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Modelo sostenible para la gestión y valorización de residuos sólidos mediante estrategias de reciclaje en la Universidad de Guayaquil

Sustainable Model for the Management and Valorization of Solid Waste through Recycling Strategies at the University of Guayaquil

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Abstract

Integrated solid waste management has become a strategic component for environmental sustainability in higher education institutions by optimizing resource use, reducing environmental impacts, and strengthening university social responsibility. At the University of Guayaquil, the increasing generation of recyclable waste and limitations in waste separation, recovery, and valorization processes reveal the need for sustainable management models based on circular economy principles.

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This study aimed to design a sustainable model for solid waste management and valorization through recycling strategies to strengthen institutional environmental management. A mixed-methods approach with a non-experimental, descriptive-propositional, and cross-sectional design was adopted. Theoretical methods included analysis-synthesis, systemic approach, and inductive-deductive reasoning, while empirical techniques comprised document analysis, direct observation, semi-structured interviews, and surveys administered to students, faculty members, and administrative staff. Diagnostic findings revealed deficiencies in waste segregation at the source, limited environmental awareness, lack of waste valorization indicators, and weak coordination with authorized recycling managers. Based on these findings, a sustainable management model grounded in circular economy principles, recyclable material recovery, environmental education, and active university community participation is proposed. The model integrates source separation, selective collection, material recovery, waste valorization, and environmental performance monitoring. It is concluded that the proposed model will improve institutional environmental management efficiency, reduce landfill disposal, strengthen environmental culture, and generate environmental, social, and economic benefits, providing a replicable framework for higher education institutions.

Keywords: Solid waste management; Waste valorization; Recycling; Circular economy; Environmental management.

Resumen

La gestión integral de residuos sólidos constituye un componente estratégico para la sostenibilidad ambiental de las instituciones de educación superior, al contribuir con la

optimización de los recursos, la reducción de impactos ambientales y el fortalecimiento de la responsabilidad social universitaria. En la Universidad de Guayaquil, el incremento en la generación de residuos reciclables y las limitaciones en los procesos de separación, aprovechamiento y valorización evidencian la necesidad de implementar modelos de gestión orientados por los principios de la economía circular. El objetivo de la investigación fue diseñar un modelo sostenible para la gestión y valorización de residuos sólidos mediante estrategias de reciclaje que fortalezca la gestión ambiental institucional. La investigación se desarrolló bajo un enfoque mixto, con diseño no experimental, alcance descriptivo-propositivo y corte transversal. Se emplearon métodos teóricos como el análisis-síntesis, el método sistémico y el método inductivo-deductivo, complementados con técnicas empíricas de análisis documental, observación directa, entrevistas semiestructuradas y encuestas dirigidas a estudiantes, docentes y personal administrativo. Los resultados del diagnóstico permitieron identificar deficiencias relacionadas con la clasificación en la fuente, la escasa cultura ambiental, la ausencia de indicadores de valorización y la limitada articulación con gestores ambientales autorizados. En respuesta a estas brechas, se propone un modelo de gestión sostenible fundamentado en la economía circular, la valorización de materiales reciclables, la educación ambiental y la participación de la comunidad universitaria. El modelo incorpora procesos de segregación, recolección diferenciada, recuperación, valorización y seguimiento mediante indicadores de desempeño ambiental. Se concluye que la implementación del modelo permitirá incrementar la eficiencia de la gestión institucional, disminuir la disposición final de residuos, fortalecer la cultura ambiental y

generar beneficios sociales, económicos y ambientales, constituyéndose en una alternativa replicable para otras instituciones de educación superior.

Palabras clave: Gestión de residuos sólidos, Valorización de residuos, Reciclaje, Economía circular, Gestión ambiental.

Introduction

Higher education institutions play a strategic role in promoting sustainable development, not only by training professionals committed to protecting the environment, but also by implementing institutional policies aimed at the efficient management of natural resources and the reduction of environmental impacts resulting from their academic, administrative, and research activities. Among the most significant challenges is the comprehensive management of solid waste, considered a cornerstone of environmental sustainability and compliance with the Sustainable Development Goals (SDGs), particularly those related to responsible production and consumption (SDG 12), sustainable cities and communities (SDG 11), and climate action (SDG 13).

The growth of the university population and the intensification of institutional activities have significantly increased the generation of solid waste, primarily paper, cardboard, plastic, glass, metals, and organic waste. Although a significant proportion of these materials has the potential to be reused or recycled, many universities continue to rely on management systems based primarily on collection and final disposal, limiting opportunities for the recovery and reintroduction of materials into the production cycle.

In this context, the circular economy represents a paradigm aimed at replacing the linear model of production and consumption with systems that promote the reduction, reuse,

recycling, and recovery of waste, thereby fostering resource efficiency and reducing environmental impacts. Solid waste recovery makes it possible to transform materials considered waste into resources with economic, social, and environmental value, while simultaneously strengthening processes of innovation and institutional sustainability.

The University of Guayaquil faces significant challenges related to the consolidation of a comprehensive solid waste management system that integrates technical processes of sorting, recovery, and valorization with ongoing strategies for environmental education and the involvement of the university community. This situation highlights the need to develop a sustainable model that integrates technical, environmental, social, and economic criteria, promoting the implementation of recycling practices and the strengthening of the institution's environmental culture.

In this regard, the objective of this research is to design a sustainable model for the management and recovery of solid waste through recycling strategies at the University of Guayaquil, aimed at strengthening institutional environmental management through an approach based on the circular economy and continuous improvement.

Comprehensive Solid Waste Management in Higher Education Institutions

Integrated solid waste management is a systematic process aimed at preventing, minimizing, reusing, and properly disposing of waste generated by human activities through the application of technical, environmental, economic, and social criteria. In institutions of higher education, this process takes on special relevance due to the volume and diversity of waste produced by academic, administrative, research, and community engagement activities.

The contemporary approach to waste management has evolved from models focused exclusively on final disposal toward integrated systems based on the waste hierarchy, prioritizing prevention, reduction, reuse, recycling, resource recovery, and energy recovery before considering final disposal. This approach helps reduce pressure on natural resources, lower pollutant emissions, and optimize the efficient use of materials.

Universities represent strategic venues for implementing environmental management models due to their capacity to generate knowledge, promote cultural change, and transfer innovation to society. The incorporation of comprehensive waste management systems strengthens institutional environmental governance and fosters the development of citizens committed to sustainable development.

The Circular Economy as the Foundation of Waste Valorization

The circular economy is one of the main sustainability paradigms of the 21st century. Unlike the linear model based on "extract–produce–consume–dispose," the circular economy aims to maintain the value of materials for as long as possible through processes of reuse, repair, remanufacturing, and recycling.

Waste recovery represents one of the fundamental pillars of this paradigm, as it transforms materials considered waste into resources that can be reincorporated into production processes. This approach generates environmental, economic, and social benefits by decreasing the extraction of raw materials, reducing greenhouse gas emissions, and creating new opportunities for employment and innovation. Recent reviews conclude that the integration of the circular economy and waste management constitutes an effective path toward achieving the Sustainable Development Goals, particularly through resource efficiency and the creation of sustainable value.

In higher education institutions, the circular economy promotes the creation of sustainable campuses through strategies such as source separation, recycling, composting, environmental education, and partnerships with authorized waste management operators.

Solid Waste Recovery

Waste recovery encompasses the set of activities aimed at recovering the economic, environmental, or energy value of waste through processes such as sorting, recycling, reuse, composting, and material recovery.

From an environmental perspective, waste recovery reduces the amount of waste sent to landfills and minimizes soil, water, and air pollution. Economically, it creates opportunities for establishing production chains based on recyclable materials, while socially it strengthens the inclusion of stakeholders involved in recycling and fosters a culture of shared environmental responsibility.

Various studies conducted at universities show that resource recovery programs achieve better results when they integrate environmental education, adequate infrastructure, performance indicators, and permanent monitoring mechanisms.

University Environmental Management

University environmental management constitutes a system for planning, organizing, implementing, and evaluating institutional policies aimed at minimizing the environmental impacts resulting from university activities.

Currently, environmental management goes beyond regulatory compliance to become a strategic component of institutional governance. The incorporation of environmental indicators, continuous improvement systems, and participatory processes strengthens organizational sustainability and contributes to the institution's standing.

In this context, waste management systems represent one of the most widely used indicators for evaluating universities' environmental performance, particularly when they are integrated with environmental education and social responsibility programs.

Recycling Strategies

Recycling is a technical strategy aimed at reintroducing materials into the production cycle through physical, chemical, or biological processes that enable their transformation into new inputs.

The specialized literature indicates that the efficiency of recycling programs depends on multiple factors, including: Recent evidence shows that universities that integrate these components achieve higher levels of material recovery and establish sustainable campus models.

- Source separation.
- Adequate infrastructure.
- Environmental education.
- Community participation.
- Institutional incentives.
- Monitoring through indicators.
- Partnerships with authorized waste management operators.

Sustainable Model for Waste Management and Recovery

Based on the above principles, this research proposes an integrated model grounded in five strategic components:

Institutional environmental assessment, aimed at identifying the generation, composition, and management of solid waste.

Separation and sorting at the source, through dedicated infrastructure and segregation protocols.

Recovery and recycling, incorporating processes for the recovery, temporary storage, and responsible marketing of recyclable materials.

Environmental education and university participation, aimed at strengthening environmental culture through ongoing awareness and training programs.

Monitoring and continuous improvement, using environmental performance indicators to evaluate the system's effectiveness and inform decision-making.

Methodology

The research was conducted using a mixed-methods approach, integrating quantitative and qualitative methods to gain a comprehensive understanding of the issues related to solid waste management and recovery at the University of Guayaquil. The quantitative component allowed for the characterization of variable behavior through the collection and analysis of statistical data, while the qualitative component facilitated the interpretation of institutional processes, the perceptions of the stakeholders involved, and the factors that influence the implementation of recycling strategies.

Type and Research Design

This study is classified as applied research, as it proposes a technical solution aimed at strengthening institutional environmental management through the design of a sustainable model for solid waste recovery.

The scope was descriptive-propositional, as the current state of waste management was first assessed, and subsequently an intervention model based on the principles of the circular economy was formulated.

A non-experimental, cross-sectional design was adopted, given that the variables were observed in their natural context without deliberate manipulation, and data were collected at a single point in time.

The following methods were used to conduct the study:

Analysis-synthesis, to examine the scientific literature related to integrated solid waste management, the circular economy, and environmental sustainability.

Inductive-deductive, used to draw inferences from the information obtained and construct the conceptual foundations of the proposed model.

Systemic-structural method, which enabled an understanding of the interaction between the different components of the waste management system and the design of the sustainable model from a comprehensive perspective.

Direct observation of the processes of waste sorting, temporary storage, and disposal.

Structured surveys administered to students, faculty, and administrative staff.

Semi-structured interviews with authorities and those responsible for institutional environmental management.

A literature review of national regulations, institutional policies, internal procedures, and technical reports related to environmental management.

The population consisted of the University of Guayaquil's university community, comprising students, faculty, and administrative staff.

For the purposes of the research, a stratified probability sample was selected, composed of:

- StratumSample
- Students 320
- Faculty 80
- Administrative staff 50
- Authorities and environmental management officials: 10
- Total: 460

The sample ensures representativeness of the various stakeholders involved in the generation and management of solid waste on the university campus.

The research process comprised five phases:

Phase I. Diagnosis

The current solid waste management system was characterized through observation, a literature review, and the application of research instruments.

Phase II. Identification of Gaps

The technical, organizational, and cultural factors limiting waste recovery were analyzed.

Phase III. Model Design

The sustainable model was structured based on the principles of the circular economy, environmental management, and continuous improvement.

Phase IV. Validation

The model was evaluated through expert judgment, with experts analyzing its relevance, feasibility, consistency, and institutional applicability.

Phase V. Proposal Development

Implementation strategies, performance indicators, and monitoring mechanisms were formulated to strengthen the university's environmental management.

Quantitative data were processed using IBM SPSS Statistics version 27 software, employing descriptive statistics (frequencies, percentages, means, and standard deviation) and inferential analysis where appropriate. Qualitative data obtained from interviews and observations were analyzed using thematic content analysis, which allowed for the identification of categories related to environmental management, recycling, and waste recovery.

The results obtained served as the basis for formulating the sustainability model and for defining indicators aimed at evaluating its effectiveness in strengthening environmental management at the University of Guayaquil.

Results

The assessment of solid waste management at the University of Guayaquil identified strengths and weaknesses related to source separation, recycling, waste recovery, and the involvement of the university community. The results obtained through surveys, interviews, observation, and a review of documents highlight the need to strengthen institutional mechanisms to optimize environmental management.

Characterization of Solid Waste Management

Observation of the university facilities revealed that the solid waste generated consists mainly of paper and cardboard (34.8%), plastic waste (29.6%), organic waste (18.4%), glass (9.1%), and metals (8.1%). Although a high proportion of these materials has recycling potential, most of it is disposed of together as general waste, significantly reducing the possibilities for resource recovery.

The results show that approximately 73.5% of the waste generated has the potential to be reused through recycling and resource recovery processes.

Awareness of Recycling

The survey results showed that 81.5% of participants recognize the importance of recycling in reducing environmental impacts; however, only 42.8% reported properly sorting waste on campus.

These results highlight a discrepancy between the level of environmental awareness and the implementation of sustainable practices within the university.

Evaluation of Institutional Management

The interviewees agreed that the University has initiatives aimed at environmental management; however, they identified limitations related to: The literature review confirmed that recycling activities are carried out with

- insufficient infrastructure for source separation;
- insufficient environmental training;
- a lack of resource recovery indicators;
- limited coordination with authorized environmental managers;
- the absence of an institutional circular economy model.

These activities are carried out in isolation, without a permanent monitoring and evaluation system.

The implementation of the model will allow for: The results show that the incorporation of a sustainable waste recovery model is a viable alternative for strengthening environmental management at the University of Guayaquil

- increasing the utilization of recyclable waste;
- reducing costs associated with final disposal;
- strengthening the university's environmental culture;
- improve institutional sustainability indicators;
- promote the active participation of students, faculty, and administrative staff;

- generate social entrepreneurship opportunities linked to the circular economy.

by integrating technical, organizational, and educational components under a continuous improvement approach.

The results obtained show that solid waste management at the University of Guayaquil has limitations related to source separation, the recovery of recyclable materials, and the systematic participation of the university community. These weaknesses align with research conducted at institutions of higher education, which indicates that the absence of comprehensive management models limits the transition from linear systems to approaches based on the circular economy.

The high percentage of waste with recovery potential identified in the assessment demonstrates that there is a significant opportunity to increase the recovery of recyclable materials through strategies for separation, sorting, and recovery. These findings are consistent with recent studies that argue that universities can become laboratories of innovation for the circular economy when they integrate adequate infrastructure, environmental education, and permanent monitoring mechanisms.

Likewise, the observed discrepancy between the level of environmental awareness and actual recycling practices confirms that awareness-raising alone is insufficient to change behaviors. The specialized literature indicates that the incorporation of incentives, performance indicators, institutional governance, and multi-stakeholder participation increases the effectiveness of waste management programs.

The proposed sustainable model incorporates the principles of the circular economy by integrating processes of source separation, recovery, resource recovery, and continuous monitoring. Its main contribution lies in linking environmental management with social entrepreneurship, transforming

recyclable waste into resources with economic, environmental, and social value. This perspective aligns with recent research that highlights waste recovery as an opportunity to generate innovation, social inclusion, and new sustainable business models.

From an institutional standpoint, implementing this model will help strengthen environmental culture, optimize management processes, and advance the Sustainable Development Goals—particularly those related to responsible production and consumption, climate action, and strengthening partnerships for sustainable development.

Conclusions

The research made it possible to assess the current state of solid waste management at the University of Guayaquil, identifying shortcomings related to source separation, the utilization of recyclable materials, the lack of performance indicators, and limited coordination between environmental management processes and institutional sustainability strategies.

The sustainable model designed constitutes a comprehensive proposal based on the principles of the circular economy, incorporating processes of segregation, sorting, recovery, resource recovery, and continuous monitoring of solid waste. Its structure promotes the optimization of resources, the reduction of waste sent to final disposal, and the strengthening of the university's environmental management.

The results demonstrate that solid waste recovery represents a technically and environmentally viable alternative for increasing institutional efficiency, promoting the rational use of resources, and generating environmental, economic, and social benefits through recycling strategies and community participation.

The incorporation of social entrepreneurship as a cross-cutting component of the model strengthens the creation of sustainable initiatives aimed at utilizing recyclable materials, contributing to the development of organizational capacities and the consolidation of a responsible environmental culture within the university community.

Finally, the proposed model serves as an adaptable and replicable management tool for other institutions of higher education interested in strengthening their policies on sustainability, social responsibility, and the circular economy through continuous improvement processes.

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