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REVIEW

Municipal Waste Management: Challenges and Perspectives from an Environmental Sustainability Perspective

Gestión de Residuos Municipales: Retos y Perspectivas desde la Sostenibilidad Ambiental

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ABSTRACT

The study addressed the issue of municipal solid waste management, highlighting its impact on public health, the environment and sustainable development. A review of national and international research showed that waste management has been limited by structural, logistical and institutional factors, despite the existence of regulations such as the General Law on Solid Waste in Peru. It was analysed how segregation at source, recovery and reduction of waste were key actions that municipalities should have promoted, although they faced significant challenges. It was also documented that the participation of citizens, businesses and educational institutions was decisive in the effectiveness of environmental management programmes. Empirical evidence showed that local public policies did not always achieve tangible changes, as in the Brazilian case, where management indicators did not improve significantly. In other contexts, such as in India and South Africa, a lack of accurate data and low waste recovery was observed, which made sustainable planning difficult. It was concluded that successful waste management depended on a systemic, preventive and participatory approach, integrating appropriate technologies, quantification methodologies and a strengthened environmental culture. Finally, the urgent need to invest in infrastructure and strengthen the institutional capacity of local governments to achieve sustainable and healthy cities was emphasised.

Keywords: Waste Management; Environmental Culture; Recovery; Sustainability; Municipalities.

RESUMEN

El estudio abordó la problemática del manejo de los desechos sólidos municipales, destacando su impacto en la salud pública, el medio ambiente y el desarrollo sostenible. A partir de la revisión de investigaciones nacionales e internacionales, se evidenció que la gestión de residuos ha sido limitada por factores estructurales, logísticos e institucionales, a pesar de la existencia de normativas como la Ley General de Residuos Sólidos en el Perú. Se analizó cómo la segregación en la fuente, la valorización y la reducción de residuos fueron acciones clave que los municipios debieron impulsar, aunque enfrentaron desafíos significativos. Asimismo, se documentó que la participación de la ciudadanía, las empresas y las instituciones educativas resultó determinante en la eficacia de los programas de gestión ambiental. La evidencia empírica mostró que las políticas públicas locales no siempre lograron cambios tangibles, como en el caso brasileño, donde los indicadores de gestión no mejoraron de manera significativa. En otros contextos, como en India y Sudáfrica, se observó una falta de datos precisos y una baja valorización de residuos, lo que dificultó la planificación sostenible. Se concluyó que el éxito en la administración de los residuos dependió de un enfoque sistémico, preventivo y participativo, que integrara tecnologías adecuadas, metodologías de cuantificación y una cultura ambiental fortalecida. Finalmente, se resaltó la necesidad urgente de invertir en infraestructura y fortalecer la capacidad institucional de los gobiernos locales para lograr ciudades sostenibles y saludables.

Palabras clave: Gestión De Residuos; Cultura Ambiental; Valorización; Sostenibilidad; Municipios.

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INTRODUCTION

One of the main problems in the world is the management and administration of waste generated by various human activities. It is a global challenge that requires improving environmental awareness across all populations. With this in mind, Zhang et al.[1] proposed that the final disposal of waste should be a priority for every country. For this reason, municipal solid waste affects people's lives and nature, and its disposal and management are essential today.[2]

In most of our actions and situations, we generate waste of various kinds that may or may not be reused. It is always very difficult not to generate waste every day, which means that it is very important to understand the responsibility we have to take on regarding this pollution of our environment, which is the source of various diseases in different populations.[3,4,5,6,7]

One of the main difficulties all districts in Peru face is the poor management of organic and inorganic waste that makes up municipal waste. The management of organic and inorganic waste is the responsibility of municipalities, as stated in the General Law on Solid Waste – Law No. 27314. Therefore, it is the mayors in their localities who are responsible for formulating, planning, executing, and controlling the respective actions to manage the problem of municipal waste.[4]

DEVELOPMENT

Around the world, we face a significant challenge that threatens the peace of mind of populations, generates health problems, causes a decline in livelihoods, harms the environment, generates various types of waste, and leads to a lack of environmental awareness regarding waste management.[8,9,10]

According to research conducted outside the country, Henríquez et al.[5] propose in their thesis, to understand the relationship between the environment and the perspective of those who consume and dispose of waste in the city of Medellín, that there are various customs for improving the environment through the grouping and storage of waste by people, even when they are not accustomed to carrying out these important practices.[11,12] This is a theoretical and conceptual study on social responsibility in solid waste management, which aims to develop indicators to measure organizations' social and environmental performance.[13,14,15] Through a document review methodology, it reflects on the commitment of managers and organizations involved in solid waste as a management approach that benefits society and the environment. Some strategies and trends are reviewed that propose a series of inclusive practices for actors in the environment, seeking to impact people's quality of life positively. Business strategies that propose added value for the organization and the environmental sustainability of society.[16,17,18,19]

According to the Comprehensive Solid Waste Management Law, it is specifically the responsibility of municipalities to continuously include plans for on-site separation and detailed segregation of solid waste in all areas under their jurisdiction, to reuse and ensure the final disposal of waste in a technical, valuable, and appropriate manner.[6] The implementation or improvement of a program to reuse waste from the point of collection responds to the search for ways to reduce the amount of solid waste, since it is at this first point of collection, i.e., at the source, where the best results can be achieved in capturing inorganic waste, which has a much higher recovery value than when combined with organic waste.[20,21,22,23,24]

In this regard, Cetrulo et al.[7] mentioned that a case study methodology was established in Brazil, a solid waste policy was implemented, and a database was created. Empirical statistical work was carried out on panel data to review whether the indicators, which are an important point for reviewing the level of municipal waste management, improved or not.[25,26,27,28,29,30] The findings suggest that the national solid waste plan has not achieved the desired changes in municipal waste management. In particular, no significant improvement was observed in the indicators studied: municipal waste generation, waste collection frequency, recyclable waste recovery rate, and proportion of sanitary landfills. In addition, the document concludes with lessons learned and supports the identification of constraints and strategies that can be extrapolated to other developing countries.[31,32,33,34,35,36,37]

Torres et al.[8] then provide insights from working groups: companies, the state, and society. The article presents important points on issues related to waste management. This work was carried out in residential areas in the Villavicencio area, to review the current situation and identify critical points as a baseline for improvements in today's processes regarding the sustainability of good solid waste management.[38,39,40,41] Its findings highlight the poor state of municipal public policies due to the state's poor perception of its functions according to regulations. It also rightly points out that the various groups involved believe that the people who make up this city are mainly responsible for the problem, and that efforts to improve the situation should be directed in this direction. It should be mentioned that 87 % of the population express their desire to participate and cooperate, as well as the need to work better on the issue of segregation, which means that future work plans or programs with their active participation would be highly sustainable.[42,43,44,45]

Similarly, Del Ángel Sánchez[9] proposed a work to comprehensively manage non-domestic and special waste in a higher education institution. Population growth also leads to an increase in solid waste, which has caused environmental problems that require attention due to the environmental impacts it can have on our environment, especially on health. At the General Mariano Escobedo Technological University in Mexico, work is being done with the population to train professionals to encourage other universities to participate in solving and improving environmental problems; the aim is to develop a plan for sustainability. An important point to consider is municipal solid waste and special solid waste. Critical generation points were identified, an 8-day sampling period was established for each property, and direct measurements and waste characterization were carried out. An increase in the generation of polyethylene terephthalate and various reusable containers as recoverable waste was observed. It was found that an average of 0,53 kg/capita/day is generated per person, reaching 19806,3 tons per year. In conclusion, there is awareness and understanding of the environmental problems related to solid waste generation, a critical issue in our country. It is essential to implement measures to recover and improve our environment to achieve sustainable development that will give us a better outlook for the future of our country, which is immersed in a growing economy.[46,47,48]

The experience of Chaudhary et al.[10] regarding total waste generation in India reported for 2018 is highly uncertain, mainly because observational data from rural regions of India are lacking. This makes it challenging to estimate rural waste and generation rates. Official government data denies the existence of rural waste generation in India. The rural data gap makes it difficult to build accurate open inventories of waste burning emissions and to plan waste and management infrastructure.[49,50,51] Our study presents activity data from poorly studied rural regions in India and establishes the interrelationship between waste generation and household income in developed and undeveloped areas of India. We use this relationship to create a dataset of waste generation and treatment and build an open waste burning emissions inventory for India (OWBEII) for the year 2021, after segregating both rural areas and urban population into five income groups with the help of socioeconomic data from national health surveys. Open-air waste burning is a widely established waste disposal practice in developing countries and emits particulate matter pollutants, a group of carcinogens.[52,53]

Similarly, Lopez[11] prepared an on-site recycling plan with selective waste collection in homes in the La Matanza-Morropon area to solve the problem of poor municipal solid waste management. To this end, 2,160 properties were located, where 379 properties were surveyed using the meta 36 method provided by the Ministry of Economy and Finance [MEF].[12] These properties participated consistently in the work and were the ones to whom the instrument was applied. The response was that 28,00 % of the solid waste collected was mostly paper (25,00 %) and cardboard (4,00 %). It has been calculated that a total of 7,89 tons of solid waste was generated in this area per month, of which 1,93 tons were sold commercially, generating an income of 701,60 soles, with paper being the waste that contributed the most (493,90 soles). Eighty-six percent of the participants said they were willing to separate the waste they generated on their property. In conclusion, the Municipality of La Matanza presented a series of situations that could not solve the pollution problem, with some setbacks in the procurement and management of cleaning services, which has been reflected in widespread discontent among the population (41,00 %).

Quispe[13], in his scientific work entitled Solid Waste Management and Levels of Environmental Pollution in Zone D of Huaycán – Ate, 2019, the main objective was to find a significant relationship between solid waste management and levels of environmental pollution in Zone D of Huaycán – Ate 2019. A descriptive correlational method with a quantitative approach was used. The number of inhabitants was 1,266 people in Zone D of Huaycán - Ate, 2019, with a representative sample of 103 families. The technique used to find the data was surveys on waste management and a questionnaire on environmental impact levels, with expert validation and finding their degree of confidence through Cronbach's alpha, 0,75 for solid waste management and 0,87 for environmental pollution, as appropriate. The work carried out showed that there is a significant relationship between solid waste management and environmental pollution in Zone D of Huaycán - Ate, 2019, with a significance level of .000.

It is then that Alvino[14], in his research on environmental management and awareness in the Ancón area in 2020, states that the overall objective of the project is to verify the relationship between environmental management and people's awareness of environmental issues in Ancón in 2020. The quantitative method was used, and the design was non-experimental. The population consisted of 1,810 residents, and the sample size was 315. The instrument used was two surveys to collect data related to the two study variables. The results determined a significant relationship between the variables of environmental management and environmental culture, as proven by Spearman's rho statistical test, whose p-value was less than 0,05. The correlation coefficient was 0,961, indicating that the environmental management level in the Ancón district, related to environmental awareness, was highly significant. Finally, it was concluded that as adequate environmental management is developed, there will be a better environmental culture in the district of Ancón, thereby benefiting the population.

Regarding theoretical and scientific foundations, we first have solid waste management. This is due to the excessive increase in municipal waste, which generates constant growth in the total population and the development of businesses and industries related to non-domestic solid waste. According to Roselli[15], this constitutes an environmental problem that extends to most countries worldwide, including developed ones.[54,55,56,57] In addition to the low awareness about recycling worldwide, the constant increase in domestic and non-domestic waste is worrying. Although some countries have laws on waste management, the vast majority do not have the necessary technological infrastructure and human resources to implement them. Several factors cause the excessive increase in solid waste, one of the most complicated being the excessive growth of populations, business and industrial development, and the increase in urban areas, many of which were previously rural. As a result of the generation of vast volumes of solid urban waste, cities are being hit by a new problem related to environmental pollution and its widespread deterioration. Among the factors that can cause improper waste management are incorrect waste collection techniques, poor and inefficient facilities for treating solid waste, and a lack of infrastructure for collection, transport, and final disposal, among others that influence this work.[1] has been used to determine the total environmental shock of municipal waste management options in strategy planning and decision-making. Existing studies have covered many detailed approaches, from waste treatment technology to applied modeling methods.

Secondly, we have solid waste management principles, which are based on and sustained by the principles of precaution and prevention.[16] Excess waste generation should be avoided, and the content of hazardous waste should be reduced. This prevents risks in terms of various diseases and pollution of the environment around us. In the long term, this policy suggests segregation to counteract waste-related difficulties and promote sustainable work. Solid waste recovery must consider its three dimensions: reuse, recycling, and energy recovery. Final disposal goes hand in hand with on-site separation to extract reusable waste. In this regard, Sereda[17] describes research into the morphological composition of municipal solid waste (MSW) in the Perm region during the period of self-isolation associated with SARS-CoV-2. It has been found that the indicator of the morphological composition of MSW is decisive in the field of MSW management and determines the choice of the most acceptable disposal method.

Thirdly, we have prevention. The environmental impact of creating products or running a business is not limited to generating various types of waste.[18] Instead, the impact of a specific type of material should be managed within a waste generation cycle. In

principle, the burden on the environment should be based on an approach that manages solid waste from start to finish. From its generation, whether domestic or non-domestic, to its final disposal. The aim is to conserve raw materials and energy and minimize the production of waste, specifically hazardous and special waste. In the longer term, we should seek to dematerialize products and processes, as waste generation cycle analysis could be instrumental in planning and organizing waste. In this way, Ibáñez-Forés et al.[19] analyze the social tasks of urban solid waste (USW) administrative management systems in developing countries. To this end, a set of social impact categories, indicators, and metrics capable of assessing the socioeconomic and working conditions of the individuals involved in municipal waste management is proposed.

Fourth, in terms of solid waste reduction. In this area, we seek to comply with all tasks based on minimizing solid waste by complying with the 6 "Rs",[20] which recommend the following:

- Reduce: The process by which the potential for waste generation is reduced through various tools (awareness, training, etc.).
- Reuse: Reuse a product a second time to give it a new or different use.
- Recycle: Separate inorganic waste as raw material.
- Refuse: Do not purchase products that generate unnecessary waste or cause pollution.
- Responsibility: task corresponding to waste generators.
- Respect: our world, our home, recognizing all living things.

Fifth, segregation is gathering many types of inorganic components or diverse physical elements for subsequent reuse in other specific tasks. It is one of the most important points for comprehensive municipal solid waste management. In this regard, Owojori et al.[21] mention that waste recovery and recycling in South Africa, as a developing economy, have not yet received the necessary attention compared to other sustainable places and cities. Measuring the composition of solid waste is a fundamental prerequisite for creating a sustainable and viable process for systems that manage solid waste well, and our country is going through a very similar situation.

Sixth, we have waste recovery. Waste recovery is a crucial issue in terms of sustainable solid waste management policy. This is what Gu et al.[22] tell us in their research on recycling, adding that it is an essential practice for the successful functioning of zero-waste cities. It is essential to understand the recycling potential of recyclable waste. Their study quantifies the recoverable waste from different cities in China. Suzhou, Yangzhou, and Suqian represent high, medium-, and low-income cities, respectively. For this reason, if waste production cannot be avoided, part of it can be reused after a process of assigning a value to each type of reusable waste, which has different prices on the market, generating extra income for both residents and the municipality that collects it.[23,55,56,57] Finally, the various products are transformed in order to produce new ones and/or, in the case of organic solid waste, undergo the appropriate processes to produce various fuels and compost, which are so important in agriculture today.

CONCLUSIONS

The comprehensive management of municipal solid waste is a critical component of environmental public policy, and its inefficiency has negative implications for public health, environmental quality, and sustainable development. Empirical and theoretical evidence shows that, although regulatory frameworks exist, such as the General Law on Solid Waste in Peru, their implementation still faces multiple structural, logistical, institutional, and cultural constraints.

The studies analyzed highlight the need to strengthen local governments' capacities for planning, executing, and monitoring programs aimed at waste recovery, source separation, and reduction. Likewise, the success of these processes depends largely on intersectoral coordination between the State, private enterprise, the academic sector, and citizens, as well as on the design of sustained environmental education and awareness strategies.

From a technical perspective, it is essential to prioritize the separate management of household and non-household waste, implement efficient treatment technologies, and develop infrastructure that allows for proper management from generation to final disposal. Similarly, the incorporation of methodologies for quantifying, characterizing, and analyzing the life cycle of waste allows for optimized decision-making in urban and rural contexts, as demonstrated by international experiences.

In this regard, solid waste management should be framed within a systemic, preventive, and participatory approach to minimize waste generation, maximize its recovery, and ensure environmentally sound final disposal. Only through institutional strengthening, investment in sustainable infrastructure, and the consolidation of a comprehensive environmental culture will it be possible to move toward a development model that guarantees environmental sustainability and the well-being of populations.

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