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ENVIRONMENTAL IMPACTS OF URBAN WASTEWATER FROM PALMAR SANTANDER ON THE SUAREZ RIVER

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ABSTRACT

The municipality of Palmar is notable for its abundant agricultural activities, which enable the production of substantial quantities of raw materials throughout the year due to its strategic location. However, the productive potential is significantly impacted by unsustainable practices in the development of agricultural and livestock complexes, along with industrial activities and an increase in tourism in recent years. Among the critical environmental challenges contributing to this situation are the inefficient use of water resources and the generation of solid and liquid waste. The economic development of the municipality is hindered by the absence of inclusive environmental education, which is necessary to foster Palmar's competitiveness in line with the principles of sustainable development. Consequently, inclusive awareness strategies were designed to promote the rational use of the identified productive potential. The methodology employed was descriptive based on qualitative and quantitative data. This approach facilitated the development of an environmental baseline, as well as the identification and subsequent assessment of environmental impacts. The study revealed that the municipality possesses significant biodiversity potential. The research identified the most significant environmental impacts of anthropogenic activities on the water source under study primarily due to the presence of wastewater and solid waste in the environment.

Keywords: Water Resource, Natural Ecosystems, Environmental Impacts, Biodiversity, Anthropic Activities.

IMPACTOS AMBIENTALES DE LAS AGUAS RESIDUALES URBANAS DE PALMAR SANTANDER EN EL RÍO SUÁREZ

RESUMEN

El municipio de Palmar se distingue por su abundante actividad agrícola, que permite la producción de cantidades sustanciales de materia prima durante todo el año gracias a su ubicación estratégica. Sin embargo, el potencial productivo se ve significativamente afectado por prácticas insostenibles en el desarrollo de complejos agrícolas y ganaderos, junto con actividades industriales y un aumento del turismo en los últimos años. Entre los desafíos ambientales críticos que contribuyen a esta situación se encuentran el uso ineficiente de los recursos hídricos y la generación de residuos sólidos y líquidos. El desarrollo económico del municipio se ve obstaculizado por la ausencia de educación ambiental inclusiva, necesaria para fomentar la competitividad de Palmar en consonancia con los principios del desarrollo sostenible. En consecuencia, se diseñaron estrategias de sensibilización inclusivas para promover el uso racional del potencial productivo identificado. La metodología empleada fue descriptiva, basada en datos cualitativos y cuantitativos. Este enfoque facilitó el desarrollo de una línea de base ambiental, así como la identificación y posterior evaluación de los impactos ambientales. El estudio reveló que el municipio posee un importante potencial de biodiversidad. La investigación identificó los impactos ambientales más significativos de las actividades antropogénicas en la fuente de agua estudiada, principalmente debido a la presencia de aguas residuales y residuos sólidos en el medio ambiente.

Palabras clave: Recursos hídricos, ecosistemas naturales, impactos ambientales, biodiversidad, actividades antrópicas.

IMPACTS ENVIRONNEMENTAUX DES EAUX USÉES URBAINES DE PALMAR SANTANDER SUR LA RIVIÈRE SUAREZ

RÉSUMÉ

La commune de Palmar se distingue par son agriculture florissante, qui lui permet de produire d'importantes quantités de matières premières tout au long de l'année grâce à sa situation stratégique. Cependant, son potentiel productif est fortement impacté par des pratiques non durables dans le développement des complexes agricoles et d'élevage, ainsi que par les activités industrielles et l'essor du tourisme ces dernières années. Parmi les principaux défis environnementaux contribuant à cette situation figurent l'utilisation inefficace des ressources en eau et la production de déchets solides et liquides. Le développement économique de la commune est freiné par l'absence d'une éducation environnementale inclusive, pourtant indispensable pour renforcer la compétitivité de Palmar conformément aux principes du développement durable. En conséquence, des stratégies de sensibilisation inclusives ont été élaborées afin de promouvoir une utilisation rationnelle du potentiel productif identifié. La méthodologie employée est descriptive et s'appuie sur des données qualitatives et quantitatives. Cette approche a permis d'établir un état des lieux environnemental, ainsi que d'identifier et d'évaluer les impacts environnementaux. L'étude a révélé que la commune possède un important potentiel de biodiversité. La recherche a identifié les impacts environnementaux les plus significatifs des activités anthropiques sur la ressource en eau étudiée, principalement dus à la présence d'eaux usées et de déchets solides dans l'environnement.

Mots-clés: Ressources en eau, écosystèmes naturels, impacts environnementaux, biodiversité, activités anthropiques.

1. INTRODUCTION

Wastewater discharges into water bodies are a matter of international concern due to their significant environmental and social impacts. According to the United Nations (UN), between 80% and 90% of the world's wastewater is discharged without prior treatment, leading to issues such as freshwater contamination, loss of biodiversity, and the spread of diseases (UN-Habitat and WHO, 2021). The United Nations environment Program (UNEP) and the world health organization (WHO) have been actively addressing this issue through several initiatives and guidelines. These efforts emphasize the importance of proper treatment processes, robust monitoring systems, and appropriate regulatory frameworks for the safe management and disposal of wastewater (UN, 2021).

In Latin America, where over 80% of the population resides in urban areas, the situation is particularly challenging. Approximately 70% of wastewater remains untreated, hindering efforts to close the water cycle, especially in terms of water reuse, as water contamination poses a significant problem (Jacobo, 2018). Current challenges, such as insufficient funding for infrastructure development, weak enforcement mechanisms, and limited public awareness of proper wastewater management, persist globally, including in countries like Colombia.

According to the national planning department (hereinafter DNP), in 2017, Colombia generated 32 billion cubic meters (m^3) of wastewater, but only 42.1% received treatment in the major cities. Out of 1,122 municipalities, 492 had some type of wastewater treatment system, with primary systems accounting for 13.9% and secondary systems for 58.9%. This means that less than one-third of the country's wastewater flow was treated before being discharged into water sources (Pimentel, 2017). Consequently, due to moderate investment in treatment facilities and limited coverage across the Colombian territory, data reveal that only 35% of the 75.95 million cubic meters per second (m^3/s) of wastewater discharged into rivers and streams underwent processing. In contrast, nearly three-quarters of the wastewater flow has not undergone treatment before being released into water sources, leading to environmental and health impacts. This situation can result in issues such as the irrigation of agricultural fields in rural areas and even the direct use of contaminated water by the population, which poses a serious public health problem (Cañete, 2019).

Urban wastewater discharges in the municipalities of Santander and their impact on the different water sources have generated concern at both local and environmental levels; for this reason, it is essential to evaluate and understand the magnitude of the environmental impacts generated by these discharges, as well as to propose mitigation and restoration strategies that contribute to the protection and conservation of this important natural resource.

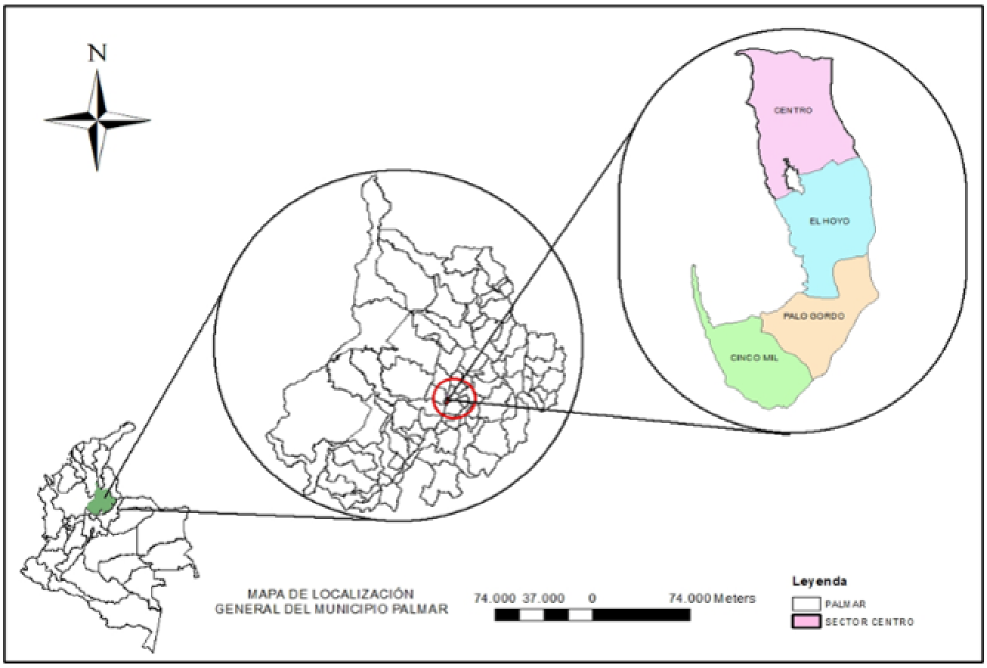
This research project focuses on assessing the environmental impacts of urban wastewater discharges in the municipality of Palmar Santander, specifically on the water source Río Suarez in the in the downtown area. The study involves the development of an environmental baseline that encompasses the region's biological, abiotic, and socioeconomic aspects. Additionally, the simplified Conesa method was used to quantify and qualify the extent of the damage caused by these discharges, providing valuable insights into the current situation. Based on the findings of the baseline assessment and recommendations from environmental management experts, mitigation, compensation, and restoration strategies are proposed

2. MATERIALS AND METHODS

2.1. DESCRIPTION AND GEOGRAPHICAL SCOPE

The municipality of Palmar is in the department of Santander, Colombia, in the Comunera province, on the left bank of the Suárez River. It borders the municipalities of Galán to the north, Socorro and Cabrera to the east, Simacota to the south, and Hato to the west. Additionally, it is situated along the corridor that connects Socorro with Zapatoca (Alcaldía Municipal de Palmar, 2021).

Figure 1. General geographical location of the municipality of Palmar.



Source: Own elaboration.

In Figure 1, the geographical location of Palmar is shown at the national, departmental, municipal, and local levels. This municipality is divided into four districts: Cinco Mil, El Hoyo, Palo Gordo, and Centro (the study area) (Alcaldía Municipal de Palmar, 2021).

2.2. RESEARCH DESIGN

For the development of the project, a descriptive research approach was carried out with both quantitative and qualitative methodologies. The analysis of various sources of information was used as a reference, aiming to identify and thoroughly evaluate the environmental impacts resulting from the problem and their effects on the water source under study.

2.3. DEVELOPMENT OF THE ENVIRONMENTAL BASELINE

The baseline was developed through an exhaustive bibliographic review of multiple information sources, including primary (field data), secondary (case studies and primary information), and tertiary sources (information previously analyzed by two authors in the same context). This approach ensured the accuracy and reliability of the data presented in the characterization of the municipality of Palmar. The specific data considered comprised the biotic, abiotic, and socioeconomic components, established by the National Authority for Environmental Licenses (ANLA, 2018).

2.4. CHARACTERIZATION SURVEY

The characterization survey served as a mechanism for collecting primary information, enabling a more accurate understanding of the community's knowledge and relationship with the area of influence and the water source under study. This was conducted during the field visit day, where the respective monitoring was carried out with the participation of actors of various ages, grouped into the following age ranges 18 to 30 years, 31 to 50 years, and over 50 years. Additionally, the participation of both female and male participants was sought.

2.5. ENVIRONMENTAL IMPACT ASSESSMENT

For the evaluation of the environmental impacts caused by the discharge of wastewater into the water source under study, the methodology known as the Simplified Conesa Method, proposed by Arboleda (2008) in his manual "Manual of Environmental Impact Assessment," was considered.

Initially, field data collection was carried out through visits to strategic points in the area, leading to the compilation of primary information related to the subject of the research. This compilation considered the perception of the environment and/or area of influence of the water source concerning the biotic, abiotic, and socioeconomic components, to identify the main activities likely to generate environmental impacts on the water source, which were identified as:

A. School activities
B. Restaurant operations

C. Washing of common, public and commercial areas
D. Vehicle repair garage and car wash facilities
E. Livestock farming (Cattle, sheep, goats, etc.)
F. Citrus and sugarcane crops
G. Traditional Maize Crops
H. Tourism activities

Table 1. Rating ranges according to the environmental impact significance.

Value	Qualification	Meaning	Color
0 ≤ 25	Low	The impact is not significant compared to the project.	
26 ≤ 50	Moderate	The impact does not establish serious damage caused by the activity.	
51 ≤ 75	High	Affecting the study area requires the recovery of environmental conditions.	
+75	Critical	The impact is within the upper threshold. A deterioration in the quality of environmental conditions is evident	
Values with a + sign are considered as zero impact.			

Source: Own elaboration.

2.6. ENVIRONMENTAL STRATEGIES

Once the environmental assessment of the impacts generated by wastewater on the water source under study was completed, strategies and/or environmental management measures were formulated to address these impacts based on their progress and complexity. These measures are focused on the protection of resources associated with each of the abiotic, biotic, and socioeconomic factors to promote the sustainability of the ecosystem.

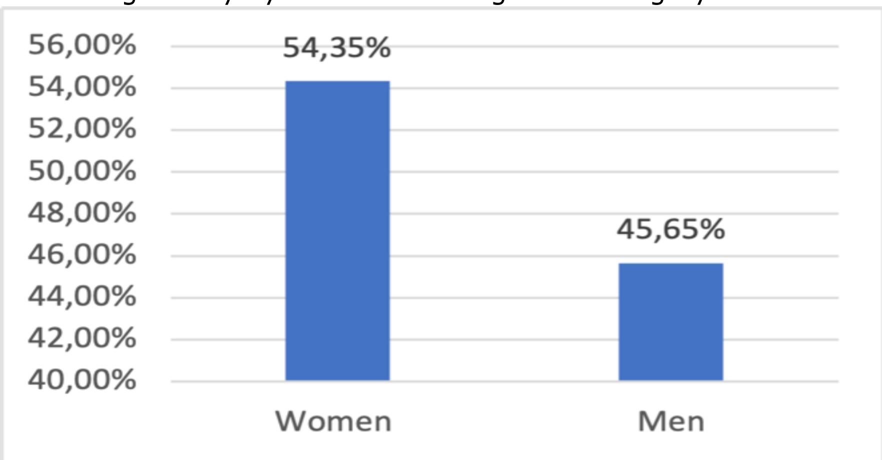
Special attention was given to the primary information collected in the surveys when formulating these management measures, as the local inhabitants, being the main actors and direct agents on the concentration of wastewater pollutants, must play a role in the proper management of resources and the disposal of all types of waste, whether liquid or solid. Furthermore, the impacts with the highest degree of ecosystem affectation were considered, prioritizing the management measures aimed at promoting the mitigation of their occurrence or, conversely, the consequences derived from them.

3. RESULTS AND DISCUSSION

3.1. CHARACTERIZATION SURVEY

To specifically characterize the population, the methodology of primary data acquisition, known as the survey, was developed. Through this method, relevant information for the study was gathered. The survey was administered to 10% of the population in the urban area of the municipality, due to its accessibility and constant interaction with the wastewater treatment plant (WWTP) and the discharge source. Of the surveyed population 54.35% were women while the remaining 45.65% were men, as shown in Figure 2.

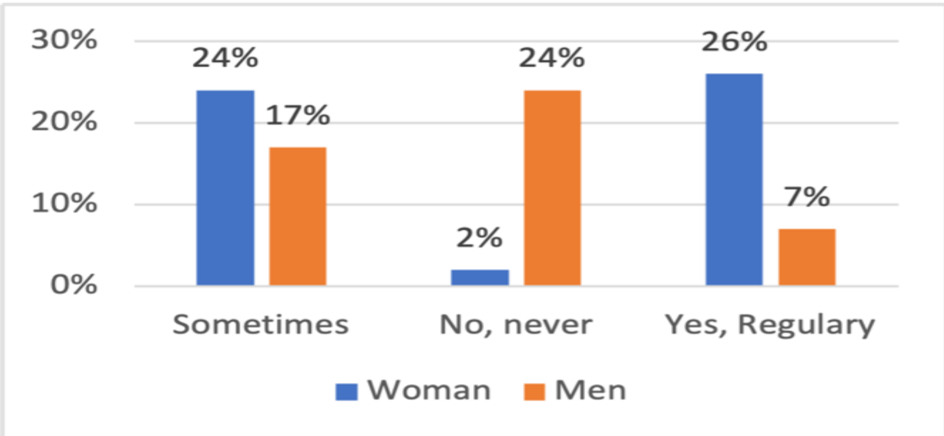
Figure 2. Percentage study by environmental gender category.



Source: Own elaboration.

The survey results show that women demonstrate a greater initiative in implementing water-saving measures in the municipality of Palmar. Nevertheless, a significant portion of the community, representing 74% of the total respondents, both men and women, engage in at least one small activity that enables them to use water resources responsibly and sustainably. This is an essential factor when evaluating the potential contaminants of the water source under study, as shown in Figure 3.

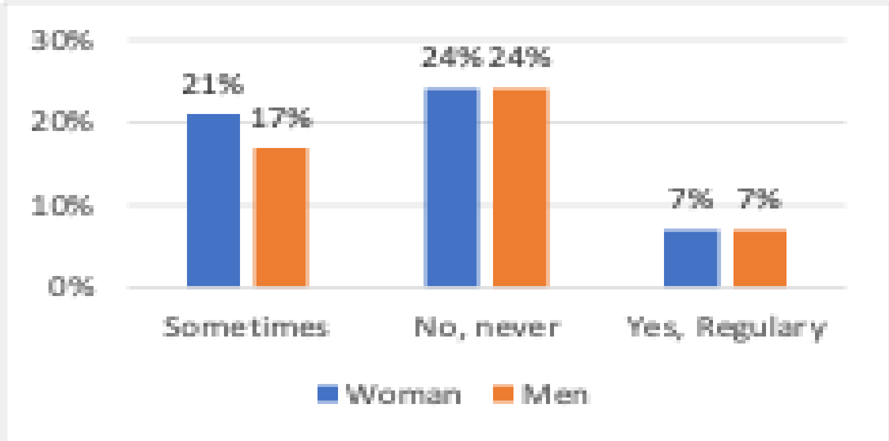
Figure 3. Knowledge about the adoption of water-saving measures in the household by gender.



Source: Own elaboration.

A determining factor in the study was the knowledge or lack of awareness regarding the wastewater treatment plant (WWTP) identified in the municipality, its location, and its functionality in treating the wastewater generated by the involved community. Based on this, the findings presented in Figure 4 were obtained.

Figure 4. Location knowledge of the WWTP by gender.



Source: Own elaboration.

Based on the responses obtained, it was found that 46% of the respondents were unaware of the location of the WWTP, a situation that could be attributed to a lack of environmental information and education, as identified in responses to previous questions. However, 40% of the respondents provided an affirmative answer regarding the location of the WWTP, while the remaining 14% were uncertain about their response.

3.2. CHARACTERIZATION OF THE WATER SOURCE

In order to assess and analyze the territorial reality of environmental impacts in urban areas, it is necessary to address the characterization of water sources. Thus, in the Figure 5 shows the state of the water source where the samples were taken.

Figure 5. Target water source.

Source: Own elaboration.

Meanwhile, in the Figure 6 shows the discharge point where the samples analyzed were collected.

Figure 6. Discharge point.

Source: Own elaboration.

3.2.1. FLOW RATE

To measure the flow rate of the water source under study, the float method was initially used, while the volumetric method was employed to obtain this parameter at the discharge point. It is worth mentioning that the flow rate was calculated both upstream and downstream of the point, and the results are shown in Table 2.

Table 2. Flow rate data obtained in the field

Measurement point	Flow rate (l/s)	Method used
Upstream	7,21	Float
Dumping	0,238	Volumetric
Downstream	7,45	Float

Source: Own elaboration.

During the monitoring, 12 aliquots were obtained, from which the final composite sample was derived. The flow rate and pH values were measured for each aliquot, and the necessary volume to form the composite sample was calculated.

The sample maintained a pH value between 7 and 7.5 units throughout the different hours of monitoring, with a total average of 7.29. Additionally, regarding the flow rate measurement, the highest value was recorded between 8:00 am and 11:00 am, and it increased considerably again at 12:00 p.m., reaching a maximum flow rate of 0.557. This factor could be attributed to the domestic and commercial activities of the area's residents.The data obtained allowed for identifying the behavior of the discharge and its variations throughout the sampling period.

3.2.2. COMPARISON OF THE PARAMETERS OBTAINED IN THE DISCHARGE AND RESOLUTION 0631 OF 2015

All the analyzed parameters are within the maximum permissible limits established by Resolution 0631 of 2015; therefore, this is an initial indication that the water treatment plant for the proper management of wastewater discharge is working properly, ensuring that the water released into the water source has contaminant concentrations that comply with the regulations and, consequently, are degradable by the ecosystem, thereby reducing environmental impacts on it.

Table 3 graphically reflects the relationship of the parameters for comparison with the regulatory standards. In the case of total coliforms, the regulation requires analysis and reporting, which is why they are not included in the table:

Table 3. Comparison of discharge with regulations

Parameter	Discharge	Regulations
BOD5 mg/L O_2	57.7	90,0
COD mg/L O_2	143	180,0
Fats and oils mg/L	19.4	20,0
Total suspended solids mg/L	10	90
Sedimentable solids ml/L	0.1	5

Source: Own elaboration.

3.2.3. COMPARATIVE RESULTS UPSTREAM AND DOWNSTREAM OF THE DISCHARGE

The level of impact and/or alteration of discharges into natural water bodies is established by comparing the physicochemical parameters of the water upstream and downstream from the discharge point. This assessment is based on the principle of the biodegradability of the contaminating matter and the water body's self-purification capacity (MADS, 2015). A comparative analysis of the COD and BOD_5 parameters was carried out at points upstream and downstream from the initial sampling point to assess the initial pollution conditions in the water source. The results obtained are shown in Table 4.

Table 4. Comparison of parameters upstream and downstream of the discharge.

Parameter	Upstream	Downstream
BOD_5 (mg/L O_2)	40	23,6
COD (mg/L O_2)	110	93,5

Source: Own elaboration.

3.2.4. CALCULATION OF THE BIODEGRADABILITY INDEX

The analysis of water biodegradability concerning the polluted material is presented. Essentially, this index measures the water body's ability to biodegrade the pollutant load through the biological action of microorganisms native to the ecosystem (Rojas, Mendez, 2015). The value is obtained from the ratio between BOD and COD, such that a higher value of this index indicates a greater presence of organic matter in the water. The biodegradability ranges are shown in table 5.

Table 5. Sampling points biodegradabilty index

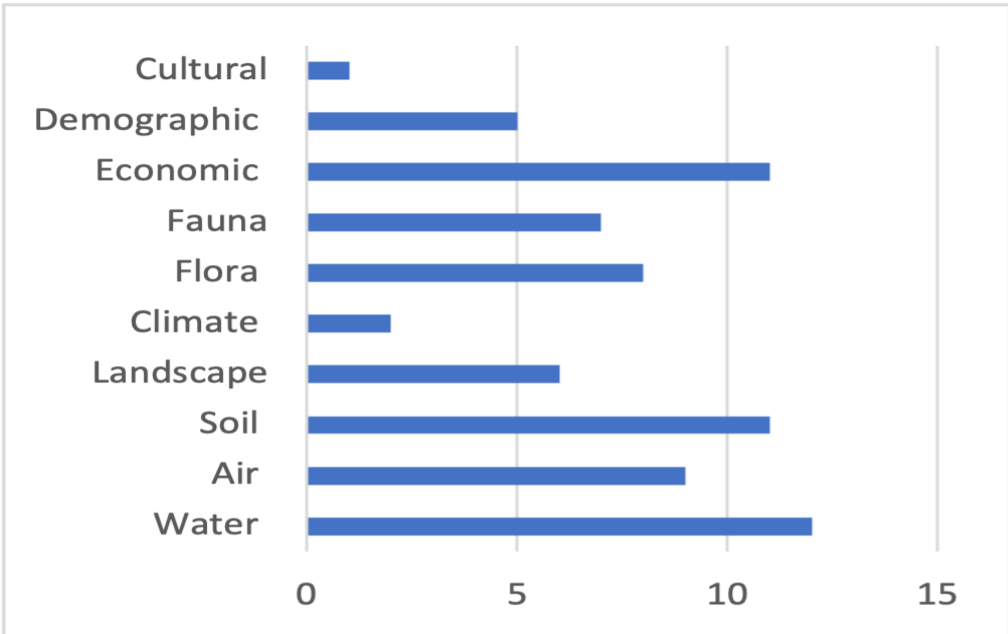
Sampling point	**BOD/COD ratio**	**Biodegrad a-bility index**
Discharge	57/143	0,399
Upstream	40/110	0,364
Downstream	23,6/93,5	0,252

Source: Own elaboration.

3.3. ENVIRONMENTAL IMPACT IDENTIFICATION AND ASSESSMENT

As shown in Figure 7, water quality was the most affected factor with a total of 12 interactions, thus being the most impacted FARI by the activities evaluated (affected by all activities); followed by the economic component and soil, each with 11 interactions, the flora and fauna component with 8 interactions respectively, landscape with 6 interactions, and finally, the cultural component showed only 1 interaction, being the least impacted.Tha qe can see, in the Figure 7 shows the behavior of the interactions identified:

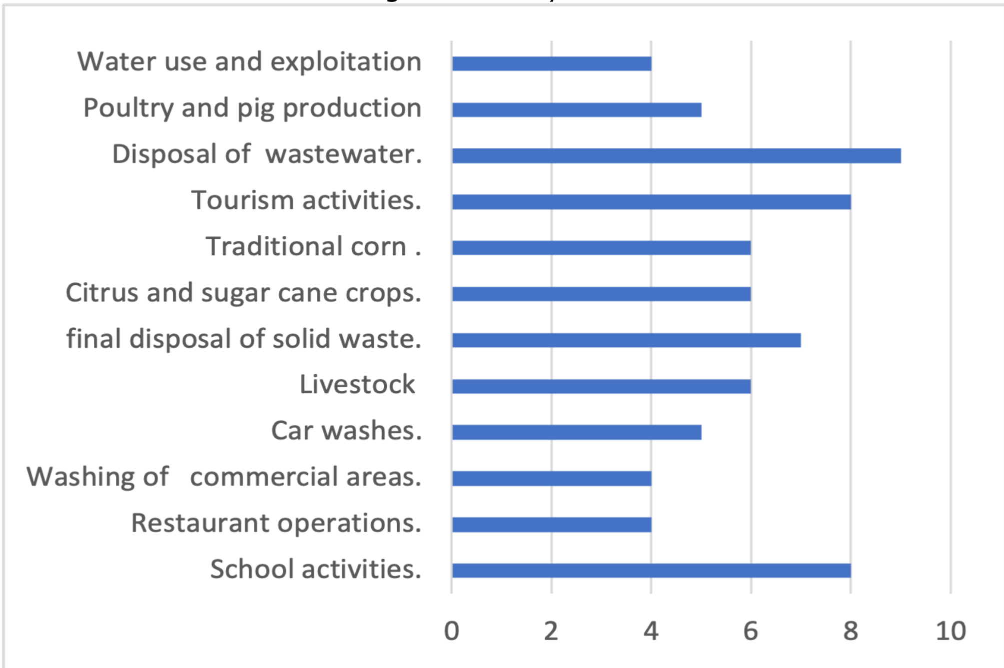
Figure 7. Number of interactions identified in FARIs.



Source: Own elaboration.

Finally, the analysis of the activities evaluated in terms of interaction with the environment is reflected in Figure 8.

Figure 8. Number of interactions generated by the activities evaluated.



Source: Own elaboration.

Thus, it was possible to identify that the activities generating the highest number of interactions with the environment, and therefore the greatest environmental impacts, were the disposal of both domestic and non-domestic wastewater, tourism activities, and school activities (mainly due to the lack of environmental education and awareness), local management and final disposal of solid waste, crops typical of the area (corn, panela, citrus fruits), livestock farming, pork and poultry production, ending with water usage for washing activities in different areas (without an adequate water use and management plan – PUEAA).

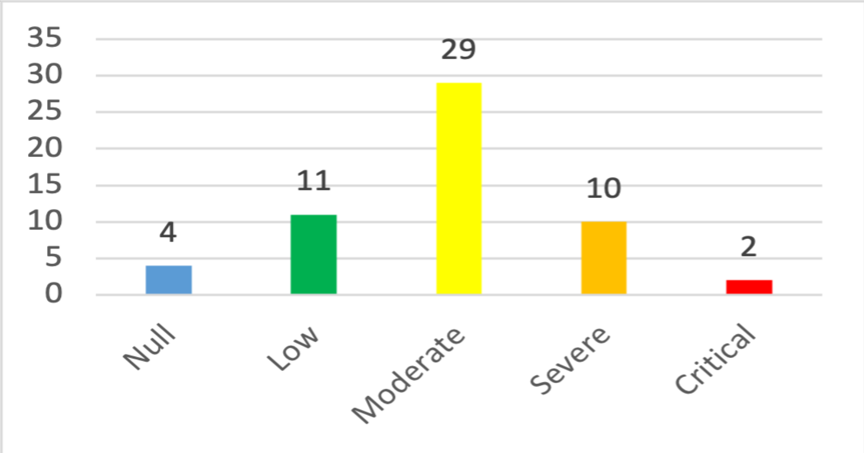
3.4. ENVIRONMENTAL IMPACT ASSESSMENT

Based on the identification of the impacts generated and Figure 10, it is possible to understand the magnitude of the effects on the different FARI and the environmental issues that arise from them with each of the evaluated ASPI. Water resources are identified as the most affected among all the components considered within the applied method.

As shown in Figure 8, most impact categories fall within the low and moderate ranges, with 29 and 11 impacts, respectively. In addition, 10 severe impacts and two critical impacts were identified, reflecting a potential threat to ecosystems, primarily affecting water and soil resources.

According to Figure 8, there are significant impacts within the severe and moderate categories, which raises an alert regarding the pressure the ecosystem is bearing, and its resilience capacity. This self-regulation ability in response to anthropogenic pressure may be irreversibly diminished, leading to natural entropy.

Figure 9. Impacts generated and their presence in the study.



Source: Own elaboration.

The impacts are predominantly classified as severe or moderate, presenting a concerning outlook for the state of the ecosystem. Wastewater discharge is one of the main drivers of severe impacts, such as alterations in the physicochemical characteristics of the water or odor pollution, both of which result from the discharge into water sources (Maza, 2007). There are also severe impacts on soil, primarily due to economic activities like livestock production and agriculture. The impacts generated on the ecosystem highlight the need for proposing treatment or mitigation strategies to prevent resource loss (Toro, Martinez y Arrieta, 2013).

3.5. ENVIRONMENTAL STRATEGIES

The following environmental sheets outline the proposed measures for reducing, mitigating, and restoring resources impacted by the assessed environmental effects, and the environmental education strategies designed to address the issues at hand.

3.5.1. WATER RESOURCE

1. Implementation area: Rio Suarez, municipality of Palmar, Santander.

2. General Objective: Establish management measures for sustainable and equitable use of water resources in the area of influence of Río Suárez.

3. Specific Objectives:

- Optimize the operation of the water treatment plant in the area by promoting equitable and efficient water use to ensure the proper functioning of processes.
- Reduce the concentration of pollutants that alter the composition, as well as the physicochemical and hydrobiological quality, of the water source.
- Update the plans and programs in the municipality of El Palmar

related to efficient water use and conservation to support the sustainable management of this resource.

4. Compliance Indicator (Impact monitoring):

% of people: (# of people/population) *100. (1)

5. Type of management: Control and preventive

6. Activities:

- Implement door-to-door awareness-raising campaigns for inhabitants with explanatory methodologies regarding the efficient use and management of water in households and productive or commercial establishments.
- Participate in the design and dissemination of programs for the sustainable use of water resources in the municipality, such as the PUEAA, in collaboration with the environmental authority and municipal administration.

7. Goals:

- Train 85% of the population contributing wastewater to the water source in urban areas and 60% in rural areas.
- Formalize and disseminate the program(s) developed in partnership with environmental authorities and the municipal administration.
- Design and implement management measures to protect and maintain the current conditions of the treatment plant in the municipality.

4. CONCLUSIONS

The municipality of El Palmar is distinguished by its highly diverse ecosystemic and environmental attributes, as demonstrated in the initial baseline assessment. The region exhibits significant biological diversity, alongside a variety of landscapes and steadily growing populations. This dynamic interplay promotes the development of complex trophic chains, which, in turn, support activities reliant on natural resources. These resources are essential for driving economic growth and enhancing the quality of life for the municipality's inhabitants.

The collection of primary information made it possible to identify that the effects of discharge into the water source are perceived with concern by the inhabitants of the municipality. In fact, both men and women stated that wastewater discharge has negatively affected water quality in the region. Additionally, inhabitants between 18 and 30 years old showed greater knowledge about the problem. Furthermore, the general population, regardless of age or sex, was unaware of the existence of the treatment plant in the municipality, its location or its operation. However, despite the perception of the impact, there was a broad willingness to develop activities to raise awareness, educate and improve environmental quality in the municipality.

Characterizing both the discharge and the water source allowed us to approach the specific impact of the discharge on the water source. Based on the analyses performed, it was evident that the wastewater treated in the municipality's WWTP complies with the maximum permissible levels given by Resolution 0631 of 2015, which indicates that the plant is working properly. However, some of the parameters measured are close to exceeding this maximum permissible value, as is the case of fats and oils, thus it is important to perform a detailed inspection of the treatment system to implement corrective measures to avoid the generation of environmental impacts derived from this parameter.

The CONESA Simplified method was an effective method for environmental evaluation since it allowed the identification and assessment of the environmental impacts with the greatest degree of affectation in the area studied, leading to the understanding that aspects such as the development of agricultural activities, inadequate management of solid waste, dumping without treatment, uncontrolled tourism, among others, are critical factors in understanding the degree of environmental contamination in the area of influence of the water source studied.

The natural resource with the highest degree of impact according to the study was water, affecting water quality, increasing adverse substances in the resource and the impact of leachates in water bodies due to the deposit of decomposing solid waste near the water source, the decrease in the volume of water in water bodies and the increase of sediments in the water. This was followed by the soils with severe impacts category, which highlighted increased concentrations of adverse substances in the resource and a change in its vocation.

Finally, based on the aspects and impacts evaluated, it was possible to complete the research with the establishment of environmental management sheets focused on the mitigation, prevention, restoration, and adequate treatment of the impacts generated as a result of ASPI's activities and the response of each of the environmental components; allowing the establishment of a sheet for each of the affected environmental components where goals focused on improving the sustainability of the municipality were established.

The environmental management sheets were considered as a guideline for the implementation of programs, policies and initiatives that allow for the effective management of the environmental impacts identified, and it is therefore important to implement the proposed measures to adequately manage both the environmental aspects that generate impacts, and the consequences derived from these impacts.

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