

Handbook T-XXIII

CIERMMI Women in Science

Engineering and Society

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ISBN: 978-607-8948-38-3
ECORFAN Publishing Label: 607-8948
HRSE Control Number: 2024-08
HRSE Classification (2024): 301224-0108

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ECORFAN CIERMMI Women in Science Engineering and Society

Volumen XXIII

The Handbook will offer volumes of selected contributions from researchers who contribute to the scientific dissemination activity of the Colegio de Ingenieros en Energías Renovables de Querétaro A.C in areas of Engineering. In addition to having a full evaluation, in the hands of the coordinators of the Colegio de Ingenieros en Energías Renovables de Querétaro A.C, quality and punctuality in its chapters, each individual contribution was refereed to international standards [V|LEX, RESEARCH GATE, MENDELEY, GOOGLE SCHOLAR and REDIB], the Handbook thus proposes to the academic community, recent reports on new developments in the most interesting and promising areas of Engineering.

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December 2024

DOI: <https://doi.org/10.35429/H.2024.8.1.113>



Preface

This volume of the Handbook “Engineering and Society” addresses a series of multidisciplinary research that explores the correlation between engineering and day-to-day problems in society, aligned with the areas of knowledge. Through eight chapters, this volume examines diverse topics, from the optimization of natural resources to the integration of technological tools and the strengthening of competencies in higher education.

The first chapter analyzes the feasibility of rainwater harvesting systems (SCAP) and their impact on the social, economic and environmental context in Zacatlán, Puebla, proposing a sustainable irrigation model to improve water use efficiency. On the other hand, the second chapter presents the design of a database aimed at facilitating real-time translation between Nahuatl and Spanish, an effort to preserve and promote Mexico's cultural richness through the use of advanced database technologies.

The following chapters reflect the ingenuity and commitment of the researchers in their proposals for sustainability and resource utilization. The conceptualization of a glass recycling pulverizing machine in the third chapter addresses the challenge of reducing dependence on imported technologies, while the fourth chapter introduces virtual learning objects (VLOs) that promote responsible ethics in the development and use of artificial intelligence in higher education, underscoring the importance of ethics in technological advancement.

The fifth chapter describes the design of a mist irrigation system that optimizes mushroom production, crucial for maintaining an efficient and sustainable crop in the region. In an energy context, the sixth chapter examines the problems of fouling in photovoltaic modules and presents cleaning strategies to mitigate the loss of efficiency in solar panels, contributing to the improvement of performance in clean energy technologies.

In addition, the seventh chapter explores sustainable construction methods with ecological adobe improved with straw and manure, providing an economical alternative that is resistant to adverse weather conditions. Finally, the eighth chapter focuses attention on leadership training in computer systems engineers, recognizing this competency as a key to educational quality and professional development in the technological field.

This volume invites readers to consider how engineering, in its various disciplines, can contribute significantly to solving critical problems of our time, promoting ethical, sustainable and culturally conscious practices.

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December 30, 2024

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Viability Evaluation in SCAP through development in different impacts





Evaluación de viabilidad en los SCAP mediante el desarrollo en distintos impactos

Hernández-Ramos, Katia^a, Hernández-Ramos, Alma Yizel^b, PanecatI-Bernal, Yesmin^c and Hernández-Corona, Sergio^d

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CONAHCYT classification:

DOI: <https://doi.org/10.35429/H.2024.8.1.15>

Area: Engineering

Field: Engineering

Discipline: System engineer

Subdiscipline: Hydrology

Key Handbooks

The main contributions are to generate a sustainable project with different impacts that help generate new benefits in different communities and the real impacts that were introduced during the field work. The impacts, the sustainability and the prevention of the water and their uses.

Citation: Hernández-Ramos, Katia, Hernández-Ramos, Alma Yizel, PanecatI-Bernal, Yesmin and Hernández-Corona, Sergio. 2024. Viability Evaluation in SCAP through development in different impacts. 1-15. ECORFAN.

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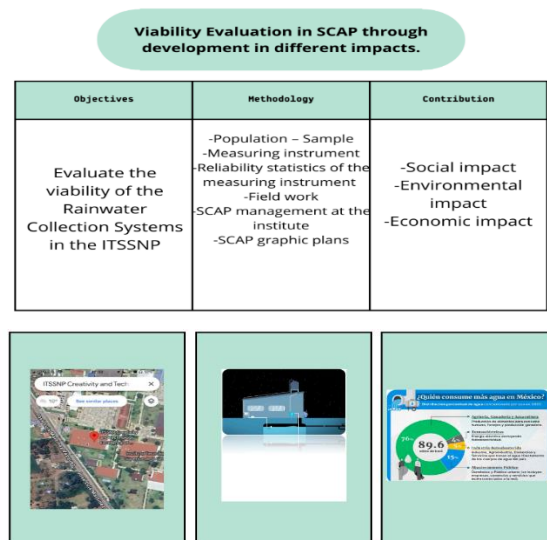
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Abstract

In this time when health has become unprecedentedly relevant, it is very important to be aware of the use and care of both drinking and rainwater. The research was carried out at the Instituto Tecnológico Superior De La Sierra Norte De Puebla, located in Zacatlán, municipality of the State of Puebla, with geographical coordinates 19° 34' 42" and 98° 18' 06" west longitude with a climate corresponding to being temperate sub-humid and an annual temperature of between 12° and 18°. The general importance of this project is determined based on the implementation of a new irrigation system in projects for use in fields or specifically in the buildings of the institution, since it is considered that rainwater is the basis of a development to innovate in different areas. Taking into account the proper functioning and development of the system within the academy, obtaining a common benefit mentioned above such as projects coming from other careers and the dependency. To mention part of the objective, it is proposed to develop an optimal model of a catchment system to guarantee the water supply and with this make a good ecological management free of contamination in our institution. Having with this a clear alternative in order to meet the needs of the community that we form, previously studied to adapt it in required areas of the institution such as the bathrooms of the institution, some of the buildings such as the practice unit and the building A and E with an effective reduction of expenses in drinking water and apply a new last of use for common benefit and take care of it.



Capture System, Rain water, Impacts

Resumen

En esta época en la que la salud ha cobrado una relevancia sin precedentes, es muy importante tener conocimiento del uso y cuidado del agua tanto potable como pluvial. La investigación se realizó en El Instituto Tecnológico Superior De La Sierra Norte De Puebla, localizado en Zacatlán municipio del Estado De Puebla, con coordenadas geográficas 19° 34' 42" y 98° 18' 06" longitud oeste con un clima correspondiente a ser templado subhúmedo y una temperatura anual de entre 12° y 18°. Se determina la importancia general de este proyecto basándose en la implementación de un nuevo sistema de riego en proyectos para su uso en sembradíos o específicamente en los edificios de la institución, dado que se considera que el agua pluvial sea corriente base de un desarrollo para innovar en distintas áreas efectuando el desarrollo en distintos impactos como son: económico, social y con mayor relevancia el impacto ambiental. Tomando en cuenta el buen funcionamiento y desarrollo del sistema dentro de la academia, obteniendo un beneficio común antes mencionado como lo son proyectos provenientes de otras carreras y la dependencia total del sistema para abastecerse dentro del Instituto. Por mencionar parte del objetivo se tiene planteado el desarrollar un modelo óptimo de un sistema de captación para así garantizar el abastecimiento de agua y con este hacer un buen manejo ecológico libre de contaminación en nuestra institución. Teniendo con este una alternativa clara para así satisfacer las necesidades de la comunidad que conformamos y cumpliendo con mayor importancia los impactos establecidos previamente estudiados para adaptarlo en áreas requeridas de la institución como se tiene contemplado que sean los baños de la misma, algunos de los edificios como son por mencionar la unidad de prácticas y el edificio A y E.



Sistema de captación, Agua de lluvia, Impactos

Introduction

All human beings are responsible for maintaining and conserving the natural resources of the planet we live on since it is full of natural resources within which there is a classification dictated by resources: Renewable, Non-Renewable and Inexhaustible. Renewable resources are those that can be reproduced, but that, if used indiscriminately, can become extinct, which includes plants, water and soil. Non-renewable resources are those that are not constantly produced and we could also say that they are those that do not exist in unlimited quantities, therefore, when humans overexploit these resources, they can run out, among them are: coal, oil, silver, copper, among others. Finally, we have inexhaustible resources, which are those that do not run out, no matter the number of productive activities that human beings carry out with these resources, since they will never be exhausted. An example of these resources are: sunlight, wind, the waves of the sea and the water of the sea.

The present project in question seeks to raise awareness in the school region of the Higher Technological Institute of the Sierra Norte of Puebla and its surroundings about the importance of the development of the different impacts for the common benefit, thus supporting other projects in development of the other careers it offers. the Institute. Also being used for projects that need irrigation systems and being the main source of drinking water for the school, therefore this project also has a Social impact.

Using as a study method a research variable that, according to the description of each of them, the one that best conforms and adapts, fulfilling all the characteristics, is TREND. Its description tells us that it is a variable that represents a measurable attribute that changed throughout the study of a project taking into account the changes made, such as in the results obtained in our measurement instrument that was applied within the Institute, which covers one of the environmental and social issues of the purpose to be carried out. Our project is made up of the support of research and various adaptations in its development such as the filters used in each system since there are three of them in the institution which have a similar way of working and developing, for this they are given a due maintenance and study hoping that it will give the best results for its prompt adaptation and development completely in the institution and its surroundings, a fact that is applicable to the economic impact.

Methodology

Hypotheses or assumptions

The harvesting of rainwater leads to a benefit and for this reason the following research question has been formulated with its respective hypotheses.

Research question:

Is it possible that the Rainwater Harvesting Systems are generating a high degree of social, environmental and economic impact on the ITSSNP facilities?

Hypothesis

- H0: It will be possible for rainwater collection systems to reduce the network's drinking water consumption and also evaluate the feasibility and high degree of effect on the development of the different impacts.
- Ha: It will not be possible for rainwater collection systems to meet the reduction of drinking water consumption in the network and also evaluate the viability and high degree of effect on the development of the different impacts.

RESEARCH APPROACH

The research approach in this project is dictated as Quantitative since in the measurement instrument we are based on the numbers according to the surveys aimed at the evaluation of viability in the different aspects presented such as the environmental, social and economic impacts that are generated in the realization of this project, its focus is redirected to the development of a capture system from the knowledge and formation of a system and its maintenance in the growth area that given the focus of the research carried out at the ITSSNP .

POPULATION – SAMPLE

Finite population using a random sample with a number of elements of 296.

$$n = NZ^2 pq \div d^2(N - 1) + Z^2pq$$

$$n = (1272)(11272,9)^2 (0.05)(0.95) \div (0.5)^2(1272 - 1) + (11272,9)^2(0.05)(0.95)$$

Box 1

Table 1

Reliability Statistics

Reliability Statistics	
Alfa de Cronbach	Number of elements
,889	296

Measuring instrument and evaluation of reliability

Dabbling in the methodology, a measurement instrument was used with the following variables:

- 1.- Knowledge
- 2.- Importance
- 3.- Use
- 4.- Quality of service
- 5.- System in your home

For which the answers that were made thanks to the students were entered into a graphics system called SPSS to verify feasibility.

The evaluation of reliability is based, according to *Ketkar, N., & Verville, (2012)*, on the calculation of coefficients, such as Cronbach's alpha coefficient. *George & Mallery, (2003)*, mention as a very general criterion the following recommendations for evaluating Cronbach's alpha coefficients:

- Alpha coefficient >0.9 is excellent.
- Alpha coefficient between 0.8 and 0.9 is good.
- Alpha coefficient between 0.7 and 0.8 is acceptable.
- Alpha coefficient between 0.6 and 0.7 is questionable.
- Alpha coefficient between 0.5 and 0.6 is poor.
- Alpha coefficient.

Regarding the calculation of the sample size to be sampled and as illustrated in the table, the reliability of the measuring instrument was validated with 37 students and through a results matrix, resulting in 0.889 which means that the measuring instrument is good. Therefore, the different impacts of this project dictate that they could be of a high degree of benefit to society as a whole.

Box 2

Table 2

Case Processing

		N	%
Cases	Valide	37	100,0
	Excluded	0	,0
	Total	37	100,0

Box 3

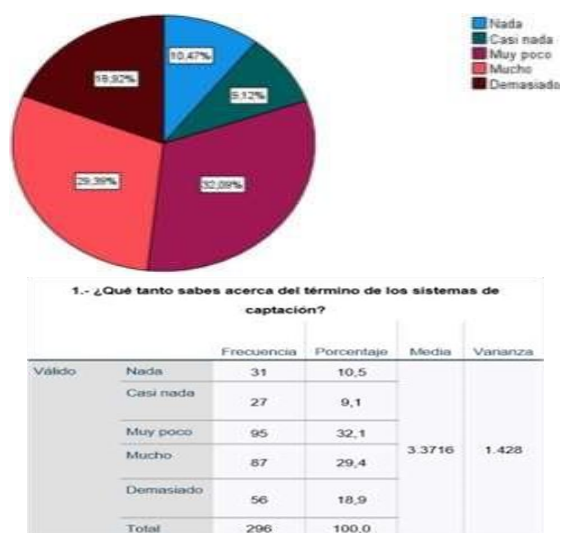


Figure 1
Measuring Instrument

Conclusion: According to the results obtained in both table 4 and graph 1, it is shown that 29.39% of the students' responses know the collection systems, while 10.47% do not know the collection systems, therefore comes to the conclusion based on the responses that there is no knowledge about the collection systems that the Tecnológico has.

Field work

Management of recruitment systems at the Institute

To carry out the work in all research projects, five stages are generally used, which are considered important in the execution when doing field work. It begins with the primary planning stage in which an action plan is described. previously prepared adapted to the research and then a methodology is generated in which the most appropriate method is chosen for the project or topic of investigation. As a third stage, observation is presented, which is essential to observe the phenomenon of study that in this case is located in building E and therefore it is studied to understand it in terms of its uses and functions, which in this case adapts to the SCAP in general and its impacts together with its benefits. The data analysis continues, which was structured in the measurement instrument and this is partly used in the methodology and in conjunction with the field work to delve deeper into the social impact to understand the central points of the project.

Finally, the last stage is presented, which is communication, which is considered constructive as previously mentioned to conclude the results obtained during the project and make improvements or give greater extension to the knowledge and importance that is at the center of the project. What are the viability of the different impacts for the benefit of the community (MASTER October 11, 2022)

Below is the field work carried out over several months to evaluate the viability of this project and continue its monitoring to achieve the desired impact over time.

Box 4



Figure 2
System cleaning

Graphic plans of the warehouse collection system

Within the field work, plans were carried out for the collection system of building A, which has had greater mobility with respect to its development in the Institute thanks to its beneficial contribution of supplying water for the use of toilets. As also shown in the graph, the filtering systems used in this collection system are proposed since its main development was the purification and sanitization of water for exclusive use in toilets, since the corresponding tests were carried out and it was taken into account that according to the pH of the water and carrying out a test, this water is not yet suitable for its development to be ingested or used for drinking

Box 5



Figure 3
Graphic plans

Results

Research contributions

Regarding the results generated from the project and fully entering into the evaluation of the viability of the economic, environmental and social impacts, complementary participation is dictated in different fields that are subject to research. The development of the filtering system generated within the Institute and adapted in the community of Ayotla is presented. This prototype of the filtering system is composed of PVC in bone color and PVC in black, the function of this is that the entire first part of The collected water settles in the filter and every third day or every week the water is drained so that later the water comes out clean and is deposited in a 5 thousand liter agrotank for the specific storage of the collection water, when the collected water enters. rain passes through the entire channel called the filtering system which, as previously mentioned, is composed of different filters generated for water sanitation and once this process is completed, the water is stored and then used in the required spaces. It is also concluded that the water treated and previously sent to the filters to then be used in daily activities, this is dictated since the water is not yet completely suitable for human consumption, meaning it can be ingested directly.

To conclude this first point, an effective viability in the environmental impact is evaluated, because different benefits are generated such as the reduction of drinking water consumption in this area of the Institute and in this case in the community of Ayotla where they were previously adapted in two homes, pollution is also reduced in the Institute since little by little there is awareness of the high impact that is had when taking into account rainwater and its collection, likewise with the new filtering system adaptations were made to the creation and use of this same filter in the community of Ayotla that is currently being implemented so that irrigation systems are also developed with this type of rainwater filtration through a connatural method.

- Research contributions
- Comparison of economic savings in drinking water and rainwater in building A
- Rules that impact the project
- Project impacts
- **Research contributions**

In the research contributions, there is a filtering system that is used in the community of Ayotla and the publication of an article aimed at environmental impact, and work has also been carried out on the implementation of other similar projects for the development of this community.

- Comparison of economic savings in drinking water and rainwater in building A

As for the other collection system, the rainwater collected in Building A is shown, from which the total number of liters per month that was collected will be determined and consequently how much water is used, taking from this building the cost that would be had if throughout the entire the time water from the potable network will be used compared to using water from the rainwater collection system and the economic savings that are generated. Considering this point as a source of results, tables were included where the specifications are found in logs of the day, month, year, cubic meter and difference that was generated in the different collection systems, such as the rainwater collection system located by the computer center and the collection system of building A. Consequently, the total expenditure per cubic meter per month is generated during the year 2022, which is currently being carried out to date. It is included as a reference to understand the difference and saving capacity of drinking water as opposed to the use of rainwater.

In addition, it was considered to add the collection that was obtained from the collection system that is in the computing area in which the tables show its collection for months. Likewise, SOSAPAZ was contacted to ask about the cost per cubic meter for the institutions. Box 1 describes the costs per cubic meter considered in SOSAPAZ.

SOSAPAZ is the organization governed in Zacatlán in charge of providing this data, which broadly speaking is the Drinking Water and Sewage Service Operator System of the Zacatlán Municipality, so a comparison analysis was carried out on the amount made in m³ for consumption in institutions. in terms of the economic savings that are developed by using rainwater collection in this building and would also delve into the economic impact causing a high-grade development.

Box 6

Table 3

Costs per cubic

16 m ³ – 30m ³	\$13.08
31m ³ – 60m ³	\$15.86
61m ³ - +	\$22.14

\$5,099.96

The figure shows the water savings for the month of September 2022 and its total liters per month. The comparison of expenses economically speaking for the month of September would be \$5,099.96, this result is obtained by multiplying the total m³ for the month of September by \$22.14, which is the corresponding price for m³ in institutions.

Box 7

Table 4

Total liters

Day	Month	Year		
1	SEPTIEMBRE	2022	10.962871	m ³
2	SEPTIEMBRE	2022	10.963361	m ³
5	SEPTIEMBRE	2022	10.96418	m ³
6	SEPTIEMBRE	2022	10.966211	m ³
7	SEPTIEMBRE	2022	10.966211	m ³
8	SEPTIEMBRE	2022	10.966211	m ³
9	SEPTIEMBRE	2022	10.966211	m ³
12	SEPTIEMBRE	2022	10.966211	m ³
13	SEPTIEMBRE	2022	10.966211	m ³
14	SEPTIEMBRE	2022	10.966211	m ³
15	SEPTIEMBRE	2022	10.966211	m ³
19	SEPTIEMBRE	2022	10.966211	m ³
20	SEPTIEMBRE	2022	10.966211	m ³
21	SEPTIEMBRE	2022	10.966211	m ³
22	SEPTIEMBRE	2022	10.966211	m ³
23	SEPTIEMBRE	2022	10.966211	m ³
26	SEPTIEMBRE	2022	10.967095	m ³
27	SEPTIEMBRE	2022	10.981538	m ³
28	SEPTIEMBRE	2022	10.982931	m ³
29	SEPTIEMBRE	2022	10.983931	m ³
30	SEPTIEMBRE	2022	10.983931	m ³

Box 4

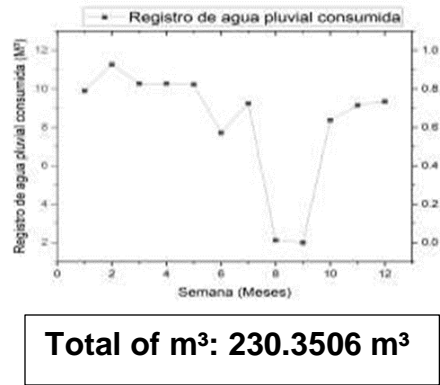


Figure 4
Register of rainwater

Standards that impact the project

Mexican Official STANDARD NOM-179-SSA1-2020,

Water for use and human consumption. Control of the quality of water distributed by water supply systems.

Mexican Official STANDARD NOM-015-CONAGUA-2007,

Infiltration artificial water supply to aquifers. Features and specifications of the works and water.

PROJECT IMPACTS

Environmental impact of SCAPS

Rainwater harvesting systems use different techniques and the construction of infrastructure to take advantage of the water resource. Its design adapts to the characteristics of the space to ensure the storage, filtration and subsequent disposal of the captured water, ensuring optimal management of it.

Addressing the environmental impact, it is considered of utmost importance that the Institute and the school community be aware that water is used in practically all human activities, so the use of this resource can be used anywhere where there are adaptable surfaces. for its collection and storage sites, without leaving aside the great impact caused by said collection actions, such as the following:

- Contributes to preserving water and natural resources.
- Collaborates in the prevention and control of runoff, landslides and erosion.
- Generates water self-sufficiency and economic savings during the rainy months.
- Ensures the availability of water for a longer period of time, with excellent quality for various uses.

The use of these systems has a positive impact on water conservation globally. By taking advantage of rainwater, the extraction of water from natural sources, such as rivers or aquifers, is reduced, which helps preserve these fragile ecosystems and maintain an adequate water balance, an example of which is the overexploitation of aquifers near the ITSSNP area in the community of Ayotla, so an imminent risk to the community is that in some areas of Jicolapa the arrival of drinking water is reduced.

Additionally, rainwater harvesting can also reduce the load on storm drainage systems, preventing potential flooding and improving stormwater management in urban areas. The broad benefit obtained at the Tecnológico was:

- Reduction of drinking water consumption in the various areas of the Institute.
- Benefit by reducing pollution in the Institute, both internal and external, taking into account rainwater in its collection.
- New irrigation systems involving rainwater filtration through a natural method.

Social impact in SCAP

In the evaluation of engineering works at the community level, social factors must always be kept in mind, represented by habits and customs that may affect the sustainability of the intervention. In effect, the professional responsible for the study must discuss with the community the advantages and disadvantages of the traditional way of water supply and the proposed technology, seeking that the community itself selects what is most convenient for it to use. This analysis, which is used as the measuring instrument within the project, must consider the convenience of adopting individual and collective solutions, the type of material used in the manufacture of its roofs, the existence of alternative materials in the place or its surroundings and the degree of community participation in the implementation of the project, for this point it is assumed that the work adapted and evolved over time and the different generations in the Institute that are chosen to continue with its mobility and follow it up in every semester.

Another example related to the social impact section is due to participation in projects for knowledge within other sectors and institutions, such as the current adaptation that is being carried out in the community of Ayotla with the purpose of providing a better quality of life to society in the Rotary Club of Zacatlán in conjunction with the ITSSNP, the “Ayotla life natures” project has been developed based on the current conditions they live in. The projection of having various specimens in this community was taken to generate the implementation of technologies green for the use of rainwater resources, improving their quality, protection and maintenance, boosting the economy of 30 homes in the community through sustainable and sustainable technologies that allow them to supply the basic needs of food, housing and self-employment.

Generating a greater social impact in the installation of the SCAP, self-employment is developed in irrigation systems developed from this same project and the knowledge of how a collection system works and the components that make it up.

- Contributions of new knowledge to the school community in innovative irrigation systems for their use in greenhouses and their expansion in the Institute.

Economic impact in SCAP

Since there is a direct relationship between the supply and demand of water, which affects the catchment area and the storage volume, it is found that both considerations are closely linked to the economic aspect, which usually results in a restriction for the majority. part of the interested parties, which makes it impossible to access a supply system of this nature. In the economic evaluation, it is necessary to keep in mind that in no case should the water supply be less than 20 liters of water per family per day, the same amount that allows them to satisfy their basic basic needs, and the aspects of personal hygiene and washing hands must be attended to. clothing from other sources of water. Likewise, the costs of the proposed system, which have a cost of \$20,000 and must be compared with the costs of other alternatives aimed at improving the water supply, this price is taken into account for the homes of the Ayotla community.

Generating the impact that the amount of water represents on the health of the people benefited by the water service, in this case the comparison or the respective economic impact is towards the facilities found in the ITSSNP that according to the studies and development of this project in building E, the projection is from one year to a year and a half, generating less consumption of drinking water, generating savings in the economic sphere and the difference that is found in terms of rainwater is summarized.

On the other hand, and previously mentioned, another economic impact is the savings from the reduction in the hiring of water pipes, which have a price of \$800 to \$900, which is a continuous expense that adding it over time would be one more expense. It is great to invest in one of these fundraising systems which also generate other methods to generate money and this is through the help of other projects also applied in this town and within the Institute.

- Cost reduction in the purchase of irrigation systems for production in greenhouses or micro tunnels.

Link with the productive and social sector

This project is being implemented in the social sector in the community of Ayotla, which is a community where most of the families do not have a drinking water network. For this reason, the need was seen to implement the project together with resources from the Club. Rotary of Zacatlán through the participation of a grant obtained in the United States for a total amount of \$1,500,000.00 so that within that amount, collection systems would be put in place that benefit 22 families in the community, starting at the Institute with the participation of the students and masters both for its installation and for its corresponding monitoring.

Conclusions

Once the viability of the impacts and their various topics of knowledge and understanding have been evaluated in conjunction with their support tools and having carried out their respective analysis with the help of graphs and the measurement instrument applied to the students, it is the right time to present below the conclusions and of this project. The development of a new system for collecting rainwater and caring for drinking water and natural aquifers allows us to unify the knowledge of the different needs in areas where there is no water supply from the drinking network, as well as generating the development of different tools in subjects taught in the Industrial Engineering career, such as occupational hygiene and safety, quality management and systems, research workshop, ergonomics, etc. And above all, apply the basic and theoretical foundations in improvement processes within innovative industries or new sources of common interests in localities.

The analysis of results indicates that the different impacts proposed in this project are capable of being implemented in a media manner for the benefit of the Institute and its respective areas or localities, since the results meet evolution criteria and establish an improvement in its processes and validation of needs and high impacts such as environmental, social and economic since this project is currently implemented outside the Institute which was sent to the community of Ayotla which also aims to be used frequently and obtain greater validation and feasibility by people who are trained to understand and use this type of systems and the benefits without high cost, also have a verification of use and knowledge of them and make use of their benefits being implemented properly.

This is why it is considered to choose to work more with this type of projects since it is established that continuous improvements are generated and the results have viability for expansion.

Annexes

Annex 1: Measuring instrument

“Management of the SCAP within the institute as a source of benefit and generator of impacts for saving water in the drinking network”

Next, you will find a series of questions aimed at knowing your judgment about the aspects that are evaluated in the project, such as the highly relevant factors such as the social, environmental and economic impact mentioned above.

The questionnaire has 5 sections which are made up of a total of 17 multiple choice questions and answers for your choice, which you are asked to read carefully and answer appropriately at your discretion, your answers being confidential and will later be gathered for a analysis according to the main point of the project, which are the different beneficial factors generated which it is desired to fulfill to frame the importance of these projects.

Thank you so much.

KNOWLEDGE

1. How much do you know about the term collection systems?

- NOTHING - ALMOST NOTHING - VERY LITTLE - A LOT - TOO MUCH

2. What knowledge do you have about the benefit they provide?

-NOTHING -ALMOST NOTHING -VERY LITTLE -MUCH - TOO MUCH

3. Do you consider that any type of water can be used for a collection system?

- DEFINITELY NOT - PROBABLY NOT - I DON'T KNOW
-PROBABLY YES -DEFINITELY YES

4. Do you have any knowledge of the four water collection systems that are installed within the ITSSNP?

-NOTHING -ALMOST NOTHING -VERY LITTLE -MUCH -TOO MUCH

Importance

5. How important do you consider rainwater collection to obtain adequate use of it?

-NOTHING -ALMOST NOTHING -VERY LITTLE -MUCH -TOO MUCH

6. Do you think it is important to save drinking water?

-NOTHING -ALMOST NOTHING -VERY LITTLE -MUCH -TOO MUCH

7. Do you think it is important to have a collection system for personal use?

-NOTHING -ALMOST NOTHING -VERY LITTLE -MUCH -TOO MUCH

8. Do you consider that the collection systems help to improve the institute's water service, obtaining care and supply benefits?

- DEFINITELY NO - PROBABLY NO - I DON'T KNOW - PROBABLY YES - DEFINITELY YES

9. How important do you consider maintaining the systems so that they function properly?

-NOTHING IMPORTANT -LITTLE IMPORTANT
-MEDIATELY IMPORTANT -IMPORTANT
-VERY IMPORTANT

Use

10. Would you use water from rainwater collection systems for human consumption (drinking)?

-NO -PROBABLY -IF I DID NOT HAVE A CHOICE -SOMETIMES -YES

11. What level of importance do you think is the installation of water collection systems for the ITSSNP service?

-NOT IMPORTANT -LITTLE IMPORTANT -MEDIATELY IMPORTANT -IMPORTANT -VERY IMPORTANT

12. Which building do you usually visit most frequently to use the toilet when you are during class time?

-BUILDING A -BUILDING E -BUILDING M -COMPUTER CENTER
-INFORMATION CENTER

Quality of service

13. When you go to the toilet, is there water available for sinks and flushing in any of the buildings you go to?

- NO MOST OF THE TIMES NO -SOMETIMES YES
- SOMETIMES NO -MOST OF THE TIMES YES
- ALWAYS

14. Do you agree that the implementation of the collection systems within the ITSSNP will lead to an improvement in the supply, reduction and care of water?

- STRONGLY DISAGREE -DIAGREE -NEUTRAL
- AGREE -STRONGLY AGREE

15. Do you consider that the collection systems help to improve the institute's water service, obtaining care and supply benefits?

- DEFINITELY NOT - PROBABLY NOT - I DON'T KNOW
- PROBABLY YES -DEFINITELY YES

System in your home

16. Knowing that building a rainwater harvesting system destroys nature a little, do you agree with its development within your personal environment?

- I WILL NEVER AGREE -I DO NOT AGREE
- I POSSIBLY AGREE -YES I AGREE
- STRONGLY AGREE

17. You would take advantage of its benefits correctly:

- DEFINITELY NOT - PROBABLY NOT - I DON'T KNOW
- PROBABLY YES -DEFINITELY YES

Annex 2: Work on the capture and filtering system

Illustration 1 Perimeter cleaning



Illustration 2 System cleaning



Illustration 3 SCAPs filling review



Illustration 4 Visit to Ayotla



Illustration 5 Arrive product for the installation SCAPs



Illustration 6 Cleaning the system



Declarations

Conflict of interest

The authors declare no interest conflict. We have no known competing financial interests or personal relationships that could have appeared to influence in this chapter.

Author contribution

Hernández-Ramos, Katia: Contributed to the project with the execution of field work and the contribution to the cleaning system and supervision.

Hernández-Ramos, Alma Yizel: Contributed to the project with the theoretical part and the beginnings investigations, also the benefits in the project.

Panecatl-Bernal, Yesmin: Contributed to the project in the methodology part and the generalities about the hypothesis and the research object.

Hernández-Corona, Sergio: Contributed to the project idea and the beginnings to the project in the Institute and the methodology.

Availability of data and materials

The data obtained in this research are precise since accurate information was obtained and instruments were also applied having a research focus and an object of study that was random since the project was applied at the institute for its own benefit and thanks to its high benefits are currently being applied in a nearby community in Zacatlán Puebla, since, as previously explained, the remuneration is highly verifiable.

Funding

This project is being implemented in the social sector in the community of Ayotla, which is a community where most of the families do not have a drinking water network. For this reason, the need was seen to implement the project together with resources from the Club. Rotary of Zacatlán through the participation of a grant obtained in the United States for a total amount of \$1,500,000.00 so that within that amount, collection systems would be put in place that benefit 22 families in the community, starting at the Institute with the participation of the students and masters both for its installation and for its corresponding monitoring.

Abbreviations

SCAP	Rainwater collection system (English)
ITSSNP	Instituto Tecnológico Superior de la Sierra Norte de Puebla
NOM	Normas Oficiales Mexicanas

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Database design to translate from Nahuatl to Spanish

Diseño de base de datos para traducir del Náhuatl al Español

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CONAHCYT classification:

DOI: <https://doi.org/10.35429/H.2024.8.16.29>

Area: Engineering

Field: Engineering

Discipline: Systems engineer

Subdiscipline: Computer Sciences

Key Handbooks

The development of a database design for translating from Nahuatl to Spanish. By means of the implemented methodology, it is possible to optimize the linguistic relations. Laying the foundations for the development and implementation of the translation of the Nahuatl language into Spanish and its different variants depending on the region. The successful implementation of the methodology in the design of databases based on the Relationship Entity Model (MER) and its respective graphical representation, it was possible to optimize the linguistic relations and guarantee an accurate and contextual translation.

Citation: Luna-Eslava, Rubí, Sampayo-Rodríguez, Carmen Jeannette and Torres-Jiménez, Jacinto. 2024. Database design to translate from Nahuatl to Spanish. 16-29. ECORFAN.

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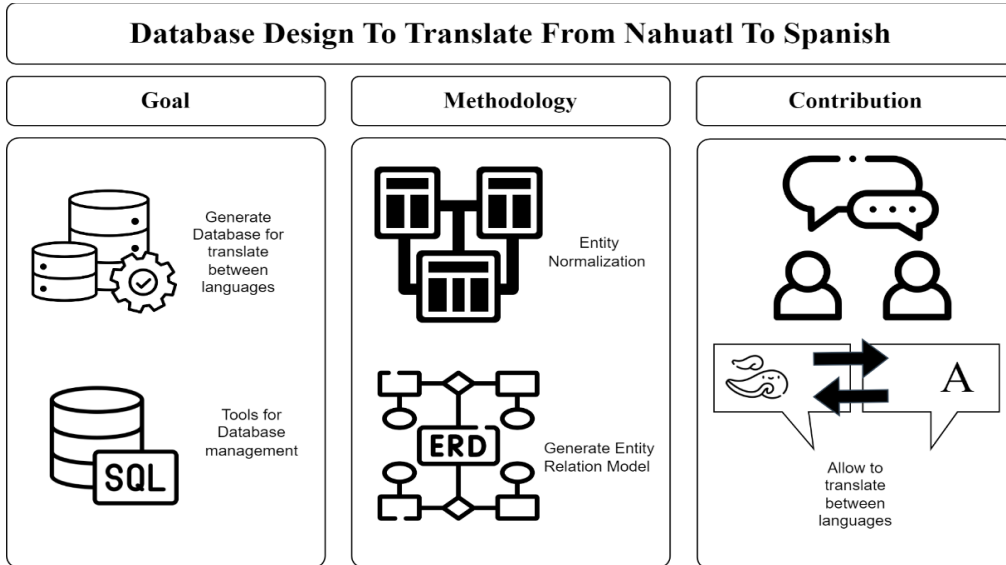
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Abstract

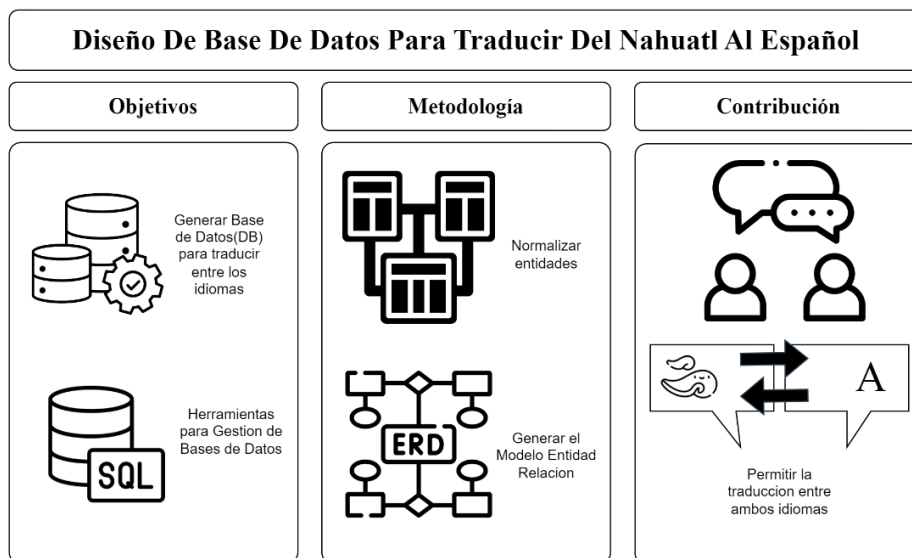
This paper presents a proposal for the creation of a knowledge base to serve as a starting point for training a real-time translation system between Nahuatl and Spanish using the Entity-Relationship Model (MER) for database design. In this model, entities and relationships are key elements, with mathematically defined attributes corresponding to specific domains. To implement this model, a specific methodology is followed, ranging from the determination of entities to the physical design of the database. Effective database design requires consideration of three essential elements: structure, relationships and integrity rules. These rules ensure that key values in relationships are defined and that attributes in one relationship properly correspond to others in a different relationship.



Database, Creation, Structure, Methodology

Resumen

En este artículo se presenta la propuesta de la creación de una base de conocimiento que sirva como punto de partida para entrenar un sistema de traducción en tiempo real entre el náhuatl y el español utilizando el Modelo Entidad Relación (MER) para el diseño de bases de datos. En este modelo, las entidades y relaciones son elementos clave, con atributos matemáticamente definidos que corresponden a dominios específicos. Para implementar este modelo, se sigue una metodología específica que abarca desde la determinación de entidades hasta el diseño físico de la base de datos. El diseño efectivo de una base de datos requiere considerar tres elementos esenciales: estructura, relaciones y reglas de integridad. Estas reglas garantizan que los valores clave en las relaciones estén definidos y que los atributos en una relación correspondan adecuadamente a otros en una relación diferente.



Creación, Estructura, Metodología

Introduction

In the country, the Nahuatl language is one of the most widespread native languages, and there are multiple variants of it. In the state of Puebla, there are four variants, however, a large part of the population is marginalised because they lack knowledge of the Spanish language. There are procedures that Náhuatl speakers carry out with the support of a family member who may or may not have knowledge of the language, which makes it difficult and complicated for them to receive attention and access services. Another problem arises when Náhuatl speakers try to sell the products they make, as it is common that they cannot communicate in Spanish, so they depend on the goodwill of the buyers, so that they do not pay them less than what they ask for their products.

It is important to be able to translate the Náhuatl language into Spanish because it would allow us to learn about the knowledge of the Náhuatl healers, constituting an important intergenerational knowledge transfer (Polanco, E. A. 2024). Another area we should consider is to maintain and cultivate our Náhuatl culture in order to learn about the worldview of our ancestors (Madajczak, J. 2024). In order to study the Nahuatl language in depth, a study of the Codex Mendoza was carried out in 2024, focusing on three important areas: 1) analysis of the material, 2) textual and stylistic interpretation, and 3) study of the reception and circulation of the codex (Caplan, 2024).

Among the existing tools for translation from Nahuatl to Spanish is the MeztlíSoft application, which was presented in 2016 and promoted during the following years, however, it has the limitation that it only translates individual words, in addition to not being available to the population and the version only includes basic vocabulary. It is important to mention that Spanish is the second most spoken native language and is the mother tongue in 20 countries (España-Bonet, C., & Barrón-Cedeño, A. 2024). Another application that translates Nahuatl into Spanish is the web application called Axolotl created by the UNAM, it is a dictionary or repository, which allows to consult and translate words of all variants of Nahuatl, however, it does not include pronunciation, grammar or semantics, required to make a correct translation or rather adaptation to allow to really understand what is being communicated.

Currently there are devices and companies that allow real-time translation of a conversation between two languages (Osborne, M. 2017), one of the most important that we can mention is Microsoft (Microsoft.com. 2023). Currently there are 3 paradigms of machine translation:

The first of these is Rule Based Machine Translation (RBMT), which requires knowledge of the grammar of the source and target language, as well as bilingual dictionaries, and the respective transfer rules, so it is difficult to translate words or expressions that do not exist within the universe of the knowledge base, (Mercedes, P. H. 2002) which makes its implementation complicated as it requires constant maintenance to ensure that it is able to translate texts or information from a new domain.

Another paradigm is Statistical Machine Translation (SMT), which consists of 3 main components, the language model, the translation model and the decoder, which calculate the probability that a sentence in the target language is correct, establish the correspondence between the languages and is trained by aligning to the sentence level, and based on the possible translations presents the most probable translation as a result of the translation. Globalisation has led to trade being conducted in the language spoken in each country, which has led to the development and use of translators (Caudet, 2011). For example, in the European community, software has been developed that uses automatic translation to make trade more agile and efficient (Abaitua, 2023).

Finally, the Neural Machine Translation (NMT) paradigm is the most recent of all, as it emerged only in 2014, although there is a precursor from the 1990s which was not carried out due to lack of powerful equipment, NMT aims to emulate the way the human brain works, making connections between the components of language with other underlying information to form associations and generate translations, it should be noted that it uses machine learning techniques, i.e. the computer learns to translate from parallel texts (García Aguilar, C. 2018). Also large companies such as Microsoft with Azure use artificial intelligence for the market with API: Application Programming Interface (azure.microsoft.com, 2023). In this research project we propose to design the database for an application that allows to translate not only words but complete sentences, using the statistical translation paradigm, in order to provide the user with the translation that is best suited to communicate their idea, for this the variant of Nahuatl of the North of Puebla will be used.

Methodology

Within the tools that will be used for the design of the database we have the software Visual Paradigma CE, a powerful tool that allows not only to make the Entity Relationship Diagrams of data modelling, but it is a powerful tool used to make UML modelling, manage requirements, and various design tools, including those that occupy us now that are for database design.

It is proposed to use SQL server, since it is a robust database management system and above all because it has a free version for developers, so there will be no licensing costs, in the case of Firebase DataBase Realtime is due to two things one for the technological part is part of the Android development environment, it is native, so when integrated into a mobile application would be very useful because the vast majority of smartphone users have Android operating system.

Therefore, a functional database for a translation application (Coronel, 2018) would help to solve the communication problem, as it would serve as a basis for training translation engines to translate from Spanish to Nahuatl.

The Entity-Relationship Model (MER) has an excellent acceptance as a tool for modelling the real world in the database design process, it operates with the concepts of entity and relationship. Entity occurrences are classified in different entities E_i , where there will be a predicate associated with each entity that will allow to compare if an arbitrary occurrence belongs to a given entity, because they can belong to more than one entity. A relation is a mathematical relation between n entities (M. J. Hernandez, 2021).

$$\{(e_1, e_2, \dots, e_n) \mid e_1 \in E_1, e_2 \in E_2, \dots, e_n \in E_n\} \quad (1)$$

And each element of that relationship has that occurrence of relationship (e_1, e_2, \dots, e_n) , where the E_1 and the n need to be different. The role in an entity in a relationship that expresses the function that entity plays in the relationship. There is additional information to the entity's predicates and relationships that can be obtained through the attributes associated with the entity. A domain value may be equivalent to another value in a domain. An attribute is defined in the SRM as a mathematical function that establishes a mapping from an entity or relationship to a domain or a Cartesian product.

$$\text{Atrib1} : E_i \rightarrow D_{i1} \times D_{i2} \times \dots \times D_{in} \quad (2)$$

$$\text{Atrib2} : R_i \rightarrow D_{i1} \times D_{i2} \times \dots \times D_{in} \quad (3)$$

Note that an attribute is always defined as a function, so it always matches a given occurrence with a single value of a tuple, as it defines a Cartesian product of domains, relations can also have attributes. So the following characteristics of attributes in this model can be highlighted is that attributes are only functional correspondences.

The fact that can be recorded about the values in this model is their domain membership, if you want to represent another property, the associated attribute must be converted to an Entity. The MER has an associated graphical representation known as an Entity Relationship Diagram (ERD).

In an ERD, entities are represented by a rectangle, each relationship by a diamond, and each domain by a circle, lines are used to connect entities to relationships, as well as entities to domains, representing attributes. Keys are underlined, for identification.

If the entity cannot be identified solely by the value of its attributes, the relationships to the attributes are used in sets to achieve unambiguous identification, these entities are known as weak entities (DE) and are represented by a double rectangle. In the MER, the relationships to be used to identify DEs are restricted to 1:n binary relationships. The key of this entity is formed by combining the key of the regular entity that determines it with some other attribute or set of weak attributes that define each DE associated to a regular entity. For each relationship its type is determined, whether it is simple or complex, and the type of correspondence is presented in the DER. When implementing the Entity-Relationship Model, the workflow to be followed is shown in Figure 1.

Database Design Methodology

The methodology for database design consists of the following steps:

1. Determination of entities and attributes.
2. Entity normalisation.
3. Determination of relationships (DER)
4. Obtaining global logical model of data
5. Physical Design of the DB.

To carry out a database design for a system, it is necessary to determine the necessary data and the functional dependencies between them. This is obtained after the analysis stage and from there, the indications that allow a good design of the DB are generated, based on what we know about the system.

Box 1

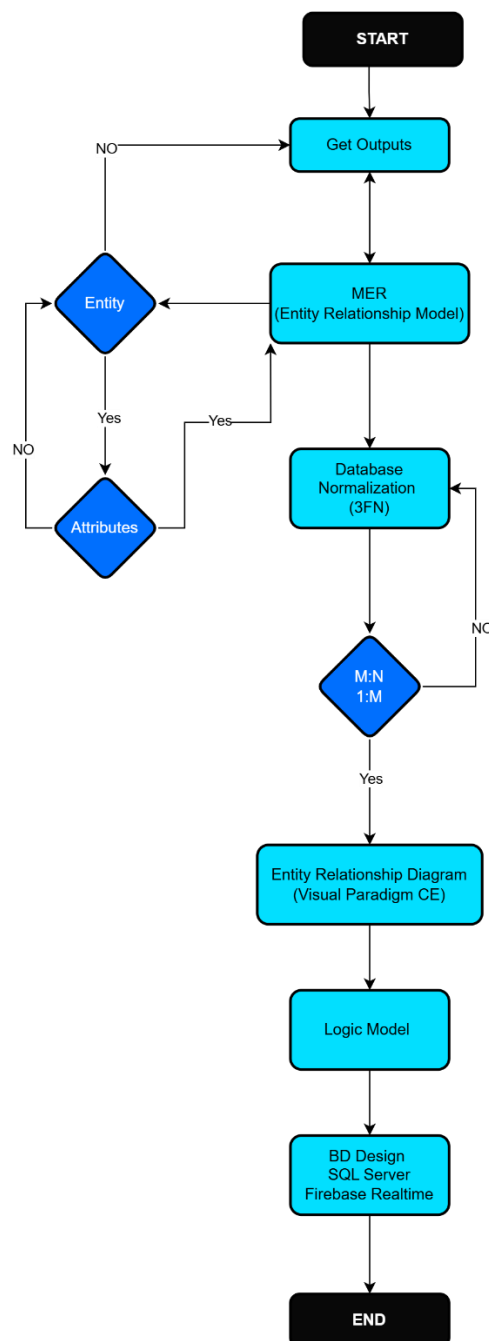


Figure 1

Workflow for implementing the Entity Relationship Model (ERM)

Relational integrity.

In any data model there should be 3 elements to consider:

- Structural element
- Integrative element
- Manipulative element.

The structural element is what we already know, the unique structure for the relational model, the relation of attributes and tuples also known as relation of degree n , where the domains define the attributes and the value of the domains is atomic, as well as complying with the 2FN, 3FN and FNBC. The integral element is composed of 2 rules:

- Entity integrity rule: dictates that the primary key values in a relationship must be defined.
- Referential integrity rule: dictates that an attribute (single or combined) of Y in a relation $R2$, its values correspond to the primary key X in the relation $R1$, so, for every value Y in $R2$ exists or is equal to the value of X in a tuple of $R1$ or, it is undefined.

To exemplify this issue:

We have a Word-TypeWord model, where the attributes of P and T of PTP refer to $WordId$ and $WordTypes$.

Relational Algebra Operations

The manipulative element, establishes a set of operations that make up the relational algebra. However, there are two variants of this element of the relational model, the relational algebra and the relational calculus, where the first is based on the procedure and the second does not take it into account, i.e. the algebra indicates how it should be done, while the calculus only focuses on what is to be obtained.

Traditional operations of set theory

When we refer to the traditional operations of set theory, we talk about the operations of union, intersection and difference that occur in the relations of two given entities A and B , when two conditions are met, the same degree (n) and the attribute of each entity is defined on the same domain ($1 \leq i \leq n$). In the Union it is defined as the set of tuples that belong to entity A or entity B or belong to both entities.

For example, a language is formed by words, so in a database we would have a language table, a table of words, then to represent the union we could say that if we have 2 databases of different languages both databases would have a table words so we would deduce that both tables have the same attributes, so we can denote a union u , where the word tables of each base of each language are in the same attributes are the same so the relationship can be represented as follows:

WordsLanguage1 \cup WordsLanguage2

The Intersection is understood as the set of tuples that belong to entities A and B , that is to say, they exist in both universes, following the example of the words of a language, we know that there are words that have their pair in each language, that is to say, their meaning is the same, however, there are others that do not have an equivalent, or pair in another language. Therefore, if we want to obtain the words that mean the same thing in both languages, we would have the following representation:

WordsLanguage1 \cap WordsLanguage2

The difference is the set of tuples that belong only to one of the compared entities, continuing with the example of the words of the languages we would have that the difference would be those words that exist in a language and have no pair in the other, for example, the word estrenar does not have an equivalent in English and would be represented in the following way

WordsLanguage1 - WordsLanguage2

The Cartesian Product is the set of concatenated tuples, i.e. entity a by entity b , where they can be of the same degree or not, the same happens with the attributes that can be in different domains, we could define it as the multiplication of the attributes of two tables, and it is represented as follows:

WordsLanguage1 ϵ WordsLanguage2

Special relational operations

For relational algebra we define special operations as Selection, Projection, Concatenation (join) and Division.

Selection

For Selection, comparison operators such as $<$, \leq , $=$, \neq , \geq , $>$ are used, so when θ is any comparison operator, then:

$R_{R.X \theta R.Y}$

It is a set of all t tuples t of R where the comparison between $t.X \theta t.Y$ takes value, where the attributes of X and Y must be defined by the same domain and the operation θ must make sense in that same domain, allowing to specify a constant such as:

$R_{R.X \theta \text{constant}}$

So we can say that the operation Selection obtains horizontal subsets of a Relation, i.e. a subset formed by the tuples of the relation that satisfy the comparison. Such comparisons θ can also be combined with the logical operators AND, OR and NOT, represented as $\dot{\cup}$, $\dot{\cup}$, and \emptyset .

To give an example, we will have the following equivalences:

$R_{C1} \wedge C2$ is equivalent to $R_{C1} \cap R_{C2}$

$R_{C1} \vee C2$ is equivalent to $R_{C1} \cup R_{C2}$

$R_{C1} \neg C2$ is equivalent to $R_{C1} - R_{C2}$

For selection, R is equivalent to both a Relation and an expression in parentheses.

Suppose we have a table with words in different languages, from which we want to identify which words are used or refer to the moon, as shown in **table 1**

Box 2

Table 1

Set of words in different languages

WORD				
Id	Word	Language	TpWord	Meaning
1	Luna	Spanish	1	Moon
2	Meztli	Nahuatl	1	Moon
3	Yatziri	Mayan	2	Moon maiden
4	Xochitl	Nahuatl	1	Flower
5	Flower	English	1	Flower
6	Moon	English	1	Moon

Then the selection would be as follows

WORD Meaning = 'Moon

So the resulting table looks as shown below in Table 2:

Box 3

Table 2

Nahuatl to Spanish translation

WORD

Id	Word	Language	TpWord	Meaning
1	Luna	Spanish	1	Moon
2	Meztli	Nahuatl	1	Moon
6	Moon	English	1	Moon

Projection

Simplifying the theory, the projection allows columns to be selected in a certain order. Then the projection of a relation R onto the attributes X, Y, \dots, Z :

$R[X, Y, \dots, Z]$

It is the set of tuples where there exists a **tuple t** in R that has the value of x in attribute X , the value of y in attribute Y , ..., the value of z in attribute Z . So the projection is a Vertical subset of a relation, i.e. the resulting subset is selected with the specified attributes in an explicit order either from left to right, eliminated in case of duplicate tuples when choosing the selected attributes, because the order is considered a relevant parameter, the projection provides the way to reorder the attributes of a table, like the selection, in the projection R can be a relation or an expression in parentheses.

It should be noted that an attribute cannot be specified more than once in the list of attributes of the projection, and if this list is omitted it is understood that the attributes have been considered in their corresponding order from left to right, i.e. the projection would be the same relation given, eliminating the repeated tuples.

Continuing with the example of the Word relation, let's suppose that we wish to obtain only the attributes meaning and TpWord, in that order that is not the same of the Word relation, then our projection on the Word table would be:

$WORD[MEANING, TpWord]$.

The resulting table is as follows:

Box 4

Table 3

Projection of the Relationship Word

Meaning	TpWork
Moon	1
Moon maiden	2
Flower	1
Moon	1

Concatenation(join)

The concatenation allows us to combine the information that is housed in different tables, the information from two tables is combined with a join based on a comparison of the last attribute of the first table with the first attribute of the second table using the $=$ operator. The result relation of the join will consist of the tuples from both tables that meet the precondition, i.e. that the comparison of the attributes is true.

Where let θ be any comparison operator, the **concatenation- θ** of a relation A on attribute X with a relation B on attribute Y , is the set of all tuples t such that t is the concatenation of a tuple and a tuple $b \in B$ and for which the predicate $a.x \theta b.y$ takes a given value. Where it must be satisfied that the attributes $a.x$ and $b.y$ are on the same domain and that the operation θ makes sense in the same domain.

The operation is called 'equijoin' if θ is the comparison $=$, since the result has to include two identical attributes. If either of them is eliminated, then the result is either a natural concatenation or a natural join or simply a concatenation (JOIN denoted by $*$), for example:

WORD * TpWORD * TpWORD ON ATTRIBUTES TpWORD on Word and IdTP on TpWORD defined on the same domain, being equivalent to:

((WORD BY TpWORD) WORD.WORD.TpWORD = TpWORD.IdTP)
 [WORD.Id, WORD.Word, WORD.Language, WORD.TpWord, WORD.Meaning, TpPWORD.IdTP, TpWORD.Description]

It is recommended that if we wish to reorder the attributes, we must make the necessary projections prior to performing the concatenation, so applying a reordering in the previous example would be as follows:

PALABRA[Id,Word,Meaning] * TpPALABRA

Division

The operation division, produces a quotient relation of degree m , by dividing a relation A of degree $m+n$ by a divisor relation B of degree n where the $m+i$ attribute of A and the i -th attribute of B are defined on the same domain, if the first attributes of A are considered as a composite attribute X and the last n attributes as a composite attribute of Y , the relation A can be visualised as a set of (x,y) pairs, just as the relation B would be a set of unique y -values, thus having the result of evaluating **A BETWEEN B**, would be the relation C with a composite attribute X where each value of x of C . X appears as a value of $A.X$, and the value pair (x,y) appears in A for all y -values appearing B , i.e. **A BETWEEN B** is the set of t -tuples t such that for all tuples $b \in B$, and tuple $t.b \in A$.

For completeness, it is worth noting that the operations special relations have a priority, where Selection is the highest priority followed by projection, and finally concatenation and division..

+	↑	Selection	
		Screening	
-		Concatenation	and
		Division	

Database Management Systems

Software that allows the use, updating, of data stored in one or several databases by one or several users from different points of view simultaneously, are called Database Management Systems ([Sanchez, O. 2021](#)).

SQL Server

This is a relational database management system, developed by Microsoft, the query language used is Transact-SQL, an implementation of the ANSI standard SQL language, used to manipulate and retrieve data, create tables and define relationships between them.

It is characterised by having good transaction support, being scalable, stable and secure, supports stored procedures, its powerful graphical administration environment, allows the use of DDL and DML commands graphically, allows work in client-server mode, where the information and data are hosted on the server and the network terminals or clients only access the information.

This database engine in its different versions regularly has 5 editions:

- Express Edition, is the free version, and even though it comes with many limitations, it is very useful for developing a small project.
- Developer includes all the features of the Enterprise version, but the licensing included does not allow us to use it for production environments, however, it is ideal for testing advanced features.
- Web, is the low cost edition for use in Web Hosters.

- Standard, this version contains Business Intelligence functionalities ideal for small and medium sized companies.
- Enterprise is the version that includes all SQL Server functionality.

SQL Server contains a large number of tools and associated functionalities, to mention a few are Data Importer and Exporter, a Profiler that will allow us to analyse the performance, SQL queries among other considerations, as well as tools to make improvements in the data schemas depending on the workloads analysed (Groff R, J., & Weinberg N, P. 2009).

Among the services we can find data replication, Machine Learning related services, support for external queries, analysis and statistics services, among many others.

Oracle DB

Oracle Database, ranked first as the most popular database manager followed by MySQL and MS SQL Server, its first version was released in 1979, currently versions 19c and 21c are available for long term and innovation.

Oracle DB is the core of the enterprise computing environment, it uses a relational database model for Oracle Database, which allows storing and representing company and customer data in the form of organised data sets. The data quantities are structured in columns, tables and rows, and the data points are related with the help of attributes. The great advantage of Oracle Database is that it organises and presents data volumes in an intuitive and efficient way. In addition, companies can decide whether they want to use Oracle Database on-premises or in the cloud.

Firestore Realtime Database

It is not a database manager as such, but a database hosted in the cloud, which stores data in JSON format, and synchronises in real time with each of the clients connected to it. When multiplatform applications are created, they share an instance of the Realtime Database, and automatically receive updates with the most recent data on the different platforms.

The points to be highlighted are the following:

Real Time: It does not use HTTP requests, but uses Data Synchronisation which allows all connected devices to get the information within milliseconds.

Offline: By using Firestore, data is retained on the device, so applications continue to work even when offline.

Accessibility: No matter the device, as it does not require an application server, real-time data security and validation is performed by rules based on expressions that are executed when reading or writing data.

Scalable: It has several pricing plans, but even the blaze, allows for scale needs to be met by splitting the data across multiple instances in the same project.

However, Firestore Realtime Database is not just a database, it is a suite that allows you to create collaborative applications with secure access to data directly from the client code, providing the end user with a rich experience even offline, and on reconnection the client synchronises with remote changes (Ganesh, C. D. 2017). It provides a flexible rules language that is based on expressions, called Firestore Database Security Rules, which define the structure of the data, as well as how and when it can be read, written and modified. It also features Firestore Authentication where devs can define who can access the data and how.

Firestore Database is a NoSQL database, which is designed to enable fast running operations, so it can meet the real-time experience to respond to millions of users without compromising responsiveness (Coronel, C., & Morris, S. 2018).

Database Analysis

Starting from this analysis the situation that will apply the database design methodology is the following: It is desired to create a database system that allows to translate word from Spanish to Nahuatl language, and to know the correct pronunciation of each phrase.

The desired outputs are the following:

1. Vocabulary List:

Nahuatl - Spanish vocabulary list with abbreviation of the word type corresponding to the Nahuatl word.

Nahuatl word

Abbreviation

Spanish word

2. Word Equivalent:

Get Nahuatl word corresponding to the Spanish word entered.

Nahuatl Word

Spanish word

3. File Path:

Get the path to access an audio file stored on an exposed server.

Nahuatl word

Spanish word

File Path

Database Design

Design considerations

- Must consider that one Spanish word may have several Nahuatl translations depending on the context.
- Must consider that one Nahuatl word may have several translations into Spanish depending on the context.
- Each word may have one or more linked audio files.

a) Entity Relationship Diagram

The design of a translation application requires optimising the handling of the relationships between the words between the languages to be translated, in order to generate a reliable and trustworthy knowledge base.

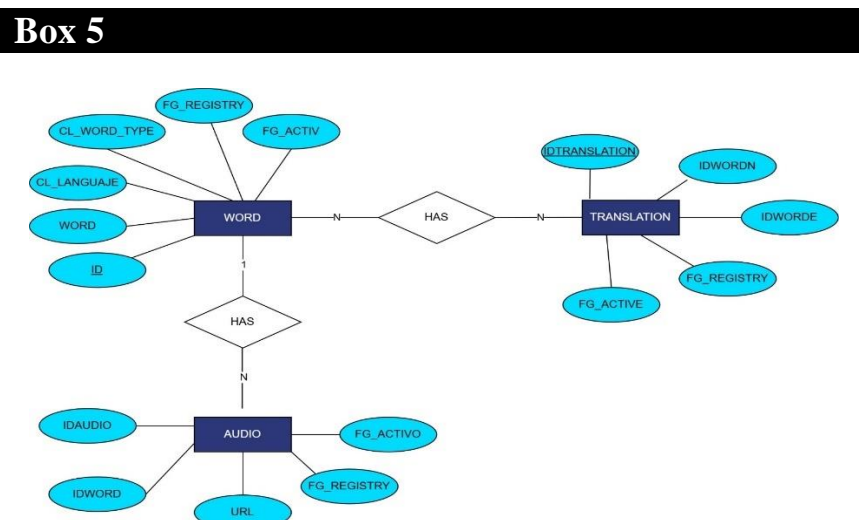


Figure 2
Entity Relationship Block Diagram

Relationships exist because:

- A word has one or more translations
- A translation has a source word
- A word has one or more audios
- An audio has a related word

b) Entities

The entities identified in the conceptual model are described below:

The Entity WORD is made up of the attributes:

IdWord is the number assigned to each word following an alphabetical order. o Word is the number assigned to each word following an alphabetical order.

- Word corresponds to the ordered set of characters that together form a word.
- The Translation Entity is made up of the attributes:
- IdTranslation is the number assigned for each translation.
- IdWordN corresponds to the idWord assigned to a word whose source language is Nahuatl.
- IdWordE corresponds to the idWord assigned to a word whose source language is Spanish.

The AUDIO Entity is made up of the attributes:

- IdAudio is the number assigned for each Audio.
- IdWord is the number assigned to each word that has an Audio linked to it.
- Url corresponds to the path where each file is located.

c) Entities and Attributes

- WORD (Id, Word)
- TRANSLATION (IdTranslation, IdWordN, IdWordE)
- AUDIO (IdAudio, IdWord, url)

d) Entity Normalisation

Functional Dependencies

A. How Id identifies the word
Id → Word

B. As IdTranslation identifies translation
IdTranslation → WordN, WordE

C. As IdAudio identifies Audio
IdAudio → Url, IdWord

Relationships

R (Id, Word, IdTranslation, WordN, WordE, IdAudio, url, IdWord)

Candidate and Primary Keys

- R1 (Id, Word, IdTranslation, IdWordN, IdWordE)
- R2 (Id, Word, IdAudio, Url, IdWord)

e) Normal Forms

For the relation we have:

- WORD (Id, Word)

- TRANSLATION (IdTranslation, IdWordN, IdWordE)
- AUDIO (IdAudio, IdWord, url)
- LANGUAGE (IdLanguage, Language)
- TYPE_WORD(Word_Type_ID, Description, Abbreviation)

The relation looks like this:

R (WORD (Id, Word, IdTranslation, IdWordN, IdWordE, IdAudio, IdWord, url, IdLanguage, Language, IdTypeWord, Description, Abbreviation))

According to the relations, the following tables are obtained:

- Word (Id, Word, Cl_Word_Type, Cl_Language)
- Translation (IdTranslation, IdWordN, IdWordE)
- Audio (IdAudio, IdWord, IdWord, Url)
- Language (Cl_Language, Language)
- WordType (IdWordType, Description, Abbreviation)

Conclusions

The successful implementation of the methodology in the design of databases allows to have a reliable source of information, and easy maintenance, which will allow our applications and systems to be more efficient over time, because its design will allow to document the relationship of each of the entities, which will support so that it can evolve if necessary, without affecting the pre-existing data.

With the Entity Relationship Model (MER) and its respective graphical representation, it is possible to optimise the linguistic relationships and guarantee an accurate and contextual translation. The methodology for the design of the database, which includes the identification of entities, attributes and relationships, provides a robust and detailed structure that could transform the way in which the Nahuatl language is interacted with, contributing to its preservation and facilitating interaction between speakers of both languages: Nahuatl-Spanish.

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
Conceptual development of a pulverizer for glass recovery

Desarrollo conceptual de pulverizadora para la recuperación de vidrio

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CONAHCYT classification:

DOI: <https://doi.org/10.35429/H.2024.8.30.40>

Area: Engineering

Field: Engineering

Discipline: Mechanical Engineering

Subdiscipline: Mechanical Design

Citation: Fuentes-Castañeda, Pilar, Betanzos-Castillo, Francisco and Cortez-Solis, Reynaldo. 2024. Conceptual development of a pulverizer for glass recovery. 30-40. ECORFAN.

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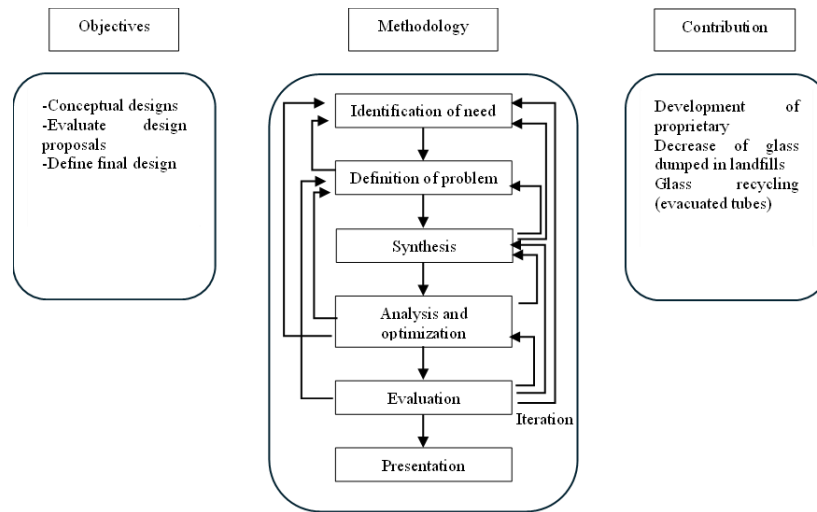
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Abstract

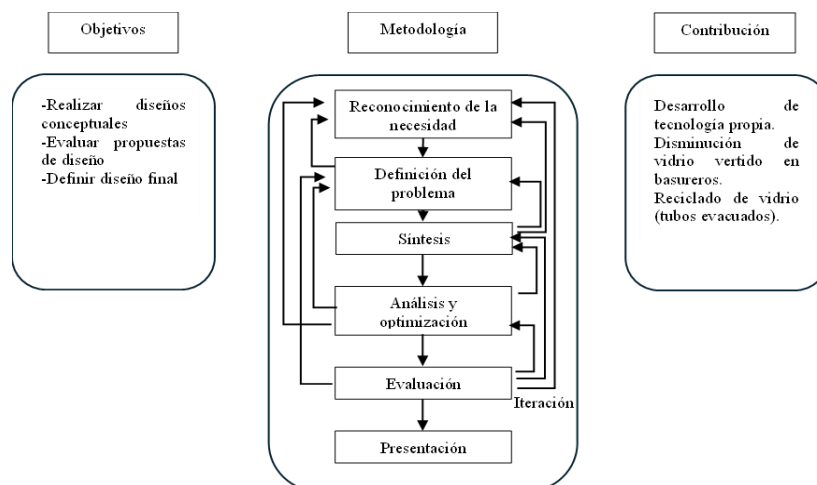
This paper describes the procedure for the development of the conceptual design of a spraying machine, which will help in the recycling of glass obtained from evacuated tubes. This design was made under the consideration of generating a proprietary technology, which would allow to obtain in the region the necessary elements for its construction, as well as for the maintenance and improvement of the prototype, because the existing ones are expensive or require maintenance to be provided by the companies that sell them, and spare parts, in some cases, need to be ordered from abroad. The development of the concept was done following the methodology for mechanical engineering design, starting by identifying a problem to be solved, glass deposition in landfills; generating sketches, identifying the elements and components to be used; evaluating the feasibility of obtaining them and generating the final concept for their manufacture.



Conceptual design, Recycled glass, Pulverizer

Resumen

En el presente trabajo se describe el procedimiento para el desarrollo del diseño conceptual de una máquina pulverizadora, la cual ayudará en el reciclado de vidrio obtenido de tubos evacuados. Este diseño se hizo bajo la consideración de generar una tecnología propia, la cual permita conseguir en la región los elementos necesarios para su construcción, así como para el mantenimiento y mejora del prototipo, debido a que las existentes son costosas o requieren que el mantenimiento sea brindado por las empresas que las venden, y las refacciones, en algunos casos, requieren solicitarse al extranjero. El desarrollo del concepto se hizo siguiendo la metodología para el diseño en ingeniería mecánica, empezando por identificar un problema a resolver, deposición del vidrio en vertederos de basura; generando bosquejos, identificando los elementos y componentes a utilizar; evaluación de la viabilidad en la obtención de éstos y generación del concepto final para su fabricación.



Diseño conceptual, Vidrio reciclado, Pulverizadora

Introduction

A lot of solid waste in urban territories has occupied too many land environments of people. As municipal solid waste can't diffuse quickly, the contamination threat they pose to the earth has long term potential. The unsafe parts in solid wastes can make potentially dangerous nature, individuals, and creatures. These ecological risk impacts can spread from people to the entire species; lastly, break the entire equalization and harm our common assets (Rajpal, Choudhury, Goswami, Chakravorty, & Raghavan, 2024).

Glass is among the most abundant materials on earth obtained primarily from silica. With the development of science, technology, and society, it has become one of the most important inorganic materials. Combining transparency, durability, chemical resistance, and a compressive strength higher than concrete and even steel, it is widely used in housing construction and daily life (Quirino Brito, Agrawal, Alves de Mélo, de Figueiredo Brito, & Rodrigues da Silva Morais, 2023). After the end use, the waste glass can be screened, cleaned and re-melted for the manufacture of new glass products. However, the impurities, multiple type, colour, and lack of screening facilities makes a barrier to this reuse, and they usually end up in stockpiles or landfills (Hamada, Alattar, Tayeh, Yahaya, & Thomas, 2022).

Due to the high cost of cleaning and colour sorting, the recycling rate for glass bottles is only about 25% and most waste glass is sent to landfill as residue; since glass is not biodegradable, landfills do not provide an environmentally-friendly solution (Tittarelli, Giosue, & Mobili, 2018). Several studies have been carried out to incorporate recycled glass in various applications, mainly in architecture, civil engineering, ceramics and dentistry, where crushing and/or pulverizing of glass is required. The main source of recycled material is glass bottles, however, there are kitchen utensils, televisions and recently, the evacuated tubes of solar heaters that also generate an increase of this material in landfills.

The interest in providing a solution to the reuse of evacuated pipes and cooperate in the reduction of this type of waste, is what motivates to make a prototype that allows to crush and/or pulverize the glass of these elements, to reuse the material and take advantage of its properties, among which stands out its resistance to chemical attacks (De Dietrich, 2024).

The pulverizing machines that have been found in the market, mostly result for another application, shredding of organic material generated in agriculture such as grains, coffee, branches, trunks, among others (Harden, 2024). In some cases, companies offer engineering solutions and project development according to the granulometry, material mix, for the manufacture of this type of machinery (Lasser/kenito, 2024); however, the cost is usually high and in some cases the equipment that meets the characteristics required by the consumer is not available.

Therefore, considering that this research is still under development, the main challenge is to have equipment that helps in the task of pulverize the proposed material, evacuated tubes. So that, by developing a pulverizing machine, it will allow improvements to be made depending on the particle size of the material obtained, with the purpose of having its own manufacturing technology for the recycling of the evacuated tubes, as well as the certainty of obtaining the pieces in the national market.

In addition, according to research conducted by Beck, the purpose of scientific research is to produce reliable knowledge and work towards understanding and solving societal, technical, and environmental challenges; related to applying open and collaborative practices along the entire process of generating and disseminating new scientific insights and translating them into innovation (Beck, et al., 2020).

In the development of the present work, the Methodology section describes the phases contained in the mechanical design process: identifying a need, generating conceptual ideas, analyzing the feasibility of the sketches generated, evaluating the options presented and defining the final prototype. In the Results, the selection of the prototype and its application are presented, followed by the Conclusions derived from the development of the conceptual design and the joint work to obtain the final prototype.

Methodology

For the development of the prototype of the pulverize machine, the phases of the process contained in the theory for the mechanical design are considered (Budynas & Nisbett, 2008), and schematically represented in the following figure.

Box 1

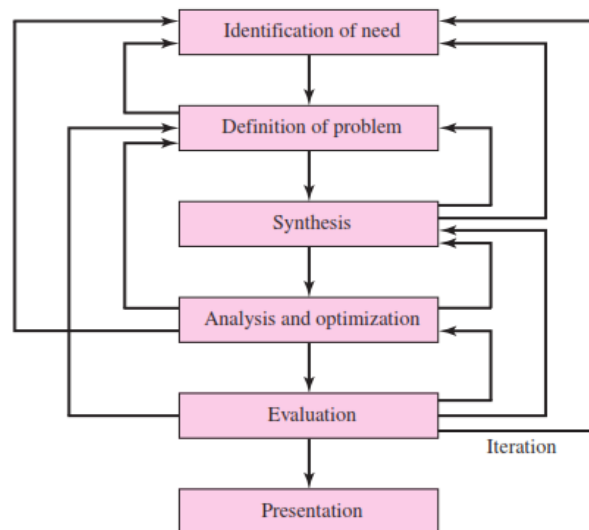


Figure 1

Phases of the design process that recognize multiple feedback and iterations

(Budynas & Nisbett, 2008)

The design of the equipment is made in such a way that it allows pulverizing the glass from which the evacuated tubes are made, which is indispensable for the development of the present project, since the pulverized glass constitutes the raw material for a second stage of the research.

Identification of need

Nowadays, many recycling company realize that they gain little or even have a loss of income by processing glass. The general process recycling included of collecting, sorting, transporting, beneficiating, and manufacturing glass back into bottles, is the most common form of glass recycling and has costs embedded in each step of the process.

Glass is produced in many forms, including packaging or container glass, flat glass, bulb glass, and cathode ray tube glass. e reused in order to avoid environmental problems. The plain glass dust waste can be recycled, but it is costly to remove the color of colored glasses and recycle again. The plain glass dust waste can be recycled, but it is costly to remove the color of colored glasses and recycle again (Nur Liza, et al., 2015).

The urgency of caring for the environment has led us to look for efficient ways to take advantage of solar energy. For this reason, solar water heaters are increasingly being used to cover hot water needs without using fossil fuels that destroy our planet. The tubes that make up the solar heater are quite resistant to heat, hail, rain and stones, but it may happen that one or more of them break and need to be replaced (Technologies, 2023).

In this context, it should be noted that different companies that provide this type of technology suggest that when a tubes breaks, it should be replaced immediately; however, they do not include any recommendation for the final disposal of the discarded pipe, which generally goes to landfills.

Box 2

Figure 2
Failed evacuated tube

Own elaboration

Currently, glass plays a fundamental role in Mexican sectors such as container manufacturing, packaging, construction and the automotive industry. This demonstrates its importance in the production chain of national strategic sectors, along with the growing trend of ecology and sustainability. However, according to data from the Ministry of Environment and Natural Resources (Semarnat) in the country only 12 percent of the more than 2.5 million tons of glass containers that go annually to the trash is recycled. This means a challenge for the Mexican market, as there is a niche to fill in terms of glass recycling (Reciclado, 2024).

From what has been described so far, it is considered that with the development of a spraying machine for the recycling of glass from evacuated tubes, it is possible to contribute to the reduction of this type of waste in landfills.

Definition of problem

The main application of recycled glass is in the construction industry, as fine aggregate (sand) (Hamada, Alattar, Tayeh, Yahaya, & Thomas, 2022) or coarse (gravel) and in some cases as a cementitious material (Redondo-Mosquera, Sánchez-Angarita, Redondo-Pérez, Gómez-Espitia, & Abellán-García, 2023).

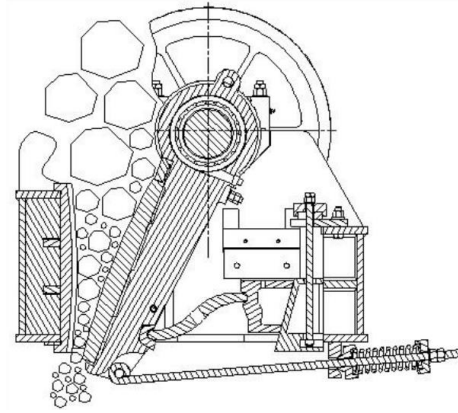
Particle size varies according to the type of aggregate, fine aggregate consists of natural sand or crushed stone with most of its particles smaller than 5 mm (0.2 in.), coarse aggregates consist of one or a combination of gravels or crushed stones with particles predominantly larger than 5 mm (0.2 in) and generally between 9.5 mm and 37.5 mm (3/8 and 1 ½ in) (Kosmatka, Kerkhoff, & Paranese, 2004).

Therefore, in the design of the pulverizing machine, the final particle size to be obtained must be considered; besides considering that the tubes will be obtained when they have failed, so the length will vary, the dimensions of the evacuated tubes are 58 mm in diameter and 1800 mm in length approximately. It should also be taken into account that the opening through which the tubes are introduced should be easy to handle, as well as when the pulverized glass is to be removed; likewise, the speed variation should be allowed for testing the parameters to be manipulated in order to obtain the product in less time.

Synthesis

In Aquino's work (2011) they mention 5 types of crushers for materials in general and they are the following: hammer mill, rotary drum or roller mill, jaw crusher, vertical impact shaft and rotating discs and breaker bars (Aquino Fajardo & Tamayo, 2011). For his part, Ares (2017), analyzes particle sizes generated in three different mills: ball, roller and blade mills (Ares, Accoroni, Ferigutti, Godoy, & Reinheimer, 2017). However, Waganoff classifies crushing machines on the basis of a characteristic element: the main crushing element(s). The jaw crushers perform the fragmentation with the jaws, regardless of their shape, flat, conical or cylindrical; the hammer crushers with hammers or similar elements (Waganoff, 1956).

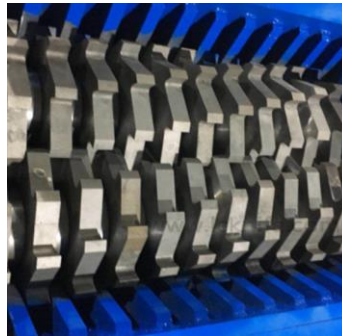
Jaw crushers are capable of crushing ores of large size and hardness. A characteristic diagram of this type of crusher is shown in Figure 3.

Box 3**Figure 3**

Jaw crusher

Mclanahan, 2020

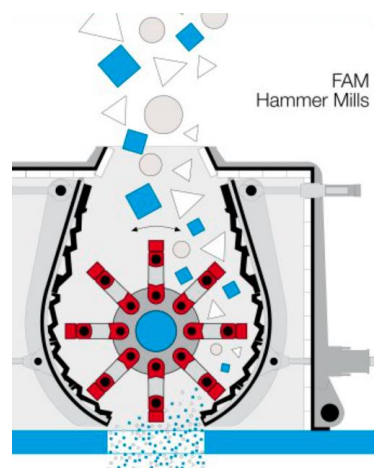
The toothed roll crusher is made up of two toothed rolls. The teeth may be blades, shark teeth, spades, grooves, among others. Figure 4 shows this type of crusher.

Box 4**Figure 4**

Toothed roll crusher

Manufactury, 2024

The hammer mill consists of rotors containing fixed or movable impingement elements that rotate at high speeds around a horizontal or vertical axis, inside a shielded chamber whose lower part may or may not be closed with a grate. A schematic of this type of mill is shown in Figure 5.

Box 5**Figure 5**

Hammer mill

Industry, 2024

There is a wide variety of crushing machines and mills, which have modifications regarding the main elements, dimensions and characteristics; these provided information regarding the shape, size and components to be considered for the development of the conceptual design. From the review carried out, different sketches were generated to develop the machine that will crush/pulverize the glass from the evacuated pipes. The generation of ideas is an important part for the final selection of the conceptual design and it is the one that is developed in this stage of the mechanical design.

The designs vary from the use of hammers, steel balls/barrels, shaft with rope, steel or stone grinding wheels; moved by motor, with rollers, hydraulic pistons; it is possible to consider at the end of the device to implement a sieve to obtain material of a defined size; it is also possible to consider two processes: crushing and pulverization and make a design that includes both processes or two designs to carry out each process separately.

Analysis and optimization

At this stage, the performance of the sketches presented is analyzed, making a comparison between the sketches made. It is considered that the proposed conceptual designs comply with the main purpose, which is to pulverize glass; however, an analysis of these designs was carried out to determine the feasibility of carrying out their manufacture, considering the elements that compose them, the way in which the crushing/pulverization of the glass is planned, additional components and equipment to carry out this task, as well as possible materials with which the prototype can be manufactured. The following table summarizes the above mentioned.

Box 6

Table 1

Summary of conceptual designs and their components

No. Prototype	Elements	Method	Components/equipment	Material	Size
1	Steel vessel	Crushing (steel shot)	Two phase motor	Solera	Regular*
2	Rectangular casing	Crushing/pulverizing (hammer)	2 Engines	Solera, steel	Robust +
3	Rectangular casing	Crushing (hammer)	Hydraulic pistons, oil reservoir	Steel	Robust
4	Steel casing	Pulverization (stone grinding wheels)	Motor, shaft with fins	Steel	Regular
5	Steel vessel and casing	Crushing/pulverizing (steel shot)	Motor	Steel	Regular
6	Rectangular casing	Crushing (shaft with hammers)	Motor, shaft with hammer	Steel, solera	Regular
7	Cylindrical casing	Crushing/pulverizing (hammer shaft)	Motor, shaft with hammer	Steel, solera	Robust /regular

* Maximum 1 m³, + Greater than 1 m³

The size consideration is due to the intended construction of the prototype, and robust equipment would increase the cost and time to manufacture.

During the development of this stage, the most representative prototypes were considered, since, during the development of the conceptual proposals, there were several that were similar to each other and were not taken into account, leaving those that could gather the main characteristics of other proposals.

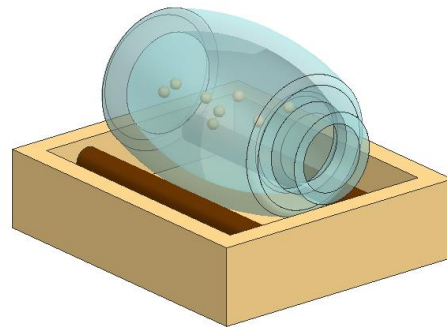
Evaluation

During this stage, the sketches presented are analyzed and optimized again, returning to the synthesis stage to define a final conceptual design. From the prototypes presented in Table 1, proposals 1, 5 and 7 were chosen to develop the final prototype. Proposal 1 is presented in Figure 6, it consists of rotating the component, through the opening deposit the material, inside there will be steel projectiles that will hit the glass to cause the grinding to be rotating all the equipment; it will be supported horizontally, the movement will be made using a motor attached to one end of the shaft.

Box 7**Figure 6**

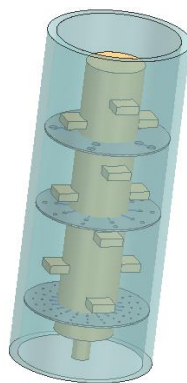
 Conceptual design of proposal 1

Figure 7 shows the proposal 5, it is a cylindrical vessel that will be rotating by the movement of rollers, in which the vessel will be placed, inside it will have steel or ceramic projectiles, depending on whether it is required to crush or pulverize. The motor drive is necessary for the movement of the rollers.

Box 8**Figure 7**

 Conceptual design of the proposal 5

In the prototype of Figure 8, the proposal 7 is shown, which is a vertical shaft with “paddles”, which rotates, it is considered that there can be different levels depending on the particle size of the material, which will be separated according to the sieve placed at the bottom of each level.

Box 9**Figure 8**

 Conceptual design of the proposal 7

From Table 1 it can be seen that most of the prototypes require the use of a motor, to perform the movement of the components/elements of the equipment intended to be manufactured. It is considered that the manufacture of the vessels, there are two proposed prototypes 1 and 5, requires special work or modification of the shape of the main container; in the case of the pots and hammers (proposal 2), special machining is required since they are elements that are not commercially available for a specific application; in the case of proposal 3 with pistons, the use of oil implies that the material may become contaminated and require additional treatment to clean it, and the cost of the pistons is high; in prototype 4 with stone grinding wheels, the wear of the stones would contaminate the material obtained and it would be necessary to clean it after pulverizing, without losing sight of the “screw” that introduces the material into the stones; in the case of prototypes 6 and 7 of the shaft with blades (horizontal and vertical), it is necessary to manufacture the shafts and blades that will be welded to the body of the shaft.

Considering the proposals and in general terms the elements that would be needed, as well as the manufacture of some of the components, a final proposal was made to be manufactured, taking into account that it can be made with recycled material or components that do not have a high cost and that are easy and quick to acquire.

Presentation

Communicating the results to others is the final and vital presentation step of the design process. The engineer, when presenting a new solution, is trying to sell or prove that the solution he is proposing is the best one (Budynas & Nisbett, 2008). Under this precept, the final prototype was presented for approval and subsequent manufacturing.

According to the different conceptual designs that were being made and considering the feasibility in terms of resources to carry out the machining, purchase of mechanical and electrical elements and the necessary material for the construction of the prototype, the following is the design that is considered viable for its manufacture. This prototype consists of a tube in which steel projectiles will be introduced, which at the time of spinning will hit the material (glass) to pulverize it, the movement of the rotation will be done through a motor, the device will be placed horizontally and will be fed through the lid at one end of the tube.

Box 10

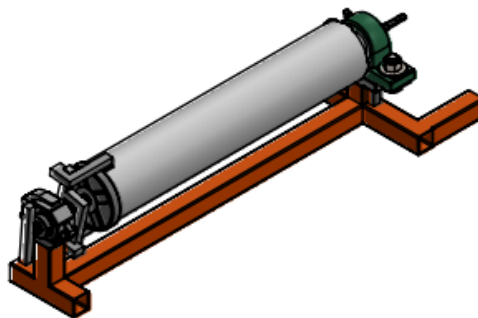


Figure 9

Final conceptual design

Results

Design thinking has become an accepted term in the innovation management discourse as an approach to creativity and innovation based on designers' practices. The design qualities are the psychological theories on creativity and human values, explaining why and how people create new value, meaning, and solutions. These design qualities clarify the construct design thinking and represent a comprehensive innovation management approach to enable design-driven innovation (Auernhammer & Roth, 2021).

Although there are different equipment and machines capable of crushing or pulverizing glass, it is important to highlight that the development of our own prototype allows the definition of requirements for obtaining the raw material, which is intended to be generated from the evacuated tubes waste. It is possible to improve or condition specific characteristics of the conceptual design, define the form of control, establish operating, installation and manufacturing conditions. Another aspect is the creation of ideas and along with it the incursion into the design of equipment that is capable of satisfying the needs of those for whom it is intended. The joint work of the participants contributed to the selection and development of the final conceptual design, since the different perspectives provide support to have a team that meets the specifications without neglecting the economic and personal safety aspects.

The final conceptual design represents the opportunity to help in the reduction of glass waste obtained from the failed evacuated tubes. With the pulverized glass, the second stage of the research project will begin, since we will have the raw material to investigate the recycling applications of this type of material.

It is known that techniques for recycling and reuse exist and are available, but the upscaling of these are met with legislative, economic and social barriers in all countries (Ministers, 2023).

Conclusions

A conceptual design was obtained from the review of existing mechanisms and equipment, allowing to generate an idea of easy manufacture and operation, it is considered of low cost because it does not require special materials for its manufacture and that are known to be found in the domestic market. As the prototype is used for glass pulverization, it can be improved in terms of particle size, run time and amount of material obtained.

Also, there was the opportunity to develop design thinking, following the phases of mechanical design theory, with a view to the improvement and innovation of equipment necessary for the development of the present research project. In addition, the collaboration and follow-up of the participants during the development of the conceptual design allowed the definition of the final prototype.

Declarations

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence in this chapter.

Author contribution

Fuentes-Castañeda, Pilar: Contributed with the project idea, generation and review of conceptual designs and writing of the project.

Betanzos-Castillo, Francisco: Contributed in the definition of the methodology and technique, generation and review of conceptual designs and writing of the project.

Cortez-Solis, Reynaldo: Contributed in the generation and review of conceptual designs and software development.

All authors participated in the discussion to define the final conceptual design based on feasibility of fabrication, time and cost; as well as in the revision of the manuscript.

Funding

The present research has not received any funding for the development of this research.

Acknowledgements

The authors would like to thank the Tecnológico de Estudios Superiores de Valle de Bravo, part of the Tecnológico Nacional de México, for the facilities provided for the use of space, time and software during the development of this research.

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Virtual learning objects to promote ethics in the development and use of Artificial Intelligence in higher education

Objetos virtuales de aprendizaje para fomentar la ética en el desarrollo y uso de Inteligencia Artificial en la educación superior

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CONAHCYT classification:

DOI: <https://doi.org/10.35429/H.2024.8.41.58>

Area: Engineering

Field: Engineering

Discipline: System Engineer

Subdiscipline: Computer Sciences

Key Handbooks

The research contributes by proposing Virtual Learning Objects (VLOs) to promote ethics in the development and use of Artificial Intelligence (AI) in higher education. The key aspects involve considering ethical theories in the development and use of AI, ensuring that the use of AI is responsible and ethical, particularly in the educational environment. Outline the main conclusions of the research.

Citation: Mireles-Medina, Antonia, Mizera-Pietraszko, Jolanta and Figueroa-Guillén, Carlos. 2024. Virtual learning objects to promote ethics in the development and use of Artificial Intelligence in higher education. 41-58. ECORFAN.

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Abstract

There are various artificial intelligence tools that generate texts, videos, audios, images, presentations, mind maps and essays, significantly supporting the educational field. However, it is important to consider the ethical implications of their use and development. Therefore, this chapter proposes the design of virtual learning objects (VLOs) to promote ethics in the use and development of artificial intelligence in higher education. The methodology employed is based on content analysis, focusing on the use of VLOs in the educational context, the ethical challenges associated with artificial intelligence, and the relevant ethical theories. It is concluded that VLOs bring significant benefits to education and can be effective in promoting ethics in artificial intelligence; it is essential to consider in its design the ADDIE methodology, the types of VLOs and ethical theories such as utilitarianism, deontology, the ethics of virtue, justice and care, in addition to principles such as simplicity, coherence, clarity, aesthetics and time.

Graphical abstract		
Objetives	Methodology	Contribution
Propose the design of virtual learning objects to promote ethics in the use and development of artificial intelligence in higher education.	The technique of content analysis has been implemented in relation to virtual learning objects, artificial intelligence and ethical theories to develop the proposal of the established objective.	A proposal has been developed for the design of virtual learning objects to promote the ethics of both the use and development of artificial intelligence.

Virtual Learning Objects, Artificial Intelligence, Ethical Theories

Resumen

Existen diversas herramientas de inteligencia artificial que generan textos, vídeos, audios, imágenes, presentaciones, mapas mentales y ensayos, apoyando significativamente el ámbito educativo. No obstante, es importante considerar las implicaciones éticas de su uso y desarrollo. Por ello, este capítulo propone el diseño de objetos virtuales de aprendizaje (VLOs) para fomentar la ética en el uso y desarrollo de la inteligencia artificial en la educación superior. La metodología empleada se basa en el análisis de contenido, enfocándose en el uso de VLOs en el contexto educativo, los desafíos éticos asociados con la inteligencia artificial y las teorías éticas pertinentes. Se concluye que los VLOs aportan beneficios significativos a la educación y pueden ser efectivos para promover la ética en la inteligencia artificial; es esencial considerar en su diseño la metodología ADDIE, los tipos de VLOs y teorías éticas como el utilitarismo, la deontología, la ética de la virtud, la justicia y el cuidado, además de principios como simplicidad, coherencia, claridad, estética y tiempo.

Resumen gráfico		
Objetivos	Metodología	Contribución
Proponer el diseño de objetos virtuales de aprendizaje para fomentar la ética en el uso y desarrollo de la inteligencia artificial en la educación superior.	Se ha implementado la técnica de análisis de contenido en relación a los objetos virtuales de aprendizaje, la inteligencia artificial y las teorías éticas para desarrollar la propuesta del objetivo establecido.	Se ha elaborado una propuesta para el diseño de objetos virtuales de aprendizaje para que se fomente la ética tanto el uso y el desarrollo de la inteligencia artificial.

Objetos Virtuales de Aprendizaje, Inteligencia Artificial, Teorías éticas

Introduction

Currently, the rapid advance of Artificial Intelligence (AI) has brought with it the opportunity to access a number of tools that support the daily work in the field of higher education, however, this technological development has generated important questions from the point of view of ethics, which entails above all a responsible attitude and action. In this scenario, Virtual Learning Objects (VLO) stand out as an effective tool that can enrich educational processes and promote ethical reflection on the development and use of AI in the educational environment (Fitria, 2021).

This study delves into the relationship between the design of Virtual Learning Objects (VLOs) and ethics in Artificial Intelligence (AI), investigating how these digital resources can be used to promote ethical awareness and practices among students, educators and developers of educational technology in the university environment. Through a detailed analysis, the advantages of employing VLOs as educational tools to develop an ethical understanding in the use and development of AI in the challenging educational environment are explored. The objective of this research is to propose the design of Virtual Learning Objects to promote ethics in the use and development of Artificial Intelligence in higher education. The main problem of this research lies in the need to promote ethics in the use and development of artificial intelligence (AI). As AI becomes more widely incorporated into this field, there is growing concern about ensuring that its use is responsible and ethical. However, a lack of awareness about the ethical consequences of AI in higher education can result in inappropriate practices.

The basis of this problem lies in the urgent need to address the ethical implications of AI in higher education to safeguard students' rights, maintain trust in the education system, and prevent the emergence of ethical and social gaps. It is essential to investigate how Virtual Learning Objects can be designed and used as effective tools to foster the understanding and practice of ethics in the development and use of AI in higher education.

Frame of Reference

Virtual Learning Objects

Citing Wiley (2003) in their article, they consider the following definition: "a Learning Object is any digital resource that can be reused to mediate learning" (Sánchez Medina, 2014), (Portilla et al., 2014) and (Revelo Alvarez & others, 2020).

In the research developed by (Urrego, 2019) he established the objective of describing the influence of a Virtual Learning Object that promoted reading strategies in an English for Specific Purposes (ESP) class of the Social Communication and Journalism careers in a private institution of higher education in Bogotá, Colombia; where the results obtained led the author to point out that the Virtual Learning Object (VLO) developed promoted the appropriation of the reading strategies proposed in the design of the course by the participants. The process with the VLO not only boosted greater reading comprehension, but also facilitated and enriched learning experiences.

The study by (Apolinario, 2022) dealt with "the use of virtual objects mediated by existing virtual platforms, which help to promote collaborative learning in the classroom, as a didactic strategy" and with respect to the results, it was possible to identify the problem of low level of collaborative learning of students in the Eighth Year of the "Francisco Pizarro" Educational Unit in the Santa Elena canton of Ecuador, and that the use of virtual objects improved student learning in the subject that requires such individual and group skills.

In the document (Pascuas Rengifo et al., 2015) they considered that one of the main problems facing the Colombian higher education system is the phenomenon of student dropout, which suggested that a large part of students abandon their studies, regularly in the first semesters. For this reason, the Ministry of National Education of Colombia and the University of the Amazon implemented an educational strategy that seeks to promote the permanence and graduation of students, through academic leveling. The development of eight virtual learning objects in different areas of knowledge was described and they stated that with the development of the VLs, the first step was taken for the Institution to define technical, technological, and pedagogical specifications, and to articulate with the ODER (Open Digital Educational Resources) strategy of the Ministry of National Education, which seeks to promote the use and production of digital educational resources.

(Moreira-Choez et al., 2021) aimed to analyze virtual learning objects as a didactic strategy for teaching and learning in higher education and in relation to the results they argued that Virtual Learning Objects can be used as learning strategies due to the vast benefits they offer in higher education, both for students and teachers. among them, it encourages the construction of learning in an interactive interface and with it a higher level of understanding, facilitates cooperative work, allows the development of innovative and creative skills, among others.

In the manuscript of (Ríos et al., 2019) it was considered as an objective to analyze virtual learning objects as a didactic strategy of teaching learning in higher education, where a methodical review was carried out about the use of virtual learning objects in the application of teaching learning, the authors obtained as results of the students that teachers frequently use methods for class development, in order to facilitate the satisfaction of the knowledge and learning of the students within the classroom, through the application of activities duly planned for the teaching-learning process.

In the research of (Carolina León-Romero et al., 2022) it was considered to support the strengthening of the training process through the use of Virtual Learning Objects in Robotics without the need for a virtual learning platform for their visualization, given the difficulty of connectivity that currently exists in educational institutions in the rural sector in Tecnoacademia in Colombia. While (Tigua-Anzules & del Rosario Cruz-Felipe, 2022) they developed a study where they analyzed the application and benefits of virtual learning objects in students that corresponds to 47 of the Paján Fiscal Educational Unit; According to general results, more than 70% of the student population stated that they benefited from the use of the virtual learning object. (Robelo et al., 2020) considered as an objective to analyze the results of the application of a virtual learning object to develop in university students the necessary competencies to develop research projects in education where they obtained as a result that the virtual learning object was a didactic resource capable of guiding and orienting students towards the development of competencies in their research projects.

Design and types of Virtual Learning Objects

According to Preciado (2013), the elaboration and design of the VLOs can be based on the ADDIE methodology, which is characterized by having an information scheme that is easy to access and manage, this model has 5 phases; Analysis, Design, Development, Implementation and Evaluation as cited in their research (Delgado-Ramirez et al., 2020), which the first phase consists of the study of a problem, then in the seventh phase it seeks to design a structure that adapts to the teaching-learning process, the third consists of identifying the program for its development, regarding its design, criteria of Raposo and Ruiz (2005) were taken into account, where they mention that the principles of simplicity, coherence, clarity, aesthetics, the use of white space and time must be respected, while in the implementation phase the Virtual Learning Objects are made known to the students and in the last phase the prior evaluation of the resource is carried out.

Quoting Gómez (2019) the authors (Valverde et al., 2020) take up the following: "Virtual Learning Objects contain a variety of didactic resources, among them we have videos, audios, animations, interactive documents, mind maps, collections of images which transmit knowledge achieving significant learning, which can be used in different ways and especially on any device".

The interoperability of learning objects (LOs)

The author (López, 2021) points out that the interoperability of learning objects (LOs) is linked to the set of elements that e-learning platforms have for the management of these contents, so it is essential to develop LOs, taking as a reference the models of standards and norms related to the topics for these resources. From a perspective of interoperability of e-learning platforms, different technology resources currently manage, structure and store e-learning content, to be used in a better way.

"Due to the boom in the use of platforms and the great demand for LO production and exchange, it is evident that the developers of this information take into account LO design models, and the standards that regulate and can comply with the interoperability of content" (López, 2021). (Colome, 2019) "The Learning Object technology was one of the solutions provided to the need to have reusable educational resources that would contribute to greater access to knowledge. Learning objects, from their conception, bring numerous advantages to the reuse and accessibility of content".

Artificial intelligence

"The term "Artificial Intelligence" was coined in 1956 at a conference at Dartmouth College, and since then, it has undergone constant development and has evolved significantly" (Navarro et al., 2023).

The accelerated progress of computer technologies has simplified the adoption of AIE (Artificial Intelligence in Education) applications, which refer to the use of AI-based technologies or programs (Artificial Intelligence) in educational environments in order to improve teaching, learning, or decision-making (Castaneda, 2023) and (López-Chila et al., 2023).

Artificial intelligence (AI) is a branch of computer science that seeks to understand and replicate aspects of human intelligence and behavior. AI is not based on a single method, but on different approaches and disciplines (Vega Jiménez et al., 2023) and (Vidal Ledo et al., 2019).

(Torres et al., 2023) Artificial intelligence in the field of education allows us to rethink the dynamics between teachers and students by transforming the relationship with knowledge and this technological innovation offers adaptive and personalized solutions, analyzing student data to provide accurate feedback and individualized recommendations that improve student understanding. However, its implementation poses ethical challenges, such as protecting data privacy and ensuring equity in access to education.

The applications and utilities of artificial intelligence are constantly expanding, and depending on their use they can be classified as narrow or weak, which are designed to perform specific functions within a particular field. These functions range from speech recognition, automatic response generation, text and image classification to computer vision and business process automation, among other applications that are becoming increasingly common in daily life (Varela & Encinas, 2023).

Artificial intelligence offers benefits to improve education by personalizing teaching in an unbiased way, optimizing teachers' work through data analysis, and creating engaging learning experiences; While it is important to address ethical challenges and ensure that it complements teachers' work, it can democratize and improve educational quality, it is also essential to carefully plan and provide adequate training on artificial intelligence to both teachers and students in education. Technological Institutes must ensure the ethical and responsible use of AI, protecting the privacy and security of student data. Talks are being held to discuss how, when and why to use AI applications, emphasizing ethical aspects and the development of human intelligence as a fundamental component. The use of applications that employ AI is on the rise, such as generators of text, images, presentations, and videos based on prompts, becoming common tools for students, although some teachers are not yet familiar with them (Sánchez et al., 2023).

The authors (Aguilar et al., 2023) after carefully analyzing the information, identified 29 studies on the role and application of artificial intelligence in university education. These studies revealed a growing trend in the adoption of advanced technological tools that seek to improve teaching and personalize it for students. These tools facilitate more intuitive activities and promote a deeper understanding of knowledge, adapting to diverse learning styles and enriching the educational experience. In addition, these authors point out, the responsible use of artificial intelligence in university education has the potential to improve learning processes, increase institutional efficiency, and develop more effective pedagogical methods to address current educational challenges.

Significant challenges of AI in the field of study of this research are addressed below according to (Vera, 2023):

1. "One of the main challenges of the integration of Artificial Intelligence in higher education is the digital divide and inequality of access to technology"; Unequal access to artificial intelligence could deepen gaps in higher education. In addition, reliance on technology and automation raises concerns about potential job losses and staff training in education.
2. "Another significant challenge lies in ensuring data privacy and security." Artificial intelligence involves processing large amounts of data, raising concerns about protecting the privacy and security of personal data. Although the General Data Protection Regulation (GDPR) does not specifically mention AI, several provisions are relevant to address the challenges in the processing of personal data. One of the key challenges of integrating AI into higher education is the gap in access and equity.

3. Ethics and privacy in integrating AI in higher education, mass data collection, and the use of AI algorithms for analysis and decision-making raise concerns about the privacy and security of student information.

The articles researched by (Cárdenas et al., 2023) highlight that artificial intelligence has a significant impact on higher education, although the main challenge lies in the lack of precision and understanding of its scope. Although its importance is recognized, it is not known with certainty to what extent it will transform higher education. Universities must understand that technology, especially artificial intelligence, is a permanent presence in the educational landscape and is here to stay. (Fajardo et al., 2024) "In the current context, some educational institutions have taken advantage of AI in its aspect of chatbots or virtual tutors to interact with students and optimize their learning by being able to monitor their progress, evaluate assignments or provide them with support instantly." (Gómez, 2023) The combination of AI and education has opened up a range of possibilities to improve the way we teach and learn.

Some of the most widely used Artificial Intelligence tools according to (Sandra, 2023) are shown in Table 1:

Box 1

Table 1

Most Used AI Tools

AI Tool	Functionality
ChatGPT, created by OpenAI	Create content, allowing copywriters to generate ideas, draft copy, and streamline workflow.
Google Bard, developed by Google Bard	Conversational system, aimed at merging traditional search and generation of contextual responses based on dialogue.
DALL-E created by OpenAI	From the creation of unique illustrations to the generation of graphic material for marketing campaigns
Midjourney, David Holz, Co-Founder of Leap Motion	Transform textual descriptions into images, which it achieves thanks to advanced algorithms and machine learning techniques.
Fireflies	Built for virtual meetings. To record and transcribe conversations.
Grammarly	It is an online writing assistant with the mission of improving texts through artificial intelligence. Check grammar, spelling, and punctuation, as well as check for plagiarism. It also offers a citation generator and essay review.
Lalal.ai	Music separation and vocal removal, with high efficiency for precise track extraction without sacrificing quality
Canva	An AI-powered image generator that allows you to convert texts into images, thus creating unique works with varied artistic styles for free.
TensorFlow	He specializes in numerical computing and large-scale machine learning
PyTorch	It provides robust tools for the creation and training of neural networks.

Source [Own elaboration, 2024]

Ethics in the development and use of artificial intelligence

(Cortés et al., 2024) The lack of knowledge of Artificial Intelligence can have a double dilemma, so its ethical regulation is necessary, it is imminent to properly plan the learning processes of students in addition to the use of the privacy of the data that is collected. (Liu et al., 2023) Higher Education Institutions (HEIs) should establish guidelines to ensure the ethical use of AI in research, including issues related to privacy, data security, bias mitigation, and transparency. This helps to maintain ethical standards and ensure that research conducted with AI technology adheres to ethical principles and safeguards.

The authors (J.-M. Flores-Vivar & García-Peñalvo, 2023) point out that creators or developers of artificial intelligence, in addition to their cognitive prowess in algorithmic design, need to consider ethical principles when developing tools that aspire to improve teaching compared to teachers. Instead, AI tools should be designed to enhance teachers' capabilities and help them reach their full potential as educators. Therefore, it is essential to establish regulations and ethics in artificial intelligence without compromising human values, without undermining diversity and without generating new disparities. (Lozada et al., 2023) It is inevitable that nowadays students use Artificial Intelligence (AI) technologies, since these tools are capable of carrying out various tasks that mimic human cognitive functions, such as solving problems or learning about specific topics. However, along with the benefits of this technological innovation, there are also risks that can negatively affect learning, such as unethical use, such as plagiarism.

(Lara et al., 2023) Artificial intelligence can be particularly valuable in personalizing the learning process and adjusting to the specific needs of each student, which is especially advantageous in online education environments. However, it is essential to address ethical aspects and through artificial intelligence they are treated responsibly and adequately safeguarded. (García-Peñalvo et al., 2024) A systematic vision is therefore needed, with a comprehensive, global and multicultural approach. In this regard, UNESCO adopted the Recommendation on the Ethics of Artificial Intelligence on 23 November 2021.

Artificial intelligence mainly uses Learning Management Systems (LMS) platforms that promote collaboration and participation between teachers and students, facilitating the quick and easy exchange of experiences, hypotheses, resources and documentation. Therefore, a study like this anticipates the impact of AI in the educational field, allowing for the formulation of informed and appropriate policies (J. M. Flores-Vivar, 2023).

Education is affected by constant changes in society. The emergence of Artificial Intelligence (AI) in this field poses new challenges and the discipline of Educational Technology must work to effectively and ethically integrate the use of AI in education (Montiel-Ruiz & Ruiz, 2023) on the other hand, (Martínez et al., 2023) believe that it is true that the use of AI and computer science in the educational field can provide significant support to teachers, whose functions have increased over the last few years.

(Latorre et al., 2024) AI can improve productivity in creative fields and represents an opportunity to innovate in arts education, but it requires careful consideration of ethical and legal implications. The most outstanding thing is that none of the teachers could detect that the document was created by artificial intelligence, and they gave it an average score of 8.88/10. In addition, the anti-plagiarism platform Compilatio also recorded an average similarity of 1%, demonstrating that it is currently not possible to distinguish between human-created documents and those generated by artificial intelligence, neither in manual review nor in anti-plagiarism platforms (Juca-Maldonado, 2023).

There are important questions in the research community about new tools that implement AI: (Saz-Pérez & Pizà-Mir, 2024) How do we weigh the need to personalize education and respect for data privacy? How do we prevent algorithms from perpetuating biases and prejudices, and, in doing so, harming equity in education? Potential risks are also highlighted, the most relevant in this document according to (García-Peñalvo, 2023) are fast and superficial learning; prevent students from developing critical and independent thinking skills, which could have long-term repercussions; impeding the development of creativity; dishonest use of tools, which occurs when the results generated are used without proper attribution, which can be considered plagiarism; The invasion of data privacy and confidentiality; among others.

(Bernaschina, 2023) I have to warn that we have to regularize (on cultural policy through use in) AI-based work to curb the danger of unprecedented advances in human extinction in the artistic-digital field.

It is not a question of artistic technology, but the use of chatbot AI and other tools through the different image and video generators to create "believable" and "very realistic".

According to (Lopezosa, 2023), emerging trends in the use of AI in research point to the following: first, that an AI like ChatGPT or any other, cannot go beyond acting as an assistant in research topics. Second, that an AI does not possess the necessary attributes to be considered an author. Third, that the use of AI systems must be totally transparent and traceable, not only indicating the prompts (requests) used, but also quoting or reproducing in the annexes or datasets the texts generated by the AI.

Fourth, that the final responsibility for an investigation always and exclusively lies with the research staff. On the other hand, (Reyes, 2023) mentions that artificial intelligence has changed the way in which the user experience is personalized on digital platforms, improving the interaction between these platforms and users. However, it is relevant to consider ethical and privacy aspects, while working on the constant improvement of algorithms and models to adapt to the changing needs of users.

Regarding some AI tools: (Baltazar & others, 2023) the strategic integration of AI tools such as ChatGPT, Intelligent Tutoring Systems (ITS), and miMente AI into education has great potential to improve the educational experience and prepare students for the technological future, but it is important to consider ethical aspects. (Guaña-Moya & Chipuxi-Fajardo, 2023) says that artificial intelligence has a significant influence on ethical aspects and the protection of data privacy. Therefore, it is essential to reflect on these aspects and establish appropriate legal regulations to ensure responsible development of this technology. This includes adopting strong ethical principles, promoting transparency, accountability in the use of artificial intelligence, and safeguarding the privacy of people's data.

Ethical theories to consider in the use and development of Artificial Intelligence

Philosophical references: "Philosophy plays an indispensable role when it comes to giving consistency to the accumulation of knowledge in which man, throughout history, has been configured as such"; each culture proposes the educational paths that each person will assume, so that this tension between culture and individual as far as education is concerned, is presented by Platon at the beginning of Book VII of the Republic, and constitutes in itself the foundation – in antiquity and validity – of educational reflection. The process of reaching the truth, through education, becomes a project, and each man embarks – in the words of Socrates – on the adventure of knowing himself in order to reach the truth, as they express it (Aparicio-Gómez & Aparicio-Gómez, 2021).

The ethical theory of utilitarianism focuses on maximizing happiness or general well-being. In the context of AI, a utilitarian approach would evaluate AI's actions and decisions based on their ability to maximize collective well-being. In terms of its application in AI, the design of AI systems could be oriented towards maximizing general well-being, but the challenge arises to define and measure this "well-being" and to balance the interests of different groups (Galiana et al., 2024).

The deontological approach has permeated certain institutions and entities, promoting self-regulation and compliance with codes of conduct. Although the deontological approach contributes to professional growth, it is important to encourage ethical reflection on a large scale, especially in aspects related to equality of opportunities, transparency, explainability, digital disparity, sustainability, among others (Rodríguez & Bernardi, 2024).

For Rezzónico, virtue ethics consists of the praxis of moral character centered on the human virtues acquired by the person throughout his or her life; it is evident that ethical virtues must always be practiced (Linares-Olano et al., 2023).

Carol Gilligan began the ethics of care from the conviction, supported by her empirical research, that there is a different way of facing the moral development of the person than the philosophy, psychology and methodological procedures of moral development proposed by her teacher Kohlberg. For the latter, moral development consists of the progressive ascent from one stage of moral judgment to another higher stage, until the subject reaches a stage of judgment about what should be done based on universal moral principles (Escámez-Sánchez & Gil-Martínez, 2023).

The ethics of justice emphasizes impartiality and universality, eliminating differences, the ethics of care emphasizes respect for diversity and the satisfaction of the needs of others. The individuals of the ethics of justice are formally equal, they must be treated equally (Fascioli, 2010).

The ethics of care transcends private conduct and, therefore, the subjective plane, assuming that it is in human interaction, broad and generalized, where its greatest bet lies. This extension of care responds to the relevance that many areas of life have acquired. Thus, a deeper understanding of "moral agency" requires broadening the foundations of the concept of care. (Terrones Rodríguez, 2023)

The digital society navigates the waters of material society to enter the sea without enough lifelines. It does not have the tools to dismantle the adverse effects it produces. Your browsing can't stop. This is what happens with each new technique (Villalobos-Antúnez et al., 2022)

Artificial Intelligence (AI) is a technology that is not a recent one, however, its development and implementation has been enhanced in recent years within society. This situation has promoted various realities in the human being ranging from economic, health, educational and personal relationship issues, which necessarily touch ethical and moral issues. For these reasons, the global community has recently initiated dialogues in various forums to generate ethical frameworks that are directed towards responsible and trustworthy Artificial Intelligence (Reséndiz et al., 2022).

The ultimate goal of artificial intelligence (AI) is to improve the knowledge of intelligence and try to make life easier for humans by building machines with the ability to perform functions very similar to those that only humans can perform (Pozo Sanz, 2022), The authors of this research consider that ethical principles should not be forgotten, So that with artificial intelligence the common good is always sought in all areas.

Methodology

The methodology considered in this book chapter is bibliographic documentary, the technique used is content analysis (Krippendorff, 2018). The flowchart details the process Figure 1:

1. **Identification of the research topic:** We have begun by clearly defining the topic on which to carry out the bibliographic review.
2. **Definition of search criteria:** The specific criteria that have been used to search for the relevant literature are established. Making use of keywords such as Virtual Learning Objects, Artificial Intelligence and Ethics.
4. **Search in academic databases and virtual libraries:** The keywords already mentioned above and the defined search criteria have been used to search the relevant academic databases and virtual libraries in databases such as Google Scholar, Elsevier, Dialnet, Redalyc, Scielo, Researchgate, Ebscohost PubMed, Web of Science, Scopus, among others.
5. **Selection of relevant documents:** The search results have been reviewed and documents that meet the predefined criteria have been selected and those that are not relevant have been discarded.
6. **Reading and analysis of the selected documents:** The selected documents have been read and their content analyzed. The findings, methodologies used, conclusions and any other information relevant to your research are identified.
7. **Extraction of relevant information:** The relevant information is extracted from the reviewed documents through the Zotero Bibliographic Manager.
8. **Organization and synthesis of the information collected:** The information collected is organized in a way that makes sense and can be easily understood by the reader.
9. **Develop the research:** The information collected and organized is used to write in a clear and coherent format, and to correctly cite all the sources used, according to the requirements of the corresponding template for the development of the book chapter.

10. **Revision and editing of the final document:** The document has been reviewed and edited to correct errors, improve the clarity and coherence of the text, and ensure that it meets the required style and formatting requirements.
11. **End:** Once all the previous steps have been completed, the process of preparing the chapter of the book is finished.

Box 2

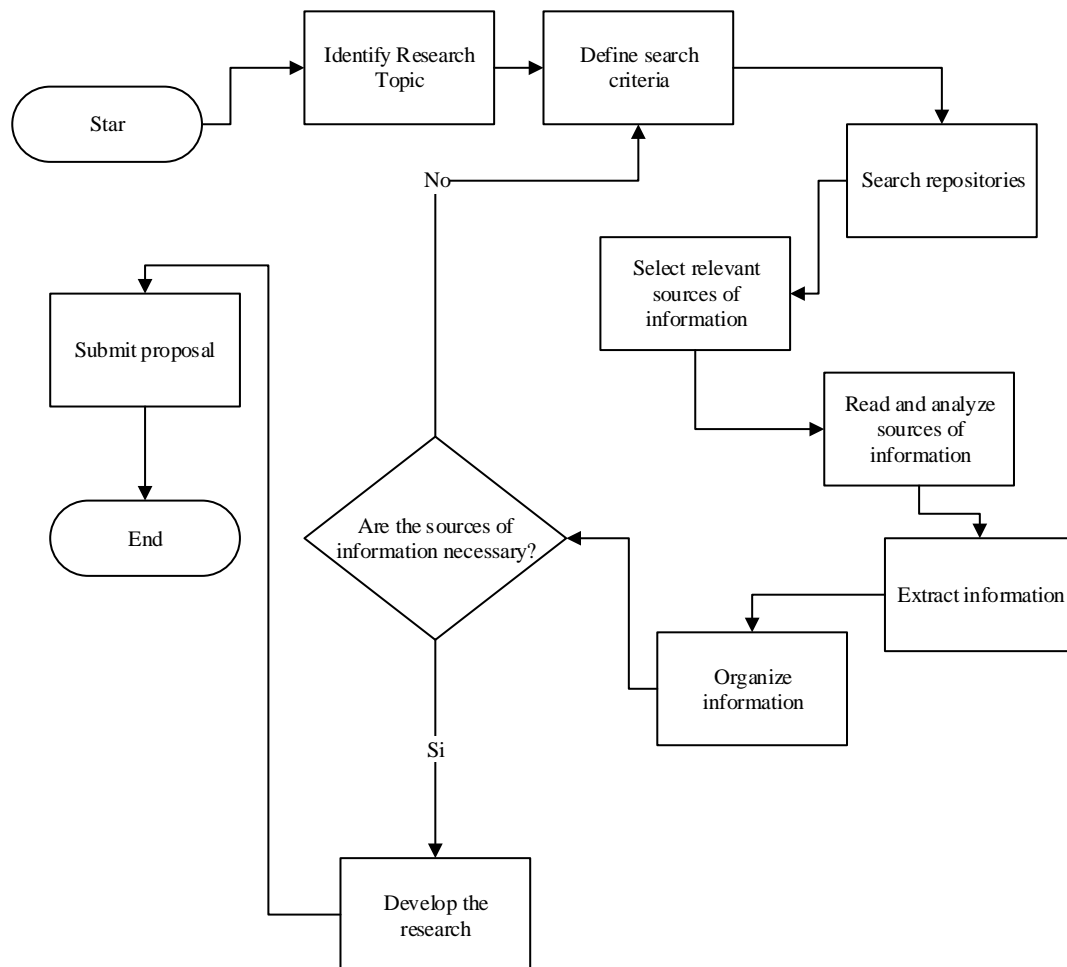


Figure 1
Methodology Process Diagram

Source [Own elaboration, 2024]

The topics consulted focused on the use and design of virtual learning objects, artificial intelligence, its challenges and ethical issues, as well as ethical theories to consider in the development and use of artificial intelligence.

Results

Taking into account the general objective of this research, which is to propose Virtual Learning Objects to promote ethics in the use and development of Artificial Intelligence, the use and implementation of VLOs in higher education is first presented. Then, the ethical theories that can be considered in the design of the VLOs are addressed. Finally, as part of the results, a figure is included that highlights the key elements of these tools.

After conducting a documentary search on studies and sources related to the implementation of OVAs in higher education, it was identified that they have been used for:

Box 3**Table 2**

Use of VLOs in Education

References	Different uses of VLOs in education	Benefits of using VLOs	Country
(Urrego, 2019)	Teaching English for greater reading comprehension	He promoted the appropriation of reading strategies for the English for Specific Purposes course.	Colombia
(Apolinario, 2022)	Fostering collaborative learning	Improved student learning.	Ecuador
(Pascuas Rengifo et al., 2015)	Encourage student retention in higher education	The development of VLOs was achieved to encourage permanence in education. They encourage the construction of learning in an interactive interface and with it a higher level of understanding, facilitate cooperative work, allow the development of innovative and creative skills, among others.	Colombia
(Moreira-Choez et al., 2021)	Didactic strategy in higher education	Learning with interactive interface, entertainment, accessibility to extra content, among others.	Ecuador
(Ríos et al., 2019)	Didactic strategy for teaching and learning in higher education	It strengthens the robotics training process.	Ecuador
(Carolina León-Romero et al., 2022)	Strengthening learning in robotics	VLOs facilitate the use of online educational content, strengthen educational practices, stimulate learning, and transform traditional classes into interactive sessions that are easy to understand content.	Colombia
(Tigua-Anzules & del Rosario Cruz-Felipe, 2022)	Analyze the application and benefits of virtual objects in academic performance	The virtual learning object turned out to be a didactic resource capable of guiding and orienting students towards the development of competencies in their research projects.	Ecuador
(Robelo et al., 2020)	Developing research competence in higher education	VLOs encourage study habits such as time distribution, reading optimization, and exam preparation.	México
(Arredondo Salcedo et al., 2022)	Encourage study habits through VLOs		México

Table 2 shows that Virtual Learning Objects have been used in various contexts within the field of higher education, addressing a wide range of educational needs and objectives. These digital tools have proven to be effective in facilitating both the teaching and learning process, providing innovative approaches to address specific challenges present in the aforementioned educational field.

Such research reveals that Virtual Learning Objects have been beneficial in solving various problems within higher education. From personalizing learning to improving the accessibility and effectiveness of teaching, then these tools have proven their usefulness in promoting dynamic and enriching learning environments.

In this context, the opportunity arises to use VLOs as strategic tools to promote ethics in the use and development of Artificial Intelligence (AI) in higher education. By considering the corresponding ethical principles, VLOs can be designed and used in ways that promote ethical reflection and responsible behavior in education. This involves integrating content and activities that stimulate discussion on ethical dilemmas related to AI, as well as providing resources and guidance for ethical decision-making in relevant situations.

When providing Virtual Learning Objects (VLOs) to students in the institutions related to this research, in order to foster ethics in the development and use of Artificial Intelligence, it is critical to consider the following ethical theories. These theories are interrelated in their application and are relevant to both VLOs and the use and development of Artificial Intelligence:

Box 4

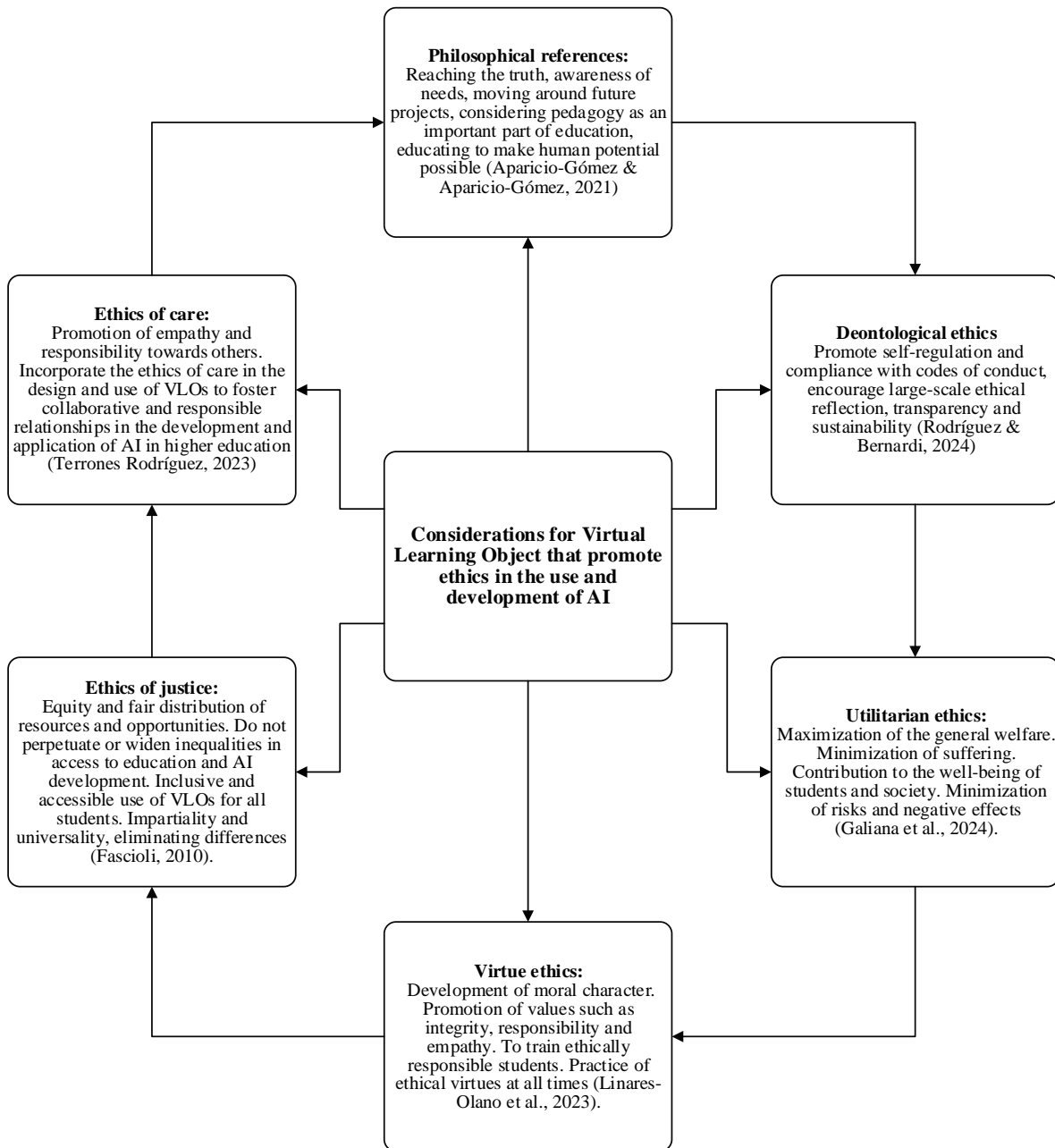


Figure 2

The ethical theories relevant to the proposal of Virtual Learning Objects aimed at promoting ethics in the use and development of Artificial Intelligence

Source [Own elaboration, 2024]

According to Figure 2, which addresses the ethical theories relevant to the proposal of Virtual Learning Objects aimed at promoting ethics in the use and development of Artificial Intelligence, each of these theories is delved into in detail:

Philosophical References: This refers to deep reflection on the fundamental principles that guide our actions in relation to Artificial Intelligence (AI) in education. This implies questions about knowledge, reality and morality. In other words, as mentioned (Aparicio-Gómez & Aparicio-Gómez, 2021), the aim is to get to the truth, to be aware of the identified needs, not to leave aside the pedagogical issue in the OVAs and, above all, to seek a way to educate in order to make human potential possible.

Deontological Ethics: Deontological ethics focuses on moral duty and obligation. In the use of AI in education, this ethical perspective emphasizes the importance of following established ethical rules and principles, no matter the consequences. (Rodríguez & Bernardi, 2024) emphasizes promoting self-regulation and compliance with codes of conduct, as well as encouraging ethical reflection on the actions to be carried out.

Utilitarian Ethics: Utilitarian ethics is based on maximizing well-being or utility, minimizing suffering, risk, and negative effects (Galiana et al., 2024). In relation to AI in education, this involves making decisions that produce the greatest benefit for the greatest number of people, considering the possible consequences.

Virtue Ethics: Virtue ethics focuses on perfecting moral traits. In this context, it implies, as they point out (Linares-Olano et al., 2023), cultivating virtues such as integrity, honesty, responsibility, and empathy; in this case in the use and development of AI in education.

Ethics of Justice: The ethics of justice focuses on equity and the fair distribution of resources and opportunities (Fascioli, 2010). In relation to AI in education, this involves ensuring that all students have access to and opportunities for learning, regardless of their background or contexts.

Ethics of Care: The ethics of care focuses on interpersonal relationships and caring for others. That is, this involves considering how the use and development of AI in education affects the relationships between students, educators, and technology developers, as well as the impact on emotional and social well-being. (Terrones Rodríguez, 2023) mentions the need to promote empathy and incorporate the ethics of care in the design and use of VLOs.

The above ethical and philosophical considerations provide a comprehensive framework for addressing the complex ethical issues related to the use and development of AI in higher education, ensuring that the well-being of all involved is promoted and the fundamental principles of morality are respected. "As Aristotle says, we have no choice but to deliberate on the means, since the ends are already given to us. And that is where we have to practice the virtues and pursue excellence" (Amo Usanos, 2023).

Below, as an important part of the results, a proposal for the design of Virtual Learning Objects to promote ethics in the use and development of Artificial Intelligence in higher education is also shown, according to the authors consulted for the development of this book chapter:

Box 5

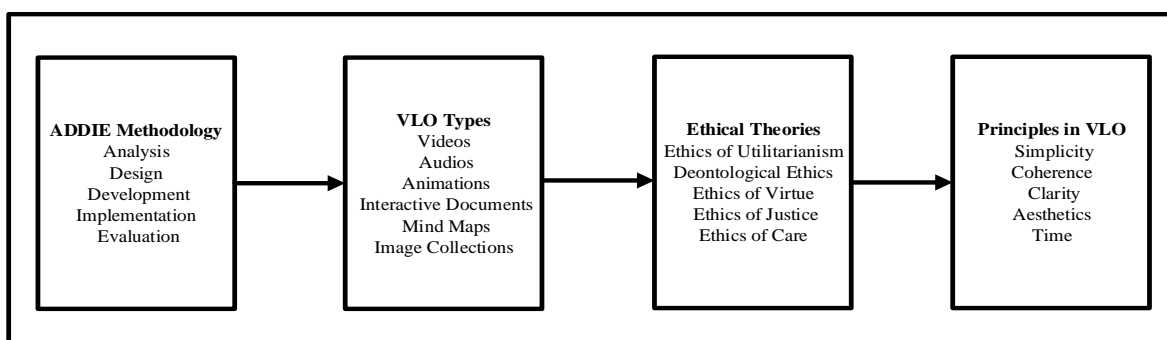


Figure 3

Proposal for the design of VLOs that promote ethics in the use and development of AI

Source [Own elaboration, 2024]

Once the use of VLOs in higher education and the benefits obtained by implementing them have been identified, as shown in Table 2, as well as the various artificial intelligence tools and their ethical challenges, the proposal presented in Figure 3 emerges. This proposal considers as a premise the development of VLOs based on the ADDIE methodology, in addition to the different types of existing VLOs and the pertinent ethical theories: utilitarian ethics, deontological ethics, virtue ethics, ethics of justice and ethics of care. The principles of simplicity, coherence, clarity, aesthetics and time are also considered, with the aim of designing VLOs that promote ethics in the use and development of artificial intelligence in the field of higher education.

Conclusions

In conclusion, the adoption of virtual learning objects (VLOs) as an educational tool in higher education has great potential to promote ethics in the use and development of artificial intelligence. Research has shown that by integrating the ADDIE methodology into the design of VLOs, it is possible to create structured and effective learning experiences that address both the technical and ethical aspects of artificial intelligence.

The inclusion of various types VLOs, such as simulations, case studies and interactive tutorials, allows for greater flexibility and personalization of learning, facilitating the understanding of complex concepts and promoting critical reflection. In addition, by incorporating ethical theories such as utilitarianism, deontology, virtue ethics, justice, and care, it ensures that students not only acquire technical knowledge but also develop a strong ethical awareness and a deep understanding of the moral implications associated with artificial intelligence.

VLOs designed with these principles not only enrich the educational process, but also play an important role in the formation of future conscious and responsible professionals. This approach ensures that students are better prepared to face ethical challenges in the field of artificial intelligence, promoting a responsible and beneficial use of this technology.

Discussion

The research used the content analysis technique to propose VLOs that promote ethics in the use and development of artificial intelligence in higher education. The findings highlight the importance of the ADDIE methodology to structure the design of VLOs, ensuring meticulous planning adapted to educational needs.

Types of VLOs, such as simulations, case studies, and interactive tutorials, were found to be effective tools for teaching ethics, facilitating the understanding and application of ethical principles in practical situations. The incorporation of ethical theories such as utilitarianism, deontology, virtue ethics, justice, and care into the design of VLOs, provides a solid foundation for ethics education, developing a deep ethical awareness in students.

Despite the benefits, the research identifies challenges such as the need to continuously update the contents of VLOs and adequate training of educators for their effective implementation.

Declarations

Conflict of interest

The authors declare that they have no conflict of interest. We have no known financial interests or contradictory personal relationships that could have influenced this book chapter.

Author contribution

Mireles-Medina, Antonia: I contributed to the generation of the idea of the project, in the development, writing and design of all the topics that comprise this chapter of the book.

Mizera-Pietraszko, Jolanta: Contributed to review, validation and formal analysis.

Figuroa Guillén, Carlos: Contributed to the review a formal analysis of the development of the book chapter.

Availability of data and materials

Regarding the availability of the data obtained in this research, the following repositories were consulted: Google Scholar, Elsevier, Dialnet, Redalyc, Scielo, Researchgate, Ebscohost PubMed, Web of Science, and Scopus.

Funding

This research has been funded by the Instituto Tecnológico Superior Zacatecas Norte.

Acknowledgments

We thank the Tecnológico Nacional de México for its support and for providing the necessary resources to carry out this research. Likewise, we extend our recognition to the Instituto Tecnológico Superior Zacatecas Norte for its collaboration and contribution in this project.

We would also like to express our gratitude to Instituto Tecnológico de Loreto and Research Methodology Division, Military University of Land Forces, Wrocław, Poland for their valuable collaboration in this research.

Abbreviations

ADDIE	Analyze, Design, Development, Implementation and Evaluation
AI	Artificial intelligence
ESP	English for Specific Purposes
HEIs	Higher Education Institutions
ITS	Intelligent Touring Systems
LMS	Learning Management Systems
LO	Learning Object
LOs	Learning Objects
ODER	Open Digital Educational Resources
VLO	Virtual Learning Object
VLOs	Virtual Learning Objects
UNESCO	United Nations Educational, Scientific and Cultural Organization

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Proposal for the design of a mist irrigation system to improve the production and quality of the mushroom fungus (*Pleurotus Ostreatus*)





Propuesta de diseño de sistema de riego por nebulización para mejorar la producción y calidad del hongo seta (*Pleurotus Ostreatus*)

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CONAHCYT classification:

DOI: <https://doi.org/10.35429/H.2024.8.59.78>

Area: Engineering

Campo: Engineering

Disciplina: Industrial engineer

Subdisciplina: Control and measurement of productive processes

Key Handbooks

The design of a mist irrigation system adapted to the climatic conditions of the Sierra Norte of the state of Puebla is shown, to increase the productivity of mushroom cultivation and improve current quality standards. Use of specialized software for the design of the irrigation system model. Variables that make up the cultivation of mushroom mushrooms (*Pleurotus Ostreatus*) in greenhouses. Characteristics of the irrigation systems currently used. Components and installation of mist irrigation system. A mist irrigation system model was generated that would provide the mushroom crops with the water resources necessary for the incubation and growth of the product. The investment cost was established, as well as the benefits that will be obtained with the physical implementation of the model. designed.

Citation: Soto-Leyva, Yasmin, Ruíz-Díaz Montserrat, Bones-Martínez, Rosalía and Martínez-Domínguez, José Antonio. 2024. Proposal for the design of a mist irrigation system to improve the production and quality of the mushroom fungus (*Pleurotus Ostreatus*). 59-78. ECORFAN.

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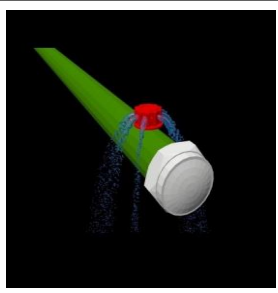

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Abstract


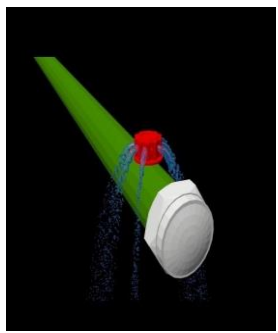

Specialized software design of a mist irrigation system to improve the production and quality of the mushroom fungus (*Pleurotus Ostreatus*), this fungus is known for its nutritional value and to achieve optimal performance, growth, development and quality, it is essential to maintain optimal conditions. proper environmental conditions, such as relative humidity, which plays a crucial role in cultivation. The design of the irrigation system is a viable solution to maintain ideal environmental conditions in mushroom crops. This study is made up of 4 phases: 1) Evaluation of current irrigation systems, 2) Determine the irrigation requirements (H_2O) for the crop, 3) Specialized software design of the mist irrigation system, 4) Economic analysis, the objective is to generate an irrigation system to provide uniform misting that maintains relative humidity in the optimal range ($80^\circ-90^\circ$). The results obtained demonstrated that the system offers greater efficiency in the use of H_2O . It is important to consider that the Design may vary, according to the conditions and available resources; Therefore, this research represents the basis for developing future research, aimed at obtaining improvements in the production of mushrooms.

Proposal for the design of a mist irrigation system to improve the production and quality of the mushroom fungus (<i>Pleurotus Ostreatus</i>)		
Objectives	Methodology	Contribution
		

Mushroom fungus (*Pleurotus Ostreatus*), Misting, Crop

Resumen

Diseño en software especializado de un sistema de riego por nebulización para mejorar la producción y calidad del hongo seta (*Pleurotus Ostreatus*), este hongo es conocido por su valor nutricional y para lograr un óptimo rendimiento, crecimiento, desarrollo y calidad, es esencial mantener condiciones ambientales adecuadas, como la humedad relativa, que desempeña un papel crucial en el cultivo. El Diseño del sistema de riego es una solución viable para mantener las condiciones ambientales ideales en los cultivos de hongo seta. Este estudio se conforma de 4 fases: 1) Evaluación de los sistemas de riego actuales, 2) Determinar los requerimientos de riego (H_2O) para el cultivo, 3) Diseño en software especializado del sistema de riego por nebulización, 4) Análisis económico, el objetivo es generar un sistema de riego para proporcionar una nebulización uniforme que mantenga la humedad relativa en el rango óptimo ($80^\circ-90^\circ$). Los resultados obtenidos demostraron que el sistema ofrece una mayor eficiencia en la utilización del H_2O . Es importante considerar que el Diseño puede variar, de acuerdo a las condiciones y los recursos disponibles; por tanto la presente investigación representa la base para desarrollar futuras investigaciones, orientadas a obtener mejoras en la producción de hongos setas.

Propuesta de diseño de sistema de riego por nebulización para mejorar la producción y calidad del hongo seta (<i>Pleurotus Ostreatus</i>)		
Objetivos	Metodología	Contribución
		

Hongo seta (*Pleurotus Ostreatus*), Nebulización, Cultivo

Introduction

The cultivation of mushroom fungus (*Pleurotus ostreatus*) is an agricultural production model that has grown exponentially in recent years, due to the high nutritional value, bringing with it a high demand in the food industry. This food product, known as oyster or oyster mushroom, is valued for its delicate flavor that results from the integration of proteins, vitamins and minerals that it has individually, as well as for its various culinary applications (De la Cruz Blanco, Arellanos, Pech, and Martínez, 2020).

In the experience of Ruiz, Salazar and Gómez (2024), the quality and yield factors of the mushroom fungus depend directly on the environmental conditions of the crop (Humidity and temperature), therefore, adequate media must be created to promote successful crops. Humidity and temperature are required during the fruiting process because the conditions derived from dry environments negatively affect the formation and growth of mushroom fungi (Silva, Cubillos and Díaz, 2010).

In accordance with the need described above, this proposal was generated, which consists of the design of a mist irrigation system, with the main objective of maintaining constant humidity levels that feed the different growth processes of the fungus. The mist irrigation model is a method that is characterized by the launch of water atomizations through small particles, creating a fine mist that is distributed uniformly in the crop planting environment. Considering the requirements for the future development of the system, the following aspects are addressed: 1) The selection of the system components, 2) The optimal distribution of the misting emitters in the cultivation area, 3) The control of the frequency and duration of irrigation, as well as safety and hygiene considerations, in addition, the importance of constantly monitoring crop conditions is highlighted, using humidity and temperature sensors to adjust the irrigation system according to the specific needs of each stage of fungal growth.

Likewise, precise management of relative humidity is widely recommended to minimize the risk of pests and increase the production of quality mushrooms. Therefore, the design of a mist irrigation system for the production of mushrooms represents a fundamental tool to optimize the cultivation of *Pleurotus Ostreatus*. By maintaining adequate and controlled environmental conditions, we seek to guarantee optimal performance, improve process efficiency and promote sustainable and high-quality production to satisfy the growing demand for this valuable food resource (Rojano, Salazar and Ruiz, 2025).

Justification

The design of a mist irrigation system for the production of mushroom fungus (*Pleurotus ostreatus*) significantly impacts the quality, yield and productivity of mushroom mushroom crops in the Sierra Norte of the State of Puebla, the benefit obtained is justified through of the following principles: 1) Flexibility in the design of the mist irrigation system: this irrigation model adapts to different sizes of greenhouses or growing areas, that is, it is designed to range from small spaces to relatively large areas, being suitable to be implemented by mushroom growers on a smaller scale, and on a larger scale by mushroom farming companies, 2) Automation and ease of management (Future recommendations): This system can be automated and programmed to supply the precise amount of water and maintain relative humidity, reducing notably manual intervention and facilitating the management of mushroom mushroom crops (Ruiz, 2013), allowing fungiculturists to concentrate on other activities that directly benefit the crop growth process, 3) Improvement in the growth and yield of the crop: The misting irrigation technique ensures a uniform distribution of H₂O in the medium, guaranteeing that the areas where the mycelium is concentrated (Incubation process) receive the ideal amount of humidity; providing uniformity in the growth of the body of the fungus, translating this uniformity into homogeneous productions with higher yields and qualified as quality crops, 4) Control of environmental humidity: Mushroom mushrooms (*Pleurotus Ostreatus*) are characterized by a high sensitivity to variability of environmental conditions, especially humidity, the proposed irrigation model generates precise control of humidity in the air with respect to other irrigation methods, promoting development and fruiting, reducing the sources that cause dehydration and growth. excessive mold in the growing bags or physical infrastructure (Greenhouses/growing areas), 5) Water savings: Mist irrigation is an optimal means that allows the efficient use of water, it includes a meticulous procedure for detachment of fine droplets of H₂O that gradually evaporate during the day.

Compared to other irrigation systems (drip/flood), misting significantly reduces H₂O consumption, being beneficial in the regional environment, where this water resource is expensive or scarce, 6) Reduction of pest risks: by physically establishing the proposed design, the relative humidity will be maintained, notably reducing the risk of spread of pests/pathogens that invade the production bags (Garrido, 2020), bringing with it increased productivity levels and greater profits for mushroom growers in the region and area of influence.

General objective

Generation of an effective proposal for a mist irrigation system for the production of mushrooms (*Pleurotus ostreatus*) for use in greenhouses/cropping areas geographically located in the Sierra Norte of the State of Puebla, through the design of the physical infrastructure in software. specialized, the establishment of the elements that make up the system and the simulation of the automation process, seeking to maintain the optimal humidity conditions, required in the mushroom cultivation process; thus encouraging proper growth of the product and increasing the productivity of this type of edible mushroom.

Specific objectives

This investigation revolves around the following specific objectives:

1. General evaluation of current irrigation systems: Quantitative comparison of the main characteristics that identify them, and subsequently select the one that best suits the stated needs.
2. Determine the irrigation requirements (H₂O) for the crop (*Pleurotus ostreatus*): Investigate and establish the optimal amount of H₂O for the proper growth and development of the mushroom fungus at each stage of its crop cycle according to the systems. of irrigation used.
3. Evaluate the optimal nebulization system: Verify the different types of nebulization (High and low pressure nebulizers), seeking to identify which one is appropriate to maintain a constant and uniform humidity in the growing medium.
4. Design misting system in specialized software: Create a technical design of the misting irrigation system, including the strategic location of the mists, water distribution, air flow and pressure to maintain an optimal environment for the growth of *Pleurotus ostreatus*.
5. Economic analysis: Determine the investment necessary for the development of the nebulization system.

Problem Description

Verdugo, Martínez and Rojo (2014), state that the cultivation of mushrooms (*Pleurotus ostreatus*) is an agricultural activity, which is present in various parts of the world. This production technique is carried out in backyards, greenhouses and specialized areas by personnel known as Fungiculturists. In Reyes' (2022) experience, fungiculturists are in charge of continuously monitoring the processes of planting, irrigation, cutting, and selling the product, these activities being the ones that represent the greatest investment of time.

As is well known, one of these actions is irrigation, which is currently carried out manually through the use of sprinklers, following 3 specific schedules during the day (morning, noon, afternoon), this activity turns out to be exhausting for the children. fungiculturists and if there is no monitoring log, irrigation is not carried out, causing the production bags to dry out and the final productivity to decrease. In the same way, by not receiving the water resource, the production attracts the intrusion of pests, contaminating the cultivation area.

The above described generates the need to design an irrigation system suitable for this crop, taking into account that this fungus grows in environments with temperatures of 20°C to 24°C; with an optimal temperature of 22°C for mycelial growth and 17°C to 18°C for primordia formation, pH of 6 to 7 with an optimum of 6.5, substrate humidity between 60% and 70%, and a relative humidity from 80% to 90% (Velasco and Vargas, 2004).

Planting the fungus *Pleurotus Ostreatus* requires the specific conditions of humidity and temperature mentioned above for optimal growth, therefore the proposed design of the mist irrigation system is a viable solution to maintain optimal conditions that will bring about the reduction of manual irrigation processes, increased productivity levels (Greater income from product sales for mushroom growers) and uniformity in the size of the mushroom body (Meet the size/flavor standards requested by the main consumers) (Figure 1 Cultivation of mushroom (*Pleurotus ostreatus*)).

Box 1



Figure 1

Cultivation of mushroom (*Pleurotus ostreatus*)

Consultation Source: Own Preparation

Theoretical Framework

To understand the objective of this research, the theoretical foundations that support the proposed design of a mist irrigation system to improve the production and quality of the mushroom fungus (*Pleurotus Ostreatus*) are described:

Contextualization of edible mushrooms

Until 1969, it was considered by the scientific community that fungi were plants (Moro, 2015), however, after various studies it was deduced that they showed a greater resemblance to animals, so they undertook the task of investigating further. depth the characteristics of these elements, once the investigations were concluded due to the particularities of the fungi, it was deduced that they required the assignment of their own kingdom, this kingdom was called the fungal kingdom.

All varieties of fungi belong to the fungal kingdom, highlighting mushrooms (*Pleurotus Ostreatus*). This type of mushroom is one of the most fruitful and is born naturally in the different forested areas of the region. Gallego (2004) infers that the reproduction of this species is carried out through spores, therefore, in its growth process it requires maintaining high humidity levels (80% to 90%), this environmental factor means that its Higher levels of production occur in times of abundant rain.

Composition of mushrooms

Salmones (2017) mentions that one of the foods with the highest nutritional content is the mushroom, it exhibits a chemical composition with a high degree of nutrients aimed at human consumption; The metabolic structure, the survival mechanisms that this food from the fungi kingdom has developed makes them unique and special, these are considered one of the most fascinating biological structures on our planet.

The formation of these edible structures arises from the incubation of the mycelium. The mycelium is the source that gives life to this type of crops. When it is visible, it is commonly called "Mold" and performs different functions, among which the following stand out: a) It is responsible for decomposing the organic matter of the soil, b) Produces the nutrients that feed the body of the fungus and nearby organisms, c) Degrades and recycles nutrients to contribute to the productive cycle of the trophic chain, d) Links the relationships between terrestrial plants through symbiotic associations, e) It is the support medium for the absorption of water and minerals from different ecosystems (Patiño and Vázquez, 2011).

Mushroom consumption

Various pre-Hispanic cultures have been involved in growing mushrooms for human consumption. Of the cultures with the greatest interest in this agricultural activity, the Aztec culture stands out. This Mesoamerican people is geographically located in the central-southern region of Mexican territory. This community called the mushrooms “Nanacatl” in response to their easy proliferation and growth in abundance (Gaitán, Pérez and Mata, 2006).

Among its main uses, gastronomy and various medicinal applications stand out. To date, consuming various dishes that contain mushrooms is a tradition in Mexican homes that is maintained and has been increasing in recent years, expanding nationally and internationally; This food being one of the most sold and produced in greenhouses and different growing areas.

Mushroom production in Mexico

The production of mushroom mushrooms (*Pleurotus ostreatus*) in Mexico is an activity that has been developing in recent years, especially in rural areas. The most relevant aspects related to the cultivation of the mushroom are described below: 1) The main use of mushrooms allows the preparation of different dishes, accompanying the diets of individuals since ancient times, 2) The annual levels of Production of this crop exceeds one thousand four hundred tons, with the State of Mexico being the one with the greatest contribution. 3) In Latin America, Mexico occupied first place in the production of mushrooms and their different varieties (Gurgua, 2019). In accordance with the aspects described above, Mexico consumes this important crop as a flavor experience accepted by the general population and appreciated from a gastronomic perspective.

Environmental conditions for mushroom production

The variables that determine the optimal environmental conditions for the production of mushroom mushrooms (*Pleurotus ostreatus*) are described below (Figure 2 Variables that determine the production levels of mushroom):

Box 2

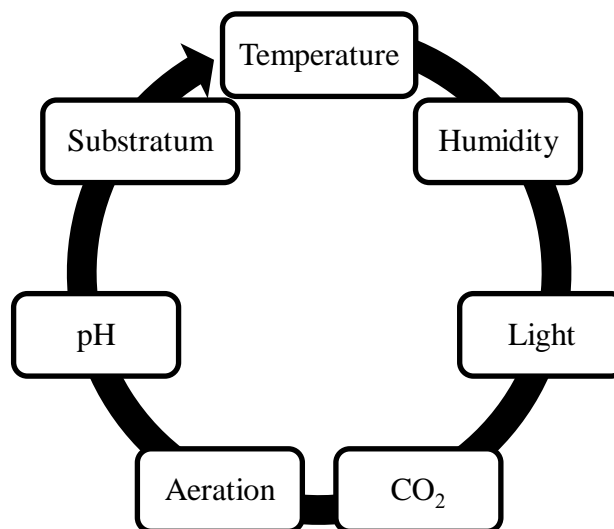


Figure 2

Variables that determine the production levels of mushroom

Consultation Source: (Aguinaga, 2012)

Each of the variables are quantitatively categorized under the following criteria (Tome, 2022): 1) The ideal temperature for the growth of *Pleurotus ostreatus* during the day is 20°C-24°C, while at night it is 18°C-22°C, 2) Relative humidity should be high, between 80-90%, to maintain turgor and promote growth, with an ideal precipitation of 6-8 mm and an evaporation level of 12-15 mm, 3) *Pleurotus ostreatus* grows in low light intensity conditions, but prefers total darkness, 4) A carbon dioxide (CO₂) level between 1,000-1,500 ppm is optimal for growth, 5) Good aeration is essential for prevent the buildup of ethylene and other gases that can inhibit growth, 6) The optimal pH for *Pleurotus ostreatus* is slightly acidic, between 6 and 7, 7) The ideal substrate is rich in lignin and cellulose, such as hardwood sawdust or residues agricultural.

Greenhouses for mushroom production

Aquino and Ruíz (2012) consider greenhouses as the physical means to produce a large number of edible products, among these products mushrooms stand out; For greater adaptability of these crops, the greenhouses are conditioned by regional fungiculturists, taking care of the following aspects: 1) Firm structure: To prevent the structure from being flexible, it must be made of highly resistant material, with dimensions that allow access to the fungiculturists and divided into two main areas: Incubation cabin and crop growth area, 2) Lining the greenhouse: It is highly recommended to line the surface of the greenhouse with two layers of two-color nylon, leaving upper vents on the sides of the structure, 3) Soil conditioning: According to the region where the greenhouse is established, the appropriate substrate is selected to maintain humidity within the area. In most of the conditioning processes, tezontle stone is used, characterized by being porous and absorbing moisture. greater amount of water; This H₂O absorption system contributes to maintaining optimal levels of relative humidity during the day, for the good proliferation of the crop, 4) Irrigation system: It is considered the means that provides the mushroom cultivation with the necessary water resource, for the system to function properly, therefore, the irrigation activity is carried out by the fungiculturists in the assigned schedules and in the ideal quantities to generate quality crops, with higher levels of productivity (Rodríguez, Araque and Perdomo, 2006).

Irrigation systems for mushroom cultivation processes

Irrigation systems implemented within mushroom crops in all their varieties are crucial because they allow humidity to be maintained and promote healthy/uniform growth of the product. The most common irrigation systems are (Table 1 Irrigation systems for mushroom cultivation processes):

Box 3

Table 1

Irrigation systems for mushroom cultivation processes

Irrigation type	Description
Aspersion	It uses nozzles to spray H ₂ O in a mist, keeping moisture in the air and in the substrate.
Drip	Supplies water directly to the base of the mushrooms, reducing H ₂ O loss and preventing waterlogging.
Immersion	Immerse cultures in H ₂ O for a set period, ensuring uniform hydration.
Nebulization	Creates a fine mist that keeps moisture in the air, ideal for mushrooms that require high humidity.

Consultation Source: (Pérez, 2016). (Liotta, Carrión, Ciancaglini and Olguín, 2015). (Oviedo, Alvarenga, Evangelista, Sepúlveda and Rodríguez, 2015). (Guachamin, 2021).

Misting irrigation system

According to Solis (page. 5, 2019), this irrigation model is characterized by expelling water the form of mist, through emitters that are placed on the top of the crops. The main advantages of this model are: a) They reduce the concentration of high temperatures within the growing areas, b) They raise the level of relative humidity inside the greenhouses. Specifically, the operation of this irrigation method begins with the capture of H₂O, subsequently the water resource is transferred through pressure pipes, until reaching the nebulizers, which expel the H₂O as a fine mist; fed evenly to crops.

Nebulization

Fogging is a process that consists of evaporating a very small drop of H₂O using a diffuser. During the evaporation process, the water resource absorbs the heat energy of the greenhouse. There are three types of nebulization, these are (Flores and Martínez, 2012): 1) Nebulization based on water pressure: It is a method that uses the energy of a high-pressure water jet to atomize a liquid, generally a medication or a solution, in small drops. This process is commonly used in nebulizers, devices that convert liquid medications into an aerosol that can be directly inhaled. 2) Low-pressure nebulization (Blank): This is a method that uses a low-pressure water jet to atomize a liquid. usually a medicine or solution, in small drops. Unlike water pressure-based nebulization, which uses high pressure to atomize the liquid, blanking uses a lower pressure and gentler water flow. 3) Air pressure nebulization (Hydrophone): It is a method that uses a jet of compressed air to atomize a liquid, usually a medication or solution, into small droplets.

This process is commonly used in nebulizers, and is characterized by: a) It uses compressed air to atomize the liquid, b) It does not require water to operate, c) Made up of small particles (generally between 1-5 micrometers), d) High flow aerosol.

Methodology

This work is developed through the intervention of the following phases (Figure 3 Intervention phases):

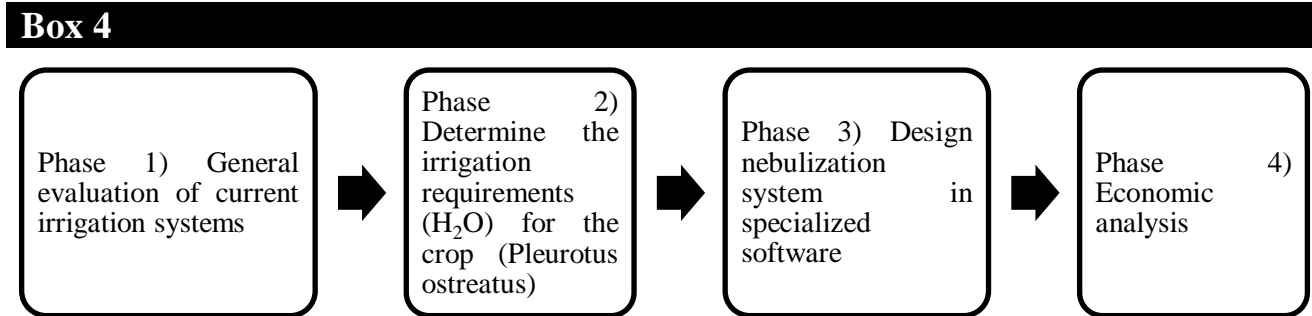


Figure 3

Intervention phases

Consultation Source: Own Preparation

Phase 1) General evaluation of current irrigation systems

The variables that make up the irrigation systems currently used for the production of mushroom crops were analyzed. The study is shown below (Table 2 Variables and quantitative and qualitative factors of irrigation systems):

Box 5

Table 2

Variables and quantitative and qualitative factors of irrigation systems

Variables	Factors	Types of irrigation			
		Aspersion	Drip	Immersion	Nebulization
Climate	Temperature	Day= 20°C-22° C Night= 15°-18°C	Day= 18°C-20° C Night= 14°-16°C	Day= 18°C-20° C Night= 16°-18°C	Day= 20°C-22° C Night= 18°-20°C
	Relative humidity	70%-80%	75%-85%	90%-95%	85%-90%
	Precipitation	6-8 mm	3-5 mm	7-9 mm	8-10mm
	Evaporation	18-22 mm/day	12-15 mm/day	20-25 mm/day	15-18 mm/day
Floor	Texture	Moist but not saturated.	Wet in the root zone and dry on the surface.	Saturated and uniform	Constantly moist but not saturated, uniform.
	. Permeability	Infiltration= 1-10 mm/hour Porosity= 30-50%	Infiltration= 10-20 mm/hour Porosity= 40-60%	Infiltration= 0-5 mm/hour Porosity= 10-30%	Infiltration= 5-20 mm/hour Porosity= 20-40%
	H2O holding capacity	20-40%	30-50%	80-90%	40-60%
	pH	6.0-7.0	5.5-6.5	5.5-6.5	6.0-7.0
H2O availability	Quality	Chlorides= < 50 ppm Sodium= <20 ppm	Chlorides= < 10 ppm Sodium= <10 ppm	Chlorides= < 5 ppm Sodium= <5 ppm	Chlorides= < 2 ppm Sodium= <2 ppm
	Pressure	Minimum= 1-2 bar Optimal= 2-3 bar Maximum= 4-5 bar	Minimum= 0.5-1bar Optimal= 1-2 bar Maximum= 2.5-3 bar	Minimum= 0.1-0.5 bar Optimal= 0.5-1 bar Maximum= 1-1.5 bar	Minimum= 2-3 bar Optimal= 3-5 bar Maximum= 5-7 bar
Environmental impact	Efficient use of H2O	Optimal use of H2O	H2O consumption by up to 50%	H2O consumption than the sprinkler irrigation system	H2O consumption than the sprinkler irrigation system
	Pollution minimization	1) Use of recycled or treated water to reduce drinking water consumption. H2O consumption.	1) Use of recycled or treated water to reduce drinking water consumption. 2) Use humidity and temperature sensors to control irrigation and reduce water consumption.	1)Use of recycled or treated water to reduce drinking water consumption. H2O recirculation system to minimize waste.	1)Use of recycled or treated water to reduce drinking water consumption. 2) H2O filtration system, to eliminate contaminants and waste. 3) Use of low pressure and flow nebulizers to reduce evaporation and H2O consumption.

Consultation Source:(Baños, 2010)

Phase 2) Determine the irrigation requirements (H₂O) for the crop (*Pleurotus ostreatus*)

During the development of Phase 1) the consumption of H₂O for each type of irrigation was determined, the established consumptions are (Table 3 Consumption of H₂O for each type of irrigation by phases):

Box 6

Table 3

Consumption of H₂O for each type of irrigation by phases

Dimension/Frequency	Phases	Types of irrigation			
		Sprinkling (Liters)	Drip (Liters)	Immersion (Liters)	Nebulization (Liters)
1 m ² /day	Incubation phase	2-5	1-3	5-15	0.5-1.5
	Growth phase	5-15	3-6	10-30	1.5-3

Phase 3) Design nebulization system in specialized software

To establish the operating parameters and design the nebulization system, the following stages were carried out:

Stage 1) Establishment of greenhouse dimensions: A recognition process was carried out to determine the measurements, and establish the dimensions for the greenhouse according to the area assigned for the mushroom cultivation process (Figure 4 Establishment of greenhouse dimensions).

Box 7



Figure 4

Establishment of greenhouse dimensions

Consultation Source: Own Preparation

Stage 2) Ground preparation: Once the area is designated, the ground leveling process begins, with the main objective of creating a flat surface, without reliefs, suitable for placing the shelf, which will be the medium where the mushroom growing bags will be placed (Figure 5 Soil preparation).

Box 8



Figure 5

Soil preparation

Consultation Source: Own Preparation

Stage 3) Greenhouse lining: This stage includes the placement of two-color nylon on the sides and dome of the greenhouse (Figure 6 Greenhouse lining)

Box 9



Figure 6

Greenhouse lining

Consultation Source: Own Preparation

Stage 4) Soil conditioning: In order to maintain adequate temperature conditions, crushed tezontle rocks were spread uniformly over the soil area. Due to their composition, these rocks have the ability to retain moisture with greater capacity and provide an optimal cooling process and circulation of relative humidity, during the course of the day and night (Figure 7 Greenhouse conditioning).

Box 10



Figure 7

Greenhouse conditioning

Consultation Source: Own Preparation

Stage 5) Gathering of information (Measures) for the realization of the Design: Once the greenhouse has been physically established, the internal and external measurements of the areas that make up the structure were taken (Figure 8 Gathering of information (Measures) for the realization of Design).

Box 11



Figure 8

Gathering of information (Measures) for the realization of Design

Consultation Source: Own Preparation

Stage 6) Placement of shelving for the mushroom cultivation process: Continuing with the conditioning of the greenhouse, we proceed to place the shelving that will be used as a loading medium, for the placement of the culture bags, intended for the incubation process. growth processes, cutting processes (Figure 9 Shelf placement for mushroom cultivation process).

Box 12



Figure 9

Shelf placement for mushroom cultivation process

Consultation Source: Own Preparation

Stage 7) Design of the mist irrigation system: The proposal for the design of the mist irrigation system is designed in the specialized SketchUp software, based on the measurements, variables and characteristics analyzed in the previous stages.

Stage 8) Scale design of the mist irrigation system prototype: The physical structure of the mist irrigation system is made through the development of the scale prototype.

Phase 4) Economic analysis

The main components recommended by Solis (Page.10-15, 2019) for the physical development of the design are: H₂O source, pump, filter, pipe, valves, emitters, drainage systems and accessories; In this phase, the functionality of each of them is described, as well as the acquisition cost (Table 4 Component analysis):

Box 13

Table 4

Component analysis

Num.	Componente	Descripción	Costo
1	H ₂ O source	Water resource that is extracted from various sources, the suggested sources are: a) Wells, b) River, c) Lakes, d) Municipal water network.	\$2,800.00 per unit (Acquisition of water tank)
2	Bomb	This component within the irrigation system is used to extract water from the source and pressurize the system.	\$1,000.00 per unit
3	Filter	The filter is the means that is responsible for eliminating impurities and particles from the water, its main objective is to avoid blockages in the system.	\$300.00 per unit
4	Pipeline	Physical PVC component that is responsible for conducting the H ₂ O, from the pump to the mushroom growing area.	\$ 1,500.00 Total meters according to the dimensions of the greenhouse
5	Valves	They are located in the opening and closing areas of the H ₂ O streams; they are responsible for controlling the flow of H ₂ O in different sections of the system.	\$200.00 Total valves
6	Issuers	They are distributed evenly in the design of the irrigation system; these components are responsible for releasing H ₂ O in the form of aerosol/droplets to water the mushroom growing bags.	\$500.00 per package of 50 nebulizers
7	Drainage system	Physical medium that is responsible for removing excess water from the irrigation area to avoid flooding, which subsequently generates pests.	\$1,350.00 to supply the dimensions of the greenhouse
8	Accessories	Set of elements that include different pieces, these pieces are of vital importance for the connection of the irrigation system, some examples are: Connectors, curves, supports and covers to connect and seal the pipes.	\$300.00 for the units necessary to connect the irrigation system.

Consultation Source: (Solis, pages 10-15, 2019)

Results

The results are evident below:

Results of Phase 1) General evaluation of current irrigation systems:

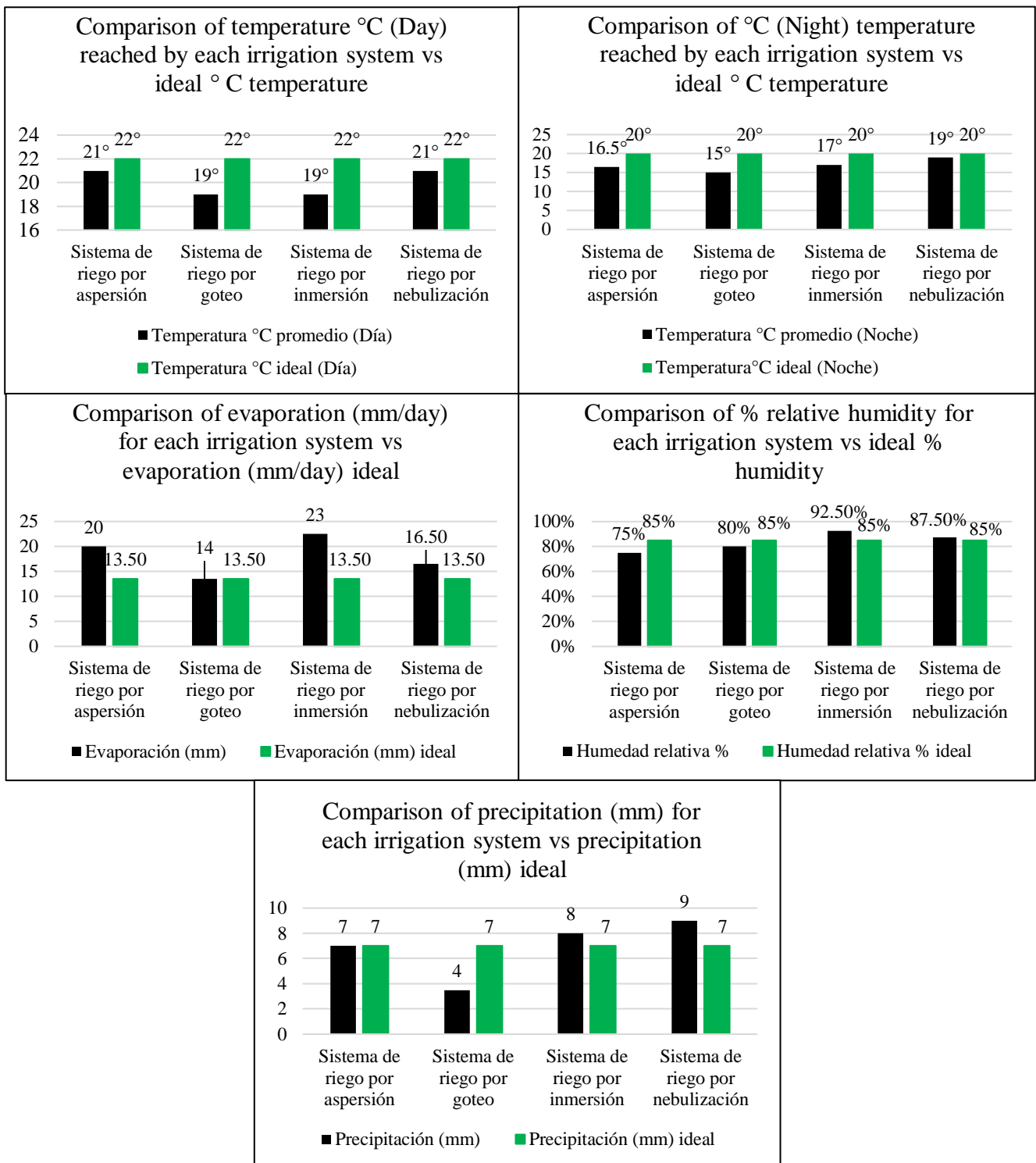
Variable: Climate

For the analysis of the information obtained in Phase 1, directly related to the measurement of the climate variable, a statistical study is carried out to compare the values and determine which of the irrigation system models (sprinkling, drip, immersion and nebulization) adapts to the requirements of the factors of temperature, relative humidity, precipitation and evaporation, the results are shown below (Graph 1 Analysis of the factors that make up the Variable: Climate):

Box 14

Graph 1

Analysis of the factors that make up the Variable: Climate



The variables corresponding to the climate allow us to observe the behavior of irrigation systems in mushroom mushroom (*Pleurotus Ostreatus*) cultivation environments, compared to the ideal requirements, concluding that:

1. In the case of temperature (Day), an ideal value of 22% is established, the sprinkler irrigation system will contribute with a temperature of 21°C, drip and immersion irrigation will maintain 19°C on average, to finish mist irrigation will provide 21°C, when compared with the ideal temperature, it follows that the ideal irrigation systems are: Sprinkler irrigation system and mist irrigation system.
2. In the case of temperature (Night), an ideal value of 20% is established, the sprinkler irrigation system will contribute with a temperature of 16.5°C, drip irrigation registers an average temperature of 15°C, immersion will maintain the internal area of the greenhouse at 17°C, to finish the mist irrigation it will provide 19°C, when compared with the ideal temperature, it follows that the ideal irrigation system is: Mist irrigation system.
3. The ideal relative humidity for growing mushroom mushrooms (*Pleurotus ostreatus*) is 85%, the irrigation system models provide on average the following humidity indices: Sprinkler irrigation system 75%, drip irrigation system 80%, immersion irrigation system 92.5%, mist irrigation system 87.5%, according to the quantitative data presented, the mist irrigation system mostly adapts to the ideal index.
4. The ideal precipitation for the crop species analyzed is 7 mm. Taking this parameter into account, we proceed to determine which of the irrigation models best fits; It is notable that the sprinkler irrigation system on average shows a precipitation of 7 mm, while drip irrigation contributes 4 mm, immersion irrigation contributes with a precipitation of 7 mm, and the mist model contributes 9 mm, therefore that the system that adjusts to the ideal precipitation rate is: Sprinkler irrigation.
5. Completing the analysis of the climate variables, evaporation is studied, whose ideal value is 13.5 mm/day. Taking this indicator into account, it is deduced that the systems that manage less variability around this variable are: Drip irrigation and mist irrigation.

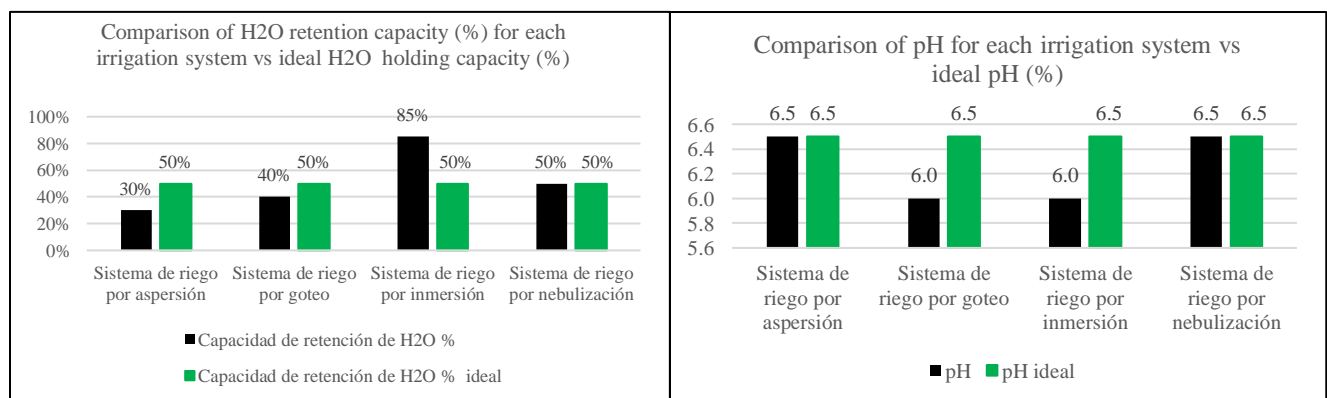
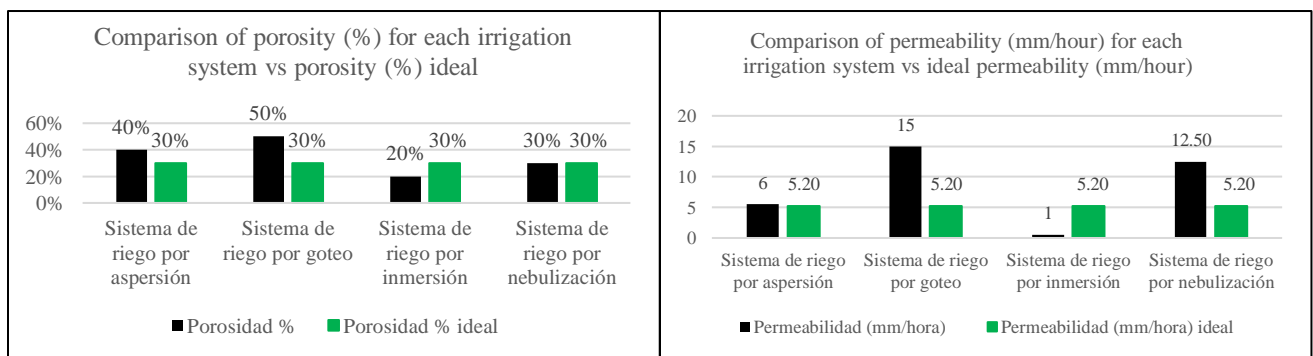
Variable: Soil

The results corresponding to the analysis of the Variable: Soil are presented below (Graph 2 Analysis of the factors that make up the Variable: Soil):

Box 15

Graph 2

Analysis of the factors that make up the Variable: Soil



Now, quantitatively it is observed that: The allowable porosity for the soil is 30%, compared to irrigation systems, in the case of the sprinkler irrigation model the porosity is 40%, with respect to the drip model is 50%, while the immersion method maintains a porosity of 20%, to finish the mist irrigation system helps the greenhouse soil maintain a porosity of 30%, therefore, the system that adapts to the ideal porosity is the nebulization; Continuing with the study, the permeability is examined, which is determined by a maximum rate of 5.20 mm/hour. In this factor, it is notable that the irrigation system that will maintain the ideal permeability is the sprinkler model.

With respect to the H₂O retention capacity of the soil, 50% is required as an ideal indicator, with the mist irrigation system being the one that adapts 100% to this need for H₂O retention; concluding the appreciation of the variable; soil, we find the pH factor, this key element for the fruiting of mushroom mushrooms indicates a level of 6.5, according to this indicator it is deduced that the spraying and misting method contribute significantly to assertively comply with this index.

Variable: Availability of H₂O

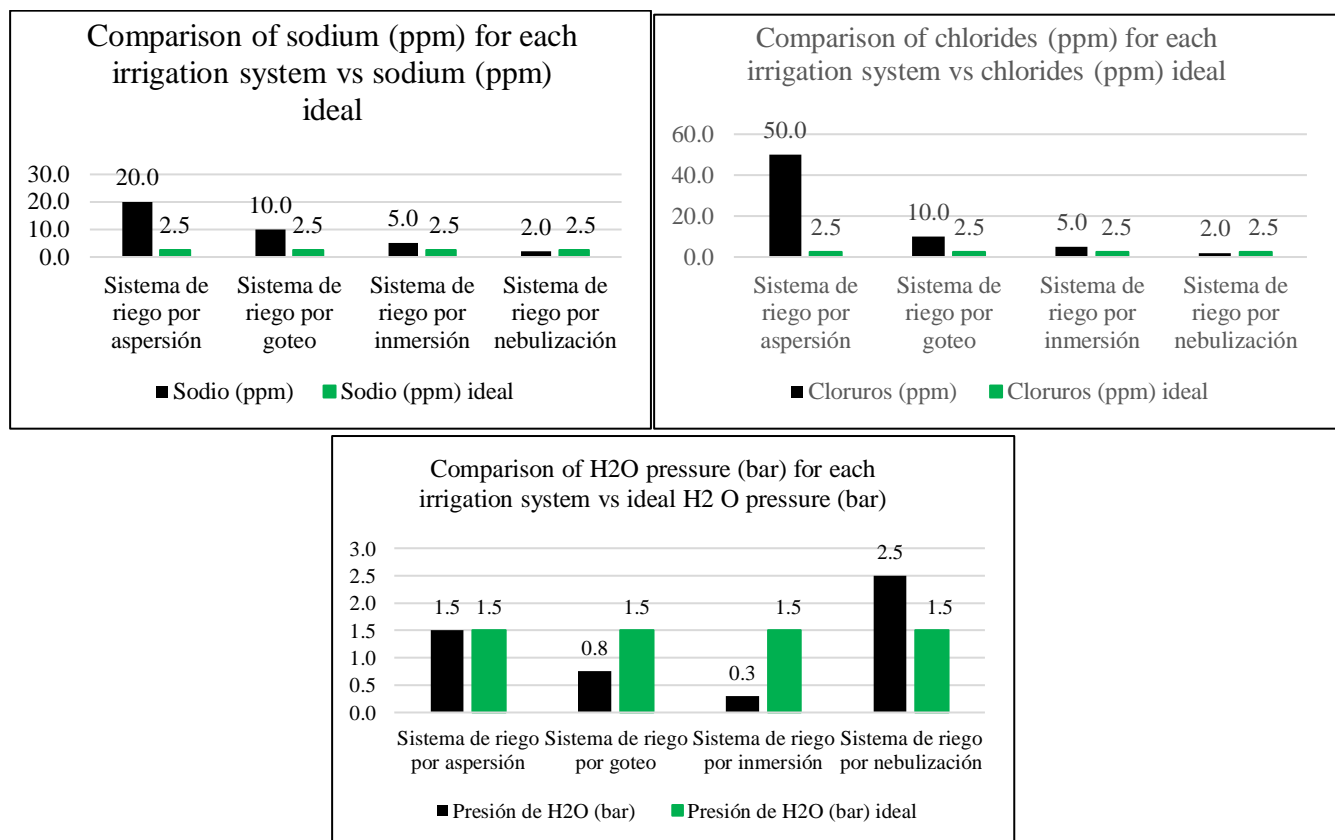
To finalize the statistical analysis corresponding to Phase 1, the one corresponding to the Variable: Availability of H₂O was carried out, the findings are: To provide the ideal quality to the water resource, the amount of chloride and sodium (ppm) is measured, this measurement indicates that in the case of chloride content a maximum of 2.5 ppm is permissible, so the mist irrigation system contributes 2.0 ppm, while the sodium content is permissible up to a range of 2.5 ppm, again it is notable that The mist irrigation system provides 2.0 ppm.

Now, the optimal pressure of H₂O is 1.5 bar, according to this index it is concluded that the sprinkler irrigation system is the one that contributes to 100% compliance with this factor, mentioning that the pressure of H₂O It is adjustable according to the emitters (Nebulizers, sprinklers, etc.) of H₂O (Graph 3 Analysis of the factors that make up the Variable: Availability of H₂O).

Box 16

Graph 3

Analysis of the factors that make up the Variable: Availability of H₂O



Once the analysis of the variables of: Climate, soil and availability of H₂O has been carried out, we proceed to determine which of the irrigation systems provides greater compatibility, taking into account that the study presented is based on the conditions environmental conditions of the Sierra Norte of the State of Puebla.

The average compatibility for each system is: Sprinkler irrigation= 37.43%, drip irrigation = 4.66%, immersion irrigation = 0%, mist irrigation = 66.2%. According to the compatibility levels described, the mist irrigation system is selected (Table 5 Compatibility analysis of irrigation system factors).

Box 17

Table 5

Compatibility analysis of irrigation system factors

Irrigation System	Compatible factors (Climate)	% Compatibility	Compatible factors (Soil)	% Compatibility	Compatible factors (H ₂ O availability)	% Compatibility
Aspersion	Temperature (Day), precipitation	29%	Permeability, pH	50%	H ₂ O availability	33.3%
Drip	Evaporation	14%	N/a	0%	N/a	0%
Immersion	N/a	0%	N/a	0%	N/a	0%
Nebulization	Temperature (Day), temperature (Night), relative humidity, evaporation	57%	H ₂ O retention capacity, pH	75%	Chlorides, sodium	66.6%

Results of Phase 2) Determine the irrigation requirements (H₂O) for the crop (*Pleurotus ostreatus*)

The standard measurement established for the greenhouse is 5m x 6m. Taking these measurements into account, an area of 30 m² is obtained, if the water consumption for a mist irrigation system is 1 liter x 1 in the incubation phase m²/day (Table 3 H₂O consumption for each type of irrigation by phases), the H₂O requirement is 30 liters per day, subsequently for the growth phase an average water resource consumption of 2.25 is needed liters, therefore, to supply the cultivation of mushroom mushrooms (*Pleurotus ostreatus*) the total requirement is 67.5 liters.

Results of Phase 3) Design nebulization system in specialized software

The final design of the mist irrigation system to grow mushrooms is revealed through the following set of images (Figure 10 Final design of the mist irrigation system).

Box 18

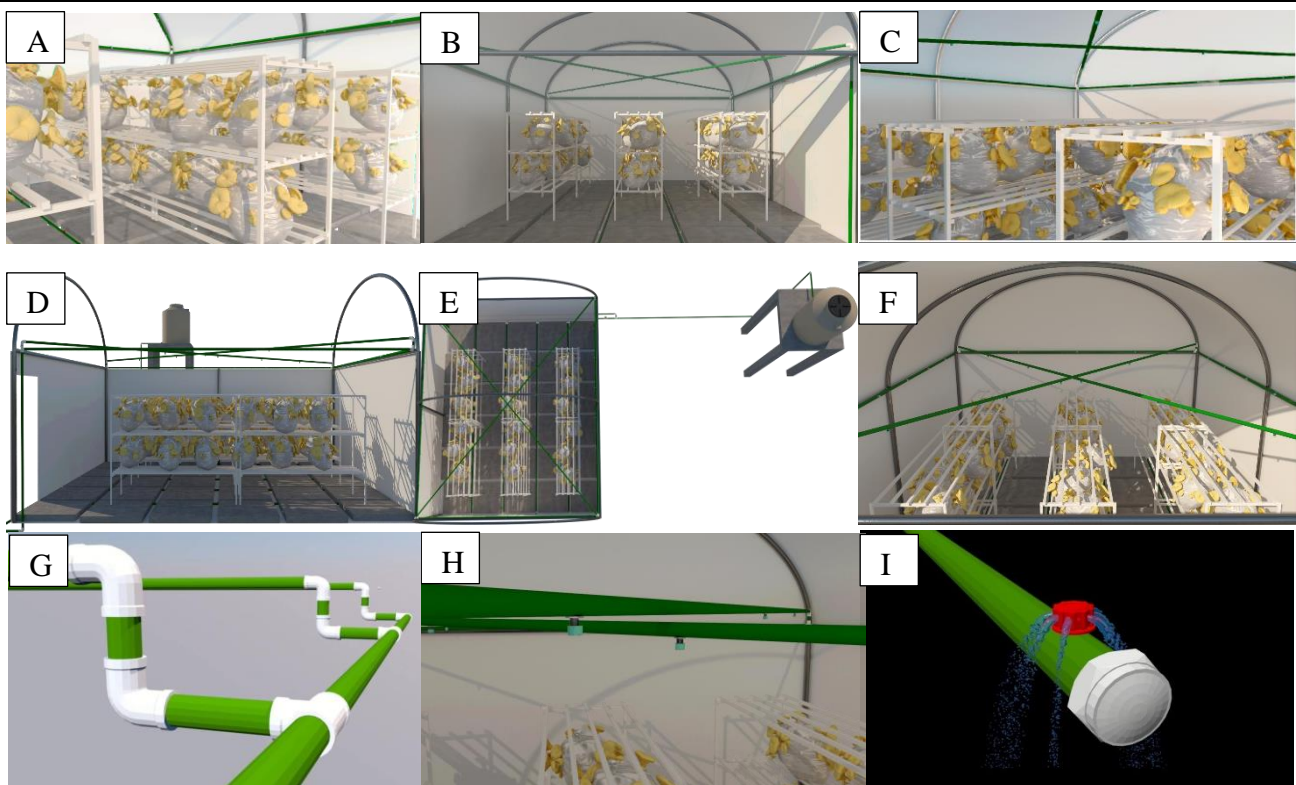


Figure 10

Final design of the mist irrigation system

In the design proposal for the mist irrigation system (Figure 10 Final design of mist irrigation system: A), you can see the simulation environment where the mushroom culture bags are located along with the shelves and distribution. of the irrigation system seen from a left side corner. The system is placed on the lateral sides and the rear part of the base of the dome alluding to a “u” shape, while in the center the “x” shape is found from corner to corner (Figure 10 Final design of the dome system). mist irrigation: B, C). The main details that make up the irrigation system are made visible through the H₂O power supply located on the left side of the model (Figure 10 Final design of mist irrigation system: D and E), later it is indicated the piping system that runs through the greenhouse area (Figure 10 Final design of mist irrigation system: F and G). To finalize the design in the SketchUp software, the location of the nebulizers is simulated as well as the H₂O output process through the mist irrigation system (Figure 10 Final design of the mist irrigation system: H, I). Once the model was generated in software, the design was manufactured, this creation is reflected in the development of a scale model, where each of the elements that make up the proposed irrigation system is physically represented (Figure 11 Prototype irrigation system physics, simulated scale environment).

Box 19



Figure 11

Prototype irrigation system physics, simulated scale environment

Consultation Source: Own Preparation

Results of Phase 4) Economic analysis

A. Costs of machinery and equipment for the construction of the mist irrigation system:

1. 2 o source =\$2,800.00
2. Bomb=\$1,000.00
3. Filter=\$300.00
4. Pipe=\$1,500.00
5. Valves=\$200.00
6. Emitters (Nebulizers) = \$500.00
7. Drainage system=\$1,350.00
8. Accessories=\$300.00

B. Greenhouse Manufacturing Cost (Variable costs)

1. Greenhouse structure installation = \$2,500.00
2. Construction of the footings = \$6,500.00
3. Construction of columns = \$5,200.00
4. Construction of earthenware = \$8,000.00

C. Monthly fixed costs

1. Repairs and Maintenance=\$1,100.00
2. Office supplies=\$1,500.00
3. Supplies=\$2,000.00

Total investment for the construction of the mist irrigation system = \$34,750.00

Conclusions

Taking into account the water requirements that significantly nourish mushroom crops (*Pleurotus ostreatus*), an efficient irrigation system is developed that meets the required indices for the variables of climate, soil, availability of H₂O and environmental impact, it is important to mention that each of the mentioned variables are made up of various factors, which must be met so that quality and productivity levels increase, and there is greater economic remuneration for fungi growers in the region and area of influence.

Taking into account what was described above, an area for improvement was detected within the mushroom cultivation processes, therefore, a mist irrigation system was designed, taking into account that it provides the following benefits:

- Temperature (Day) of 21°, with a decrease of 4.5% with respect to the ideal temperature.
- Temperature (Night) of 19°, with a 5% decrease with respect to the ideal temperature.
- Relative humidity, the nebulization process shows an average humidity of 87.5%, with an incremental of 2.9%, being beneficial for the cultivation phases taking into account that the greater the amount of relative humidity, the greater the growth of the product.
- In compliance with the precipitation factor, a contribution of 9 mm is observed, with an increase of 2.85% in relation to the optimal index.
- The evaporation factor (mm/day) is established at 13.5 mm/day, the mist irrigation system increases this index by 22.22%.
- The porosity of the ideal soil is 30%, nebulization is characterized by maintaining 30% porosity in the soil of mushroom-producing greenhouses.
- H₂O retention capacity must be 50%, the mist irrigation system provides 50% H₂O retention.
- The pH level of the soil must be maintained at an index of 6.5 on average. Analyzing the different irrigation systems that are currently used confirms that the mist irrigation system is the one that maintains the indicated level.
- The assessment related to the availability of H₂O is analyzed through the content of chlorides and sodium, taking into account that, for mushroom cultures to bear fruit, they must contain the minimum amount of these elements, therefore, it is determined that The ideal system is the nebulization model, because for both elements it only provides 2.5 ppm. It is important to mention that the ideal H₂O outlet pressure is 1.5 bar, the nebulizers provide a pressure of 2.5 bar, but with the possibility of adjustment, according to irrigation needs.

The study described above confirms that the mist irrigation system is optimal, and when designed according to regional needs it will bring with it multiple benefits, among which the following stand out:

- A. Increase in current production levels: The development of the mist irrigation system model has proven to be beneficial for the cultivation of the mushroom, since it provides a uniform distribution of humidity in the environment, which favors the growth and development of the mushroom mycelium. This results in a significant increase in mushroom production.
- B. Improves the quality standards of the mushroom: Adequate humidity is essential for the development of fruitful elements characterized by being of quality, the nebulization process guarantees optimal environmental conditions, bringing with it that the cultivated products significantly improve the following consumption characteristics: 1) Texture, 2) Flavor, 3) Appearance; These improvements add significantly to meeting the dietary needs of local, regional and national consumers.
- C. Increased profitability: The synergy resulting from the combination of the following benefits: Higher production levels, compliance with quality standards, water savings and automation of the process, contribute to increased profitability when producing mushrooms, with a recovery in the short term of the investment by implementing the mist irrigation system (\$34,750.00) in the greenhouses.

In conclusion, the development of this project contributes directly to the economic growth of the Sierra Norte of the State of Puebla (ODS 8 of the 2030 agenda), as well as to the generation of efficient production systems, oriented to the consumption of resources (H₂O) in a responsible manner (ODS 12 of the 2030 agenda) by the population.

Author contribution

- Soto Leyva-Yasmin contributed to the generation of the idea, the development of the Methodology of this Project and the performance of the statistical analyses.
- Ruíz Díaz–Montserrat contributed to the development of the theoretical framework, the description of the existing problem, the establishment of the objectives and the establishment of the conclusion.
- Bones Martinez-Rosalía and Martínez Domínguez Jose Antonio: They contributed to the development of the prototype in specialized software, as well as the construction of the physical prototype that represents the mist irrigation system and the economic analysis.

Availability of data and materials

The data and materials used were extracted from various practices carried out in mushroom cultivation crops (*Pleurotus ostreatus*) located in the Sierra Norte of the State of Puebla, as well as from the installation of greenhouses, and the simulation of mist irrigation models.

Funding

The research presented was funded by the General Directorate of the National Technology of México/Instituto Tecnológico Superior de Huauchinango.

Acknowledgements

To the Tecnológico Nacional de México/Instituto Tecnológico Superior de Huauchinango, to the Division of Industrial Engineering and to the academic body ITESHUUAU-CA-4, as well as to the Council of Science and Technology of the State of Puebla CONCYTEP for the facilitations provided in the preparation and presentation of this chapter.

Abbreviations

H ₂ O	Water
ODS	Sustainable Development Goals

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
Soiling of photovoltaic modules: impact on performance and mitigation strategies





Ensuciamiento de módulos fotovoltaicos: consecuencias en el rendimiento y estrategias de mitigación

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CONAHCYT classification:

DOI: <https://doi.org/10.35429/H.2024.8.79.91>

Area: Engineering

Field: Engineering

Discipline: Energy engineering

Subdiscipline: Solar energy

Key Handbooks

Drive the development of more efficient and sustainable cleaning technologies, such as advanced automated systems and innovative methods that reduce water use. In addition, by providing data-driven guidelines on cleaning frequency and methods, research can optimize resources and costs associated with module maintenance. Identifying and mitigating the effects of dust fouling can lead to the development of innovative coatings, such as superhydrophobic nanoparticles, that provide increased resistance to soiling and decrease the need for frequent cleaning. This research can lead to the creation of predictive models and diagnostic tools that can anticipate the impact of fouling on module performance. This contributes to the energy and economic efficiency of PV systems by minimizing yield losses and optimizing the operation of solar plants. Finally, by exploring fouling mitigation strategies, it promotes the adoption of more sustainable practices in the PV industry, reducing water use and decreasing the environmental impact of cleaning operations. Taken together, these contributions advance knowledge in the field of solar energy and promote greater sustainability and efficiency in renewable energy generation. To apply universal knowledge to the study of PV module fouling, it is crucial to understand how fouling affects module efficiency and to evaluate the various cleaning technologies available. This includes the effectiveness, costs and environmental impacts of methods such as the use of pressurized water, automated brushes and nanoparticles. The development of innovative coatings, such as superhydrophobic nanoparticles, can reduce the need for frequent cleaning and improve sustainability. Finally, it is crucial to examine how fouling mitigation strategies contribute to the sustainability of the PV industry, including reducing water use and minimizing environmental impact. Considering also the costs associated with module cleaning and maintenance and how these affect the economic viability of PV systems helps to balance maintenance costs with energy efficiency benefits. Understanding these aspects enables the development of comprehensive knowledge that optimizes fouling management, improves performance and promotes sustainable practices in the solar energy sector.

Citation: Escobedo-Márquez, Diana Laura, Castillo-Campos, Nohemí Alejandra, Esmeralda-Gómez, Alma Graciela and Álvarez-Macías, Carlos. 2024. Soiling of photovoltaic modules: impact on performance and mitigation strategies. 79-91. ECORFAN.

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Handbook shelf URL: <https://www.ecorfan.org/handbooks.php>



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Abstract

Solar energy is a natural resource that is used to generate electricity using photovoltaic technology, based on the photoelectric effect. Although useful, this technology faces challenges such as intermittency, environmental impact, installation costs, and energy storage. A specific problem is the dust that accumulates on the surface of the photovoltaic modules, the particles of which the dust is composed reduce their efficiency by absorbing or reflecting part of the solar radiation needed for the solar cells. To maintain the efficiency of the modules, it is essential to clean them regularly, using dry or wet cleaning methods. This research analyzes the factors that affect the performance of PV modules and compares the advantages and disadvantages of both cleaning methods. The results of the study indicate that wet cleaning is more effective in maintaining the optimal performance of PV modules.

Soiling of photovoltaic modules: impact on performance and mitigation strategies		
Objectives	Methodology	Contribution
<ul style="list-style-type: none"> Analyze the factors that affect the performance of photovoltaic modules. Compare the cleaning techniques used in the maintenance of photovoltaic modules. Evaluate Dry Cleaning Versus Wet Cleaning 	<ul style="list-style-type: none"> Documentary research Comparison of cleaning techniques for photovoltaic modules Experimental tests with dry cleaning and wet cleaning 	<p>This research shows a compendium of cleaning techniques commonly used for the maintenance of photovoltaic installations. Likewise, the analysis of the most effective type of technique to maintain good performance of the photovoltaic modules is presented.</p>

Photovoltaic modules, Cleaning techniques, Solar energy

Resumen

La energía solar es un recurso natural que se utiliza para generar electricidad mediante tecnología fotovoltaica, basada en el efecto fotoeléctrico. Aunque útil, esta tecnología enfrenta desafíos como la intermitencia, el impacto ambiental, los costos de instalación y el almacenamiento de energía. Un problema específico es el polvo que se acumula en la superficie de los módulos fotovoltaicos, las partículas de las que se compone el polvo reducen su eficiencia al absorber o reflejar parte de la radiación solar necesaria para las celdas solares. Para mantener la eficiencia de los módulos, es esencial limpiarlos regularmente, utilizando métodos de limpieza seca o húmeda. Esta investigación analiza los factores que afectan el rendimiento de los módulos fotovoltaicos y compara las ventajas y desventajas de ambos métodos de limpieza. Los resultados del estudio indican que la limpieza húmeda es más eficaz para mantener el rendimiento óptimo de los módulos fotovoltaicos.

Ensuciamiento de Módulos Fotovoltaicos: Consecuencias en el Rendimiento y Estrategias de Mitigación		
Objetivos	Metodología	Contribución
<ul style="list-style-type: none"> Analizar los factores que afectan el rendimiento de los módulos fotovoltaicos. Comparar las técnicas de limpieza utilizadas en el mantenimiento de módulos fotovoltaicos. Evaluar la limpieza seca contra la limpieza húmeda 	<ul style="list-style-type: none"> Investigación documental Comparación de técnicas de limpieza para módulos fotovoltaicos Pruebas experimentales con limpieza seca y limpieza húmeda 	<p>Esta investigación muestra un compendio de las técnicas de limpieza comúnmente utilizadas para el mantenimiento de instalaciones fotovoltaicas. Así mismo se presenta el análisis del tipo de técnica más eficaz para mantener un buen rendimiento de los módulos fotovoltaicos.</p>

Módulos fotovoltaicos, Técnicas de limpieza, Energía solar

Introduction

The applications of photovoltaic solar energy are diverse and continue to multiply with innovative designs, such as flexible or translucent cells. Additionally, the various sizes of modules available on the market allow this technology to be applied to a wide range of uses, from powering a solar calculator to generating electricity for large companies or buildings. It is worth noting that photovoltaic energy is particularly relevant in areas where the electricity distribution network has not yet reached or where access to the grid is difficult. The systems available for effectively using solar energy and converting it into electricity are divided into two main groups: autonomous off-grid systems and grid-connected systems (Puig et al., 2007).

Using photovoltaic modules, whether in standalone systems or connected to the grid, offers several advantages. These include low environmental impact, no harmful waste production, global availability of solar energy, no ongoing costs aside from simple maintenance, independence from utility companies, silent operation, a lifespan of over 20 years, resistance to extreme weather conditions (hail, rain, wind, etc.), no fuel consumption, and modularity, meaning that the installed capacity can be increased by adding additional components (Méndez et al., 2012).

However, photovoltaic generation also has disadvantages, such as the need for storage systems (e.g., batteries) that contain hazardous chemicals, which can harm ecosystems due to the land area required for large installations and visual pollution if modules are not integrated into the environment properly (Méndez et al., 2012). Other drawbacks include the high initial investment cost, making access challenging, and the relatively low efficiency of photovoltaic systems compared to other forms of energy generation. Today, modules with efficiency levels above 19% are considered high-efficiency; commercially, the highest efficiency ranges from 22% to 25%. However, various institutes and researchers have focused on increasing cell efficiency, achieving rates of 40% to 85.1% in laboratory settings (Castañón, 2022; Lorenzo, 2015). Another disadvantage of solar energy is its intermittency, which depends on the climate and geographical conditions of the installation site, resulting in inefficiency during periods with low sunlight or solar radiation (Mendez et al., 2019).

Considering the last two disadvantages mentioned, the application of solar panels requires adapting each system to the installation site's specific conditions. Regions with the greatest potential for solar energy are often arid or semi-arid, where dust accumulation is a significant issue, leading to the need for more frequent cleaning (Shehri et al., 2017). In these regions, low annual rainfall makes it difficult for natural cleaning to occur (Shehri et al., 2017). Furthermore, due to the droughts experienced in these areas, using water for artificial cleaning methods is not ideal (Shehri et al., 2016).

Several factors can affect a module's efficiency, such as received irradiation, orientation, temperature, shading, thermal performance, and dirt. Dirt accumulates on the module due to environmental factors like birds, wind, pollution, and dust (Flores et al., 2018). This dirt causes interference between the irradiance and the solar cells, with dust particles absorbing or reflecting part of the incident radiation, resulting in shading (Jiang et al., 2017). This significantly reduces the module's efficiency and can also lead to hot spots.

The impact of dust goes beyond energy production, leading to economic maintenance costs and potential damage to solar cells, such as increased temperature and corrosion due to the chemical nature of the dust. Given the significant disadvantages associated with dirt accumulation, analyzing its effects on photovoltaic systems has gained importance in recent years, as it is well known that dust exposure negatively impacts energy production (Torres et al., 2017).

Studies have consistently shown that dirt on a module reduces its efficiency. For instance, research by Jiang et al. (2011) found that the efficiency of a module decreased by 26% due to a dust layer of around 0 to 22 g/m² in indoor experiments (Jiang et al., 2017). Additionally, Elminir et al. (2006) reported a decrease in power output of up to 70% after exposing panels to weather conditions for six months in Egypt (Shehri et al., 2016). In Kuwait, a study by Wakim (1981) determined that the performance of the analyzed photovoltaic system was reduced by 17% due to dust accumulation after only six days of exposure to the elements (Shehri et al., 2017).

Factors Affecting the Efficiency of a Solar Module

The performance of a photovoltaic module is directly proportional to the amount of sunlight it receives and its technological capacity to harness that sunlight. This is why the efficiency of a panel is influenced by various factors such as the time of year, time of day, region, and geographical location. Additionally, the module's efficiency can be compromised by ambient temperature, which can alter the cell temperature, as well as by system inefficiencies, such as wiring failures. More importantly, severe environmental conditions like sandstorms, high levels of air pollution, snow, hail, and intense UV radiation can also impact performance (Shehri et al., 2017). However, when photovoltaic technology is used in different regions and environments, it is exposed to environmental conditions that differ from standardized ones. As a result, the efficiency calculated from the data provided in the panel's technical specifications often differs from the actual efficiency, which reflects the panel's performance at its installation site. This real-world efficiency is affected by factors such as shading, regional ambient temperature, and the level of irradiance at the site.

The following section discusses how these factors, among others, influence the operation of a PV module.

1. Dirt

It refers to the dust adhered to the surface of the panel and depends on different factors such as those indicated below (Aly et al., 2015);

Properties of the powder

The surface texture and size of dust particles influence how easily they can be removed; particles with rougher surfaces are easier to remove than those with smoother surfaces. Similarly, larger particles tend to detach more easily (Jiang et al., 2017). The density of the particles and their state of aggregation also play a role. Chemical bonds, along with gravitational effects, are the primary causes of particle deposition (Shehri et al., 2016).

Photovoltaic panel composition

The accumulation of dust also depends on the contact material of the photovoltaic module. For instance, dust accumulation is lower on glass surfaces compared to plastic ones. Additionally, some modules feature special coatings designed to reduce sunlight reflection and repel dust (Shehri et al., 2017).

PV Panel Orientation

Another factor is the inclination of the installed module, horizontally positioned modules tend to accumulate more dust than those in vertical positions. The dust distribution pattern can depend on the distribution of the panel, as well as the angle of inclination of the panel and the weather conditions (Shehri et al., 2016).

Surrounding environment

Shobokshy and Hussein (1993) conducted research on the effects of various dust particles commonly found on the surface of solar panels. Their study included cement, lime, and carbon in different particle sizes, and it was determined that 5 μm carbon particles caused the most significant power losses in the panels, severely impairing their performance (Shehri et al., 2016). This finding suggests that carbon emissions should be a key consideration in the frequency of panel maintenance, especially in areas with heavy traffic or high industrial activity where emissions are elevated.

Wind Speed

The accumulation of dust is proportional to the wind speed, as the wind increases, so does the dust. The elevation of the modulus with respect to the ground also influences. Higher elevation represents reduced dust accumulation at high wind speeds (Shehri et al., 2017).

Temperature and humidity

Dirt is difficult to remove during wet periods, as water promotes the formation of sludge (Shehri et al., 2016). Regions near the equator, where annual insolation is highest, are typically arid. Although these areas can effectively harness solar energy, the desert climate often leads to the accumulation of sand and dust on the surface of photovoltaic modules (Shehri et al., 2017; Aly et al., 2015).

Disadvantages of a dirty solar module

Dust in arid regions

The process of cleaning the surface of photovoltaic modules has become a significant concern, as it is crucial to maintain their original efficiency, especially in desert environments. Despite the high levels of irradiance in these regions, the severe weather conditions—characterized by hot days for most of the year and minimal rainfall—pose challenges (Shehri et al., 2017).

The constant decline in the efficiency of photovoltaic panels installed in arid areas is largely attributed to the accumulation of dust and the lack of rain to naturally clean them, necessitating the use of manual or automated cleaning methods (Shehri et al., 2017).

Energy deficiency

The dust accumulated on the surface of solar panels reduces energy conversion efficiency because the incident radiation is refracted and/or absorbed by the dust particles. As the amount of dust on the surface increases, the panel's transmittance decreases, ultimately affecting the power output of the photovoltaic system. While the relationship between the reduction in photovoltaic module performance and the duration of exposure to the elements varies by region, it is well-established that dust accumulation negatively impacts energy generation, underscoring the importance of regular cleaning (Shehri et al., 2016; Jiang et al., 2016). Studies have shown that around 2 mg of dust per cm² on a solar panel can reduce power output by up to 30% (Mufasa et al., 2015).

Damage to materials

As previously mentioned, dirt impacts the transmittance of photovoltaic modules, obstructing the free entry of photons and the efficient absorption of energy. Over time, this can lead to a reduction in the lifespan of the photovoltaic installation or result in permanent or long-term failures of the technology, particularly in desert regions (Mufasa et al., 2015). Additionally, the accumulation of dust affects the temperature of the photovoltaic cells, potentially causing them to overheat. Dust particles can retain and absorb heat from the sun, leading to increased cell temperatures (Shehri et al., 2016).

Shading introduces another issue known as a hot spot. When cells are connected in series, they are expected to work in direct polarization to combine their voltage. However, when shading or dirt interrupts solar radiation to a cell, that cell shifts from being a generator to a receiver. This results in inverse polarization, which causes negative electrical power and raises the temperature at that point. The increased heat must be dissipated, which can lead to severe damage to the system and its encapsulating materials. The effects on the current are typically minimal (Méndez et al., 2012).

To mitigate this problem, bypass diodes are used inside the module's junction box. These diodes are connected in parallel with groups of cells in series, as illustrated in Figure 3. Under normal operation, the diodes are inactive. However, if a cell is affected, the diode provides an alternate path for current flow, thereby limiting the power dissipation per cell. Additionally, as discussed in Section 2.8.2, shading can cause power fluctuations that damage other components of the photovoltaic system, such as inverters and batteries (Gonzalez et al., 2009).

Economic disadvantages

The economic impact of dust accumulation on panels can be approximated and demonstrate that it has a significant financial impact. The reading (Shehri et al., 2016) carries out an analysis of the economic impact of dirt taking into account the results of their study. The analysis is as follows.

The average decrease in absolute permeability during the permeability test was approx. 7%. This causes a decrease in the efficiency of solar panels by about 8%. In this analysis, the case is considered in which a 100 MW power plant generates approx. 600 MWh/day or 219 GWh/year. Assuming an energy cost of about \$0.04/kWh, the annual production potential is about \$8,760,000.

If the panels are cleaned every two weeks, which is a common practice using human labor, it can be assumed that the average efficiency loss over these two weeks is around 8%, which is half of the total expected reduction assuming a linear model for the effect of dust depositions on transmittance during this period of time. This leads to a reduction in the production of electrical energy equivalent to \$701,000 per year (Shehri et al., 2016). This means that both the cleaning procedure and leaving the modules dirty represents an economic expense.

Cleaning the photovoltaic modules

Basic maintenance of a photovoltaic installation includes cleaning the modules, which is crucial for ensuring optimal performance. Cleaning should be performed when excessive dirt, bird droppings, or other debris are observed on the panels, as well as when dirt accumulates near the frame or when opaque stains cover all or part of the cell. PV module cleaning can be categorized into two main types: wet cleaning and dry cleaning. Wet cleaning involves using water or an aqueous solution to remove dirt, while dry cleaning includes methods that do not require water and typically rely on physical actions, such as brushing or vibration (Shehri et al., 2016).

Dry cleaning

Dry cleaning does not require the use of water and is usually based on physical methods such as brushing or vibration. Unlike wet cleaning, dry cleaning is not as efficient as with water due to the lack of chemical factors since water acts as a means of transport to carry away dust, facilitating the complete removal of dirt by dissolving many particles adhered to the area. The use of water during cleaning helps to restore the module's original optical characteristics. In contrast, dry cleaning can cause superficial damage due to friction exerted (Elminir et al., 2006).

Wet cleaning

Wet cleaning is a commonly used method for maintaining PV modules and ensuring optimal performance. It involves using water or other liquids along with appropriate tools, such as soft cloths or sponges, to remove dirt, dust, bird residues, and other impurities from the module surfaces (Verhorf, 1988).

Wet cleaning should be performed outside of peak solar radiation hours to avoid thermal stress. This thermal gradient occurs when the hot surface of the modules comes into contact with cold water, potentially leading to damage due to thermal stresses. Therefore, it is advisable to carry out cleaning during times of the day with less solar radiation to minimize these risks.

Types of solutions and techniques

Water plays a crucial role in the module cleaning process due to its ability to soften, dissolve, and physically dislodge dirt deposits. Initially, dirt is softened by using pressure cleaning or gently spraying water on the surface. Various solutions and techniques can be employed for wet cleaning of PV modules. Two of the most common methods are presented in Table 1 (Verhorf, 1988).

Box 1

Table 1

Aqueous solutions for wet cleaning

Solutions	Cleaning technique
Pure water	This technique involves the use of water without chemical additives or detergents. It is applied directly to the surface of the modules.
Deionized water	The deionized water cleaning technique can help reduce the formation of stains and marks after drying by removing minerals and other contaminants that could leave residue on the surface of the modules.
Soap	For this technique, use a neutral or biodegradable soap without abrasive chemicals, phosphates, ammonia or bleaches. Mix a small amount of soap in water and apply with a spray bottle on the modules. Clean with a soft cloth, with circular movements and rinse with plenty of water.
Window cleaner	The technique consists of spraying the glass cleaning solution on the surface of the modules and removing it with a puller

Verhorf, 1988

Cleaning techniques

Cleaning techniques are varied, and may or may not require human effort, and some may be more sophisticated than others. Figure 1 shows the classification of the cleaning techniques studied.

Box 2

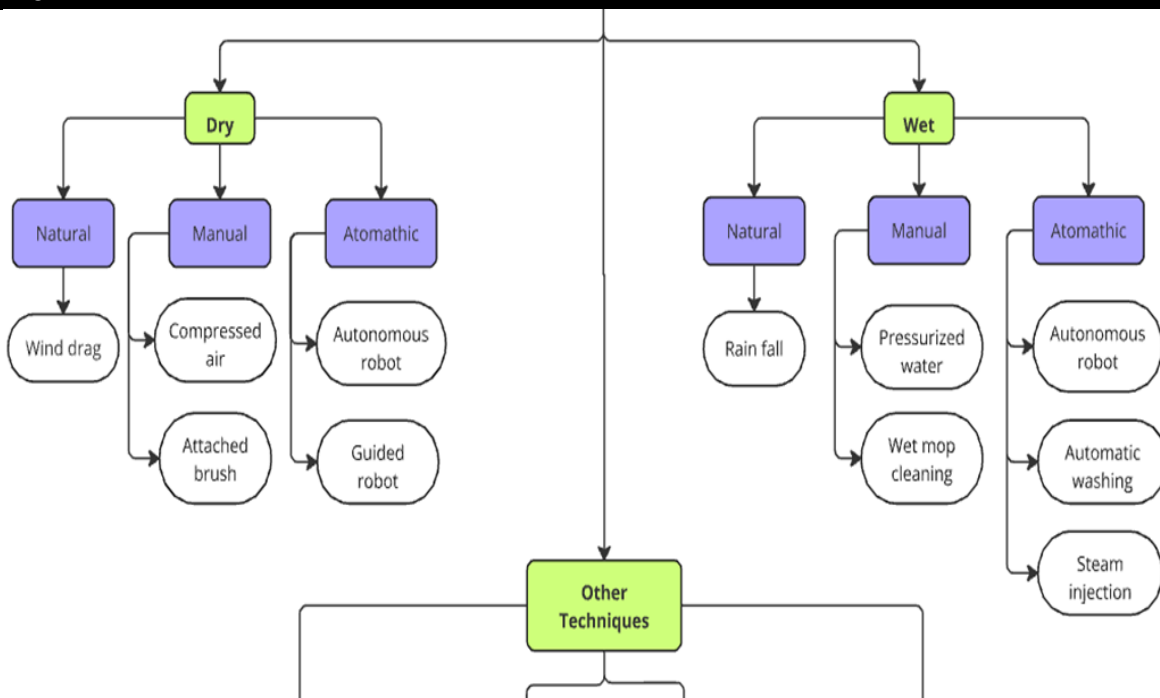


Figure 1

Classification of cleaning techniques for photovoltaic modules

The table 2 provides a detailed description of PV module cleaning techniques, classified according to their application method: natural, manual or automatic. It includes information on each technique, its characteristics and a complete overview to select the most suitable method according to specific needs and operating conditions.

Box 3**Table 2**

Cleaning techniques

Cleaning of photovoltaic modules		
Dry cleaning		
Application	Technique	Description
Natural	Wind drag	The wind speed required to remove particles varies according to their size: the smaller, the higher the speed required, and the larger, the lower the speed. In addition, a higher shear force is needed to remove particles on smooth surfaces, while less is required for rough particles (Shehri et al., 2017).
Manual	Compressed air	Compressed air is used to blow dust and light dirt off the modules. This technique uses a gun connected to a compressor that applies a pressure of 3 to 5 bar, enough to clean without damaging the surface (Alonso, 2021).
	Attached brush	Involves the use of a tractor-mounted rotating brush. As the tractor travels through the rows of modules, the brush sweeps the surface of each module, removing dust and dirt. This technique is efficient for covering large areas quickly and ensures uniform cleaning of the panels (Solar Clean Hymach, 2019).
Automatic	Autonomous robot	Is performed by devices equipped with brushes that sweep the surface of the modules, removing dust and dirt. These robots do not require physical guides, as they are designed to move freely over the modules, adapting to their shape and ensuring thorough and efficient cleaning. This technology is ideal for large facilities where automation can improve efficiency and reduce the need for manual intervention (Ecoppia, 2024).
	Guided robot	Is performed by a system of rotating brushes that, thanks to a precise guiding system, follows a set path on the modules. These brushes, which can be motorized or manually driven, have rubber or nylon bristles. The soft, flexible rubber bristles prevent scratches on the surface, while the stiffer nylon bristles are more effective but can cause abrasions. The guide ensures that the robot cleans uniformly and efficiently, following a predefined path that maximizes the coverage and efficiency of the cleaning process (Ecoppia, 2024).
Wet cleaning		
Application	Technique	Description
Natural	Rain fall	Rain is a natural and economical method of removing surface dust from photovoltaic modules. When it rains, water washes away particles accumulated on the surface of the modules, effectively cleaning them, but this technique depends on the frequency and intensity of rainfall (Shehri et al., 2017).
Manual	Pressurized water	This method of cleaning photovoltaic modules uses a system that combines water and pressurized air. Water guns, which are manually operated by an operator, are used to perform the cleaning. Although effective, this technique presents risks, as excessive pressure can cause cracks or breaks in the surface of the modules (Sun, 2023).
	Wet mop cleaning	This cleaning is performed using damp cotton, microfiber or plastic mops to remove dirt and debris adhering to the surface of the modules. It is crucial to apply the technique carefully and meticulously to ensure thorough cleaning.
Automatic	Autonomous robot	This automated cleaning procedure uses a robot that cleans the surface of the modules with brushes and water, with an advanced displacement system that allows remote control by means of a joystick. This technology is ideal for medium-sized solar plants (Serbot.Ch, 2024).
	Automatic washing	This technique uses automated systems that employ pressurized water to clean photovoltaic modules. Equipped with rotating brushes and spray nozzles, these systems ensure uniform and efficient cleaning by addressing the entire surface of the panels. The combination of pressurized water and rotating brushes effectively removes dirt and debris, optimizing module performance and reducing the need for manual intervention.
	Steam injection	Steam injection cleaning of photovoltaic modules uses hot water vapor to loosen and remove dirt and debris without the need for additional chemicals. This method has the advantage of using less water than traditional methods, which is beneficial in areas with limited water resources. However, the energy consumption to evaporate the water can be significant (Solar Bright, 2024).
Other techniques		
Technique	Description	
Ultrasonic self-cleaning	Uses high frequency waves (above 20 kHz) to remove contaminants such as dirt, oil and grease from materials such as metals, glass and ceramics. The process creates micrometer-sized bubbles by alternating pressure waves. These bubbles explode at extreme temperatures and pressures, generating droplets that travel at speeds of up to 400 km/h, effectively cleaning even small cracks and fine particles (Kazem et al., 2020).	
Nanofilms	Uses superhydrophilic coatings, such as titanium dioxide (TiO ₂), which activate a photocatalytic process under ultraviolet light. This process breaks down organic dirt on the surface of the modules. Rainwater or additionally applied water then washes away the residues, completing the cleaning. The technique is effective in areas with frequent rainfall, but its effectiveness decreases in dry regions Syafiq et al. (2018)	
Electric curtain	This technique uses an electrical wave to generate a moving barrier that repels particles deposited on the PV module. By keeping the surface of the panel constantly electrically charged, it helps prevent the accumulation of dirt. However, this method can present risks during rainy days, as the electrical charge on the surface may not be safe in wet conditions (Adams et al., 1967).	
Super hydrophobic aircraft	The technique consists of applying a hydrophobic coating on the surface of the photovoltaic module, creating a layer that prevents water adhesion. Water droplets on these surfaces trap and carry away dirt particles, keeping the module clean. This method is effective in rain, but not in dry environments, as it requires water or precipitation to function properly (Kazem et al., 2020)	

Methodology

To evaluate the effectiveness of the two types of cleaning, dry cleaning and wet cleaning, we experimented with the application of both cleanings on photovoltaic modules of the same technology. In the case of wet cleaning, an automatic washing prototype was used, while a cleaning prototype with nylon brush coupling was used to apply dry cleaning, the prototypes can be seen in Figure 2.

Box 4

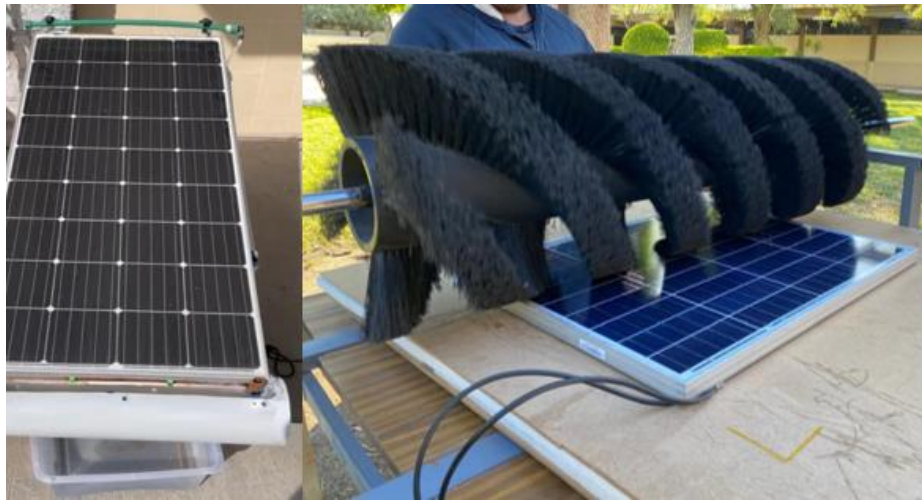


Figure 2

Photovoltaic module cleaning prototypes. Left. Wet cleaning prototype. Right. Dry cleaning prototype

For the analysis, 3 photovoltaic modules were used, one of which was kept clean, another was wet cleaning and another was piled dry cleaning. The application of cleanings was carried out repeatedly to obtain an average of the efficiency of each module subjected to cleaning, for this the modules were soiled and cleaned on multiple occasions using the corresponding prototypes and the values obtained were compared with the values generated by the module that was kept clean. This is illustrated in Figure 3.

Box 5

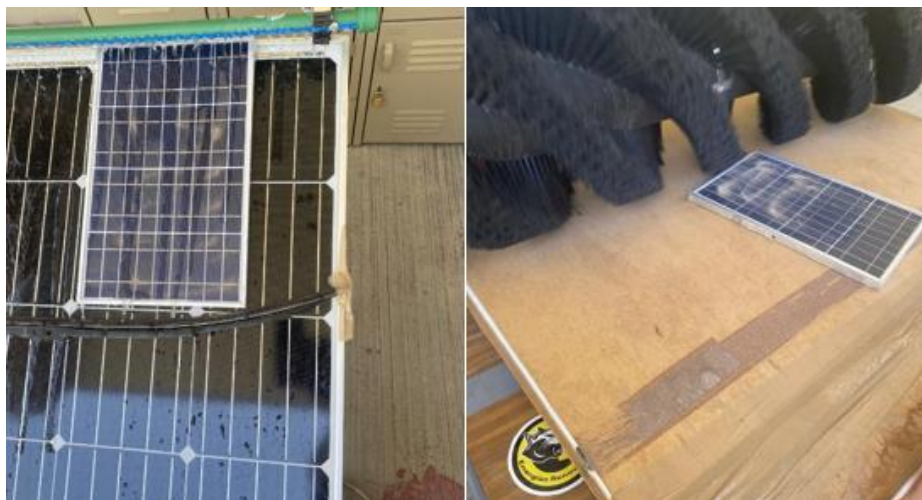


Figure 3

Cleaning applied to photovoltaic modules. Left: Wet cleaning prototype. Right: Dry cleaning prototype

Likewise, the time it took each prototype to clean the modules was timed, and according to the time their energy consumption was obtained

Results

Regarding the comparison of the efficiency of the modules after being cleaned with the wet cleaning and dry cleaning prototypes, Figure 4 is available.

Box 6

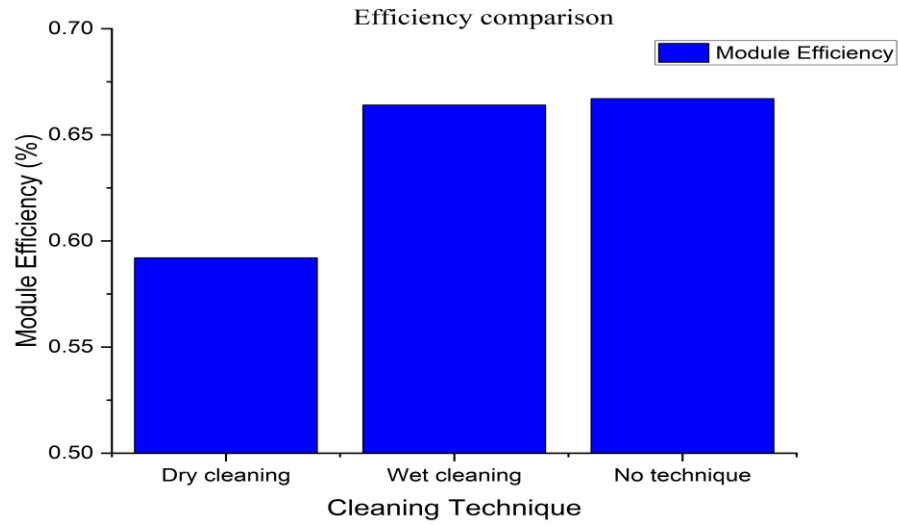


Figure 4

PV module efficiency comparison using wet and dry cleaning

By author in OriginLab Pro 8

Figure’s 4 graph shows that the wet cleaning method is able to maintain the efficiency of the module at the level of the module that was kept clean, making it an effective technique for module maintenance. On the other hand, the dry cleaning method is less effective, however, it proves to be functional in removing most of the dust from the surface of the modules.

A factor to take into account when deciding which technique to use is the time of application of the cleaning, since it is usually sought that the cleanings are carried out in less time. For the case study, the analysis of wet and dry cleaning application time is shown in Graph 5

Box 7

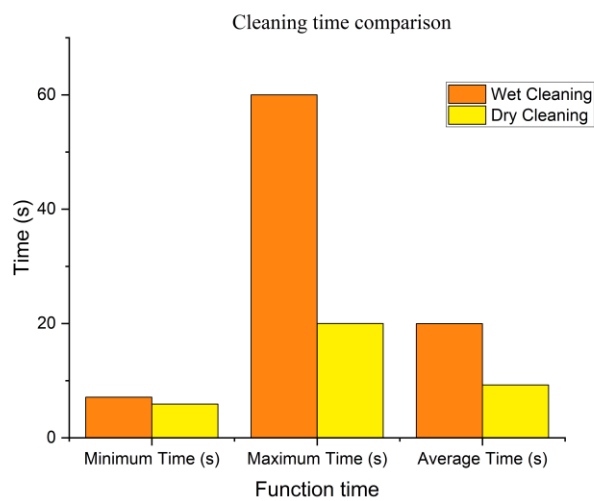


Figure 5

PV module efficiency comparison using wet and dry cleaning

By author in OriginLab Pro 8

Figure 6 shows that applying wet cleaning to modules takes longer than applying dry cleaning. This factor is considerable for solar parks that have hundreds of modules, in this aspect it is better to apply dry cleaning.

Based on the time taken by each type of cleaning, the energy consumption of each cleaning prototype is obtained as shown in Graph 6.3, considering that the power of the wet cleaning prototype has a power of 25 W and the dry cleaning prototype has a power of 372.8 W.

Box 8

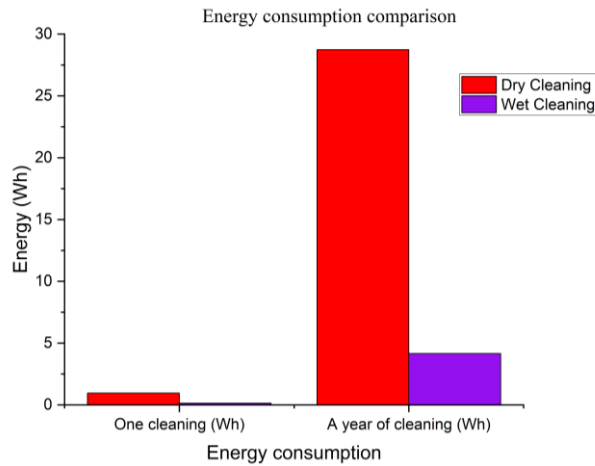


Figure 6
 Comparison of the energy consumed by wet and dry cleaning prototypes
By author in OriginLab Pro 8

It can be seen in Graph 6 that the wet cleaning system consumes less energy than the dry cleaning system. The wet cleaning prototype can consume as little as 4.16 Wh per year cleaning a module, while the dry cleaning prototype consumes 28.74 Wh per year.

To analyze the economic factor, Graph 7 is available, which compares the cost of using wet and dry cleaning prototypes based on the energy consumed by each one.

Box 9

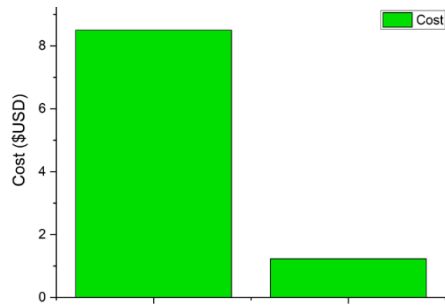


Figure 7
 Comparison of the cost for the use of wet and dry cleaning prototypes
By author in OriginLab Pro 8

The lower energy consumption of wet cleaning is reflected in Graph 6.4 where the cost for its application is also lower. In the same way, since the dry cleaning prototype consumes a greater amount of energy, the annual cost of its use is expensive than that of wet cleaning.

Conclusions

In this study, the negative factors of module soiling were analyzed, as well as the techniques for mitigating this problem through different cleaning techniques. Through this research, it was found that although cleaning techniques are varied, the main aspects of their classification are wet cleaning and dry cleaning. In turn, cleaning techniques can be divided into natural cleaning, manual cleaning, and automatic cleaning.

The experimental comparison of the dry cleaning method against the wet cleaning method showed that wet cleaning is more effective in maintaining the performance of PV modules than dry cleaning due to the ability of water to drag dust particles. On the other hand, subjecting the modules to a dry cleaning process is faster than subjecting them to wet cleaning. This is because the dry cleaning prototype was more powerful than the wet cleaning prototype, which in turn led it to consume more energy. Consequently, the wet cleaning technique is more economical than the dry cleaning technique.

Dry cleaning is effective enough to be applied in photovoltaic module maintenance, it has the great advantage that it avoids the use of water unlike wet cleaning, and it is faster, so, despite being more expensive, it is an excellent alternative for arid regions where water tends to be scarce.

Wet cleaning is a good option if you use a system that minimizes water consumption, as the modules can be cleaned using little energy, and the performance of the module will not be impaired by fouling.

Declarations

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence in this chapter.

Author contribution

Escobedo-Marquez, Diana Laura: She contributed whit the project idea, bibliographic research, data collection and article writing.

Castillo-Campos, Nohemí Alejandra: She contributed whit the project idea, carried out the research method and technique, data collection and writing of the article.

Esmeralda-Gómez, Alma Graciela: She contributed whit bibliographic research and article writing.

Álvarez-Macias, Carlos: He contributed to the supervision of the project, as well as the review and editing of the writing and verification of bibliography.

Funding

This research was supported by CONAHCyT, México by the scholarships 1188232, 1271718, as well as the IFLAG-CA-10 academic body strengthening project of PRODEP. Furthermore, the authors thanks to TecNM projects.

Abbreviations

h	Hour
MW	Mega watts
PV	Photovoltaic
S	Seconds
USD	United States Dollar
W	Watts
Wh	Watts per hour

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Ecological waterproof adobe brick based on straw and manure

Adobe ecológico impermeable a base de paja y estiércol

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CONAHCYT classification:

DOI: <https://doi.org/10.35429/H.2024.8.92.105>

Area: Engineering

Field: Engineering

Discipline: Systems engineer

Subdiscipline: Production research

Key Handbooks

Experimental development, innovation centers, biotechnology development, innovation of prototypes and models. The Properties of Adobe, Sustainability and Tradition and the Development of a Sense of Ethics and Responsibility. As we know, adobe is a sustainable and culturally relevant building material in many regions of the world. Its use combines ancestral knowledge with technological innovations, to generate greater resistance to humidity and other factors that deteriorate the material. The characteristics of adobe must be identified and understood, such as its composition (clay, sand, straw) and its mechanical resistance, since it is essential for its development due to the application of new technologies that provide better characteristics to the material. Considering the environmental and social impact of the use of adobe is essential for ethical and sustainable construction, ensuring and reducing a significant percentage of environmental contamination.

Citation: Bones-Martínez, Rosalía, Soto-Leyva, Yasmin, Ruíz-Díaz, Montserrat and Santos-Osorio, Arturo. 2024. Ecological waterproof adobe brick based on straw and manure. 92-105. ECORFAN.

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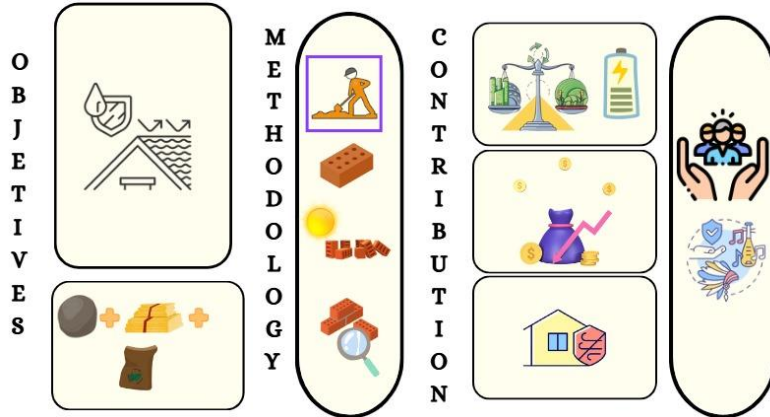
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Abstract

Waterproof ecological adobe brick made from straw and dung is one of the oldest building materials used by humanity, it is a sustainable and efficient solution for construction, it is a traditional building material that has been used by man for centuries due to its sustainability and thermal efficiency, especially in areas where conventional building materials are not easily accessible or expensive. Adobe consists of a mixture of soil, water, and often straw or manure, which is molded into blocks and dried in the sun. Combining adobe with materials such as straw and manure can improve its properties, including water resistance, this traditional method uses natural and local materials, providing an ecological and economical alternative. To improve the resistance and durability of the walls that protect them against humidity, thus avoiding problems such as degradation and mold formation, which are the main causes that put people who have their homes at risk. of this material. In this way, a more durable construction is achieved and suitable for different climates.

Ecological Waterproof Adobe Brick Project based on Straw and Manure

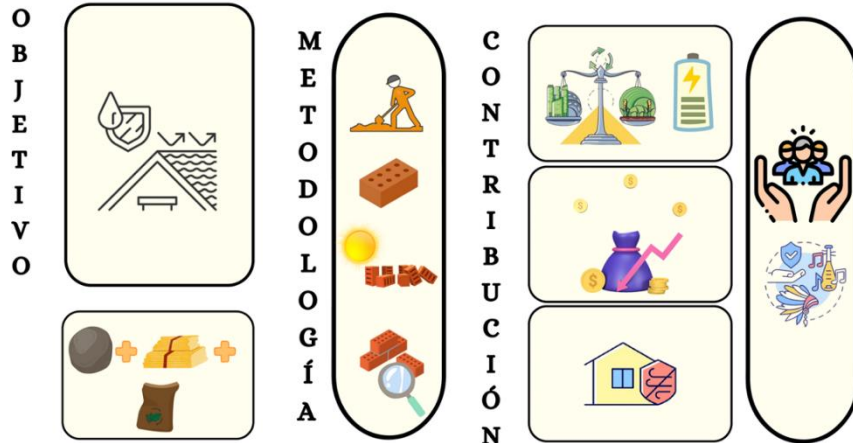


Ecological, sustainable, sustainability, efficiency, conventional, resistance, formation, traditional, properties, alternative, Adobe, Ecological, Waterproof

Resumen

El adobe ecológico impermeable a base de paja y estiércol es uno de los materiales de construcción más antiguos utilizados por la humanidad, es una solución sostenible y eficiente para la construcción, es un material de edificación tradicional que ha sido utilizado por el hombre durante siglos debido a su sostenibilidad y eficiencia térmica, especialmente en áreas donde los materiales de construcción convencionales no son fácilmente accesibles o son costosos. El adobe consiste en una mezcla de tierra, agua, y a menudo paja o estiércol, que se moldea en bloques y se seca al sol. La combinación de adobe con materiales como paja y estiércol puede mejorar sus propiedades, incluida la resistencia al agua, este método tradicional utiliza materiales naturales y locales, proporcionando una alternativa ecológica y económica. Para mejorar su resistencia y la durabilidad de las paredes que las protege contra la humedad, logrando de este modo evitar problemas como la degradación y la formación de moho, los cuales son los principales causantes que ponen en riesgo a las personas que tienen su casa hecha de este material. De este modo, se logra una construcción más duradera y apta para diferentes climas.

Proyecto de Adobe Ecológico Impermeable a Base de Paja y Estiércol



Ecológico, sustentable, sustentabilidad, eficiencia, convencional, resistencia, formación, tradicional, propiedades, alternativa, Adobe, Ecológico, Impermeable, Adobe, Ecológico, Impermeable

Introduction

The adobe, one of the world's oldest and most sustainable building materials, has been used for millennia due to its accessibility, low cost and thermal properties. The adobe has been used for more than 10,000 years in various areas and climates around the world. From the muddy river areas of ancient Egypt to the ancient architecture of the Middle East, adobe bricks have left their mark on building history. Molds for adobe bricks are manufactured on site, allowing for a variety of morphological shapes. This contributes to the iconic character of adobe buildings. Traditionally composed of a mixture of soil, water and natural fibers such as straw; the adobe is valued for its ability to keep interiors cool in hot and cold climates. However, one of the main limitations of conventional adobe is its susceptibility to water damage, which can compromise the durability and structural integrity of adobe buildings.

The searching of methods to improve the water resistance of adobe brick has led to the exploration of various natural additives. Among these, straw and manure stand out not only for their abundance and low cost, but also for their material-improving properties. Straw, when mixed with mud, acts as a reinforcement that reduces cracking and improves the cohesion of the adobe (Catalán, P., & Moreno, J. Y 2019). On the other hand, manure, especially cow manure, contains natural fibers and natural compounds that can act as binders and stabilizers, improving both the cohesion and water resistance of adobe (Minke, 2000). The combination of straw and manure in the production of adobe brick not only enhances its physical and mechanical properties, but also reinforces the sustainability of the material by using renewable and recycled resources. This project focuses on the production of ecological adobe blocks that integrate straw and manure, with the objective to create a construction material that is both resistant and waterproof. The implementation of these natural additives promises a significant improvement in the durability of adobe brick, allowing its use in a wider range of climatic and environmental conditions.

By addressing traditional adobe brick challenges through the use of eco-friendly techniques and materials, this project not only contributes to the preservation of traditional construction methods, but also promotes sustainable and environmentally friendly practices. Through rigorous testing and a structured methodology, it seeks to demonstrate that improved ecological adobe remains a viable and durable solution for sustainable construction in the 21st century. In short, adobe brick is a building material that combines tradition, sustainability and energy efficiency. Its use remains relevant today, especially in regions where its positive impact on the environment is valued. *The waterproof ecological adobe brick that we offer has some characteristics that distinguish it from others, such as two different sizes, nopal as a natural binder and smooth walls of the blocks.*

Methodology

Selection and Preparation of Materials.

Clay soil

Box 1



Figure 1

Red earth

Reference: image own authorship_red earth

The Mud, also known as clay, is a natural material composed mainly of fine mineral particles that are mixed with water to form a malleable mass; The structure of mud particles is essential to understand its properties and applications in various processes, such as ceramics, adobe construction, among others.

The characteristics of the particle structure of mud are described below:

1. **Particle size:** Clay particles are extremely small, with an average size of less than 0.002 mm. This gives them plastic and cohesive properties, which allows the clay to be easily molded and shaped.
2. **Constituent minerals:** Clay is mainly composed of minerals from the phyllosilicate family, such as kaolinite, illite and montmorillonite. These minerals have a layered, lamellar structure, which contributes to the clay's plasticity and plasticity.
3. **Electrical charge:** Clay particles usually have a negative surface charge due to the presence of ions in their structure. This electrical charge influences the clay's ability to retain water and its behavior in the presence of other materials.
4. **Water retention capacity:** The porous structure of the clay particles allows the mud to retain water in its interstices. This property is important in drying, firing and ceramic forming processes.
5. **Interactions between particles:** Clay particles can interact with each other through cohesion and adhesion forces, which determines the plasticity and strength of the clay. These interactions are influenced by factors such as humidity, temperature and pressure.
6. **Crystalline and amorphous structure:** At the microscopic level, clay particles can have a crystalline or amorphous structure, depending on the mineral composition and the formation process. This structure influences the mechanical resistance and thermal stability of the clay. The soil used must have a high clay content to ensure the cohesion and plasticity necessary for the adobe mixture. Collect soil samples and perform sediment tests to determine the proportion of clay, silt and sand. Ideally, the soil should contain at least 30% clay (Catalán, P., & Moreno, J. Y 2019).

Straw preparation

It is an excellent thermal and acoustic insulator, breathable, healthy, moisture regulator, very versatile, easy to work with and binds very well with clay and lime. It is a long-lasting material that does not require major restorations or rehabilitation. Great thermal and acoustic insulation. Straw is a material with optimal insulating properties, achieving energy savings of up to 75%, however, straw usually facilitates the penetration of insects, in particular wasps that nest inside the adobes, creating within them “tunnels” of small diameter, which in the long run produces weakening. Some features are the following:

Combustibility

Although straw in its natural state burns easily, in the bales, since the straw is compacted, there is no air and therefore, its combustibility is minimal, if not zero. Added to this is the obligatory lime or earth plaster, which protects it even more. Studies carried out by technicians and professionals prove it.

Water

It is important to waterproof the base, the crown of the wall and the window openings well, to prevent the central part of the bundle from getting wet. Capillary humidity is avoided with a simple foundation and the harassment of rain with adequate eaves.

Repairs

It is essential to have a good design and take the necessary precautions to prevent the walls from deteriorating, however, it is easy to repair a straw wall. If a part of the construction deteriorates, it can be replaced without affecting the rest of the placed material.

Construction systems – walls

There are many different techniques for building with straw bales, but they can generally be grouped into two methodologies: load-bearing wall construction and independent or additional structure construction. Straw acts as a natural reinforcement, improving cohesion and reducing cracking. It is recommended to cut the straw into pieces of approximately 2-5 cm in length before adding it to the soil mixture (Minke, 2000).

Box 2**Figure 2**

Straw

*Reference: image own authorship_straw***Horse and cow manure**

It usually has a moderate nitrogen content compared to other manures such as sheep or chicken manure. Due to its low contribution of nutrients (0.6% nitrogen, 0.6% phosphorus, 0.4% potassium and trace elements), it is advisable to complement its use with liquid worm humus. It improves the structure of the soil, provides quality organic matter and favors the presence of microorganisms responsible for the fertility of the land. This represents an extra supply of nutrients, which favors the development of the roots. It is used to fertilize crop fields, orchards and gardens. In the artisanal Adobe process, horse manure is used, which generates a certain permeability to the mixture because it contains horse manure.

The Manure, preferably horse and cow, provides fibers and organic compounds that improve cohesion and water resistance; Therefore, use fresh manure and dry it in the sun for 3 or 4 days to reduce the moisture content before incorporating it into the mixture (Hussain & Ishida, 2013).

Box 3**Figure 3**

Horse Manure

Reference: image own authorship_horse Manure_itsh

Nopal

The use of the cactus as a binder in construction has deep historical roots, especially in Mesoamerica, where it was used in the construction of buildings and other structures. The ability of the cactus to act as a binder is due to its high content of mucilage, a gelatinous substance found in its cladodes (the blades of the cactus). This mucilage has adhesive properties that, when mixed with lime, earth or other materials, can improve the cohesion and resistance of the mixture (Rodríguez-González, S. 2000)

The nopal has been used in construction since pre-Hispanic times. A notable example is its use in the production of calicanto, a type of mortar made of lime, sand and cactus mucilage, which was used in the construction of important structures such as churches and colonial buildings in Mexico. (Torres Acosta, A. A. 2017).

In more recent research, the study of cactus pear has been resumed as an additive in mixtures for mortars and concrete, due to the search for more sustainable materials with less environmental impact. According to studies, the incorporation of cactus mucilage in construction mixtures can increase the plasticity and workability of the material, reduce permeability and, in some cases, improve the durability of structures (Torres Acosta, A. A. 2017)

Preparation of the Mixture

Base Mix

The selected soil must be removed from all types of stones and foreign elements and completely moistened, allowing it to rest for two days before molding. Find the ideal place to place the adobe production. To prevent the adobe from sticking to the floor, sand should be spread over the entire floor. About two people are needed to produce considerable adobe in a single work day under very good working conditions, and with wooden molds which are called adoberas.

The straw is added during the trampling of the adobe. Water must be added to the mixture in small quantities, taking care that it does not become too wet. When placing it in the mold and removing it, it must remain in its state without considerable deformations if at all. Not much water was added to this one.

Summary of the preparation of mud for adobe.

- Make the mud and sleep it for 1 to 2 days.
- Mix the straw with the mud, recommended dosage, 1 shovel of straw for 5 shovelfuls of mud and mix with the shovel.

Recommendation

Soil Sifting: Sifting soil to remove stones and other debris.

Initial Mixture: Mix the soil with water until obtaining a plastic and homogeneous consistency.

Incorporation of Straw: Add straw in a proportion of 5-10% of the total volume of the mixture. Make sure the straw is well distributed throughout the mixture.

Manure Incorporation: Add manure in a proportion of 3-5% of the total volume. Mix well to ensure uniform distribution (Catalán, P., & Moreno, J. Y 2019) (Minke, 2000) (Hussain & Ishida, 2013).

Block Molding

- When adding the mud to the adobe mold, it should be sprinkled with sand to prevent the mass of earth from sticking to the mold when it is removed.
- In the line to place the adobes, an insulating layer of sand must also be added to the floor, to avoid wetting processes of the adobe.
- Turn them on their edge in an average of 4 days for optimal drying.
- A week later, stack them in a warehouse.

Appropriate percentages for the production of abobes.

According to several studies carried out for the production of adobes, the earth must consist of sand, silt and clay materials.

- Sand: 55% to 75%
- Limos: 10% to 28%
- Straw: 15% to 18%
- Organic matter content: < 3%

Keep in mind that, in some cases, other types of materials are added, such as goat excrement and residues from barley or oat crops. The adobe blocks are adhered to each other with the same mud to build the walls or walls.

Procedure:

Use of Molds: Use standard size wooden molds to form the adobe blocks. This mold measures 14 centimeters wide by 20 centimeters long and 10 centimeters high. It is made of wood. This mold will help us make blocks to shape the adobe so that we can work in a simpler way and be able to handle the adobe without so much problem.

Box 4



Figure 4

Wooden Mold

*Reference: image own authorship_ wooden
Mold_itsh*

Compaction: Compact the mixture inside the molds to eliminate possible air pockets and ensure uniform density.

Extraction and Initial Drying: Remove the blocks from the molds and place them on a flat, well-ventilated surface for initial drying (Catalán, P., & Moreno, J. Y 2019).

Drying and Curing

The bricks or adobe blocks must be left to dry for 3 weeks. After 10 days, the adobe blocks are placed on their sides or edges for uniform drying so that they acquire high resistance capacities. After all, these processes can be stack.

¿How to make adobe more resistant?

The key to making very strong adobe bricks is in the mixture. The ingredients must be combined wet and then added water. The best resistance is obtained when the beaten mud does not stick to the feet when finished. This process of stepping on the mud must be done for at least 10 minutes.

Straw and, to a lesser extent, coarse sand should be added to control the micro-cracking of the mortar during the drying process, to improve the resistance of the adobe.

This earth used for adobe must have between 15% and 18% clay, and the rest must be sand or coarser aggregates, an excess of clay can produce cracks in the long term and a shortage of clay can produce fragmentation due to a lack of cohesion.

The mixture must be introduced into the mold, then compacted in it, removed from the mold and allowed to dry (drying is known as curing, as in concrete), this outdoor drying process can last around 10 to 10 minutes. 21 days (3 weeks), to then raise the walls.

Procedure:

Sun Drying: Dry the blocks in the sun for at least two weeks, turning them regularly to ensure even drying.

Final Curing: Continue drying in a covered area for at least another two weeks to allow complete curing and minimize cracking (Minke, 2000).

Tests and Evaluation

Compression Strength

Carry out random compressive strength tests on the dry blocks using a hydraulic press which have a value between 1.2 and 2.5 MPa. Record the maximum strength before failure of the material. (Catalán, P., & Moreno, J. Y 2019).

Reference: "Compression testing is crucial to ensure the structural integrity of adobe blocks." (Catalán, P., & Moreno, J. Y 2019).

Waterproofing

Water Absorption Test: Immerse the blocks in water for a period of 24 hours and measure the weight gain to determine water absorption. **Simulated Rain Test:** Expose the blocks to a continuous stream of water for a period of time and observe the resistance to surface erosion (Minke, 2000).

Reference: "Water absorption tests are essential to assess the effectiveness of natural additives in enhancing adobe's water resistance." (Minke, 2000).

Durability

Wetting and Drying Cycles: Subject the blocks to several wetting and drying cycles to evaluate their durability under conditions of fluctuating humidity (21 repetitions).

Crack Observation: Visually inspect the blocks after each cycle to detect the appearance of cracks or structural damage (Hussain & Ishida, 2013).

Reference: "Durability testing through wetting and drying cycles helps in understanding the long-term performance of earthen materials." (Hussain & Ishida, 2013).

Results

Section.1 Field investigation

The field research for the creation of the adobe involved studying the composition of the local soil, the availability of materials such as clay and straw, to obtain the material, in which we investigated which materials were suitable and which ones we had in the locality, for example, the red earth in which we found in a nearby area which made it easy to obtain.

Section.2 Material selection

Sustainable natural materials were selected, such as clay, manure, sand, straw, water and cactus as a natural binder. To make the adobe, it was organized to distribute the material and each person get what was provided to us.

Section.3 Change of shape to reach said product

It was observed that ecological adobe can be made in various ways of mixing, such as being processed by machining or traditionally as we do in the samples obtained, in which after mixing the materials we compact it in a mold to give it shape. Adobe blocks improved with straw, manure and cactus showed a 30% increase in compressive strength compared to traditional blocks. Blocks with 10% straw and 10% manure by weight proved to be the strongest, reaching an average strength of 3.5 MPa (mega pascals).

Box 5

Table 1

Resistance in MPa of different mixtures

Percentages of mixed materials for adobe tests, made with 5 blocks of each type of mixture					Resistance in Mpa.
Clay	Straw	Manure	Nopal	Lime	
60	20	10	5	5	2.90MPa
70	10	10	5	5	3.2MPa
75	10	10	5	0	3.5MPa
70	20	10	0	0	2.45MPa
65	15	10	0	10	2.84MPa
70	10	15	5	0	3.3MPa

Section.4 Production

In this stage, the continuous manufacturing of the adobe is carried out, which will depend on the amount of resources that are at hand, such as the amount of raw materials, molds, labor, space for the adobes to rest. , product demand, among others.

Box 6

Table 2

Title [average production Time]

Mix Quantity	Number of adobes Brick 30*20*10	Mixing Time in minutes	Molding Time in minutes	Average Production Time in Minutes
1m3	156	20	2	2.12820513

Section.5 Drying and Curing

The bricks or adobe blocks must be left to dry for 20 days. After 10 days, the adobe blocks are placed on their sides or on their edges for uniform drying so that they acquire high resistance capacities, after all these processes. can be stacked, it can be seen that the longest waiting time is the drying time, which means that each batch of 156 adobes takes 20 days to reach the customer.

Box 7

Figure 5
Adobe brick

*Reference: image own authorship_ Adobe
brick_itsh*

Section.6 Inspections

At this stage, the drying process of the adobe was reviewed to avoid cracks, so if it was very dry, little water was added to obtain a piece of good quality and with the necessary specifications for sale. The blocks were subjected to water absorption tests by soaking them in water for 24 hours and measuring the weight gain. 50 adobes were also exposed to simulated rain for 48 hours, and their impermeability responded very well.

The improved blocks absorbed 40% less water than traditional blocks. After exposure to simulated rainfall, the straw and dung adobe blocks maintained their structural integrity, while the traditional blocks showed signs of surface erosion.

For the adobe that was obtained, with an average weight of 6.5 kilograms, it was observed that it only absorbs 1.08 liters of water, which is 18% absorption.

Box 8

Table 3

Water Absorption

Mix	Resistance in Mpa.	Absorption of liters of water
1	2.90MPa	1
2	3.2MPa	1.17
3	3.5MPa	1.17
4	2.45MPa	1.8
5	2.84MPa	0.97
6	3.3MPa	1.24

Section.6 Finished product

The adobe was completed according to the established time and the process was carried out properly so it meets what is necessary for manufacturing and sale. A life cycle analysis was carried out to evaluate the environmental impact from the extraction of materials to the construction of an adobe wall. As seen in the table, tests were applied to 156 adobes, which gave an average resistance of 3.2 KPa.

Box 9**Table 4**

Average Resistance of the Different Mixtures

Variable	N	Average	Standard Error of the Average	Standard Deviation	Minimum	Median	Maximum
Resistance in MPa	156	3.0644	0.0260	0.3241	2.4500	3.2000	3.50000

Conclusions

- The production of improved adobe resulted in 20% less CO₂ emissions compared to the production of concrete blocks.
- The use of manure and straw, waste materials, minimizes the need for additional resources and reduces agricultural waste.

The production of waterproof adobe is a process that requires a careful selection of materials and a correct combination of them to achieve a waterproof and durable final product. In the case of working as a team, collaboration and coordination between members are essential to guarantee success in the manufacture of waterproof adobes.

Using materials such as sand, red dirt, dirt, straw and water, each team member will play a crucial role in the making process. Sand and red soil will provide the necessary structural strength, while earth and straw will help improve the plasticity and adhesion of the mixture. Water will be the key element to achieve the proper consistency in the mixture.

During the production of waterproof adobes, it is important that the team follows a detailed work plan that includes the preparation of the materials, their proper mixing, and the molding and drying of the adobes. Each team member will have to perform specific tasks, such as accurately measuring the materials, kneading the mixture evenly, and carefully shaping the adobes.

Effective communication between team members will be essential to ensure that instructions are followed correctly and that any issues that may arise during the production process are resolved in a timely manner. Additionally, collaboration and mutual support will foster a positive and productive work environment.

At the end of the production of the waterproof adobes, the team will be able to enjoy the fruit of their joint work, obtaining a quality product that can be used in various construction applications.

Shared experience during the manufacturing process will strengthen the bonds between team members and build trust in the ability to work together to achieve a common goal.

In conclusion, the production of waterproof adobe made as a team with materials such as sand, red earth, dirt, straw and water is a process that requires effective collaboration, individual skills and teamwork. The final result will be a resistant and durable product that will reflect the effort and dedication of the team in achieving a common goal.




Annexes**Box 10****Table 5**

Advantages And Disadvantages of Adobe Brick

Advantages	Disadvantages
Good Thermal and Acoustic Insulation.	Tends to Be Fragile.
Easy Manufacturing and Dries simply in the sun.	When it is Used for construction it is not possible to add more Weight to this.
Its price is Affordable.	Does not Resist Torsion.
It is Ecological.	It is not shock Resistant.
Absorbs Heat and Keeps Cool.	It can Be Destroyed in very drastic weather such as Storms.

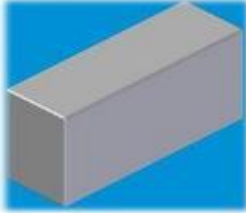

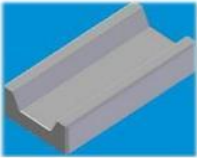
Box 11**Table 6**

Types of Adobes

Types of Adobes		
SIMPLE ADOBE (Not standardized)	Solid block of unsewn earth may have straw and/or small stones in engraving mode	
ADOBE SEMI STABILIZED	Brick resistant to moisture due to its usual composition of 3% to 5% stabilizing agent or waterproofing agent.	
STABILIZED ADOBE	Solid block of unsewn earth that also contains more elements such as: asphalt, lime, cement.	

Box 12**Table 7**

Adobe Shape Table

Forms and uses of adobe brick		
	ADOBE CLASSIC	Approximate weight: 6kg Construction: traditional on first floors, mortar of the same composition is glued to the pavement.
	HALF ADOBE CLASSIC	Approximate weight: 3kg Construction: traditional on first floors. Used for the edges on the walls where doors and windows go, avoiding cutting adobe by hand.
	SOLID GUTTER	Approximate weight: 3.5kg Construction: traditional. It is used to internally reinforce walls with iron and concrete making walls, beams, doors, windows.

Declarations

Conflict of interest

The Academic Body of the Industrial Engineering career ITESHUAU-CA-4 Optimization of Production Systems and collaborators assigned to this project, express that they do not have any conflict of interest that could harm their personal and work relationship, such as: interests in profits of the sale of the adobe, sale of the project and other benefits that may accrue.

Author contribution

Bones-Martínez, Rosalía: Contributed to the idea of the project, analysis of the benefits of adobe and materials to be used.

Soto-Leyva, Yasmin: Contributed with the contribution of the methodology.

Ruiz-Díaz, Montserrat: Contributed with results and tests of the adobes.

Santos-Osorio, Arturo: Compiled the project contributions.

Availability of data and materials

Funding

This work has been funded by the academic body of the Industrial Engineering degree ITESHUAU-CA-4 Optimization of production systems.

Acknowledgements

We thank the Higher Technological Institute of Huauchinango and the academy of the Industrial Engineering educational program, for the support and facilitations provided for the formulation and writing of this project.

Abbreviations

cm	Centimeter
°C	Degrees celsius
Hr	Hours
ITSH	Higher Technological Institute of Huauchinango
Kg	Kilo gram
m	Meter
m ³	Cubic Meter
mm	millimeters
min	minutes
Ph	Acidity

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Leadership in the professional training of Computer Systems Engineers





El Liderazgo en la formación profesional de Ingenieros en Sistemas Computacionales

Hernández-Cruz, Luz María*^a, Mex-Álvarez, Diana Concepción^b, Llanes-Chiquini, Charlotte Monserrat de Jesús^c and Fuentes-Caraveo, Eugenia de los Ángeles^d

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CONAHCYT classification:

DOI: <https://doi.org/10.35429/H.2024.8.106.113>

Area: Engineering

Field: Engineering

Discipline: Systems engineer

Subdiscipline: Computer Sciences

Key Handbooks

The present research provides a field study in Computer Systems Engineering students with respect to Leadership competence and the type of Leadership predominant in them. The importance lies in the perspective that researchers have of the development of this competence and its importance in professional training. The primary aspects of the study involve discerning Leadership as a key competency for success in Computer Systems Engineering.

Citation: Hernández-Cruz, Luz María, Mex-Álvarez, Diana Concepción, Llanes-Chiquini, Charlotte Monserrat de Jesús and Fuentes-Caraveo, Eugenia de los Ángeles. 2024. Leadership in the professional training of Computer Systems Engineers. 106-113. ECORFAN.

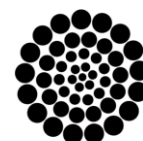
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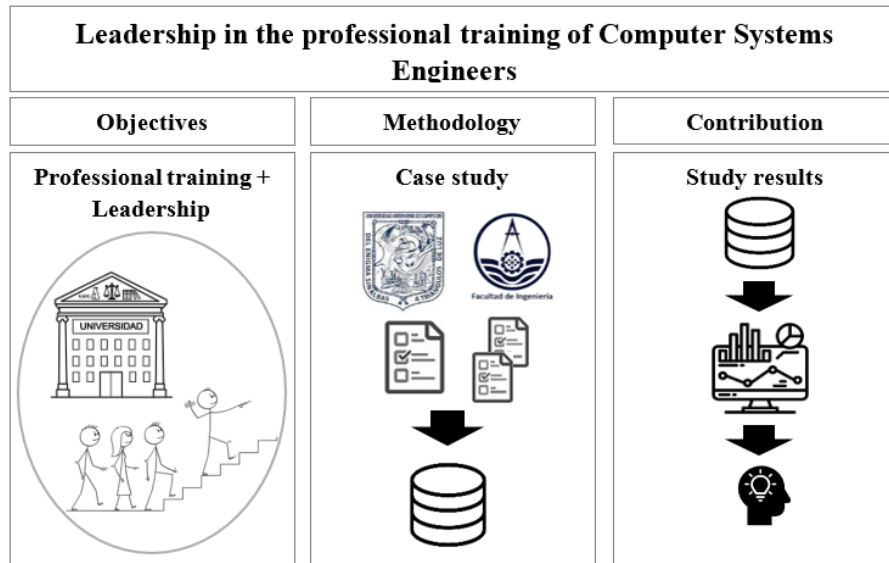
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Abstract

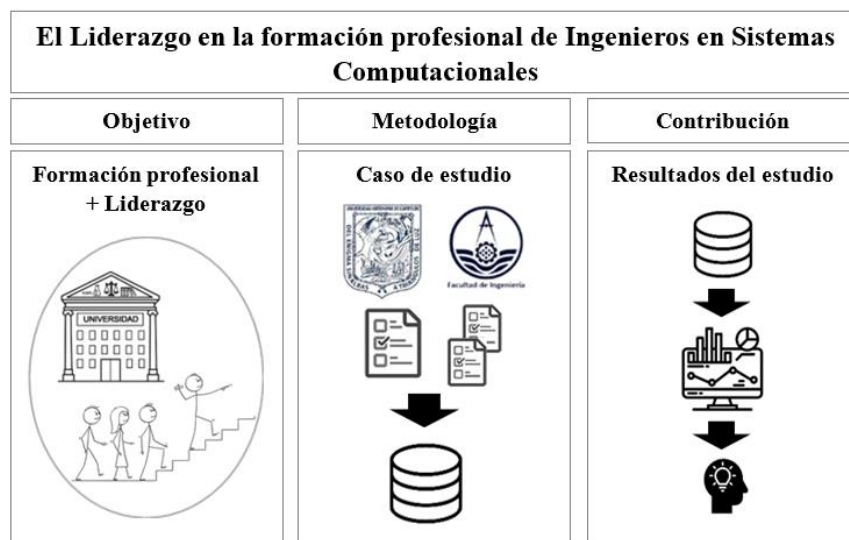
This study arises from recognizing Leadership as a fundamental soft skill in Higher Education. The above allows us to propose an exploratory and purposeful field investigation with the objective of exhibiting significant data that shows an intrinsic but compelling panorama in the tireless search for quality professional education, allowing professionals to function successfully in their disciplinary area. The method used is the case study applying the survey technique as a tool for data collection. The development of the field work is carried out at the Faculty of Engineering of the Autonomous University of Campeche (UACAM) with students of the Computer Systems Engineering (CSE). The results presented in this study serve to identify new lines of research and paths to achieve quality professional training in computer sciences.



Leadership, Professionals, Computer Systems Engineers

Resumen

El presente estudio surge de reconocer al Liderazgo como una competencia blanda fundamental en la Educación de nivel Superior. Lo anterior, permite plantear una investigación de campo exploratoria y propositiva con el objetivo de exhibir datos significantes que revelen un panorama intrínseco pero apremiante en la incansable búsqueda de la educación profesional de calidad, permitiendo a los profesionistas desenvolverse exitosamente en su área disciplinar. El método empleado es el caso de estudio aplicando la técnica de la encuesta como herramienta para la recolección de datos. El desarrollo del trabajo de campo se realiza en la Facultad de Ingeniería de la Universidad Autónoma de Campeche (UACAM) con estudiantes de la Licenciatura Ingeniería en Sistemas Computacionales (ISC). Sirva los resultados presentados en este estudio para identificar nuevas líneas de investigación y caminos para el logro de una formación profesional de calidad en el área de las ciencias de la computación.



Liderazgo, Profesionales, Ingeniería en Sistemas Computacionales

Introduction

Leadership is a fundamental concept in various disciplines, and in recent years it has gained special relevance in technical fields, such as computer systems engineering. Leadership can be defined as the ability to influence and guide a group of people towards the achievement of shared goals and objectives (Northouse, 2018). This skill goes beyond the simple management of tasks and resources; it also involves the creation of a collaborative, motivating work environment capable of adapting to rapid technological and organizational changes. Nowadays, leadership is not only limited to hierarchical positions within an organization, but is also reflected in the ability of engineers to assume leadership roles in development projects, team management, and complex problem solving (DuBri, 2023).

In the context of computer systems engineering, leadership takes on particular characteristics due to the nature of projects that involve high technology, collaborative work and constant innovation (Castillo Elizondo, Álvarez Aguilar & Treviño Cubero, 2018). A leader in this field must be able to understand and manage both the technical and human aspects of the work. This includes the implementation of agile methodologies, the ability to adapt to new programming languages and emerging technologies, as well as the ability to foster a culture of continuous improvement and collective learning within their team (Cazares, 2023).

The importance of leadership in computer systems engineering lies in the fact that, in addition to technical project management, engineers need interpersonal skills to lead diverse teams, collaborate across multiple areas, and maintain a strategic focus on technological innovation (Yukl, 2019). As the complexity of technological systems and applications grows, engineers must not only master the technical aspects, but also be able to motivate, communicate effectively, and lead through uncertainty (Maxwell, 2019). According to Garcia and Fernandez (2021), in the digital age, organizations that do not have strong leaders on their engineering teams risk falling behind in a highly competitive market.

Finally, the rapid evolution of technology and changes in working methodologies have made leadership in systems engineering a determining factor in the success of projects. Leaders capable of managing change, fostering innovation and adapting their leadership style to different situations are essential for the sustainable development of the industry (Collins, 2020).

This study conducts field research to evaluate leadership styles in students from the Autonomous University of Campeche, and how they will face (in the near future) their insertion into the labor market as leaders in the disciplinary area of computer science as a result of their professional training.

Methodology

This exploratory and purposeful field research is carried out through the case study method, applying the survey technique as a tool for data collection.

Data collection instrument

The Goleman Test is based on evaluating EI, to obtain the leadership style. This test assesses the five fundamental leadership skills described below:

- *Self-awareness*: A leader's ability to recognize his or her own emotions, strengths, and limitations.
- *Self-regulation*: The ability to appropriately control and channel emotions, especially under pressure.
- *Motivation*: The internal drive that guides a leader toward clear and challenging goals.
- *Empathy*: The ability to understand and connect emotionally with others, key to creating solid work relationships.
- *Social skills*: These include effective communication, the ability to manage conflict, and the ability to lead and inspire others.

Goleman's approach tells us that the most effective leaders are those who have a high degree of emotional intelligence (EI) (Goleman, 2021).

The model proposed by Daniel Goleman classifies managers according to the personal capabilities that produce outstanding performance within organizations, such as technical skills, cognitive skills, and competencies that demonstrate emotional intelligence.

Goleman in his book *Leadership. The power of emotional intelligence* specifies leadership styles into 6 types: dominant, democratic, conciliator, coach, visionary and exemplary then study their profiles, their effects, as well as the ideal areas of action.

Box

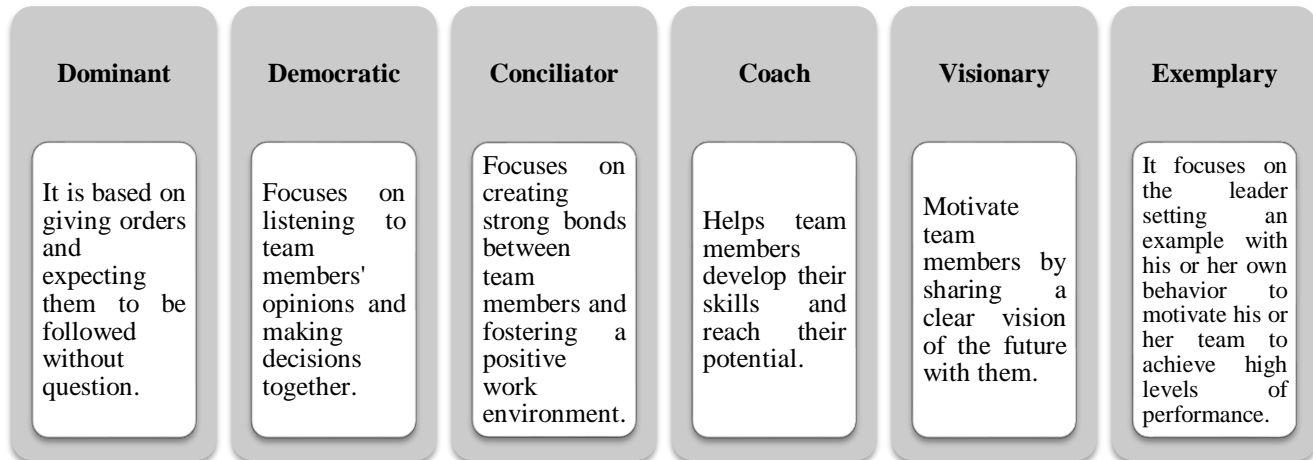


Figure 1

Daniel Goleman's Leadership Styles

Source (Goleman, D., Boyatzis, R. & McKee, A., 2016)

The Test by Daniel Goleman is an instrument designed with the objective of comprehensively evaluating leadership competence. It is made up of 20 elements and descriptors are classified into six domains (leadership styles). All items were rated using a Likert scale with five levels: strongly disagree (1), disagree (2), indifferent (3), agree (4) and strongly agree (5) (Goleman, 2022).

Case Study

The present study arises from the inter-institutional project between the Autonomous University of Campeche and the Higher Technological Institute of Hopelchén called “Diagnosis of Leadership as a skill of students from indigenous communities (Los Chenes area)” with registration code 077/UAC/2023.

As a critical phase of the project, an evaluation of Leadership is proposed by applying the Goleman Test to students of the Computer Systems Engineer educational program at the Autonomous University of Campeche, the objective is to identify the predominant leadership style at the end of the professional training completed.

The field study population covers two groups from the last semester of the Computer Systems Engineer Educational Program, with around a total of 60 students who are studying the last semester at the Autonomous University of Campeche (UACAM, 2024). From this, the normal distribution is used to calculate the minimum sample size for the study.

For the sample size, the following formula is utilized:

$$n = \frac{(k^2 qpN)}{((e^2 (N-1) + k^2 pq))} \quad [1]$$

Table 1 shows the values, and the calculation carried out to define the sample size

Box 2

Table 1

Sample size calculation

<i>Parameter</i>	<i>Description</i>	<i>Value</i>
<i>N</i>	Total number of people who could be surveyed.	60
<i>k</i>	Probability that the answers are true. A confidence level of 95% was proposed here.	1.96
<i>p</i>	Proportion of individuals in the population that possess a specific characteristic.	50%
<i>q</i>	Proportion of individuals that do not possess a specific characteristic, q=1-p. With equal probability of success and failure.	50%
<i>e</i>	Difference between the responses of the sample and the total population.	5%

$$n = \frac{((1.96)^2 (0.50)(0.5)(60))}{((e^2 (60-1) + (1.96)^2(0.50)(0.50)))} = 52 \quad [2]$$

Therefore, the recommended sample for the study is 52 respondents calculated as the minimum capacity of two groups of the Computer Systems Engineer Educational Program taking the last semester.

Study design

Data was collected from January to May 2024 at UACAM. The students completed the instrument Test “Evaluating Leadership”. In total, 56 students completed with a response rate of 100%.

Data collection and processing

The technological tool used to implement the data collection instrument was Google Forms. This allowed the digital survey to be distributed via email; After its application, the data is stored directly in a spreadsheet for analysis.

Results

The students of the last semester of Computer Systems Engineering met in the Computer Room at the University facilities to answer the digital survey on Google Forms. It is worth mentioning that the survey allows for anonymous responses and also includes an informed consent form.

Figure 2 shows the data collected in the field research, highlighting the maximum values obtained in each leadership style per respondent

Box 3

<i>Visionary</i>	<i>Coach</i>	<i>Conciliator</i>	<i>Democratic</i>	<i>Exemplary</i>	<i>Dominant</i>	<i>Visionary</i>	<i>Coach</i>	<i>Conciliator</i>	<i>Democratic</i>	<i>Exemplary</i>	<i>Dominant</i>
8	10	9	8	10	9	14	14	14	13	13	13
14	13	11	11	12	10	13	12	13	13	11	9
10	12	11	12	11	12	14	15	14	13	10	9
11	10	11	11	9	8	12	12	12	9	11	12
9	12	14	10	11	12	12	12	12	12	12	11
14	14	11	12	12	7	13	8	14	13	9	8
12	9	12	12	14	7	12	9	13	12	8	7
12	12	11	12	11	12	14	12	13	13	10	10
11	9	12	9	13	12	12	11	13	11	11	12
12	9	12	13	12	11	12	11	13	11	11	12
13	13	11	12	9	12	15	15	13	15	14	15
10	9	13	11	11	12	12	11	11	14	9	14
10	10	12	10	11	11	13	10	11	12	7	9
10	13	13	10	9	10	11	11	13	12	10	11
12	12	13	12	11	10	13	10	13	12	10	8
10	12	11	10	7	11	13	10	11	12	11	13
11	12	10	11	11	9	12	12	12	11	11	9
10	10	12	11	12	10	5	7	3	5	6	4
13	10	10	9	8	14	15	15	15	15	14	15
12	13	11	14	13	10	13	10	13	11	7	8
13	13	9	13	13	12	13	10	13	11	7	8
12	11	9	13	11	13	12	12	11	12	11	9
13	10	10	11	13	12	9	12	9	8	11	12
13	14	13	12	10	11	5	6	5	3	7	7
11	13	12	13	13	13	12	9	12	13	11	7
11	11	12	14	10	15	13	10	10	9	12	10
11	12	11	14	8	12	11	9	11	11	11	11
13	13	13	13	10	12	12	12	12	12	12	12

Figure 2

Dan data collected in the field research

After collecting the data, it continues to be analyzed using the parameters defined in the Goleman test for interpretation. In this sense, each leadership style groups specific questions on the test.

Table 2 shows the items to evaluate each of Goleman's learning styles

Box 4	
Table 2	
Results UACAM. Daniel Goleman's Leadership Styles	
<i>Leadership Styles</i>	<i>Test Items</i>
<i>Visionary</i>	1 – 2 – 15
<i>Coach</i>	3 – 12 – 14
<i>Conciliator</i>	6 – 7 – 17
<i>Democratic</i>	4 – 5 – 13
<i>Exemplary</i>	8 – 9 – 18
<i>Dominant</i>	10 – 11 – 20

Figure 3 shows the predominant total of students for each of Goleman's leadership styles

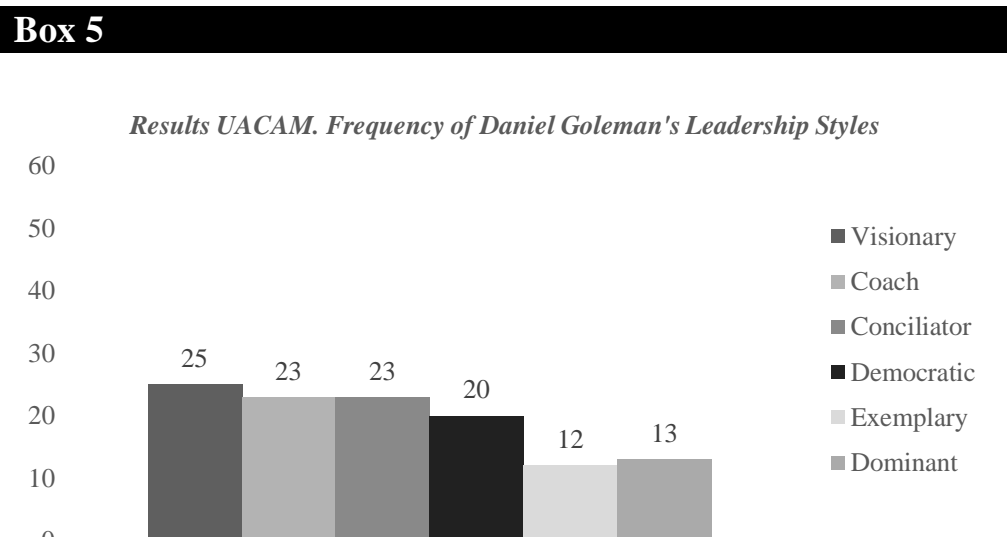


Figure 3
Results. Daniel Goleman's Leadership Styles

The findings of the research conclude that the predominant leadership style in CSE student ts is Visionary, obtained from 25 respondents out of a total of 56, equivalent to 44,64% of the sample. The Coach and Conciliator predominates in 23 respondents equivalent to 41,07%.

With only 12 respondents being 21.42%, the Exemplary corresponds to the least significant leadership style in the sample. The Dominant leadership style is the second least prevalent, having only 23.21% with 13 respondents.

Conclusions

The results obtained were very encouraging, the leadership style with the highest percentage in the CSE students of the UACAM was the Visionary.

Leads with a clear vision of results, characterized by the ability to motivate people. Given his self-confidence, he can transmit his vision of ideas effectively, thus aligning the team around the same objective. It is considered the most effective type of leadership of all, so it should be used as long as possible. However, it is also important to mention that the percentage of students with this leadership style obtained less than 50% of the sample.

If the results are analyzed globally, an orientation towards a particular leadership style cannot be identified, which suggests the need to take strategies that allow the development of Leadership as a soft skill during their professional training.

Engineering invites you to lead, to act, to experiment, to test various ideas, programs, methods, initiatives, proposals, for more improbable or contrary as they may seem. Therefore, it is important to recognize leadership as a key and indispensable factor in the professional training of CSE students.

The limitations of this case study are numerous, due to the wide scope of the concept of Leadership, through Daniel Goleman only a perspective of how to evaluate the skills and characteristics of each leadership style is exhibited. Likewise, through this study it was possible to discern the opportunity to carry out new research studies in relation to Computer Systems Engineering and the development of Leadership skills

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Author contribution

The contribution of each researcher in developed in this research was:

Hernández-Cruz, Luz María: Contributed to the project idea, methodology and discussion.

Mex-Álvarez, Diana Concepción: Contributed to the abstract and introduction.

Llanes-Chiquini, Charlotte Monserrat de Jesús: Contributed to the results and conclusion.

Fuentes-Caraveo, Eugenia de los Ángeles: Contributed with the analysis of the information and presentations of graphics and tables.

Abbreviations

CSE	Computer Systems Engineering
EI	Emotional intelligence
UACAM	Autonomous University of Campeche

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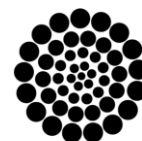
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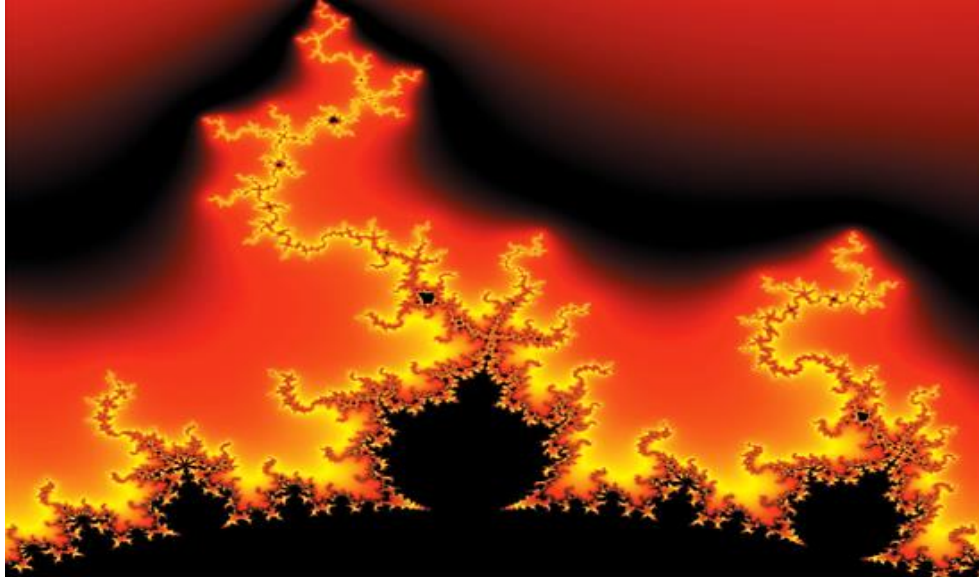


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