsen en servicios públicos, Diario Oficial de la Federación, 21 de Septiembre de 1998.

Norma Oficial Mexicana, NOM-001-SEMARNAT-1996, Que establece los límites máximos permisibles de contaminantes en las descargas de aguas residuales en aguas y bienes nacionales, Diario Oficial de la Federación, 23 de Abril de 2003.

Norma Oficial Mexicana, NOM-002-SEMARNAT-1996, Que establece los límites máximos permisibles de contaminantes en las descargas de aguas residuales a los sistemas de alcantarillado urbano municipal, Diario oficial de la Federación, 3 de Junio 1998.

Norma Oficial Mexicana, NOM-014-SSA1-1993, Procedimientos sanitarios para el muestreo de agua para uso y consumo humano en sistemas de abastecimientos de agua públicos y privados, Comité Consultivo Nacional de Normalización de Regulación y Fomento Sanitario, 12 de agosto de 1994

Norma Técnica Estatal Ambiental NTEA-019-SeMAGEN-DS-2017. Que establece las condiciones de protección, conservación, fomento, creación, rehabilitación y mantenimiento de las áreas verdes y macizos arbóreos de las zonas urbanas en el territorio del Estado de México.

OMS/UNICEF, 2005, Water for Life. Ma Ramalho R.S. (2003). Tratamiento de aguas residuales, Reverté. ISBN: 84-291-7975-5. México.

Soto F. (2010) Water hardness as basic indicator the presence fouling in domestic sanitary facilities, ISSN: 14057743. SCIELO, México.

UNAM (2013) Selección de tecnologías para el tratamiento de aguas residuales municipales. Guía de apoyo para ciudades pequeñas y medianas. ISBN: 978-607-02-4822-1 México

UNESCO (2017) Informe Mundial de las Naciones Unidas sobre los recursos hídricos 2017. Aguas residuales desaprovechadas.