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The 6th Workshop on Environmental Engineering was held between 20 and 22 September 2023 in Rio de Janeiro as a hybrid in-person and online event, after a hiatus of 3 years without a workshop due to COVID19 pandemics. The theme of the 6th edition was Sustainable Innovations. The event involved 13 lectures of prominent Brazilian invited speakers and 2 short-courses, in addition to a short oral session for presentation of students (MSc and DSc). The major motivation for the event was to provide complementary formation of Masters' and Doctors' degree students, through lectures on contemporary topics and presentation of their own research. To qualify for the short oral session, the students were required to submit an extended abstract to the event, which are collected here in this issue of the Proceedings of Workshop on Environmental Engineering.

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SUMMARY

Roles of Robotics in Architectural and Engineering Construction Industries: A Critical Review and Future Trends

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Abstract:
Over the past two decades, the field of Robotics in Construction (RiC) has evolved into an interdisciplinary research domain that combines a multitude of pressing technologies. This work introduces an innovative review framework that assesses the interconnection between Robotic in Construction (RiC) and automation, while also examining advancements in technologies like the Internet of Things (IoT), Artificial Intelligence (AI), and Deep Learning (DL). In this research, a novel classification framework was created and a comprehensive literature review was performed to shed light on recent developments in the field of Robotic in Construction (RiC). The objectives are to delineate the diverse dimensions of RiC, uncover the underlying themes and sub-themes within these dimensions, identify key research gaps in the current studies, and provide recommendations for future research endeavors. This paper concluded that predominant focus of extant research endeavours within this field has focused on technical facets, with comparatively less attention directed towards environmental considerations. Thus, future research on the topic should focus on subjects such as sustainability, energy efficiency, and life cycle assessment of RiC projects.

Keywords:
Robotic in Construction (RiC), Building Information Modelling (BIM), Automation, Technology,

1 Introduction

In the ever-evolving realm of construction, technological advancements have ushered in a new era marked by efficiency and precision. Robotic construction, a cutting-edge field at the intersection of robotics and architecture, promises to reshape the way we build the world. By harnessing the power of automation and artificial intelligence, robotic construction presents a paradigm shift in the construction industry, where robots and machines are becoming indispensable tools on construction sites (Baduge et al., 2022; Klarin & Xiao, 2023; Pan & Zhang, 2021; Sánchez-Garrido et al., 2023).

RiC is a field of technology and engineering that involves the use of robotic systems and automation in various aspects of the construction industry (Lundeen et al., 2017). When combined with RiC techniques, BIM becomes a potent catalyst for innovation, enabling architects, engineers, and builders to optimize the construction process in unprecedented ways (Anane et al., 2023; Ding et al., 2020; Gradeci & Labonnote, 2020; He et al., 2021).

This paper focuses on RiC and its relationship to BIM, automated construction applications and dimensions, information and communications technology, and sustainability and energy efficiency. This paper develops a classification framework to cover the different aspects associated with the use of robotic technology in the construction industry. Thus, this research provides a comprehensive overview of where the research on RiC has focused, the aim is to define the main gaps in the current studies and to address recommendation for future research of the field.

2 Research Methodology

A comprehensive literature review was undertaken to fulfil the objectives of this study, involving a thorough examination of various facets and concerns pertaining to robotic construction. Two distinct analytical approaches, bibliometric and bibliographic, were employed. The bibliometric analysis aimed to delineate the multifaceted subjects encompassing robotic construction through citation analysis and keyword clustering. Subsequently, the bibliographic analysis was executed to qualitatively apprehend the ongoing initiatives within specific thematic areas by scrutinizing the content of the research papers. The combination of these two analytical methodologies was imperative to foster a comprehensive comprehension of the extant literature.

The research methodology comprises the following pivotal phases: Step one involves Collection of relevant materials; step two entails a comprehensive descriptive analysis of the examined literature; step three involves the development and presentation of a classification framework designed to categorize the studies on robotic construction that have been examined; and finally, step four is dedicated to the evaluation of the collected materials in step 1, utilizing the classification framework devised in step three.

3 Findings and Discussion

This section explains how the objectives of this paper were achieved after the literature have been reviewed. There are three main focal points when it comes to RiC research dimensions: technology, automation, and sustainability. The technology dimension encompasses robotic construction studies that examine the use of technologies, while subject such as prefabricated construction, robotic arms, and concrete drilling were discussed in the automation dimension. Finally, for the sustainability dimension, life cycle characteristics and sustainable building design are frequently examined in RiC.

This research also classified the topics discussed in the literature into themes and sub-themes. The following are some themes and related to RiC: Automation and RiC, BIM, sustainable construction, safety and risk management, smart and resilient infrastructure, digital twins and simulation, robotic material handling, data analytics and decision support, human-computer interaction, and regulatory and ethical considerations.

It could be noticed that predominant focus of extant research endeavours within this field has predominantly centred on technical facets, with comparatively less attention directed towards environmental considerations. However, this paper addresses some gaps in the RiC aspects that haven’t been adequately discussed in the current studies such as: Sustainability and energy efficiency; Long-term performance assessment; Integration of robotics with existing construction processes. Identifying and addressing these research gaps is crucial to advancing the field of Robotics in Construction and realizing its potential to transform the construction industry.

4 Conclusion and Future Direction

Employing content analysis, this paper examined more than 140 journal articles to illuminate the principal dimensions and subjects within the realm of RiC. The main objectives of this paper were: (i) To identify the different dimensions that RiC literature focuses on; (ii) To identify the themes and sub-themes associated with these dimensions; (iii) To define the main gaps in the current studies and address recommendation for future research of the field.

Based on the recommendations derived from the developed framework, the study herein predicts that future research should focus on subjects such as sustainability and energy efficiency, life cycle assessment of RiC projects, customization and adaptability, data management and analysis, global adoption and accessibility, and customization and adaptability. Another expanding future direction should be the collaboration between experts from various fields (robotics, construction, materials science, etc.) to address complex challenges in RiC effectively. Finally, some ethical considerations related to job displacement, privacy, and societal impacts of RiC need thorough examination.

5 Acknowledgment

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Recovery of nutrients from wastewater for agricultural use

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Abstract:
Traditional sewage treatment methods often fail to effectively remove nutrients such as nitrogen and phosphorus, which can contribute to algae overgrowth in water bodies. Recent studies have shown that bioclastic granulates from Lithothamnium calcareum can effectively remove phosphorus from treated sewage, landfill leachate, and eutrophic lake water. In addition, many studies have demonstrated that biochar can recover nitrogen and phosphorus from liquid effluents. Combining these two materials could be an attractive option for recovering nutrients for agricultural use. This study aims to evaluate the feasibility of using a combination of Lithothamnium calcareum and biochar beds in tertiary treatment to recover nutrients for a more efficient and sustainable process for bioinput production.

Keywords:
Biochar, bioclastic granulates, biofertilizers, nutrient recovery, sewage treatment.

1 Introduction

Sewage discharge into water bodies is a significant hazard to public health. The presence of too many nutrients in water can reduce oxygen levels, which could be harmful to aquatic life. Phosphorus, for example, is one of the nutrients that can lead to excessive algae growth and eutrophication. Nitrogen, in different forms such as organic nitrogen, free ammonia, nitrate, and nitrite, is found in raw sewage and aquatic environments. Free ammonia can be toxic to fish, and converting ammonia to nitrite and nitrate can further decrease dissolved oxygen levels. Moreover, nitrate has been linked to certain human illnesses (Von Sperling, 2009).

One of the most common marine calcareous algae in Brazil and worldwide are *Lithothamnium calcareum*, which belongs to the *Corallinaceae* family. This algae has been used for a long time in agriculture and rural environments to improve soil quality for various crops and as a dietary supplement for animals. Due to its high porosity and large surface area, this material has been studied for its use as an adsorbent in water and wastewater treatment (Caletti, 2017; Nogueira, 2019; Portella, 2022; Veneu et al., 2016, 2017, 2019, 2023), and the results obtained indicate high potential for phosphorus recovery present in lakes and eutrophic reservoirs using this bioclastic granulates.

The potencial of biochar to adsorb soluble N and P has been extensively researched owing to its economically and ecologically viable nature (Xiang et al., 2020; Zhang et al., 2020). Enhancement of this substance boosts soil productivity by efficiently attracting organic and inorganic nitrogen from runoff water (Saarela et al., 2020), mitigating climate change, and promoting sustainability through ecological impact assessments and extended field trials. (Murtaza et al., 2021).

This thesis project aims to enhance comprehension of nitrogen and phosphorus removal processes from liquid effluents using two adsorbent matrices. In addition, this study strives to assess the feasibility of using the end residues from this post-treatment in the production of biofertilizers.

2 Research Methodology

Samples of the effluent treated at the Piraí WWTP will be collected to determine nitrogen and phosphorus concentrations. The results of this analysis will be a north for the choice of concentration ranges to be used in column tests and kinetic studies. Lakewater samples will also be characterized by the amount of organic matter and the presence of nutrients. The methodologies used to determine the parameters will be based on the procedures presented in the Standard Methods for the Examination of Water and Wastewater (APHA, 2018).

Aqueous solutions with different initial concentrations of nitrogen and phosphorus will be prepared for conducting the tests using bioclastic granulate and biochar, separately, for 1) batch tests to obtain the kinetic and thermodynamic parameters of the sorption process and 2) continuous tests in fixed bed columns with both matrices to evaluate the feasibility of applying this post-treatment methodology. The columns will also be operated with sample feeding of lakewater and effluent from the WWTP. Samples of the adsorbent material used in these tests will be collected and will undergo surface characterization using X-ray fluorescence (XRF) and scanning electron microscopy (SEM) techniques to confirm the sorption of nutrients.

Various mixtures of bioclastic granulate and saturated biochar will be applied to a selected culture to assess the nutrient-supplying effectiveness. This experiment will be conducted in a greenhouse with randomized treatments and vessel arrangements. The evaluated parameters include the total number of individuals (TN), plant height (PH), root length (RL), shoot fresh weight (SFW), root fresh weight (RFW), total dry weight (TDW), and chlorophyl meter value. The progress of plants that receive conventional synthetic supplementation will be compared with those that receive varying proportions of the granular/biochar mixture.

3 Conclusion

Maintaining the quality standards of water treatments is vital for preserving the integrity of aquatic environments and protecting the organisms that rely on them. A well-executed water treatment plan should also consider potential social, economic, and public health issues. It is crucial to constantly enhance and optimize treatment methods to guarantee efficiency and sustainability. Furthermore, the research goals align with at least four of the seventeen Sustainable Development Goals (SDGs) of the United Nations, which aim to eradicate poverty and hunger, safeguard the environment, and combat climate change (UN, 2015).

4 Acknowledgment

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Landslide Susceptibility Modelling by Machine Learning: Angra dos Reis City (RJ), Brazil

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Abstract:
This work carried out a landslide susceptibility modelling in Angra dos Reis city, once is an area where recurrent mass movements occurred. After a review of the 98 references for last decade, we identified many studies related to susceptibility mapping, statistical methodologies and machine learning. The first work step we proceeded a combination of the documentary and geospatial data, in order to prepare the landslide inventory from 2010 to 2021. The present modelling involves a combination of the geospatial data preparation (geology, geomorphology and land use parameters), grid sampling and supervised algorithms such as Principal Component Analysis and Logistic Regression. Classification analysis with Support Vector Machine (SVM) and Random Forest (RF) algorithms further evaluates model performance. Results indicate that SVM outperforms RF have more significant performance in several metrics and, it can be considered the best choice for this classification task, contributing to the assessment of landslide susceptibility analysis.

Keywords: Landslide Susceptibility, Machine Learning, Random Forest, Support Vector Machines.

1 Introduction

Angra dos Reis City is located on the seashore of Rio de Janeiro State (Figure 1) and present recurrent landslides, usually resulting in deads and injuries. Susceptibility map is necessary to allow temporal analysis in landslide causes, however new methodologies are emergent in order to be able to improve this map. Currently, there are several approaches to prepare landslide susceptibility maps, including heuristic, deterministic and statistical methods (Zêzere et al., 2017). In statistical methods, the weights related to the landslides are found by landslide inventories, based on previous occurrences. The premise of this approach is that past landslide events can inform future occurrences (Guzzetti et al., 1999; Fell et al., 2008).

Considering advances in Remote Sensing and Machine Learning (ML), some studies have employed new approaches to susceptibility mapping (Hader et al., 2022) such as analysis of landslide occurrences and non-occurrences and morphometric terrain attributes, employing the ML algorithms Random Forest (RF) and Support Vector Machines (SVM) to identify susceptible slopes (Marjanovic et al., 2011). The present work we perform a statistical Landslide Susceptibility Model (LSM), as well as which Landslide Conditioning Factors (LCFs) most influence the variability of the model. The final result of this model will support the Landslide Susceptibility Chart.

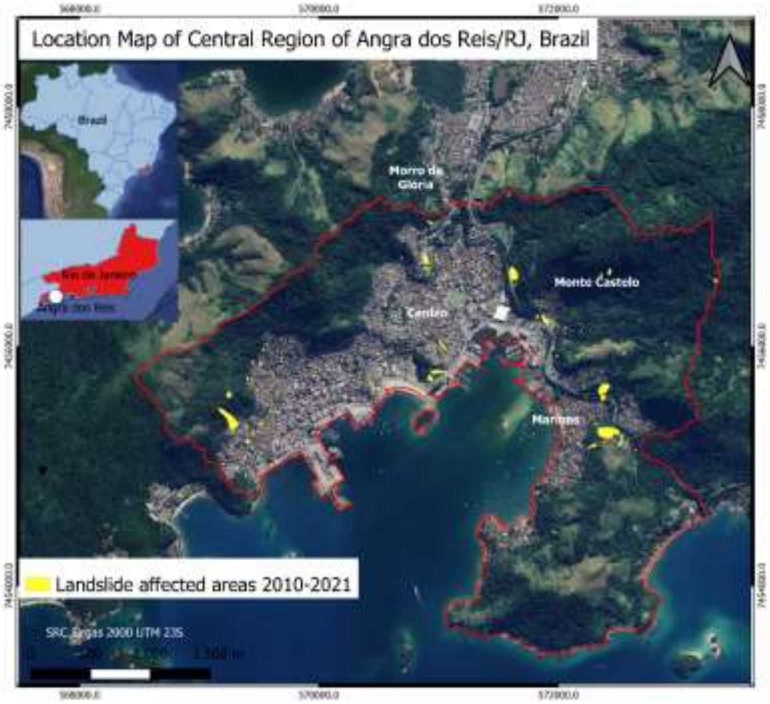

Figure 1: Study Area

2 Research Methodology

The research method began with an literature review focused on the RF and SVM algorithms in LSM. This review encompassed academic sources, such as articles, theses, and dissertations, resulting in the identification of 98 pertinent references. They were selected by themes, location, typology, and date, resulting in 68 papers, 12 textbooks, and 18 mixed (thesis, abstracts, meeting paper and reports). Inside this literature 23 focused on landslides, 12 on multivariate analisys, 27 on methodological and statistical aspects, and 36 on ML. Around 80% of references were international, reflecting a notary trend of increased in ML at the past decade. In addition to the literature review, data from the State Geological Survey (DRM/RJ) and Civil Defense of Angra dos Reis were analysed, focusing on mass movement at the city since 2010 to 2021.

2.1 Landslide Susceptibility Modelling (LSM) in Angra dos Reis

The study conducted in Angra dos Reis commenced by compiling landslide data, which was used to create a Landslide Inventory (LI). This inventory was established based on the geographical coordinates, temporal information, and geometrical characteristics of previous landslides identified in Google Earth images spanning from 2010 to 2021. These landslide polygons were superimposed onto a topographic map generated from a Copernicus DGED 30 digital elevation model and Landsat-8 imagery in the green, red, and infrared bands. Simultaneously, 11 LCFs were incorporated into the topographic map. These LCFs included lithology, geomorphology, elevation (hypsometry), slope, aspect, curvature, plane curvature, curvature profile, Normalized Difference Vegetation Index (NDVI), Normalized Difference Building Index (NDBI), and Topographic Wetness Index (TWI).

The 2nd phase of the study consisted of grid sampling with 30m resolution across the entire study area, aligning with the pixel resolution of the orbital images. Subsequently, all collected data was normalized and conducted for Weight Analysis between LCFs. In the third step, the analysis of LCF weights was performed using a combination of supervised algorithms, specifically Principal Component Analysis (PCA) and Logistic Regression (LR). LR, recognized as one of the widely used methods in multivariate analysis, was used due to its ability to solve non-linear problems, incorporating a regression function suitable for the case of binary variables. On the other hand, PCA algorithms helped determine the essential components among the 11 conditioning factors necessary to explain data variability with a probability of at least 95% and identify interactions between them.

After that, Classification Analysis was conducted using SVM and RF supervised classification algorithms. Both were employed to predict landslide susceptibility and calculate associated probabilities. Both were tested to determine their respective performance on the model. Subsequently, the LSM was validated using a confusion matrix, allowing a comparison between actual and predicted landslides. Consequently, a curve was established plotting the true positive rate against the false positive rate, producing an area under the curve (AUC), which served as a parameter to evaluate the model's ability to distinguish between susceptible and non-susceptible areas. Ideal models have an AUC close to 1.

3 Findings and Discussion

PCA analysis revealed a strong positive correlation between the slope, elevation, and NDVI parameters, as well as a strong inverse correlation between NDVI, NDBI, and TWI. Furthermore, among the LCFs inputted in the LSM, only 7 parameters are sufficient to explain 95% of the data variability. The LR summary reinforced the considerations raised by the PCA analysis, indicating that the 7 LCFs are the most influence the model (by importance order): elevation, slope, NDVI, Curvature Profile, Lithology, NDBI and Curvature. The application of RF method showed an average accuracy of 76% for both classes “No occurrence of landslides” and “Occurrence of landslides”. The AUC resulted in 0.85.

The SVM model (Figure 2a) showed an average accuracy of 89% for both classes, highlighting the algorithm's robustness in classification. The ability of the algorithm correctly identify positive cases in 61% for “No occurrence of landslides” and a surprising 99% for “Occurrence of landslides”. The AUC of the SVM surpassed that of the RF, reaching a value of 0.90. The analysis of the false negative results obtained by applying the RF and the SVM, brought to light different results for both algorithms. In a new round of analysis focused only on occurrence values, it was evident that the SVM algorithm excelled in predicting more true positives compared to false negatives, while the RF (Figure 2b) leaned toward predicting more false negatives than true positives.

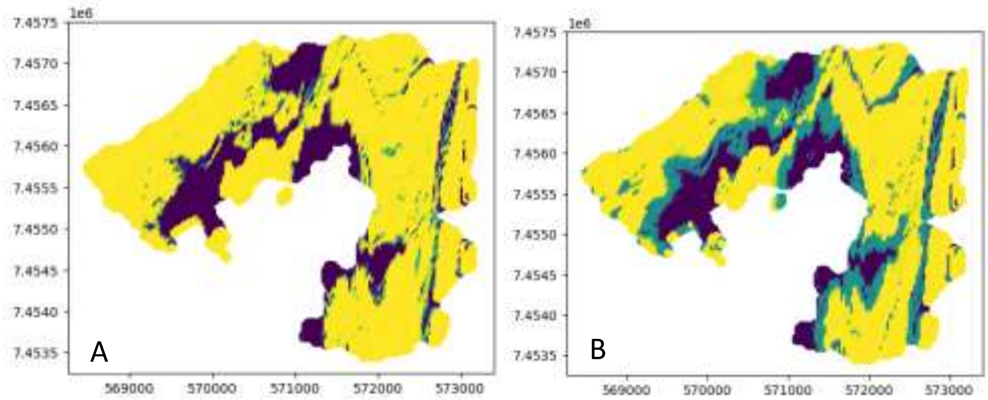

Figure 2: LSM Charts generated with SVM and RF

4 Conclusion

Weight analysis through PCA and LR revealed that 7 out of 11 LCFs are the most influential on LSM variability. The SVM algorithm showed better performance in LSM compared to RF. The false negative check found that the RF method misclassified more false negative values, resulting in poor performance.

5 Acknowledgment

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Enhancing Concrete Property Prediction through Advanced Neural Network Modeling

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Abstract:
The rising concern over building energy consumption has spurred a demand for high-performance construction materials with superior thermal attributes. Accurately assessing these properties is pivotal for crafting energy-efficient materials. However, conventional methods for characterization involve labor and cost-intensive experiments, presenting formidable barriers to precision. Thermal conductivity (TC) is an essential thermal property and a precise TC knowledge is vital for designing materials capable of efficiently managing heat flow within structures. Additionally, compressive strength is a cornerstone property influencing concrete performance and longevity in construction. It signifies a material's resistance to axial loads and is crucial for structural integrity. Accurate compressive strength prediction is paramount for optimizing concrete mixes and ensuring building safety. This comprehensive study introduces a novel methodology in deep learning employing artificial neural networks, specifically a Multilayer Perceptron (MLP) and Generative Adversarial Network (GAN) to predict these properties based on its chemical composition. The dataset for model training was developed from the published literature. We've tested various ANN structures, including a two-hidden-layer MLP with 200-100 neurons, and first results achieved a remarkable consistency (RMSE: 0.176, R^2: 0.98). By bridging the gap between accurate property prediction and cost-effective experimentation, this research aims to revolutionize energy-efficient building material development while ensuring structural integrity, thus contributing significantly to sustainable construction practices.

Keywords:
Artificial neural networks, Building materials, Concrete, GAN, MLP, Thermal conductivity.

1 Introduction

Due to the constant concern about the energy consumption of buildings, there is a growing demand to improve thermal performance. Utilizing thermal efficiency materials in the construction sector is necessary as they preserve indoor thermal comfort, despite fluctuations in the outdoor environment conditions [1]. Many building materials can be used as thermal energy storage materials. As energy efficiency relies on the material's thermal properties, an accurate prediction of their properties is vital for optimizing their performance in a building.

Concrete is one of the most used materials in construction and as a thermal energy storage material (TES) due to its unique features, such as high compressive strength, heat capacity, and low cost. However, as its chemical composition can vary significantly, its properties can undergo significant variations. For this reason, and to be effective as a TES material, it is crucial to have an ideal composition to ensure that its thermal properties meet the required design specifications [2].

Due to the pressing need for energy-efficient building materials, numerous studies have turned their attention to the analysis of thermal properties in construction materials. Consequently, the development of a predictive model capable of accurately estimating the thermal behavior of them emerges as a valuable tool for optimizing their application. While the analysis of thermal properties, like thermal conductivity, is crucial, another fundamental property, compressive strength, profoundly impacts construction materials' performance. Compressive strength is vital to assess a material's ability to withstand axial loads and is to ensure the structural integrity in construction applications.

Deep learning (DL) models can be used to develop such predictive models by learning from large datasets and finding patterns to make predictions. By incorporating DL, the predictive models can adapt to varying conditions and continuously improve their accuracy, making them a valuable tool in optimizing the performance of building materials [3]. Among the models, the Artificial Neural Network (ANN) is one of the most employed ones to solve complex problems and has various applications in several fields [4], [5]. The importance of ANNs lies in their ability to learn and make decisions based on data, which makes them highly valuable. In this way, ANNs can be used to solve problems that conventional or other computational methods have difficulties [6].

ANNs provide an alternative prediction method that is faster, cheaper, and more accurate than traditional methods. However, a few papers are progressing on models to determine the thermal properties and do not have a generalist model. This work intends to fill this gap and develops predictive models encompassing both thermal conductivity and compressive strength using ANN based on the constituents' composition and the concrete's density. This research seeks to advance the field of energy-efficient building materials while ensuring the structural resilience of construction materials, thus contributing significantly to sustainable construction practices.

2 Research Methodology

The following methodology outlines the development of an ANN model for predicting the properties of concrete based on its features, which enables the evaluation of the model potential to foresee this property and shows the efficiency in the prediction speed when compared to the time-consuming experiments, which will provide a reliable model to predict the concrete's thermal conductivity. This methodology is broken down into three steps (Figure 1).

The first one corresponds to the literature review and data collection of a diverse variety of concrete. If the database presents an inadequate representation of the problem, the model cannot predict the property effectively, thus reducing the model's reliability. Furthermore, for the model to be representative, there must be a sufficiently large amount of data to ensure diversity. First, the model's inputs and outputs are defined according to the available data and the dependent variables. Then, the available data sets from the literature are organized in a CSV file to develop the ANN model. The second one is related to the general process of building the ANN model to predict the thermal conductivity and the compressive strength, i.e., the selection of an appropriate neural network architecture for the prediction task, defining the learning rate of the neural network, the number of hidden layers and neurons in each layer, and the metrics to find the best model for the dataset. The last step is analyzing a case study, where the dataset based on previously published works is plugged into the model to evaluate its accuracy. Besides that, a Generative Adversarial Network (GAN) is also developed for data augmentation to improve the model and guarantee a good prediction.

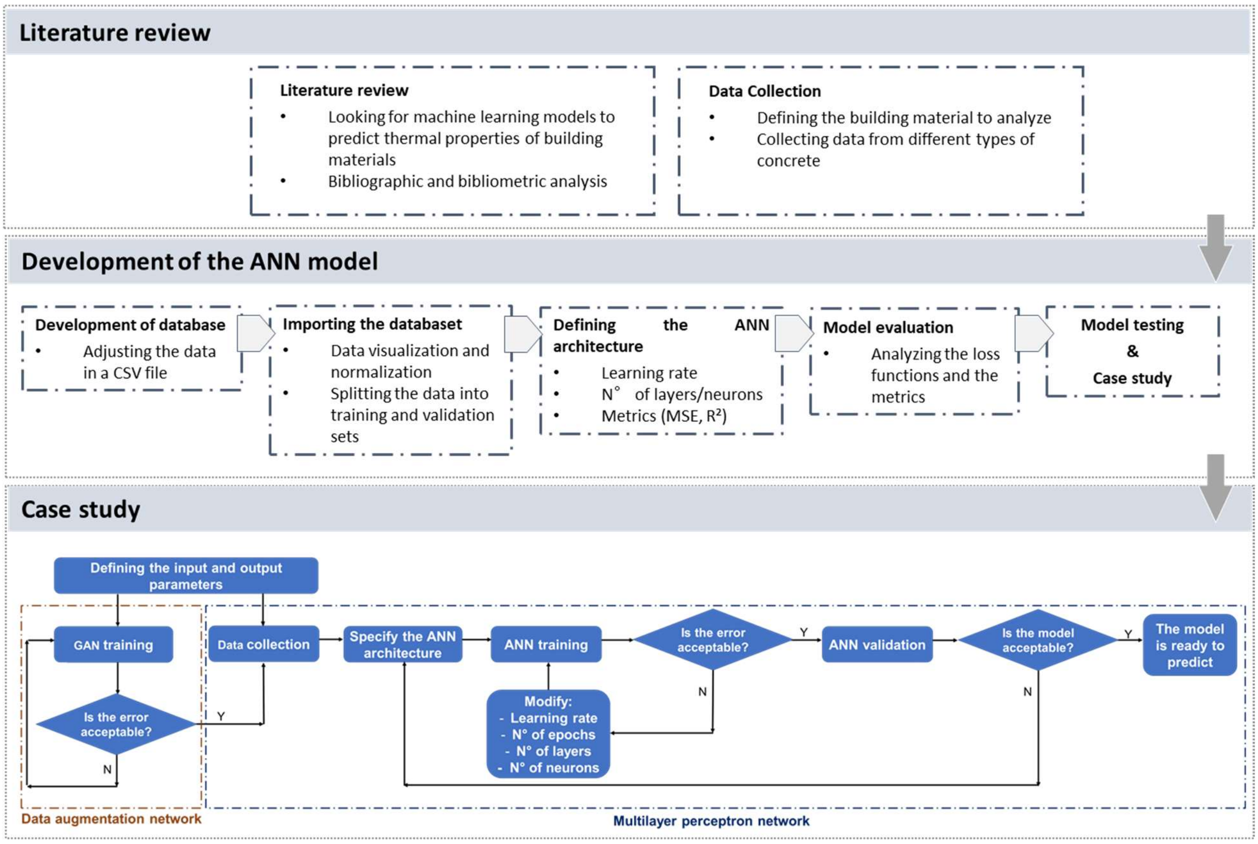

Figure 1. Methodology framework

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Assessment of urban resilience to floods in the disaster risk management cycle. Case study of the Piraquê-Cabuçu river basin, RJ

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Abstract:
Due to the increasing frequency of floods observed in recent years, it is necessary to implement a strategy that strengthens urban resilience to floods. Therefore, to reduce the damage caused by flood events in urban areas, it is important to assess resilience throughout the disaster risk management cycle. Thus, the present research aims to evaluate the behavior of urban resilience to floods, through a set of indexes that are capable of mapping resilience at each stage of the disaster risk management cycle, with the proposed indexes being tested in the basin of the Piraquê-Cabuçu river, located in the city of Rio de Janeiro, through hydrological and hydrodynamic modeling of the basin, using, as a computational tool, the flow cell model MODCEL, developed at UFRJ. As a result, through the proposed indexes, it is possible to assess urban resilience to floods in the basin, providing a basis to aid decision making in the adoption of actions and measures in risk management.

Keywords:
Risk management, floods, mitigation, prevention, resilience.

1 Introduction

In recent years, worldwide, it has been verified that floods were the type of disaster that occurred most frequently, when compared to other types of extreme natural events (CRED, UNDRR, 2020). The impact of floods can be reduced by adopting measures related to integrated flood risk management (WORLD BANK, 2012). Therefore, it is important to develop resilient systems that have the capacity to prevent, reduce and live with the risk of floods, making it possible to improve this capability in each stage of the disaster risk management cycle (SCHELFAUT *et al*., 2011). Thus, this research aims to evaluate urban resilience to floods, in each of the stages of the disaster management cycle, which include prevention, mitigation, preparation, response and recovery, to support decision making in implementation of flood risk management actions and measures. The assessment is based on the development of performance indexes, which can be used to quantify the increase in resilience through interventions in the planning of disaster reduction strategies. The proposed methodology is applied in a case study, in the Piraquê-Cabuçu river basin, with hydrological and hydrodynamic modeling of the basin being carried out, using the MODCEL model, developed by Miguez (2001), and using information from the 2010 Demographic Census (IBGE, 2010).

2 Research Methodology

To prepare this research, the following general methodological procedure was adopted:
1) literature review; 2) definition of the flow cell model, MODCEL, as a computational tool for hydrological and hydrodynamic modeling of the basin; 3) development of urban flood resilience indexes for different stages of the disaster risk management cycle; 4) adoption of a case study, for the purpose of validating the proposed methodology, using the Piraquê-Cabuçu river basin, located in the city of Rio de Janeiro, where there are records of urban flooding occurrences; 5) basin flood modeling and model calibration; 6) application of flood resilience indexes in the basin under study, based on the results of hydrological and hydraulic modeling; 7) assessment of urban resilience to flooding for each stage of the disaster risk management cycle, highlighting, in this document, the treatment of the first three stages, preliminary to the actual occurrence of the disaster: prevention, mitigation and preparation.

3 Results and Discussion

The urban flood resilience indexes for the prevention, mitigation and preparation stages of the disaster risk management cycle are estimated, respectively, by Eq. (1), by Eq. (2) and by Eq. (3):

Prevention

$$I_{Prev} = a.(1-I_{ofTR10}) + b.(1-I_{ofTR25}) + c.(1-I_{ofTR50}) + d.(1-I_{ofTR100}) \quad (1)$$

Where: I_{Prev} - urban flood resilience index in the prevention stage; $I_{ofTR10,25,50,100}$ - river flood strip occupancy indicators, for TR 10, 25, 50 and 100, respectively; *a*, *b*, *c* e *d* - weights relative to each indicator in Eq. (1).

Mitigation

$$I_{Mitig} = a.[1-(I_E^{n1} \, . \, I_H^{n2})] + b.[1-(I_{EI}^{n3} \, . \, I_{HI}^{n4})] \quad (2)$$

Where: I_{Mitig} - urban flood resilience index in the mitigation stage; I_E e I_{EI} - indicators of exposure of buildings and urban infrastructure (REZENDE, 2018); I_H e I_{HI} - flooding depth indicators in relation to buildings (REZENDE, 2018) and urban infrastructure ; *a*, *b*, n_1, n_2, n_3 e n_4 - are weights associated with each portion of Eq. (2).

Preparation

$$I_{Prep} = 1 - (a.I_{RMU} + b.I_{DAP} + c.I_{DS}) \quad (3)$$

Where: I_{Prep} - urban flood resilience index in the preparation stage; I_{RMU} - urban mobility risk indicator; I_{DAP} - indicator of difficulty in accessing support points; I_{DS} - aid demand indicator; *a*, *b* e *c* - are weights associated with each portion of Eq. (3).

The estimated urban flood resilience indexes are presented in Figure 1.

From the results it is possible to observe that, in the current situation of the basin under study, the preparation phase is the one with the lowest urban resilience to floods, when compared to the prevention and mitigation phases, which makes greater attention necessary in this phase when adopting measures to reduce disaster risks. Still in this preparation phase, it is possible to observe, from Figure 1 (c), that measures are necessary to increase support points and urban mobility for the population. Then, it can be seen, in Figure 1 (a), that in the prevention phase, the lower and flatter areas are those with less resilience to flooding, due to this area being reached more quickly in flood situations, while in areas with higher elevations the index has a higher value, which suggests that this area is more resilient to flooding at this stage. On the other hand, in the mitigation phase, it is observed in Figure 1 (b), that in the area further downstream of the basin and in the region near to the headwaters of the Cabuçu river, the resilience index presents a lower value, which indicates that priority actions regarding the adoption of risk management measures in this area, to reduce the impact of the flood event.

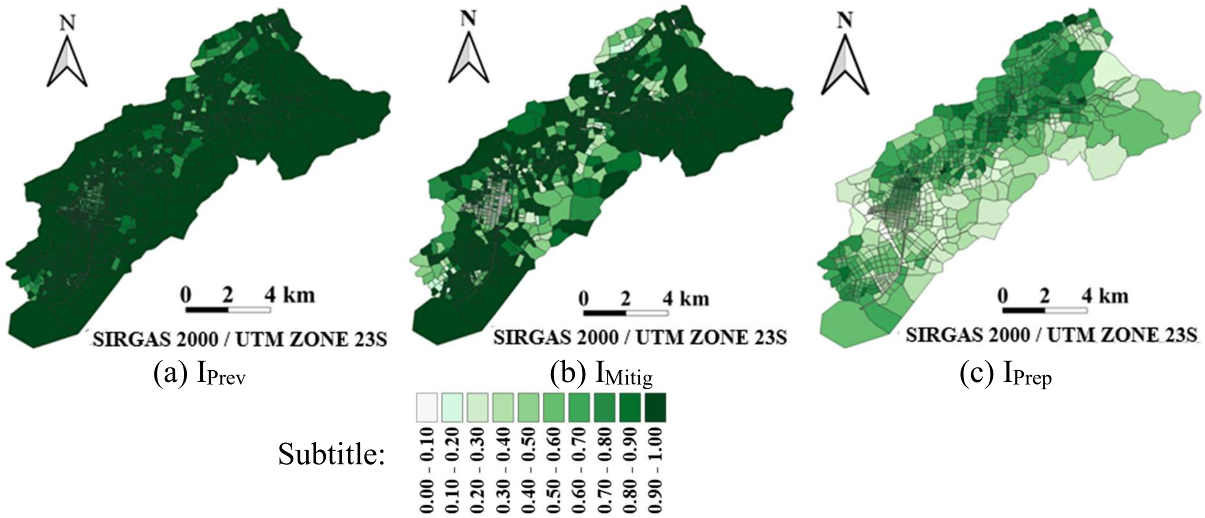

Figure 1 (a), (b) e (c)**.** Flood resilience indexes, in the prevention, mitigation and preparation stage.
Source: Prepared by the author (2023).

4 Conclusion and Next Steps

Based on the results achieved, it is possible to observe that the application of the proposed indexes helps to plan priority actions regarding flood risk management. These results, however, are still under review. In the case study adopted, the preparation stage is the one with the lowest resilience to floods, making it necessary to adopt priority measures at this stage.
As continuation of this research, urban flood resilience indexes will be estimated in the response and recovery stages of the disaster risk management cycle. When it will then be possible to evaluate all stages of the cycle globally. To better support decision making regarding the adoption of flood risk management measures, the present study can be used to compare different hydraulic simulation scenarios in the basin under analysis, including drainage solutions and different intervention measures.

5 Acknowledgments

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Sustainability Assessment in the Life Cycle of Biogas from Agriculture

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Abstract:
The significant global dependence on fossil fuels and the associated greenhouse gas emissions have raised concerns about climate change. Brazil's industrialized agricultural sector is a significant contributor to energy consumption and greenhouse gas emissions, particularly methane from waste production, making biogas an attractive environmentally friendly alternative. This study aims to conduct a comprehensive sustainability assessment of biogas production in Brazil using agricultural raw materials. The Life Cycle Assessment (LCA) method will be employed to analyse the three pillars of sustainability: economic, environmental, and social aspects, and to assess both small and large-scale production scenarios. The study will also develop a mathematical tool with parameters and indicators to help stakeholders identify the best biogas production alternatives based on economic, social, and environmental factors. Ultimately, this research aims to promote sustainable biogas production in Brazil, especially in remote areas with limited access to conventional energy sources.

Keywords:
Biogas; Sustainability; Live cycle Assessment (LCA); Agricultural waste.

1 Introduction

There is a significant global dependence on the use of fossil fuels (coal, oil, and natural gas), resulting in substantial greenhouse gas (GHG) emissions due to the energy demands of industrialization and population growth. Energy consumption has been rapidly increasing in recent years and is expected to continue rising in the future, leading to climate changes (Gao *et al.*, 2018). The Coronavirus Disease 2019" (COVID-19) pandemic has created uncertainty in the energy sector, with estimated reductions in global energy demand, CO2 emissions, and energy investments in 2020 (Cozzi *et al*., 2020).

Brazil's agriculture sector, currently industrialized and of great importance for the country (IBGE, 2022), is responsible for high-energy consumption and significant GHG emissions, especially methane, due to waste production (Dick *et al.*, 2015). In this context, biogas, one of the renewable energy sources obtained from biomass emerges as an economically (Tabatabaei *et al*., 2020; Lee et al., 2020) and environmentally friendly alternative compared to fossil fuels, aiming to reduce environmental impact in the sector (Hollas *et al.*, 2021).

Brazil has a growing number of operational biogas production plants, mainly for electricity generation, contributing to the decarbonization of the sustainable Brazilian ecosystem. However, available data are limited to plants authorized by Available Brazilian databases, making it challenging to obtain information about smaller and more rudimentary projects, typical of small-scale farmers.

Life Cycle Assessment (LCA) has been a common approach to analyzing the environmental impact of biogas production, but many studies are still incomplete and do not include all life cycle stages (Ebner *et al.*, 2015). Research scopes have emerged to address economic, social, and environmental aspects of biogas production, both in isolation and in terms of its potential as biomethane (Yan *et al.*, 2021) and its role in the circular economy (Kapoor *et al.*, 2020).

This study aims to conduct a holistic sustainability assessment of biogas production in Brazil, focusing on pig and cattle confinement, considering economic, environmental, and social aspects. Subsequently, a numerical tool will be developed to evaluate the best scenario for biogas production on both small and large scales.

2 Research Methodology

The present study adopts an approach that goes beyond waste management and recycling, as well as optimize resource utilization. Initially, the study employs a multifaceted approach, including a comprehensive literature review on the life cycle of biogas production, anaerobic digestion (AD) technologies, and bioenergy production predominantly used in Brazil.

Life cycle assessment (LCA) plays a fundamental role in the study, providing insights into the impacts throughout the entire biogas production process. Social life cycle assessment (SLCA), environmental life cycle assessment (ELCA), and economic life cycle assessment (EcLCA) will be developed. After the elaboration and analysis of these three LCAs, relevant indicators will be established for each, allowing for their integration into subsequent quantitative analysis.

The methodology does not include resource allocation methodology (for co-products) since for the ISO the allocation method is not an appropriate option. Thus, Thus, a system expansion methodology will be implemented to understand the process as a whole and consider all the co-products generated.

Finally, the study develops a numerical tool to assess the economic, environmental, and social sustainability of implementing the biogas production system on both small and large-scale farms. This aims to support informed decision-making and promote sustainability in Brazilian agriculture, minimizing resource extraction while maximizing reuse, efficiency, and sustainable development.

3 Expected results

This study aims to provide valuable insights into biogas in Brazil, particularly in the context of anaerobic digestion using agricultural raw materials. The expected outcomes of this research include:

Primary Databases: The study aims to establish primary covering various stages of the biogas life cycle in Brazil. This data will form a crucial foundation for understanding and optimizing the production process.

Literature Review: A comprehensive literature review on biogas production in Brazil will be conducted. This is a valuable contribution as there is currently limited literature on this topic, providing a comprehensive overview of the state of biogas production in the country.

Life Cycle Assessment: This study aims to calculate and analyze all inputs and outputs, as well as impacts associated with each stage of the environmental, economic, and social life cycle within the biogas production life cycle, under different scenarios. Biogas can be of sufficient quality for various on-farm activities, ensuring efficient utilization without significant investments in purification equipment.

Small- and large-Scale Analysis: The research anticipates that small-scale biogas production (on-farm) will initially have advantages in terms of practicality and ease of implementation. It allows for better control and management of the system compared to large-scale production.

Large-scale biogas production may face challenges in the short term in Brazil. This is due to the scale of mechanization in field operations, which plays a critical role in defining environmental impact, economic viability, process knowledge, production, maintenance, and the need for qualified labor.

Mathematical Tool: The study intends to develop parameters or indicators that can be used within a mathematical tool. This tool will assist farmers and stakeholders in identifying the best biogas production alternative (small or large scale) based on economic, social, and environmental factors.

4 Conclusions

This research holds promise for advancing biogas production in Brazil, offering solutions for energy production, waste management, and agricultural sustainability, particularly in remote areas with limited access to conventional energy sources.

5 Acknowledgment

This study was partially funded by Coordination for the Improvement of Higher Education Personnel (CAPES) – Brazil, under Finance Code 001 and the BRANOR project administered by the University of Stavanger (UIS) and NORCE Research, science and innovation institute.

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Technological roadmap on the reuse of polyester fibers from mooring ropes from decommissioned offshore platforms: a vision according to the circular economy

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Abstract:
The Intergovernmental Panel on Climate Change (IPCC) issued a new report in 2021 detailing how greenhouse gases (GHG) produced by anthropogenic activity are harming the world; It states that there is no doubt that human activity has caused the atmosphere, ocean, and land to warm. The circular economy is viewed as a solution to climate change and carbon footprint reduction. By 2050, circular economy solutions can cut world GHG emissions by 40%. Regarding the oil and gas industry, nearly 15% of energy related GHG are attributed to oil and gas operations. Additionally, the demand for sustainability has created both obstacles and opportunities for the industry's future. Moreover, one of the most difficult difficulties facing the oil and gas sector is the management of decommissioned platforms, and sustainable management of end-of-life platforms will reduce environmental impacts. Mooring ropes are residues produced by decommissioned platforms; each platform generates roughly 50 tons of mooring ropes, which have high mechanical resistance, good chemical resistance, and high tenacity. These characteristics add value to discarded mooring ropes and justify their reuse. This study will conduct scientific and patent research to develop a technology roadmap for the reuse of synthetic fibers from offshore mooring ropes.
Keywords:
Mooring ropes, synthetic fibers, circular economy

1 Introduction

The transition to a low-carbon economy is urgent due to global environmental change and its environmental and social impacts (Linnenluecke, Han, Pan, & Smith, 2019). Circular econom is seen as a strategy to tackle climate change. By 2050, circular economy solutions have the potential to reduce global GHG emissions by 40% (United Nations Development Programme, 2023).

Concerning Oil and gas industry, its operations are responsible for around 15% of energy related GHG emissions (IEA, 2023). The demand for sustainability has produced both opportunities and difficulties for the industry's future (World Economic Forum, 2023). Thus, oil and gas industry can benefit from the circular economy, as it promotes the closure of production cycles, through innovation, the efficient use of water, energy and materials, and the reuse of raw materials and waste (Ministerio de Ambiente y Desarrollo Sustainable, 2019). Moreover, one of the biggest challenges of the oil and gas industry is the management of decommissioned platforms. Mooring ropes are type of waste from decommissioned platforms, each platform discards mooring ropes that have characteristics of high tenacity, good chemical resistance, and high mechanical resistance. These mooring ropes are made of synthetic fibers, which contribute to the increase in GHG (Shirvanimoghaddam et al., 2020), because they demand a huge amount of energy and so generate a greater amount of CO2 (Rana, Pichandi, Moorthy, & Bhattacharyya, 2015). The process of reusing mooring ropes offers an "opportunity for financial gains due to the increase in available resources for environmental and socioeconomic benefits" (Sudaia et al., 2018). The aim of this study is to develop a technological roadmap about the reuse of synthetic fibers from offshore mooring ropes. To fulfil this purpose, a scientific and patent research will be conducted.

2 Research Methodology

To fulfil the main purpose of this study, first is carried out the pre-prospective stage, where the research of the state of the art of reusing anchor ropes in a circular economy context. After, it goes the prospective stage to define keywords and research strategies. Moreover, a technological prospecting study based mainly on articles and patents related to the reuse of mooring ropes from offshore platforms. Scopus is used for the prospection of articles. Furthermore, to develop the technological roadmap, it is used the methodology developed by NEITEC – Study Center Technological Industries from EQ/UFRJ, coordinated by Profa. Suzana Borschiver. Lastly, the post-prospective stage with vertical and horizontal analysis of the technological roadmap, identifying technological trajectories and maturities, partnerships, key technologies, and sales windows opportunities for anchor cable applications aimed at the textile industry.

3. Findings and Discussion

The technological roadmap allows you to outline the technological changes around a company or process. This study implements the method for technological roadmap proposed by the work team of Professor Suzana Borschiver, which consists of three stages: i) pre-prospective stage, ii) prospective stage and iii) post-prospective stage. In the pre-prospective stage, there was the opportunity to accompany the laboratory tests carried out in the doctoral work supervised by Professor Ana Lucia Nazareth da Silva, where the objective is to develop the recycling of anchor cables for making fabrics. In the prospective stage the Scopus platform was used to provide the scientific articles, and the keywords were chosen according to the results obtained and modified to obtain more results related to the topic of interest. The research strategy is defined below:

(TITLE-ABS-KEY (*"mooring rope*"* OR *"anchor rope*"* OR *"polyester mooring rope*"* OR *"polyester mooring line*"* OR *"polyester mooring system*"* OR *"synthetic fiber mooring"* OR *"synthetic fibre mooring rope*"* OR *"FPSO mooring"* OR *"FPSO mooring system"* OR *"floating production, storage and offloading mooring system"* OR *"floating production, storage and offloading mooring"* OR *"nylon mooring rope*"* OR *"HMPE mooring rope*"*) OR TITLE (*"synthetic fiber"* OR *"synthetic fibre"* OR *"polyester fiber"* OR *"polyester fibre"* OR *"HMPE fiber"* OR *"HMPE fibre"*) AND TITLE-ABS-
KEY (*recycling* OR *recycled* OR *refurbish* OR *refurbished* OR *remanufacturing* OR *remanufactured* OR *recovering* OR *recov ered* OR *"other application*"* OR *recyclability* OR *reuseability* OR *circular* OR *circularity*))

210 results were obtained. The meso analysis results shows a taxonomy identified regarding the type of application.

The types of application for recycled synthetic fibers are the following:

- Applications in cement reinforcement with polyester fiber: Polyester fibers alone or accompanied by other additives.
- Polymers reinforced with synthetic fibers: Recycled polyethylene reinforcement with polyester fibers, Polymers reinforced with natural/synthetic hybrid fibers.
- Depolymerization of polyester fibers.

- Reuse and transport of mooring ropes for new projects.
- Catalytic pyrolysis to recover energy from polyester.
- Improve the quality of recycled polyester fiber.
- Increasing soil resistance with nanoclay combined with polyester fibers.
- Acoustic absorption.
- Development of fabrics from recycled polyester fibers.
- Improvement of paper sludge dehydration by residual polyester fiber.

With a majority of the articles focused on applications in cement reinforcement followed by polymers reinforced with synthetic fibers.

3 Acknowledgment

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A novel flood and flash flood susceptibility mapping method using multi-criteria decision-making method in GIS environment

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Abstract:
The present study introduces an index-based approach based on a multi-criteria decision-making method and developed in a GIS environment able to qualitatively assess flood-prone areas. The methodology intends to simplify the phenomenum representation, emphasizing the role of the user/modeler and with validation process based on a comparative analysis by the hydrodynamic modeling of watersheds within the study area. The first index, named Physical Susceptibility to Floods Index, has as its main objective to classify river floods in low-land areas. This index was developed and first applied in the city of Rio de Janeiro, as part of the Rio de Janeiro Climate Change Adaptation Plan, and a second version in under development. The third index, also in development, aims to classify flash floods in hillslope areas.

Keywords:
Flood risk management, floods, flash floods, MCDM, GIS

1 Introduction

Floods can be characterized as the natural disaster in third biggest cause of economic losses, behind storms and earthquakes natural but with the highest frequency and the most number of people affected. Between 2006 and 2021, floods represented 50% of the annual amount. South America is the second most affected continent, behind Asia (CRED, 2022, WANNOUS, VELASQUEZ, 2017).

Considering the context of the Flood Risk Management (FRM) approach, an anticipated risk analysis is a strategic demand for more resilient cities in current and future adverse scenarios of increasing urbanization and climate change (SAYERS, YUANYUAN, *et al.*, 2013). At the end of 2021, approximately 56% of the world's population lived in urbanized areas. In Brazil, this percentage is around 87% (WORLD BANK, 2022).

The identification and classification of flood-prone areas comprise a preliminary and fundamental step in the FRM approach, providing subsidies for land use planning, floodproofing policies, mitigation measures and early warning systems, among others (SAYERS, YUANYUAN, *et al.*, 2013). In this sense, this study aims to develop a flood and flash flood susceptibility mapping method, named Physical Susceptibility to Floods Index (PhySFI) (MIRANDA, Francis, FRANCO, *et al.*, 2023) and Physical Susceptibility to Flash Floods Index, respectively. The main contribution of the present study consists of the reduced number of representative Flood Conditioning Factors (FCFs) in comparison with other similar studies. The development of a new, reduced set of FCF emphasizes the role of the modeler in the interpretation of physical phenomena both in the hydrologic–hydrodynamic modeling step and in the choice of indicators, normalization classes, weights and the final equation in the MCDM method adopted.

2 Research Methodology

The Physical Susceptibility to Floods Index (PhySFI) is based on an MCDM approach and developed in a GIS environment. The method presupposes a critical discussion of what could be the minimum significant and representative set of variables commonly used and works by choosing indicators, normalization classes, weights and the final equation itself. The validation process is based on a comparision with hidrologic-hydrodynamic models of basins within the study area.

The choice of PhySFI indicators was influenced by autors like (KAZAKIS, KOUGIAS, *et al.*, 2015, MAHMOUD, GAN, 2018, RAHMATI, ZEINIVAND, *et al.*, 2016, TEHRANY, PRADHAN, *et al.*, 2013) and involves practical observations: the terrain slopes (I_S) are one of the most important characteristics for mapping flooding (only nearby plain areas are effectively floodable); the distance to the major drainage network (I_{PROX}) reflects the threat represented by overflows; the terrain elevation accounts for flow accumulation and additional restrictions imposed by tides and backwater effects (I_E) (particularly important to coastal cities); and land use impacts runoff generation (I_{IMP}), which can imply increased flooding.

A new version, PhySFI v2.0, is under development and pretend to better represent coastal areas as preliminary tested in (CABRAL, ALVES, *et al.*, 2021, MIRANDA, Francis Martins, CABRAL, *et al.*, 2016). In this uptade, a new formulation is proposed, where Elevation indicator can assume values greater than 1, as presented in Equation 2.

$$PhySFI\ v2.0 = \left[{I_S}^{E1} \cdot (c1 \cdot I_{IMP} + c2 \cdot I_{PROX})^{E2}\right] \cdot I_E \quad (1)$$

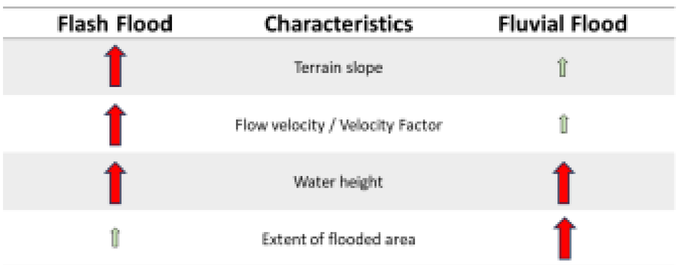
$$If\ PhySFI\ v2.0 > 1 \Rightarrow PhySFI\ v2.0 = 1$$
$$If\ PhySFI\ v2.0 \leq 1 => PhySFI\ value \quad (2)$$

Where,

- I_S – Slope Indicator;
- I_{IMP} - Imperviousness Indicator;
- I_E – Elevation Indicator;
- I_{PROX} - Proximity to Drainage Network Indicator;
- C1, C2, E1 and E2 – Index weights;

For representing flash flood phenomenon, a Physical Susceptibility to Flash Floods Index is also under development, following the same premises of PhySFI. The Figure 1 summarizes a qualitatite comparision between main characteristics of floods and flash floods.

Figure 1. Qualitatite comparision between main characteristics of floods and flash floods.



Equation 4 represents a potential formulation for the new flash flood index. Slope and proximity indicators receive new classification processes and elevation were removed.

$$FlashFloodIndex = I_S FF^{E1} \cdot (c1 \cdot I_{IMP} + c2 \cdot I_{PROX} FF)^{E2} \quad (3)$$

Where,

- $I_S FF$ – Slope Indicator to Flash Flood;
- $I_{PROX} FF$ - Proximity to Drainage Network Indicator to Flash Floods;

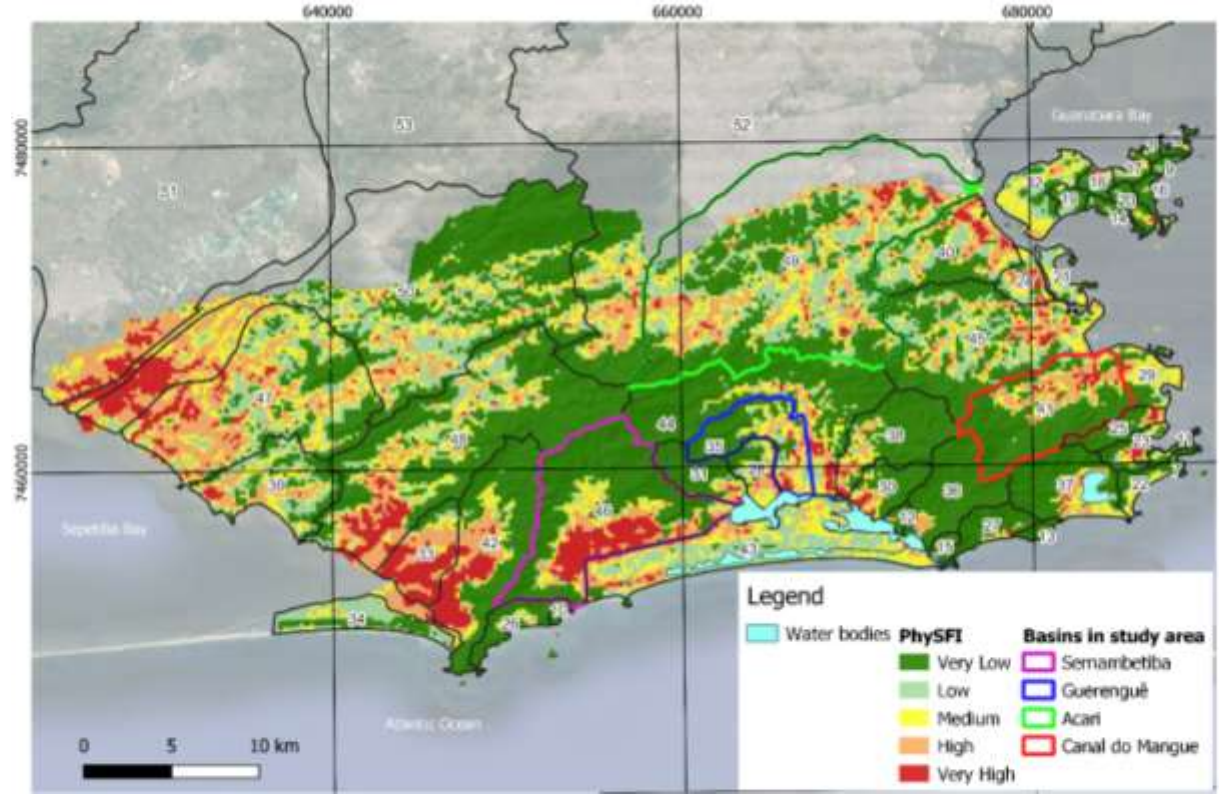
3 Findings and Discussion

Results and discussions about PhySFI methodology, application and results can be found in (LA ROVERE, SOUSA, 2017, MIRANDA, Francis, 2016, MIRANDA, Francis, FRANCO, *et al.*, 2023, SUPCLIM/SEA, 2018). The index weightining based on application for Rio de Janeiro city is presented in Equation 1.

Figure 2 presents the PhySFI result spatialized for the city. Results of PhySFI v2.0 and Physical Susceptibility to Flash Floods Index are preliminary and will be presented in a next step.

$$PhySFI = {I_S}^{0,25} \cdot (0,4 \cdot I_{IMP} + 0,4 \cdot I_{PROX} \cdot +0,2 \cdot I_E)^{0,75} \quad (4)$$

Figure 2. PhySFI result for the city of Rio de Janeiro.



4 Conclusion and Further Research

The main goal of the present study is to develop a simple and robust method to measure the physical susceptibility to floods and flash floods of a certain territory, using widely available data and geospatial tools in open and free GIS software. All the steps taken in the indexes development procedure were based on choices that allow their reproducibility for other cases.

In large and/or non-coastal basins, the elevation indicator can be neglected by using a zero weight. In general, all indicators may be adjusted for the applied region, considering existing data and geographical conditions and also including changes in their classes and weights. Further steps in this research could benefit from a set of different applications, such as using urban watersheds with different characteristics in order to assess the indicator's sensitivity and map eventual gaps in the formulation.

5 Acknowledgment

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DEVELOPMENT AND IMPLEMENTATION OF METHODOLOGIES FOR ASSESSING EFFECTS ON MARINE ORGANISMS THROUGH ECOTOXICOLOGICAL TESTS

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Abstract:
Ecotoxicology plays a crucial role in evaluating how substances impact organisms. These tests are vital for ensuring compliance with quality standards, guiding approval, registration, selection, proper utilization, disposal, and establishing preventive actions. The tests involve exposing organisms to varying concentrations of the substance sample and assessing acute and chronic effects in comparison to a control. To assess environmental risks effectively, various species are used due to the diversity of organism responses. The project aims to implement and improve ecotoxicological test procedures with marine species, especially focusing on evaluating tolerance limits to products and waste from the oil industry. Specific objectives include conducting experiments with the fish Atherinella brasiliensis *and assessment of effects on embryos and larvae development, as well as evaluating the effects of substances on the reproduction and life cycle of the deep-sea polychaete* Ophryotrocha *sp. Expected results include the establishment of protocols for ecotoxicological tests in deep-sea marine environments and understanding the effects of oil and gas industry products on the fish embryo and larvae development. The relevance of the project lies in contributing to the development of standards and protocols for environmental impact assessment.*

Keywords:
Ecotoxicology, *Atherinella brasiliensis, Ophryotrocha* sp.

1 Introduction

Ecotoxicology is crucial for assessing environment quality and the effects of substances on organisms (Arguello-Pérez et al., 2019), as required by environmental laws (CONAMA Nos 393/2007, 430/2011 e 454/2012). The results determine compliance with quality standards, guide approval, registration, selection, proper use, and disposal, and influence preventive measures, such as the choice of low-toxicity products and efficient effluent treatment technologies.

Ecotoxicological tests characterize environmental impacts, considering synergistic effects of complex mixtures or isolated parameters on organisms (Di Marzio et al., 2018). They encompass exposures to different sample concentrations and assess acute or chronic effects compared to a control. These tests can be conducted in the field or in a laboratory, following ABNT standards or international references. The diversity of organism responses to substances necessitates the use of various species in environmental risk assessment studies (Rand et al., 1995).

1.1 Objectives

General Objective

This research project aims to implement and/or refine procedures and conduct ecotoxicological tests using different marine species to assess tolerance limits to various products and discharges from the oil and gas industry.

Specific Objectives

(1) Conduct experiments to improve the *Atherinella brasiliensis* maintenance procedures and implement methodologies to assess the effects on the embryos and larvae development;

(2) Evaluate the effects of different substances on the reproduction and life cycle of the deep-sea polychaete *Ophryotrocha* sp. (Annelida, Dorvilleidae).

2 Research Methodologies

Infrastructure

LABTOX will offer a controlled laboratory environment with temperature and photoperiod regulation, along with an aeration system and a decontamination facility. A refrigerated chamber will be employed for cultivating and conducting experiments with deep-sea polychaetes. The dilution water used will consist of natural seawater collected in Cabo Frio (RJ), filtered through a 5 µm mesh.

Organisms sampling and laboratory maintenance

Adults of *A. brasiliensis* will be captured in the shallow region of an estuary and transported to the laboratory in thermal containers equipped with aeration and water from the collection site. In the laboratory, they will be kept in 100-liter aquariums equipped with proper filtration system. The polychaete *Ophryotrocha* sp., which will be used in this study, was collected in association with the deep-sea coral *Desmophyllum pertusum* in 2018 and has since been cultivated at LABTOX in 20-liter glass aquariums containing filtered natural seawater, in a cold room at 12°C in the dark.

Ecotoxicological tests

Acute and chronic tests with effluents from the oil and gas industry will be conducted with the target organisms. Lethal and sublethal effects on these organisms will be monitored. Test conditions will be established based on pre-tests to determine the concentrations to be tested. Additionally, acute (96 hours) and chronic tests using DSS, zinc, and copper as reference substances for ecotoxicological tests will be conducted. These reference substance tests aim to establish intra-laboratory control, serving as a positive control test. This will allow for obtaining a sensitivity baseline for the tested organisms and comparing sensitivity among different species used as test organisms.

Data analysis

The results will be analyzed to determine the initial lethal concentration for 50% of the organisms tested at 48 and 96 hours (LC(I)50; 48 and 96 h) with a 95% confidence interval. Abbott's correction will be applied when necessary to correct abnormality or mortality in the control group. Mean LC50 values and coefficients of variation (CV %) will be calculated. Other statistical analyses will be used to compare lethal and sublethal effects among different treatments.

3 Expected Results

Enable *Ophryotrocha* sp. as a test organism for deep-sea environments, establishing cultivation and testing protocols, as well as a reference substance control chart. Gain a better understanding of the effects of oil and gas industry products on the embryo larval development of *A. brasiliensis*, and develop assay protocols and a reference substance control chart.

4 Relevance

This project will enable the development of protocols and methodologies for ecotoxicological tests, particularly focused on deep-sea, estuarine, and coastal marine environments. These tools are essential for assessing and mitigating the impacts of the oil and gas industry on these ecosystems, providing a solid foundation for informed decisions, and promoting environmental sustainability.

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Critical Review of the Current Status of Energy Transition, Industrial Sectors, and Sustainable Development Goals

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Abstract:
Climate actions (SDG-13) aim at limiting global warming by targeting carbon emissions reduction. With the energy industry recognized as a significant CO_2 emitter, SDG-13 policies mostly translate into energy transition to renewables (SDG-7) and the electrification of end-users, both energy-demanding sectors and society (cities, households, and mobility). The present work critically reviews the literature by applying The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method considering the interconnections between SDGs and emitter sectors in the context of energy transition. Additionally, was considered for this assessment only articles and review articles delimited by the years 2016 until February 2023 were considered for this review. As evidenced by the number of citations of the reviewed works, decarbonization, and electrification have multiple realization paths and impact the industrial metabolism, SDGs are interconnected with synergies and trade-offs. Prioritization of SDGs by policymakers is necessary for resilience and robustness in aching climate goals within a systems dynamics approach. This critical review identifies niches in decarbonization and electrification, enlightening the industrial metabolism under the lens of SDGs.

Keywords:
Climate policies, energy policies, energy transition, industrial metabolism, sustainable development goals.

1 Introduction

Endorsed by the United Nations in 2015, the 17 Sustainable Development Goals (SDGs) is a worldwide directive to "action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity" (UN, S.D.). The 17 SDGs are inherently interconnected, so interventions in one sector trigger other effects. SDG-7, SDG-8, and SDG-13 illustrate a complex interplay of environmental and socioeconomic issues. SDG-7 (Affordable and Clean Energy) fosters the developing and disseminating renewable and sustainable energy resources. By targeting to limit energy carbon intensity, it enforces SDG-13 (Climate Action), which focuses on urgent measures to combat climate change and its impacts. These environment-oriented goals (SDG-7 and SDG-13) act on industry and society, modifying their economic and social performances, and impacting SDG-8 (Decent Work and Economic Growth). Such interconnected system – environment, economy, and society – mimics a metabolism named Industrial Metabolism. Several decarbonization alternatives are underway, from the retirement of fossil-based feedstocks and growth of the share of renewables in the energy matrix to innovative technologies. Carbon Capture and Storage (CCS) is becoming crucial to closing the decarbonization gap by reducing emissions from fossil-fueled power plants (new and existing) and hard-to-decarbonize sectors. Although the perception of SDG interlinkage has been explored in the literature in a broader context – e.g., Burke and Melgar (2022), policymakers have mostly overridden the remaining UN SDGs and driven transitions majorly weighted by

SDG-13. This work surveys the literature to identify the impacts, synergic and antagonistic, of climate policy on energy transition and how SDGs are co-adjuvating in the energy transition. Summing up, answer the following question: How is the energy transition coping with the SDGs?

Additionally, it is worth noting that the present work is an extraction of the author's Ph.D. thesis, and the complete published review article can be read at Boa Morte *et al.* (2023).

2 Research Methodology

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) is used to review and identify the most relevant scientific literature. PRISMA is an evidence-based minimum set of items for reporting in systematic reviews and meta-analyses (Ortiz-Martínez *et al.,* 2019). PRISMA items under the specificities of the present work comprise: (i) Protocol and registration; (ii) Eligibility criteria – The eligibility criteria are based on the Sustainable Development Goals; (iii) Information sources – The bibliographic search includes articles and reviews from the Scopus database published from 2016 to 2023; (iv) Search – The keywords applied in the Boolean strings aim to evaluate the proposed question (industry OR sector OR activit* OR company* AND (safety OR storage) AND (decarbonization OR “carbon capture” OR electrification) AND SDG); (v) Classification – Information in each article is extracted from Title, Abstract, and Keywords; and (vi) Analysis – The information extracted is analysed with the content of the most relevant articles in each sector and each SDG.

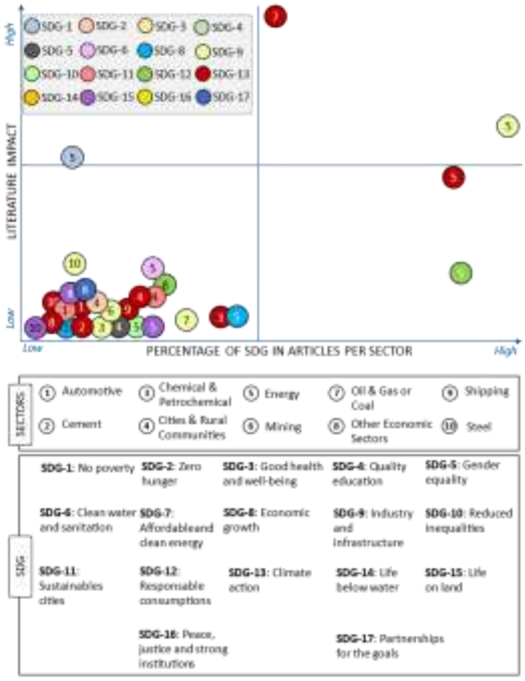
3 Findings and Discussion

The PRISMA method results in 486 documents that were identified for the keywords. Application of the eligibility criteria eliminated 376 works; 2 were not written in English; 7 were not in the year limitation; and 367 were excluded from the final analysis for not being neither articles nor reviews).

Among innovations in the electrification of the automotive sector is the implementation of hydrogen Fuel-Cell Vehicles (FCV), a demand-side decarbonization requiring public policies. Another potential benefit brought to Electric Vehicle (EV) architecture is the dual Hybrid Energy Storage System (HESS). Dual HESS-EV offers a driving range-per-cost ratio higher than the best single HESS EV solution. On the other hand, Nhuchhen et al. (2022) evaluate the electrification and decarbonization potential of the cement sector with oxy-combustion coupled to CCS using either oxygen from air separation units (ASUs) or byproduct oxygen from water electrolysis to generate hydrogen fuel. However, the cement sector must consider the reliability of the supply and the economic benefit hydrogen producers require from their byproducts. Furthermore, the oil and gas *(O&G) or Coal* sectors rely strongly on CCS. Bach (2017) states that traditional patterns of interaction between the *O&G* industry and the climate regime have been disrupted as firms joined or created climate governance initiatives. The sector is exploring a low-carbon role, relying on technologies (e.g., CCS), economic instruments (e.g., carbon pricing), and process optimization (e.g., flaring reduction and energy efficiency). However, the industry must confront its historical responsibility for climate change and its future role in a low-carbon world; more apparent roles and responsibilities are needed (Bach, 2017). On the side of *Cities and Rural Communities,* it is observed heavily invest in solar panels, hydropower, and wind energy.

Figure 1 displays the Materiality Matrix condensing survey. It considers the number of citations for each article (literature impact) and the percentage of articles dealing with a given SDG and sector. From the results presented, the energy transition is biased by SDG-13 and SDG-7, suggesting that the other objectives have been neglected despite their recognized impact on society.

Figure 1. Materiality Matrix to answer the question *"How is the Energy Transition Coping with the SDGs?*". Literature Impact & Articles per SDG and Sector. Assuming that SDG-7 is related to all sectors, once these assessment is related to Energy Transition.



4 Conclusion and Further Research

The work applies a critical literature review from selected industry stakeholders targeting to identify interconnected reactions to climate policies. Also, hidden consequences from those policies in other SDGs are evaluated, and prioritized SDGs are identified in large-scale, hard-to-decarbonize sectors where electrification finds barriers. The interconnection of industries and society in a metabolic-like structure shows missing bridges among climate, social, and environmental objectives when the following question is investigated: *How is the energy transition coping with the SDGs?* The climate and energy policies that have driven the substitution of fossil-fuel-based energy for renewables follow SDG-13 and SDG-7, as most references reviewed show.

5 Acknowledgment

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EFFECT OF PET FIBERS FROM MOORING ROPES OFFSHORE POST-CONSUME ON MORTAR CONSISTENCY INDEX

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Abstract:
By 2030, an average annual decommissioning of almost 100 offshore oil and gas assets is expected, surpassing 150 between 2030 and 2040, due to the large number of platforms around the world and the near deadline until the end of their useful lives (IEA, 2022). The decommissioning of offshore platforms is a complex process, which should aim at the sustainability of the process, which includes the management of their plastic waste (Nicolette et al., 2023). One of the materials resulting from these structures are the mooring ropes, consisting basically of polyester fibers based on polyethylene terephthalate (PET), which can reach more than 40 km and 30 tons of cable per platform (de Castro et al., 2022). Cables have high added value, encouraging their use as a raw material, with a wide variety of applications (Sudaia et al., 2018). This study aims to analyze the properties of PET fiber from mooring ropes, added to the mortar, in order to improve its performance and obtain more relevant characteristics such as: workability, mechanical behavior, resistance and susceptibility to cracking, besides being a sustainable alternative for the disposal of this material.

Keywords: Mortar, Waste, PET Fibers, Workability.

1 Introduction

The decommissioning of oil platforms in deep waters (offshore) is a process that occurs in the final stage of an oil and natural gas exploration and production project, after 25 years of exploration of the well. Decommissioning is the process of buffering and abandoning wells, where production platforms are decommissioned and taken to the docks, where they are cleaned and dismantled. Some parts of the platforms are abandoned at sea to form artificial reefs (DELGADO et al., 2021), others are reused, but some do not have a suitable destination (MARTINS, 2015). In 2018, the National Agency of Petroleum, Natural Gas and Biofuels (ANP) estimated in Brazil the existence of 158 offshore production facilities, 24 drilling rigs and the forecast of installation of 18 new production units by 2022 (MACEDO, 2018). In addition, according to the ANP, 41% of offshore projects in the country in 2018 had been in operation for more than 25 years, while 44% had between 15 and 25 years of operation (MACEDO, 2018). With the aging of offshore oil and gas fields in operation, Brazil has entered the era of decommissioning, once mature fields have reached the end of their economic cycle or ceased to be productive (REBELLO, 2019).

Among the different types of offshore production facilities, FPSO-type floating platforms have anchor lines composed of synthetic polyester cables. These cables are composed of thousands of poly (ethylene terephthalate) filaments, or PET, joined in subcables, coated by filter element and braided cover. The mooring ropes that have as raw material the polyester based on PET, because they are not biodegradable can not be discarded on the seabed or used in artificial reefs (SUDAIA et al., 2018). In addition, because they have been subjected to tensile efforts for years, the reuse of these cables on a new platform is not indicated. The resolution of the National Agency of Petroleum, Natural Gas and Biofuels that provides for the decommissioning of oil and natural gas exploration and production facilities, in its definition of decommissioning of facilities explanation must highlight the research design, collection of data, and analytical methods adopted or to be adopted in the research includes the proper disposal of materials, waste and tailings, which shows the importance given to the environmental theme (ANP, 2020). In short, with the decommissioning of offshore platforms in the country, in the coming years a high amount of synthetic polyester cables will be discarded, which makes it urgent to study ways to reuse filaments of these cables.

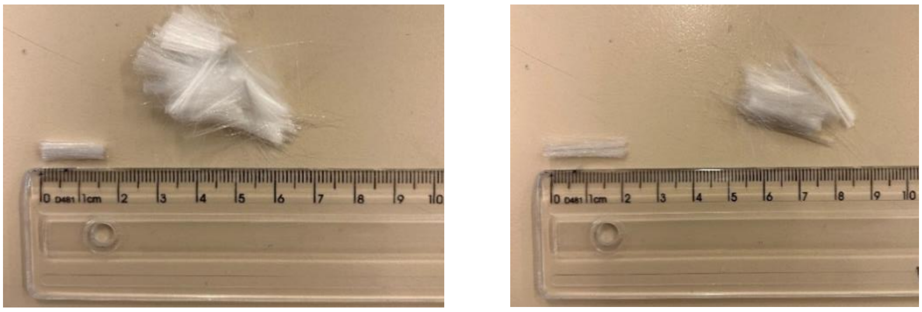
The use of waste in civil construction has become an attractive alternative for its final destination and protection of the environment, occurring mainly through recycling processes (NIBUDEY et al., 2013). An interesting way for the reuse of polyester cable filaments is as fibrous reinforcement in cementitious mixtures, since the low deformation capacity normally presented by these materials can be mitigated by the incorporation of PET fibers, due to their stress transfer bridge effect in the matrix.

Recycled plastic materials have been widely used as reinforcement for concretes and mortars, in view of their technical, economic and environmental benefits (BOINY et al., 2016). In the literature there are studies in which PET fibers were adopted as aggregates in concrete (OLIVEIRA et al., 2020) and as fibrous reinforcement in microconcretes (MAGALHÃES and FERNANDES, 2015; TEIXEIRA and BALTHAR, 2023). Oliveira et al. (2020) evaluated the effect of anchor cable PET residues on concrete water compression and absorption. The reference concrete was composed of cement, sand, gravel and water (w/c = 0.55) and the sand was replaced by PET fibers at 5% and 10% contents. At 28 days, the concretes reached the strengths of 25.7 ± 1.5MPa (REF), 29.0 ± 2.4 MPa (5% fibers) and 18.5 ± 0.7 MPa (10% fibers). Total water absorptions were 6.3% (REF), 5.0% (5% fiber) and 8.1% (10% fiber). The authors attributed the drop in resistance by the use of fibers to the degradation of this material in an alkaline environment, which is related to the geometry of the fiber, the degree of dispersion and fibermatrix adhesion (OLIVEIRA et al., 2020). Magalhães and Fernandes (2015) evaluated the mechanical behavior of microconcretes produced with PET fibers produced by extrusion of bottle flakes, with 14 μm in diameter, 32 mm in length and specific mass of 1430 kg/m^3. At 28 days of age, the compressive strength was 39.8 MPa (reference, without fibers), 37.7 MPa (1.0% fiber), 17.7 MPa (1.5% fiber) and 18.6 MPa (2.0% fiber). The fibrous mixtures showed post-cracking behavior in the flexural tensile tests, while the reference mixture suffered rupture with the opening of the first crack. According to the authors, although the losses in compressive strength were up to 55.5%, the benefits observed in the behavior under flexion showed that the use of PET fibers is promising for the production of sustainable cementitious materials for semi-structural applications (MAGALHÃES and FERNANDES, 2015). Teixeira and Balthar (2023) adopted PET fibers obtained from an anchor cable used on an offshore platform for 10 years. The reference microconcrete presented the following material consumptions: 453.06 kg/m^3 (CPV-ARI cement), 189.43 kg/m^3 (silica fume), 269.47 kg/m^3 (ceramic microsphere), 448.08 kg/m^3 (water) and 11.73 kg/m^3 (dispersant). The fibers were 10 mm long, 28.9 μm in diameter (average of three measurements in the length of 22 filaments) and average tensile strength of 1014 MPa. The reference (REF) was reinforced with PET fibers by substitutions of all materials in the volumetric fractions of 0.5% (PET0.5) and 1.0% (PET1.0). The authors verified the damage caused by the fibers in the workability, since the area measured in the mini-slump test of the reference mixture was 76.6 ± 7.6 cm^2, with reductions in the fibrous mixtures of 61.2% (PET0.5) and 81.8% (PET1.0). Reductions in compressive strength were also observed between the reference and the fibrous mixtures, which were equal to 26.5 MPa (REF), 15.4 MPa (PET0.5) and 13.7 MPa (PET1.0). The modulus of elasticity showed the same behavior, with results of 7.9 GPa (REF), 6.4 GPa (PET0.5) and 5.9 GPa (PET1.0). The authors concluded that although the fibers have caused losses in some properties, the resistances achieved were enough for the manufacture of structural sealing panels and the use of PET fibers promoted benefits to the deformation capacity (TEIXEIRA and BALTHAR, 2023).

In order to seek more sustainable alternatives for the destination of mooring ropes of offshore platforms consisting of polyester fibers based on polyethylene terephthalate (PET), this study arises with the purpose of exploring the potential of PET as fibrous reinforcement in mortar. To date, the effect of PET fibers on the workability of a reference mortar (without fibrous reinforcement) has been investigated, in different volumetric fractions (0.25%, 0.50%, 0.75% and 1.00%) and two distinct lengths (15 mm and 20 mm). The experimental program was carried out at the Núcleo de Ensino e Pesquisa em Materiais e Tecnologias de Baixo Impacto Ambiental na Construção Sustentável (NUMATS – POLI/COPPE/UFRJ).

2 Research Methodology

The following materials were adopted for the manufacture of the mortars: CPV-ARI cement (Lafarge-Holcim), washed river sand, water from the RJ supply system and PET fibers. For the production of the fibers, a piece of cable had its outer layer (layer and filter element) cut, a subcable of its interior was removed and, finally, its filaments were cut in lengths of 15 mm (Figure 1a) and 20 mm (Figure 1b). The two types of fibers obtained were stored separately.



(a) (b)

Figure 1 – Aspects of the fibers after the cuts: (a) Fibers with 15 mm in length; (b) fibres 20 mm long.

2.1 Characterization of Materials

The following cement properties were evaluated: chemical composition, by semiquantitative analysis by X-ray energy dispersive fluorescence spectroscopy; loss to fire, in muffle furnace, according to the procedure of ABNT NM 18 (2012); particle size distribution, by laser particle size; specific mass, by helium gas pycnometry. The sand was characterized as to specific mass and water absorption, according to the procedure of ABNT NBR 16916 (2021), and particle size distribution, according to the methodology described in ABNT NM 248 (2001). The PET fibers were evaluated in relation to the specific mass by pycnometry, diameter measurement by scanning electron microscopy (SEM), in addition to direct tensile strength, with preparation of the samples according to the methodology of ASTM C1557 (2014).

2.2 Dosage, Preparation and Characterization of Mortars

The ratio between the cement and sand masses of the reference mortar (REF) was 1: 3 and the water-cement ratio was 0.7. The consumption of the reference mortar materials was as follows: 452.20 kg/m^3 (cement), 1356.60 kg/m^3 (sand) and 316.54 kg/m^3 (water). Fibrous mortars made with fibers of 15 mm in length were studied and, in addition, fibrous mortars produced with fibers of 20 mm in length were also studied, in different volumetric fractions for both lengths. The proportions between the granular materials and the water were maintained and the fibers partially replaced all the materials in volumetric fractions of- 0.25% (M15-0.25 and M20-0.25), 0.50% (M15-0.50 and M20-0.50), 0.75% (M15-0.75 and M20-0.75) and 1.00% (M15-1.00 and M20-1,00). In the continuity of the research will be evaluated the mechanical performances of the two sets of fibrous mortars to verify the length of fibers that will provide the greatest anchorage with the matrix and, consequently, the best performance regarding toughness.

The mortars were prepared according to the procedure of the ABNT NBR 16541 (2016) standard, in a mortar with a capacity of 5 liters (Figure 2a). The mortar mixing procedure was performed according to the following steps:

- Weighing of granular materials in a plastic bag and weighing of water in a beaker;
- Insertion of granular materials in the mixer bolw;
- Realization of the mixture at low speed (V1) for 30 seconds, with the inclusion of 75% of the volume of water in the vat during the first 10 seconds and of the fibers in the remaining time;
- Change of speed to high (V2) and maintenance of the mixture for 60 seconds;
- With the equipment turned off, scraping the bowl and beater shovel;
- Re-establishment of the mixture at low speed with the addition of the remaining water (25% of the volume) for 10 seconds and maintenance of the mixture until 60 seconds.

The mortars were characterized in the fresh state in terms of workability, through the consistency index test, performed according to the procedure of the ABNT NBR 13276 (2016) standard. After preparation of each mortar, the assay was performed in triplicate according to the following methodology:

- Cleaning of the table and cone trunk, followed by the positioning of the conical mold in the center of the table (Figure 2b);
- Placement of the mortar in the cone trunk in three successive layers with approximately equal heights, with the application of 15, 10 and 5 strokes with a socket in each layer, respectively;
- After the total filling of the mold by the mortar, performing the scraping of the surface with a metal ruler;
- Removal of the mold by raising it vertically and activation of the crank of the table, so that 30 movements of ascent and descent are carried out uniformly for 30 seconds;
- Measurements of three distinct diameters of the scattered mortar (Figure 2c).

(a) (b) (c)

Figure 2 – Preparation and characterization of mortars: (a) Mortar; (b) Table for consistency index with mold and socket; (c) Indications of diameter measurements.

3 Presentation and Analysis of Results

3.1 Characterization of Materials

The chemical composition of the cement and its loss to mean fire (3 samples) and standard deviation are presented in Table 1. The cement is composed mainly of CaO and SiO_2 and meets the criteria of ABNT NBR 16697 (2018) in relation to the contents of PF and MgO (less than or equal to 6.5%) and SO_3 (less than or equal to 4.5%). The particle size distributions of cement and sand are shown in Figure 3 and Figure 4, respectively. The granular materials presented the following minimum (D_{10}), average (D_{50}) and maximum (D_{90}) diameters, with the respective coefficients of variation: D_{10} = 2.71 ± 0.01 µm, D_{50} = 17.07 ± 0.06 µm and D_{90} = 42.47 ± 0.08 µm (cement); D 10 = 0.21 ± 0.01 mm, D50 = 0.70 ± 0.02 mm and D90 =2.11 ± 0.03 mm (sand). The specific mass of the cement was equal to 3080.6 ± 3.5 kg/m^3. The sand presented the following specific masses (ME): 2386.4 ± 15.0 kg/m^3 (dry condition); 2442.3 ± 18.0 kg/m^3 (dry surface saturated condition); 2527.8 ± 55.0 kg/m3 (real ME, according to ABNT NM 52, 2009). The sand presented water absorption equal to 2.34 ± 0.13 %.

Table 1 – Chemical composition of cement.

Material	SiO_2	Al_2O_3	Fe_2O_3	CaO	K_2O	SO_3	SrO	TiO_2	PF
CPV-ARI	12,57	3,54	4,10	68,74	0,46	3,55	0,32	0,26	6,34 ± 0,05

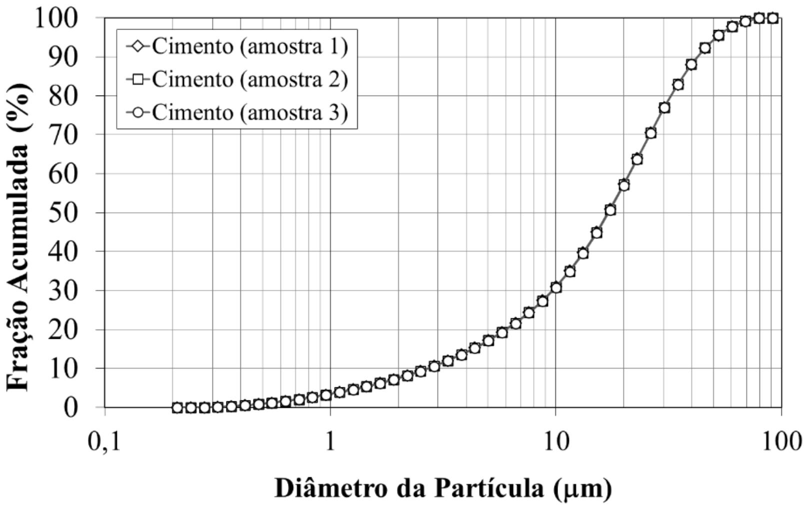


Figure 3 – Cement particle size distribution.

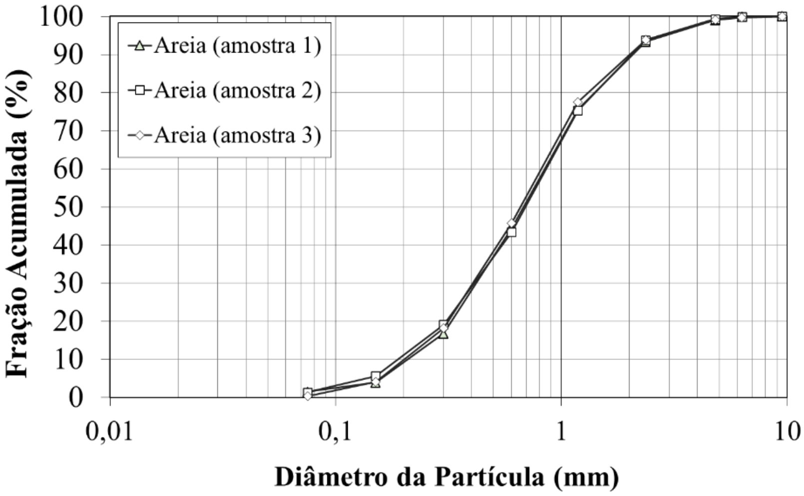
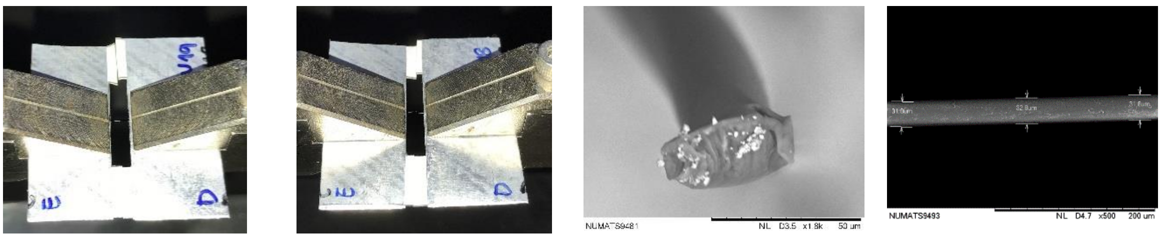


Figure 4 – Particle size distribution of sand.

The specific mass of the PET fibers was equal to 1445.0 ± 0.9 kg/m^3. The mean diameter of the fibers, measured at 3 points along the length in 22 filaments and the standard deviation, were 30.8 ± 1.6 µm. The result is in line with Miranda (2008), who obtained the average diameter of 30.8 ± 0.8 µm in filaments of a cable used for 7 years and also with Teixeira and Balthar (2023), whose average diameter of filaments of a cable used for 10 years was equal to 28.9 ± 1.4 µm. The mean tensile strength of 14 PET fiber samples and the coefficient of variation were equal to 1033 ± 195 MPa (18.8%). The traction obtained is in line with Teixeira and Balthar (2023), whose PET fibers presented resistance of 1014 MPa. The aspects of the fiber before and after the traction test are illustrated in Figure 5a and Figure 5b, respectively. The cylindrical morphology of the fiber can be seen in Figure 5c (SEM, magnification 1800x), while the measurement of the diameter is shown in Figure5d (SEM, magnification 500x).



(a) (b) (c) (d)

Figure 5 – Fiber aspects: (a) Intact fiber; (b) ruptured fiber; (c) fiber SEM (cylindrical shape); (d) SEM of the fiber (diameter).

3.2 Characterization of Mortars

The aspects of mortar consistencies are presented in Figure 6a (REF), Figure 6b (M15-0.50), Figure 6c (M20-0.50), Figure 6d (M15-1.00) and Figure 6e (M20-1.00). The values of the consistency indices of the mean mortars and the respective standard deviations (SD) and coefficients of variation (CV) are presented in Table 2. According to the results, the fibrous reinforcements with both fiber lengths impacted on reductions in scattering of up to 41%, when comparing mortars M20-1.00- and REF.

However, it is possible to observe that the mixtures did not present segregation or exudation even for the highest fiber fractions, which demonstrates the workability and, consequently, the ease to be molded only with mechanical vibration.

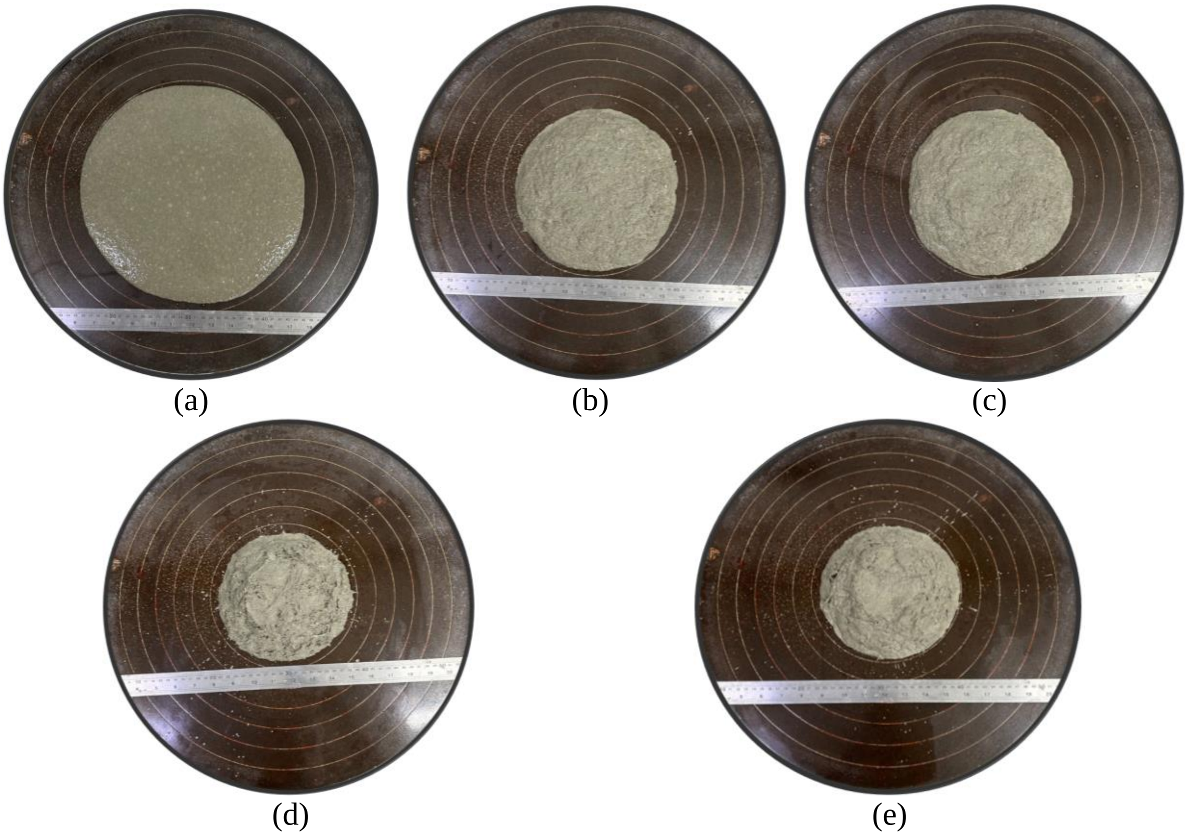


Figure 6 – Aspects of the scattered mortars: (a) REF; (b) M15-0.50; (c) M20-0.50; (d) M15-1.00; (e) M20-1.00.

Table 2 – Mortar consistency indices.

Mixture	Fiber Length (mm)	Consistency Index ± SP (mm) / CV
REF	-	309 ± 1,0 / 0,3
M15-0,25	15	256 ± 7,7 / 3,0
M15-0,50		228 ± 3,5 / 1,5
M15-0,75		207 ± 2,5 / 1,2
M15-1,00		188 ± 6,3 / 3,4
M20-0,25	20	258 ± 1,7 / 0,6
M20-0,50		231 ± 6,7 / 2,9
M20-0,75		206 ± 4,2 / 2,0
M20-1,00		182 ± 1,7 / 0,9

4 Conclusion

The purpose of this work is to explore the potential of PET from mooring ropes used on an offshore platform, as fibrous reinforcement in mortar. In the experimental studies carried out to date, it was possible to investigate the effect of PET fibers on the workability of a mortar, by determining the consistency index according to NBR 13276/2016. The method was applied to the reference mortar (without fibrous reinforcement), in different volumetric fractions (0.25%, 0.50%, 0.75% and 1.00%) and two different lengths (15 mm and 20 mm), with this, we analyze the viscosity of the mixture (spreading diameter) and the tendency to segregation. The results showed that there was a reduction in the spreading of mixtures with fibrous reinforcements, when comparing mortars M20-1.00 and REF this reduction was up to 41%. The mixtures did not show segregation or exudation, even in the highest fiber fractions, demonstrating their workability and, consequently, the ease of being molded with just mechanical vibration. As the research continues, the mechanical performance of the two sets of fibrous mortars will be evaluated to verify the length of fibers that will provide the greatest anchorage with the matrix and, consequently, the best performance in terms of tenacity. The use of polyester fibers from mooring ropes of maritime platforms as partial replacements for mineral aggregates in mortars, consists of an alternative solution for reusing this waste, and can be applied in other segments of economic activities, such as Civil Construction, in addition to contribute to reducing environmental impacts.

5 Acknowledgment

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Study the link between the level of automation and the levels of sustainability, to manage efficiently the facilities system of a building

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Abstract:
The integration of technological advances, such as the automation of processes to the built environment are required to increase the levels of sustainability. Nowadays, the studies integrating both concepts still needing further research to take advantage of the computational advances. This research pursues to link automation and sustainability to diminish the negative impacts of the building industry; for that reason, a methodology is expected to be created for integrating both concepts, in this case, studying the facilities systems of a building during its operational stage. The results awaited include the production of 5 scientific papers studying the different phases of the research. With this, an enhancement of the sustainability levels in the built environment are expected as contributions to the science, as well as an optimized utilization of the automation strategies that can be applied to buildings.

Keywords:
Digital Twin, BIM, Automation, Sustainability, Facilities Systems.

1 Introduction

The combination of automated systems in the built environment present deficiencies, especially in the transference of data for real-time simulations between the physical and the digital models (Yoon 2022). Also, representing the Facilities System in a BIM environment is difficult since there is not a common data environment, avoiding a correct management (Soliman et al. 2022; Marzouk and Zaher 2020). Likewise, there is a lack of BIM applications for estimating the service life of the facilities systems in a building during its operational stage (Jing et al. 2019; Yan et al. 2020). Lastly, managing digital and physical assets demands a high capacity to handle data for a proper synthesis; however, there is a lack of intelligent control algorithms; difficulties to integrate devices using IoT with logistics; deficiencies in correct programming; absence of common standards and governability; and insufficient correct solutions (Zhang et al. 2021; Shikhli et al. 2022).

It has been identified that several automated solutions do not lead to sustainable practices, it could be caused by the fact that the concepts of automation, creation of digital twins, BIM modelling, creation of smart algorithms using artificial intelligence, virtual reality and so on, show a lot of troubles since they still on development. Then, this research question is: to what extent the automation strategies in facilities systems of a building lead to sustainable solutions for the decision-making process during its operational stage? Considering this, the objective stated for this research is to study the link between the intelligence of smart devices by using algorithms and optimization formulas, with the level of automation presented in different devices, to obtain high levels of sustainability when managing the facilities systems of a building during its operational stage.

This research is necessary since there is a need to increase the levels of sustainability worldwide; the construction industry is one of the most contaminant industries in the world, and the buildings are responsible for the emission of greenhouse gases and the consumption of resources. The facilities systems are one of the less studied building systems in terms of automation and intelligent management and control; if studied, an optimized management would bring difference in the operational and maintenance regime, preventing the systems to fail by detecting problems, and increasing its service life. The advances in technology and the crescent popularity of automation sets a scenario where it is possible to think that automated solutions can be implemented in the construction industry to improve the current reality.

2 Research Methodology

To accomplish this research, the first step is to execute a literature review to understand the matter; then, a proposal of methodology is expected to stablish a relationship between automation and sustainability concepts; and finally, a validation process to determine the correctness of the methodology proposed.

2.1 Literature Review

In the first phase, several articles would be evaluated to obtain the most valuable knowledge about sustainability, automation, digital twin, facilities management, and BIM environment, and to understand how they are related, as accomplished by (Feng and Wan 2022; Cho and Choi 2020). Then, it would be necessary to organize the information to develop the integration between the abovementioned matters.

2.2 Proposal of Methodology

With the information already organized, the next step is to create a methodology, which would validate the integration between sustainability, automation, digital twin, facilities management, and BIM environment.

2.3 Validation Process

The validation process would be obtained by applying the proposed methodology in a real building, focusing on the water and energy systems; also, the development of its digital twin, which will be necessary to execute the studies of measuring the levels of sustainability and automation. In this case, a proper process of digitalization would be accomplished to model the facilities system of the existent building. It is expected the utilization of drones, cameras, scanners, thermometers, sound meters, and so on. It will be employed the software REVIT as the environment to develop the digital twin.

A common platform of integration within the BIM environment will be utilized to achieve an accurate communication between the physical and the digital models. With the “current model” properly modelled, the next step is to determine the sustainability and automation levels. The automation level will be obtained by identifying how many automated solutions exist for managing the facilities systems in the building; and the sustainability level is going to be determined by the following the methodology of Life Cycle Sustainability Assessment, applied to the facilities systems.

It is expected to rectify the management process of the current model by applying artificial intelligence algorithms to improve the performance of the facilities systems. The automation and intelligence growths when more smart solutions are included in the process of management.

Finally, it is necessary to observe again the levels of automation, intelligence and sustainability accomplished, this time in the “new model”; it would be necessary to compare the results with the levels in the previous model, to prove if it is possible to obtain real facilities systems presenting higher automation and sustainability levels, greater than the earlier ones. To understand graphically the methodology expected to be applied in this research, a flowchart was constructed and shown in Figure 1.

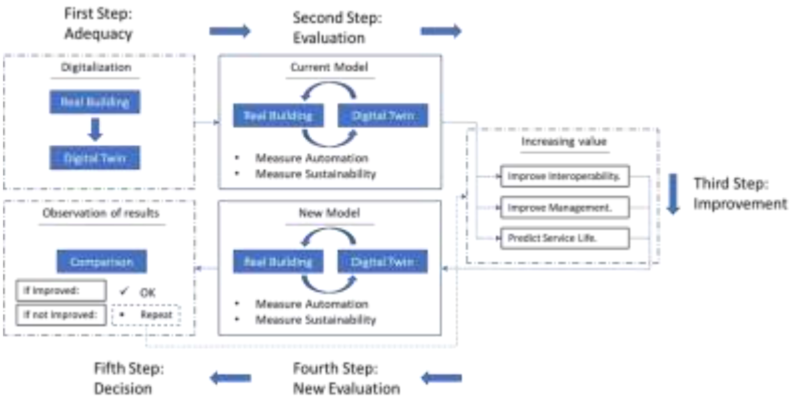

Figure 1: Expected methodology of the research.

3 Expected Results

First and second steps in the Figure 1, are part of the "Evaluation" stage. It is expected that this stage finishes in February 2024, and would lead to the production of two papers: the first one is a systematic literature review; the second one, to propose the methodology of interoperability. The third step is part of the "improvement" stage. It is expected to finish in August 2024, and that they yield two more papers: one to improve the performance of the facilities system by using artificial intelligence; and the other attending the prediction of the service life of the facilities system of the building. Finally, the fourth and fifth steps are part of the "Results" stage. In here, the obtention of the outcomes from the abovementioned measurements, expected to end by December 2024 would lead to the execution of one more paper comparing and analysing the results.

4 Acknowledgment

This study is financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES).

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Synergizing Sustainability and Smartness: Integrating Life Cycle Sustainability Assessment with Digital Twins for Buildings

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Abstract:
In recent years, the construction industry has increasingly recognized the critical link between construction projects and the three fundamental sustainability pillars: economy, society, and environment. Achieving sustainable outcomes in construction projects has become a global imperative, but it presents critical challenges. Life Cycle Sustainability Assessment (LCSA) emerged as a comprehensive methodology rooted in life cycle thinking, comprising the three sustainability pillars. However, Building LCSA is typically focused exclusively on the early design stages and does not consider real-time information, limiting the decision-making process of building projects. This research addresses these challenges by exploring the synergies between LCSA and Digital Twin (DT) technology. DTs provide precise virtual models mirroring the physical asset's properties, conditions, and behaviors throughout its lifespan. By merging LCSA with DTs, this study aims to enhance the triple-bottom-line sustainability framework in the built environment. This investigation seeks to fill a critical research gap, offering practical strategies to combine LCSA and DTs for sustainable building design and operation.

Keywords:
BIM, Digital Twin, Life Cycle Sustainability Assessment, Sustainable Construction.

1 Introduction

The literature has widely discussed a strong association between the construction industry and the three sustainability pillars: economy, society, and environment (Goh et al., 2020). Achieving sustainable outcomes in construction projects has thus become a primary concern for professionals and scholars worldwide. However, developing sustainable building projects considering a triple-bottom-line approach is not without its obstacles, both in research and practice; managing a vast amount of data is necessary when considering all functional and technical requirements of a built asset during the assessment (Figueiredo et al., 2021).

In this vein, the Life Cycle Sustainability Assessment (LCSA) started to be implemented in the construction industry. This thorough methodology is based on the life cycle thinking approach that considers that all phases in a product's life cycle impact the environment and have socio-economic repercussions. LCSA is the result of combining three methodologies (Llatas et al., 2020): Environmental Life Cycle Assessment (E-LCA), Social Life Cycle Assessment (S-LCA), and Life Cycle Costing (LCC). Unfortunately, the three pillars of sustainability have different maturity levels when it comes to databases related to construction, which makes it challenging to integrate the three approaches and hinders the broad implementation of LCSA.

Over the past few years, researchers have utilized this approach as a decision-making tool, particularly during the initial phases of a building's design (LLatas et al., 2022). Nonetheless, when considering its use throughout the whole building's life cycle, a new challenge arises regarding the need for more temporal information in the assessments. It is worth noting that the existing methods for LCSA lack a dynamic approach, which overlooks crucial factors that change during the building's life cycle, such as the decline in material quality, fluctuating energy usage, and technological advancements (Francis & Thomas, 2022). As a result, building sustainability assessments are typically inaccurate.

In this context, combining LCSA and Digital Twin (DT) seems appropriate. A DT is a precise virtual model that imitates the physical asset's current properties, condition, and behavior throughout its lifespan (Haag & Anderl, 2018). In the construction industry, the benefits of implementing DTs range from real-time data visualization to constant monitoring of assets and the advancement of self-learning capabilities. A building DT can be used from the beginning of the design project throughout the whole life cycle of the built asset. During the operation phase, both physical and digital assets coexist and exchange data and information (Figueiredo, Hammad, et al., 2023).

Therefore, this research explores the potential of enhancing Building LCSAs through model-based approaches and data-driven solutions. This objective seeks to fill the existing research gap related to the application of building LCSAs that occur mainly during the early stages of a building design and are typically based on data from historical series, which hinders the use of LCSA for rapid corrective actions on a project. Specifically, this work aims to investigate the role of DTs in enhancing the triple-bottom-line sustainability framework in the built environment, exploring practical ways of combining LCSA and DT to improve decision-making during buildings' pre-construction, construction, and post-construction phases.

2 Research Methodology

A comprehensive literature review of the application of LCSA and DT concepts in the construction industry is conducted, offering a scientific evolution analysis and defining the state-of-the-art of these concepts. Based on this, a solution to address the lack of integration of LCSA and DT in the construction industry is proposed, characterized by the design and development of an integration process and software architecture to be implemented in building projects. The proposal should be demonstrated and validated through the application in an actual building case study. Finally, the challenges to implementing the proposed integrative framework are evaluated, with the definition of the future exploratory directions.

3 Findings and Discussion

This work represents an ongoing exploration of the intersection between LCSA and DT within the construction industry context. Despite the early stage of this investigation, the existing gap in the literature concerning the LCSA-DT integration has been distinctly delineated. Numerous papers discovered during the literature review search mention the DT application but fail to present a thorough explanation of its implementation in building projects. Additionally, various articles utilize the term "Digital Twin" yet do not use real-time data or establish a genuine connection with the physical asset, resulting in only a digital representation of the facility rather than a genuine DT. Unfortunately, the discourse on this subject is still underdeveloped, mainly focusing on conceptual and theoretical aspects (Figueiredo, Tam, et al., 2023).

In addition to investments from the government and businesses, a shift in mindset among construction professionals and researchers is crucial for progress in this area. Much debate is still needed to move forward and apply this proposal in actual construction projects, given that the construction sector has historically been hesitant to accept technological innovations.

4 Conclusion

The discussion presented in this work set the stage for future research and implementation of dynamic LCSAs during buildings' pre-construction, construction, and post-construction phases. Still, this proposal presents several challenges. Notably, conducting a sustainability assessment of a built asset that considers all three pillars of sustainability is a difficult task that requires a thorough understanding of uncertainties and processing a large amount of data. The integration of LCSA and DT throughout the whole building life cycle may face various technical barriers. However, further research is necessary to realistically quantify the impacts generated by the construction industry, promoting a sustainable and smart built environment. Future studies will focus on developing an integrative platform and validating its use through building case studies. Investigating innovative technologies, refining assessment methodologies, and exploring real-world applications will solidify the proposed integration's potential for transformative change in sustainable building practices.

5 Acknowledgment

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PROPOSAL OF MITIGATION STRATEGIES FOR STORMWATER AND SANITARY SEWER SYSTEM FAILURES THROUGH URBAN WATER MODELING IN THE MUNICIPALITY OF MARICÁ

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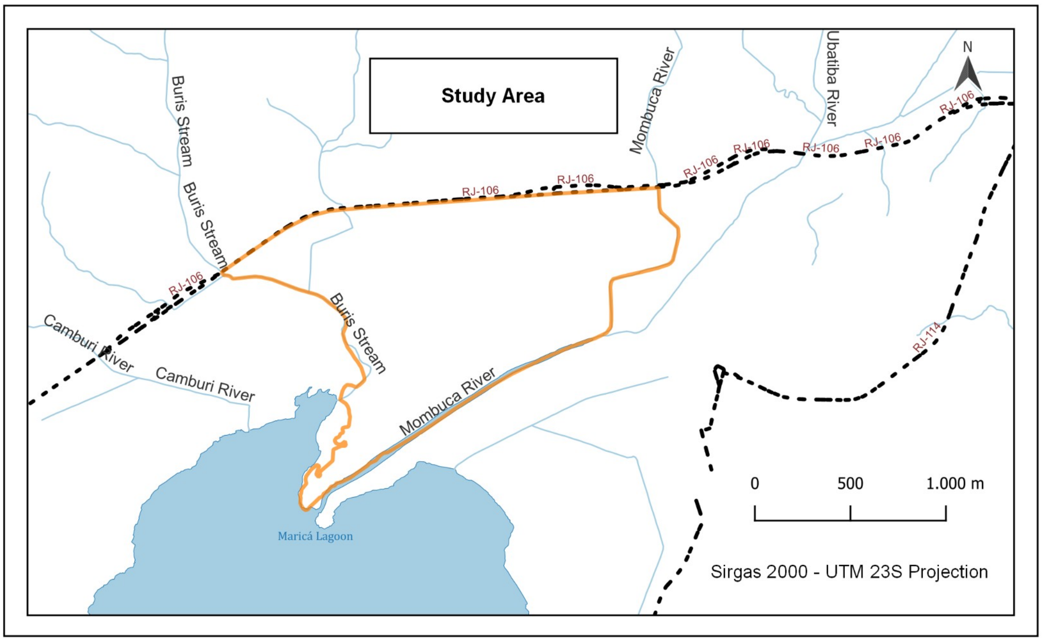
Abstract:
The current study aims to initiate a discussion regarding the interactions between stormwater and sewage networks in a coastal lowland city. The research employs mathematical modeling, utilizing a quasi-2D multilayer model, to simulate three sewage system scenarios, each representing distinct sanitation scenarios. This discussion holds significant importance in gaining a deeper understanding of the challenges arising from the absence of a sewage collection network and the complexities involved in implementing a separate sewer system. The results obtained through the modeling process will be utilized to explore opportunities for more effective urban waters management, leading to a reduction in undesirable interactions between urban stormwater and sanitary sewage networks.

Keywords: Flow, ModCel, Modelling, Sanitary Sewage, Urban Drainage.

1 Introduction

As reported by Caprario and Finotti (2019), the increase in the frequency of flood and the number of people affected by them has gained significant attention in recent years. This increase is believed to be a consequence of unplanned urbanization and anthropogenic changes in the environment, among others. It is important to highlight that floods consist of an overflow of drainage systems and watercourses, leading to the concentration of water in urban infrastructures such as backyards, streets, sidewalks and other areas. In most cases, rainwater does not impact the place where it precipitate but rather downstream locations of the city where the drainage system is deficient or non-existent (Caprario; Finotti, 2019). Moreover, many municipalities lack sewage collection systems, leading to water body contamination. This contamination intensifies during rainy periods, exacerbated by clandestine discharges into watercourses. In this context, the “Geosmina Crisis” (G1, 2021) in the Metropolitan Region of Rio de Janeiro can be highlighted. This water crisis is characterized by the release of a volatile organic compound produced by heterotrophic bacteria or cyanobacteria in aquatic environments with high nutrient concentrations, especially in untreated sewage-receiving water courses (UFRJ, 2020). Therefore, the need to examine the interaction between sewage and stormwater systems and its potential impact on water bodies environmental quality became evident. The chosen study area was the territory around the downstream reach of Mombuca River in Maricá city, located near to urban central area of the municipality and the Marica Lagoon (see figure 1).

Figure 1. Study area.



Source: Authors.

2 Research Methodology

The research development will be subdivided into method stages, as following:

1. A literature review aimed at establishing a theoretical foundation.

2. Characterization of the municipality of Maricá, with a specific focus on the areas of Mumbuca, Ubatiba, and Itapeteiu.

3. Mathematical modeling using a quasi-2D multilayer model called MODCEL (MIGUEZ, 2001; MIGUEZ *et al*, 2017).

4. An assessment of the feasibility of implementing the Dry Weather Capture System, Unitary System, and Separator System, as well as the creation of a reservoir to manage rainy periods.

5. Development and application of an indicator to assess the current state and project scenarios, including issues related to drainage and sewage system failures across the territory.

For the theoretical foundation, the study will be based on legislative literature at the international, national, state, and municipal levels in order to contextualize the measures adopted in different locations around the world and on different scales, beyond recent scientific papers. For the municipal characterization stage of the Maricá territory, hydrologic, hydrographic, topographic and socioeconomic data will be collected from the responsible government institutions in order to understand the environmental sanitation problems in the study area, calibrate the hydrodynamic model and understand the social vulnerability status of the exposed population in the analyzed region. This modeling is being developed in the MODCEL software (Miguez; Mascarenhas, 2001; Sousa, 2017). Finally, the results obtained through the modeling process will be utilized to explore opportunities for more effective urban waters management, leading to a reduction in undesirable interactions between urban stormwater and sanitary sewage networks.

3 Conclusion and expected outcomes

Finally, it is expected that the products of the research developed will add value to society and help in solving problems arising from urban drainage and sewage systems, present in most Brazilian regions and which greatly degrade water bodies. The discussion is cutting-edge and aligns with the strategies adopted by the Metropolitan Region of Rio de Janeiro to advance the expansion of the sanitation system coverage in the state, aiming to a better result in reverse the pronounced environmental degradation of water bodies witnessed over the past decades.

4 Acknowledgment

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Development of hybrid systems based on biodegradable polymers to produce sustainable active packaging

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Abstract:
Active packaging is designed to maintain or improve packaging conditions in the food industry. Natural bio-sourced materials, such as PLA, have been used as a matrix for developing these films, although their poor processing properties are a huge problem. Therefore, the mixture with PBTA can be an alternative for creating materials with better process conditions and the same biodegradation characteristics. The present study focuses on the creation of a film with PLA and PBAT as biodegradable packaging films. Oxide Niobium will be applied as a load to increase the film's barrier and antimicrobial properties, which will increase the packaging condition for food application.

Keywords:
Active packaging; Polylactide; Poly (butylene adipate-co-terephthalate); Niobium Oxide; Bio-composites.

1 Introduction

According to the European Commission (EC) Regulation No 450/2009, active packaging is a material developed "to extend the shelf-life or to maintain or improve the condition of packaged food. They are designed to deliberately incorporate components that release or absorb substances into or from the packaged food or the environment surrounding the food."

The active package could interact with the environment (inside and outside) or directly with the food, both of which are intended to maintain the safety and quality of the product. Therefore, the active agent can be a collector, absorbing moisture or water, residual oxygen, and ethylene resulting from food decomposition; or a releaser, emitting in the package environment or directly in the food something to inhibit bacterial development, for example (Azevedo *et al*., 2022). In recent years, research has increased the interest in biopolymers, natural or organic materials, such as plant extracts, and essential oils (Ataei *et al*., 2020).

Polylactide (PLA) has been extensively used as an alternative to substitute non-biodegradable polymers in the packaging industry because of its desirable properties, such as high mechanical strength and stiffness, biocompatibility, easy processability, and competitive price compared with other matrix materials. On the other hand, PLA presents processing limitations, especially for flexible package film applications, because it has poor thermal stability and flexibility, high brittleness, and low toughness (Thiyagu *et al*., 2022; Chen *et al*., 2023).

The alternative to increase PLA processability is to combine it with other bio-based polymers to create biocomposites. Poly (butylene adipate-co-terephthalate) (PBAT) is a good bedding material for PLA because it provides good mechanical properties, high flexibility, and low cost, while still allowing easy biodegradability for the final product (Thiyagu *et al*., 2022). However, PLA and PBAT do not have accurate compatibility because of their morphology and weak adhesion (Chen *et al*., 2023).

2 Research Methodology

The polymers used during the experimental phase were bio-based package PLA, grade FC 50010, provided by Eart Renewable Technologies (ERT) and developed for 3D printing monofilament, plus PBAT, grade C 1200, provided by Ecoflex for compostable film processing and similar LDPE properties. The mineral component used as an additive to the polymer matrix was niobium oxide (Nb_2O_5) with high purity, supplied by CBMM.

The experimental methodology was divided into three parts: Nb_2O_5 treatment, PLA/PBAT/Nb_2O_5 composite preparation and analysis, and PLA/PBAT/Nb_2O_5 composite film extrusion and investigation.

The first part of the experiment focuses on Nb_2O_5 morphology and properties. The commercial oxide was modified by a hydrothermal reaction with sodium hydroxide (NaOH) 10 M solution to modify its surface morphology and properties. For this, a general full-factor statistical design (Table 1) was created with two factors: temperature and reaction time.

Table 1. Statistical design for experimental methodology part 1.

Factors	Levels		
Temperature (ºC)	160	180	
Reaction Time (min)	90	120	180

The second part of the experiment focuses on composite processing by extrusion. This stage uses a two-factor statistical design (Table 2) with two factors: PLA/PBAT mass proportion and Nb2O5 mass concentration. The extruded composites will be morphological, thermal, rheological, and mechanically characterized to understand the effect of niobium oxide on the PLA/PBA polymer matrix.

Table 2. Statistical design for experimental methodology part 2.

Factors	Levels		
PLA/PBAT (%m/m)	75/25	50/50	25/75
Nb_2O_5 (%m/m)	3	1,5	0

The composite with the best properties will be used for the third part of the experiment, which focuses on film processing. The thermal transformation will occur on a film extruder, and the films will be tested by permeation, fracture, and antimicrobial analysis. Furthermore, the final stage must concentrate on real food experiments to evaluate the effect of the new film package in the real world.

3 Findings and Discussion

The experiments have still been conducted; therefore, the results are still being worked on. It is expected that the morphological transformation of Nb_2O_5 from the hydrothermal reaction will result in a fibber-modified oxide, which will increase the composite barrier properties and provide UV absorption and antimicrobial characteristics.

Furthermore, the incorporation of Nb2O5 in the PLA/PBAT blend should help their compatibility, while increasing the final product properties, creating a final product with good processing properties, in addition to accurate mechanical and thermal properties to allow it to be used by the packing industry. Moreover, it is expected that the final product will maintain its biodecomposition behavior.

4 Acknowledgment

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Integrated biomethane and electricity production from açaí seeds

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Abstract:
Açaí seeds represent 85% of the whole açaí fruit mass, and are often wasted without adequate disposal and economic use. This work prescribes a heat-and-power self-sufficient process where seeds are subjected to acid hydrolysis, followed by anaerobic digestion of the hydrolysate, for the production of biomethane. CO_2 capture is addressed by chemical absorption with aqueous monoethanolamine. The process is evaluated by simulation in Aspen HYSYS, which indicated that conversion of 16 t/h of açaí seeds results in 740 kg/h of biomethane and 19.7 MW of electricity to local grids, in addition to 1.76 t/h of CO_2 to storage and 19.9 t/h of concentrated digestate to fertigation. Technical viability of such a biomass conversion process is demonstrated, enabling new possibilities for optimizing the açai production chain.

Keywords:
Biogas, *Euterpe oleracea*; CO_2 capture; chemical absorption; process simulation.

1 Introduction

About 1.7 million tons of açaí were produced in 2022 in Brazil (IBGE, 2022) and since its edible pulp corresponds to only 15% of its mass, about 1.5 million tons of seeds were generated, most of which is regarded as waste without an adequate destination. Studies have shown that açaí seeds have high concentration of carbohydrates, with mannan – a polymer of mannose – being the main carbohydrate (Monteiro et al., 2019). The production of biogas is an option to avail these seeds (Ferreira et al., 2021). Anaerobic digestion of different substrates has been widely studied in the literature (e.g., cheese whey) (Antonopoulou et al. 2008), but few works considered the use of açaí seeds. In addition, most works are essentially experimental, without looking at the wider picture of a process to produce pure biomethane. The objective of this work is to simulate the process of such a biomethane plant, where hydrolysate of açaí seed is availed as substrate for anaerobic digestion, with captured CO_2 being compressed and dispatched for geological sequestration. The solid residue of hydrolysis is sent to a combined heat and power plant, which meets process demands.

2 Research Methodology

The simulation was carried out in *Aspen HYSYS* version 8.8. The main premises are described in Table 1. An overview of the process is presented in Figure 1. The plant is divided into five main blocks. The first one – S-100 – embraces grinding, acid hydrolysis and anaerobic digestion of soluble hydrolysate. CO_2 capture by aqueous monoethanolamine 28%w occurs next in S-200 to produce biomethane with 2.91%mol CO_2, which is followed by compression of captured CO_2 in S-400 for dispatch at 150 bar. For a better use of the liquid effluent from the digestion process, part of the water present in the digestate is recovered in S-300 through a multi-effect evaporator system. In S-500, the filtered solid fraction from the acid hydrolysis is burned to generate low-pressure steam for process heating and high-pressure steam for electricity.

Table 1. Premises for modelling a biogas plant with carbon capture using açaí seeds as a substrate.

Thermodynamic models	ASME Table (free H_2O systems), Hysys Acid Gas Package (S-200), NRTL+Peng-Robinson (S-100, S-300), Peng-Robinson (S-400, S-500)
Acid hydrolysis	T=158°C, P=5bar, Residence time 9 min (Jorge et al., 2022)
Anaerobic digestion	T=40°C, P=5bar, Residence time 6 days, Conversion=70% (Mei et al., 2016)
Steam cycle (cogeneration)	Turbine: $\eta^{adiabatic}$=90%, T^{inlet}=550°C, P^{inlet}=30 bar, P^{outlet}=0.10 bar; Low-pressure steam (heating utility): 4.76 bar
Process feed (design capacity)	16 t/h açaí seeds (dry-basis); mass composition: 57.09%Mannan; 17.98%Lignin; 10.76%Extratives; 9.14%Glucann; 2.23%Xylan; 1.64%Galactann; 0.68%Arabinnan; 0.48%Ash

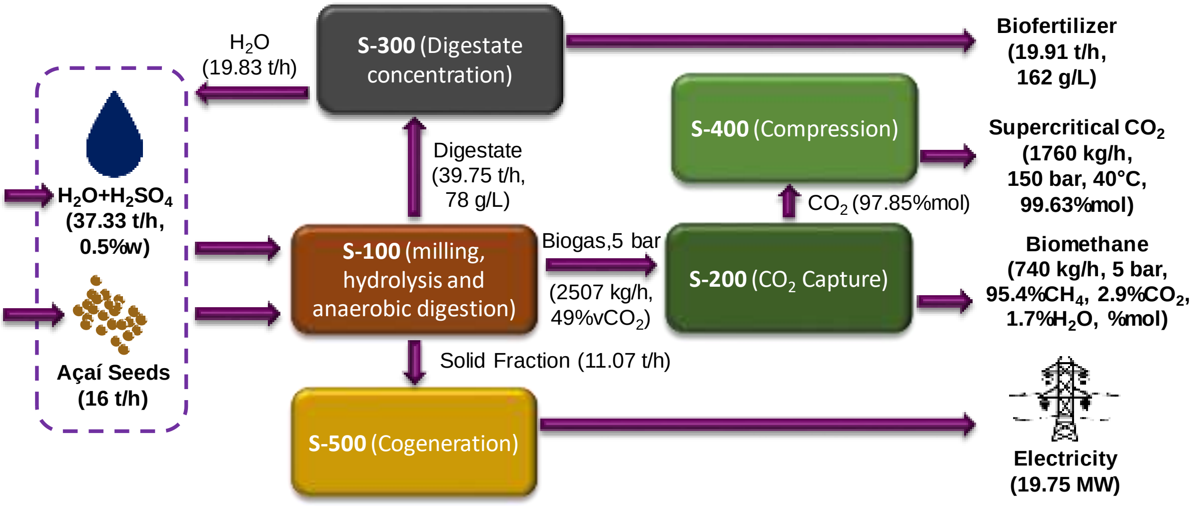

Figure 1. Overview of the biogas plant based on açaí seeds and flowrate of main streams.

3 Findings and Discussion

The conversion of 16.00 t/h of açaí seeds results in 740 kg/h of biomethane to local gas grid, 1760 kg/h of CO_2 to storage, and 19.73 m^3/h of concentrated digestate (162 g/L) to fertigation. Only the hydrolysate is sent to anaerobic digestion to allow lower residence times, which explains relatively low product/feed ratio. Electricity generation from combustion of hydrolysis solid residue (11.07 t/h) totalizes 20.05 MW, of which 0.30 MW is consumed in the plant, with the excess being sold to the local power grid. The idea of performing anaerobic digestion at 5 bar avoids two stages of downstream gas compression, saving nearly 0.14 MW. The exportation of 1.76 t/h of supercritical CO_2 can be monetized by selling it as a product to another company (e.g., for enhanced oil recovery). Alternatively, since the concept prescribes the capture of biogenic CO_2, from the viewpoint of carbon lifecycle, the process can be regarded as a negative-emission technology and can also be remunerated through carbon credits. This could leverage economic performance of the proposed system, together with digestate sales.

4 Conclusion

Açaí seeds conversion into biomethane and electricity in an integrated plant was evaluated by process simulation and the concept proved to be theoretically feasible. In the proposed design, since only the soluble hydrolysate is sent to anaerobic digestion, electricity appears as the major product. Economic evaluation of this process will be addressed in future work, possibly with support of a rigorous biogas generation model, aiding optimization of digestion conditions.

5 Acknowledgment

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Life cycle assessment of biorefinery with waste treatment

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Abstract:
Climate change and fossil fuel depletion have increased attention on the development of multiproduct biorefineries. Life cycle assessment has been considered a crucial tool to determine the environmental benefits of biorefineries over petroleum refineries and confirm the achievement of the expected energy and environmental benefits. This work performs a life cycle screening study of a biorefinery for oil extraction from microalgae biomass, integrating waste treatment processes in algae and hydrogen production. The life cycle inventory was built on secondary data taken from the literature and the ecoinvent database. Eighteen categories of environmental impact of the Recipe 2016 Midpoint (H) method were analyzed. Results show that of the eleven steps that make up the preliminary proposal for the biorefinery, extracting oil from microalgae biomass and removing acidic gases in hydrogen production represent hotspots.

Keywords:
wastewater treatment, life cycle assessment, microalgae, municipal solid waste, green diesel

1 Introduction

Since the 18th century, a period marked by the Industrial Revolution, in which western societies established a new model of economic development, the Earth's average temperature has increased significantly due to the burning of fossil fuels (IPCC, 2007; EPA, 2020; IEA, 2020). Between 1750 and 2021, the main gases that contribute to the greenhouse effect increased in their concentrations in the atmosphere: CO_2 by 47%, methane (CH_4) by 156%, and nitrous oxide (N_2O) by 23% (IPCC, 2021).

An alternative to the use of fossil fuels are biofuels generated from renewable sources, for example, microalgae biomass. Microalgae produce lipids, an energy-rich substance that can be used for the production of different liquid biofuels, such as green diesel, biodiesel, biokerosene (Soares *et al.*, 2019). An important advantage of this primary material is that it does not generate direct competition with food production (Shuba; Kifle, 2018; Singh *et al.* 2015).

Currently, low-carbon policies have clearly motivated the use of residual raw materials to produce biofuels (Capaz *et al.*, 2021b). In this sense, ANP Resolution No. 842 of May 14, 2021, establishes specifications for the commercialization of green diesel in the national territory. The National Petroleum Agency (ANP) proposal complies with the National Biofuels Policy (RenovaBio), established by Law 13.576 of 2017 (ANP, 2020).

The present study is in line with current research trends in the biofuel sector, mainly regarding the production of green diesel from microalgae. As a way of contributing to the social and scientific spheres, the research is aimed at investigating the environmental impacts of the green diesel production chain through the life cycle assessment.

2 Research Methodology

The research uses the life cycle assessment method recommended by ABNT NBR ISO 14040 and 14044 (ABNT NBR, 2006) to assess the potential environmental impacts generated by the production of green diesel. The production of biofuel occurs through the hydrotreatment route of microalgae oil, extracted from biomass cultivated during the bioremediation of urban sanitary effluent, and the use of hydrogen produced by the gasification of urban solid waste.

The data used for the preliminary proposal for the biorefinery is based on the literature and the ecoinvent database. These secondary data serve to determine the mass balance and energy balance of the processes and consolidate the life cycle inventory. After defining the inventory using the software OpenLCA, the same software is used to calculate the environmental impacts in the eighteen categories of the Recipe 2016 Midpoint (H) method. The ReCiPe Midpoint (H) methodology was used for being the most representative method on a global scale with a focus on environmental issues, making it the most qualified method for this study (Prè, 2013).

Finally, the interpretation of the results obtained in the inventory analysis and life cycle impact assessment phases was carried out. In this phase, the consistency of the model results was verified, and the inconsistencies of the previous stages were reviewed and adjusted, as defined in ISO 14040 and 14044 (ABNT NBR, 2006).

3 Findings and Discussion

When analyzing the results of the contribution tree of the eighteen impact categories of the biorefinery supply chain, only two categories were selected, namely: global warming, and scarcity of fossil resources. The choice occurred because both represent sensitive points for biorefinery and sustainability, given the context of the proposal (Ubando *et al.*, 2022).

The greatest contributions to observed environmental impacts come from the stages of extracting oil from microalgae biomass (extraction), with contributions above 92%, followed by the hydrodeoxygenation stage, represented by the nickel markets with contributions varying between 1.03% and 3,35% and the molybdenum market emitting between 0.84% and 3,33%, and finally, the hydrogen sulfide (H_2S) removal stage (Selexol), with emissions lower than 1%.

The extraction process uses hexane and ethyl acetate solvents to remove oil from microalgae biomass. According to the literature, it is possible to recover 95% of these compounds, however, this study does not consider the extraction process's recovery. The same occurs with nickel, molybdenum, and Selexol, both are subject to recovery.

Table 1. Summary of total supply chain contribution tree results.

Global warming			
Contribution	**Process**	**Amount**	**Unit**
92.90%	Extraction - BR	8,07E+13	kg CO2 eq.
03.35%	market for nickel, class 1 | nickel, class 1 | Cutoff, U - GLO	2,91E+12	kg CO2 eq.
03.33%	market for molybdenum | molybdenum | Cutoff, U - GLO	2,90E+12	kg CO2 eq.
00.33%	Selexol - BR	2,85E+11	kg CO2 eq.
Fossil resource scarcity			
Contribution	**Process**	**Amount**	**Unit**
97.90%	Extraction - BR	8,01E+13	kg oil eq.
01.03%	market for nickel, class 1 | nickel, class 1 | Cutoff, U - GLO	8,44E+11	kg oil eq.

00.84%	market for molybdenum | molybdenum | Cutoff, U - GLO	6,83E+11	kg oil eq.
00.21%	Selexol - BR	1,75E+11	kg oil eq.

Source: Author, 2023

4 Conclusion

The identification of the extraction, hydrodeoxygenation and Selexol processes as hotspots paves the way for testing other solvents and catalysts. Through the results obtained, it was possible to conclude that improvement opportunities fit in the proposal, such as modelling the processes in a virtual environment to have more accurate input and output data about the processes and to test new technological routes from this study to make the best use of inputs and waste generated in the biorefinery.

Even with limitations and opportunities for improvement, the research can serve as a basis for the development of new studies related to the theme. The use of secondary data helped in the development of the work; however, most of the data has the global north as a reference, which does not reflect the reality of Brazil and, consequently, generates greater inconsistencies in the results and their interpretations. In other words, having a robust database for the reality of Brazil can help improve studies.

5 Acknowledgment

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