

ENVIRONMENTAL EDUCATION AS A FUNDAMENTAL PILLAR OF SUSTAINABLE SOLID WASTE MANAGEMENT: AN INTEGRATIVE APPROACH TO SOCIAL AND ENVIRONMENTAL CHANGE

¹ALBA JOSEFA VARGAS BUITRAGO, ²CARLOS ALBERTO AMAYA CORREDOR, ³JOSÉ LUIS BAUTISTA GONZÁLEZ

¹ ALBA JOSEFA VARGAS BUITRAGO, FACULTAD DE CIENCIAS NATURALES E INGENIERÍAS, PROGRAMA DE INGENIERÍA AMBIENTAL, UNIDADES TECNOLÓGICAS DE SANTANDER, BUCARAMANGA, COLOMBIA.

² CARLOS ALBERTO AMAYA CORREDOR, FACULTAD DE CIENCIAS NATURALES E INGENIERÍAS, PROGRAMA DE INGENIERÍA AMBIENTAL, UNIDADES TECNOLÓGICAS DE SANTANDER, BUCARAMANGA, COLOMBIA.

³ JOSÉ LUIS BAUTISTA GONZÁLEZ, INSTITUCIÓN EDUCATIVA DE SANTANDER, BUCARAMANGA, COLOMBIA.

EMAIL: ¹ avargas@correo.uts.edu.co, ² camaya@correo.uts.edu.co, ³ joseluisbago@bucaramanga.gov.co
ORCHID ID : ¹ 0000-0003-1879-7022, ² 0000-0002-6116-4880, ³ 0009-0000-5630-2735

Abstract— In a world in which the generation of solid waste is increasing by leaps and bounds, the proper management of this waste is a decisive challenge for society. Lack of environmental awareness, excessive waste generation, and inadequate waste management and disposal have a negative impact on the environment and public health. In this context, environmental education emerges as a necessary tool to encourage sustainable practices and promote a paradigm shift in the society-environment relationship. The methodology used in the research was descriptive with a qualitative approach, under a deductive method, in which, an exhaustive bibliographic review was carried out in scientific databases, using keywords such as “environmental education”, “waste management”, “sustainability” and “behavioral change”. Published articles were selected that analyzed the subject strictly and provided empirical evidence on the impact of environmental education on waste management. The review of the information showed a general consensus on the importance of environmental education as a differentiating element for effective and sustainable waste management. The studies analyzed highlight, among other benefits, the promotion of social responsibility, greater environmental knowledge and awareness, and the adoption of responsible habits. It is concluded that environmental education is a transcendental pillar for effective and sustainable waste management. Its implementation in different contexts is crucial to encourage behavioral change, promote citizen participation and build a more environmentally responsible society.

Index Terms — Environmental education, environmental impacts, environmental culture, sustainability, solid waste management.

I. BACKGROUND

The accelerated growth of urban areas and the predominant consumption model have generated a significant increase in solid waste production, which poses serious challenges for environmental sustainability and public health [1]. In many cities, the infrastructure for waste collection, treatment, and disposal is insufficient to cope with the magnitude of the problem [2]. Although technologies and public policies aimed at improving waste management have been developed, they tend to focus on technical solutions, leaving aside the social and educational component that is essential to achieve structural change [3].

Environmental education emerges as a fundamental tool to face this challenge, since it allows the formation of citizens who are aware, critical, and committed to caring for the environment [4]. Its purpose is not limited to the transmission of information, but seeks to transform attitudes, values and behaviors related to waste generation, separation and disposal [5]. Through formative processes ranging from formal education to community campaigns, environmental education promotes the adoption of sustainable practices such as recycling, reuse and source reduction [6] [7].

Waste composition also reflects profound global inequalities. [8]. In high-income countries, organic waste represents on average 32% of the total, while in poorer regions this percentage can exceed 50%, indicating a higher presence of biodegradable waste that could be exploited by composting or anaerobic digestion [7].

However, recycling rates are still very low: the world average does not exceed 19%, and only some developed countries such as Germany, South Korea or Austria achieve rates above 50% [9]. This situation evidences the urgent need to adopt comprehensive approaches that include the circular economy, environmental education and citizen participation as strategic axes to close the materials cycle and reduce pressure on natural resources. Public policies should be oriented towards sustainable models that prioritize waste generation prevention, product redesign and extended producer responsibility, in order to achieve more resilient and equitable management systems worldwide [10].

Solid waste management represents one of the most urgent environmental challenges in Colombia, due to population growth, accelerated urbanization and unsustainable consumption patterns; therefore, the generation of urban solid waste has grown considerably in the last two decades, from 21,000 tons per day in 2005 to more than 32,000 tons in 2023. According to the National Planning Department (DNP), the country generates more than 12 million tons of solid waste per year, of which only 17% is used [11], while the rest ends up in sanitary landfills, many of them with a useful life close to exhaustion (DNP, 2021). This situation reveals the need for structural strategies for prevention, reduction and use that integrate citizens in the solution of the problem, being environmental education a key tool to transform habits and promote a culture of sustainability.

In the Colombian context, environmental education has been normatively recognized since Law 99 of 1993 [12], and has been incorporated in policies such as the National Environmental Education Plan (PNEA). However, its implementation has been uneven across regions, and its impact limited by sociocultural and economic factors (Ministry of Environment and Sustainable Development [MADS], 2018) [13]. In intermediate cities such as Bucaramanga, capital of the department of Santander, solid waste management faces specific challenges related to the informality of recycling, low community participation, and insufficient institutional articulation [14].

In Colombia, the classification of solid waste is regulated by Resolution 2184 of 2019, issued by the Ministry of Environment and Sustainable Development, which establishes the color code for separation at source and promotes the standardization of waste management nationwide. [15]. This measure seeks to promote a citizen culture oriented towards recycling and the circular economy, in addition to improving utilization rates and reducing the amount of waste arriving at sanitary landfills, many of which present capacity and management problems [11]. The implementation of the color code also responds to international commitments on sustainability and environmental management, framed in the 2030 Agenda for Sustainable Development, specifically in Sustainable Development Goals (SDGs) 11 and 12 related to sustainable cities and responsible production and consumption [16]. However, their implementation still faces significant challenges, such as the lack of environmental pedagogy, resistance to habit change and logistical limitations in some municipalities of the country [17]. In this context, strengthening environmental education is essential to ensure proper waste sorting and move towards efficient and sustainable integrated management in Colombia. [18].

The final disposal of solid waste in Colombia continues to be a critical stage in the management cycle, since more than 80% of the waste is deposited in sanitary landfills, many of which face problems of capacity, technical operation, and environmental compliance [19]. Law 142 of 1994 establishes the general framework of the public sanitation service, including final disposal as an essential component, while Decree 1077 of 2015 and Resolution 0472 of 2017 regulate the technical, operational and environmental conditions of disposal sites [20], [21]. However, it has been identified that at least 30% of landfills do not comply with the required standards, generating risks of contamination of soils and water bodies, as well as social conflicts due to their location [19]. Despite the efforts of the Ministry of the Environment and the Superintendence of Public Utilities, there is still a need for a transition towards circular economy models and regionalization of infrastructure, reducing dependence on final disposal and guaranteeing sustainable waste management.

The National Policy for Integrated Solid Waste Management (PNGIRS) establishes that final disposal in landfills should be the last resort, after having exhausted recovery and treatment options. The policy also emphasizes the importance of waste separation at the source to facilitate recovery and reduce the amount of waste going to landfills [11].

Environmental education is understood as a continuous process that seeks to form critical citizens committed to sustainability, capable of identifying environmental problems and actively participating in their solution [22]. In the area of solid waste, its objective is to promote cultural changes around consumption habits, separation at source, recycling and waste minimization [23], as can be seen in Figure 1, which establishes the Relationship between environmental education and waste management.



Figure 1. Relationship between environmental education and waste management

Recent studies have shown that environmental education programs aimed at urban communities can significantly improve the effectiveness of waste management strategies [24]. Citizen participation, when articulated with educational processes, can strengthen inclusive recycling, the circular economy, and the reduction of waste generation from the source [25].

From a pedagogical perspective, environmental education should be critical, contextualized and participatory, promoting meaningful learning that connects knowledge with action. The approach should be adapted to the socio-cultural realities of the territory, incorporating the experience of professional recyclers, organized communities and institutional actors [25].

All of the above is useful to be able to see the research realities that exist at the global, national and local levels with respect to solid waste management. Therefore, this study is carried out with the notion that the amount of solid waste increases over time in an indiscriminate manner, since there is a lack of knowledge about proper management, causing a global health problem, being responsible for multiple diseases.

The objective of this article is to analyze the role of environmental education in the sustainable management of solid waste, highlighting its contributions, challenges and potential in urban contexts. It is argued that, without an informed and committed population, any waste policy is doomed to fail, no matter how technologically advanced it may be. In this scenario, strengthening environmental education not only contributes to the formation of aware and responsible citizens, but also allows progress in reduction, reuse and recycling processes. In this way, an integrated solid waste management that favors the environmental, social and economic sustainability of the Colombian territory is promoted.

II. MATERIALS AND METHODS

The methodological design adopts a mixed approach that combines documentary analysis with the collection and comparison of empirical data from previous studies. This research was developed under a descriptive qualitative approach, based on the deductive method. Qualitative research techniques were used to comprehensively assess the negative impacts of inadequate solid waste management and its transformation involving environmental education strategies to transform behaviors [26], [27].

A documentary and bibliographic review was conducted in recognized scientific sources (Scopus, Redalyc, SciELO, Google Scholar), using combinations of keywords such as “environmental education”, “solid waste”, “waste management”, “behavior change” and “sustainability”. Reports from international organizations such as the United Nations Environment Organization (UNEP), the International Union for Conservation of Nature (IUCN) and the World Bank (World-Bank) were also included. In addition, official documents from governmental entities and NGOs dedicated to environmental monitoring were analyzed.

The criteria for the selection of sources included thematic relevance, methodological rigor and the timeliness of the information (publications within the last 15 years). Priority was given to studies that evaluated ecological, social and economic impacts, ensuring a holistic view of the problem. Case studies implemented in school, university, community and municipal contexts were also included, which made it possible to establish common patterns and contrast pedagogical approaches, achievements and limitations. The review also incorporated normative documents, public policies and technical guides relevant to the Colombian and international context.

The analysis of the information was structured in four key dimensions:

- 1) Ecological impacts: evaluation of studies on land use change, air pollution, biodiversity loss and ecosystem affection, alteration of water bodies and increased climate change [28] [29] [30].
- 2) Social impacts: Analysis of reports on public health risks, violation of the rights of informal recyclers, social and territorial conflicts, and inequality in the provision of sanitation services [31] [32] [33].
- 3) Regulation and sustainability: Comparison of existing regulatory frameworks and responsible sustainability strategies.
- 4) Economic evaluation: Study of the hidden costs of inadequate solid waste management and the potential benefits of sustainable economic alternatives [34] [11].

A comparative approach with studies of responsible waste management in other regions was applied to assess the feasibility of prevention strategies through environmental education.

We investigated how inadequate waste management affects the daily lives of local populations, especially in terms of changes in their lifestyles, social structures, and community relations. Inadequate waste management can generate social conflicts, alterations in community organization, and transformations in traditional cultural practices [11].

In this order of ideas, the method of analysis led to the collection of secondary information sources, among which books, reports and articles stand out. It also includes digital spaces that house experimental, explanatory or informative information by means of search engines and exclusion and inclusion criterion.

III. RESULTS AND DISCUSSION

A. Environmental Impacts..

Soil contamination.

Inadequate disposal of solid waste, especially in open dumps or poorly designed landfills, leads to serious soil contamination. In the absence of a solid environmental culture, citizens are unaware of practices such as separation

at the source or the responsible use of materials, which generates a mixture of organic waste, plastics, heavy metals and hazardous substances in the soil. These materials degrade slowly and release toxic compounds, such as leachates rich in ammonium, phenols, and heavy metals that alter the physical and chemical properties of the soil, affecting soil fertility and biodiversity [35]. The lack of environmental education hinders the understanding of these processes and limits social pressure towards better integrated waste management practices.

Contamination of water bodies.

One of the most severe impacts of poor solid waste management is the contamination of water sources. In areas where adequate environmental education is not practiced, it is common to observe that rivers, streams and rainwater channels are used as clandestine dumps. This practice facilitates the dragging of plastic waste, decomposing organic matter, and toxic products into water bodies, which reduces the quality of water resources, affects aquatic species, and endangers human supply [29]. Studies show that poorly managed urban waste contributes significantly to the pollutant load in urban and peri-urban aquatic ecosystems [36]. Environmental education could foster citizen awareness of the impact of these actions and promote solutions such as composting, recycling, and differentiated hazardous waste management.

Greenhouse gas emissions

When solid waste, especially organic waste, is disposed of improperly without separation or treatment, it generates large volumes of greenhouse gases, such as methane (CH₄) and carbon dioxide (CO₂), derived from its anaerobic decomposition. The lack of environmental culture reduces citizen participation in processes such as composting or the use of biodigesters, which intensifies the problem. According to the UN, solid waste accounts for approximately 5% of global greenhouse gas emissions, a figure that could be drastically reduced with massive environmental education strategies [37]. This educational omission reinforces a linear model of consumption and disposal that actively contributes to climate change [38] [39].

Biodiversity loss

The accumulation and improper disposal of waste in natural ecosystems (such as forests, wetlands or reserve areas) generates devastating effects on local flora and fauna. The entry of non-biodegradable waste, such as plastics, can cause the death of species by ingestion or entanglement, while the introduction of toxic substances alters trophic chains and affects reproduction and feeding processes. In contexts where environmental education is weak, people are often unaware of the ecological value of the environments they inhabit and reproduce unsustainable consumption and disposal practices. Research has shown that poorly managed solid waste is one of the main threats to wildlife in urban and rural areas [40]. Strengthening environmental awareness is thus presented as a key factor to mitigate this loss of biodiversity.

Degradation of the landscape and impact on ecosystem services

The accumulation of waste in public spaces, green areas, water bodies or natural environments generates a visual and functional alteration of the landscape, which directly affects ecosystem services, such as climate regulation, water infiltration or the provision of recreational spaces. This situation, in addition to reducing the quality of urban life, deteriorates the ecological value of the territories. The deficient environmental culture prevents citizens from understanding the link between their daily actions and the environmental deterioration they produce, perpetuating an unsustainable model of relationship with the environment [41]. The design of educational strategies based on experience and recognition of the territory is fundamental to reverse this process

B. Social Impacts

The inadequate management of solid waste has serious social consequences that mainly affect health, equity, community cohesion and citizen participation. In contexts where there is little access to environmental education, these impacts are accentuated, since the population lacks the tools to understand, prevent or transform the situation. One of the main impacts is the risk to public health, since improper waste disposal favors the proliferation of disease-transmitting vectors (rats, mosquitoes, cockroaches), as well as the emission of offensive odors and toxic gases that generate respiratory and gastrointestinal ailments, mainly in children, the elderly and informal recyclers [29]. The lack of environmental education programs prevents the adoption of practices such as separation at the source, the use of adequate containers, and the management of hazardous waste, which increases exposure to health risks.

The social vulnerability of informal recyclers is a structural problem aggravated by the lack of knowledge of their role within the waste management system. These workers play a fundamental role in the circular economy, but face precarious conditions, without job security or institutional recognition. The lack of generalized environmental education contributes to their stigmatization and exclusion from formalization programs [42] [43].

Another relevant impact is the deficit of citizen participation, due to limited understanding of waste management processes and environmental rights and duties. This weakens community initiatives, prevents the demand for quality services, and generates disinterest in social control of projects such as landfills or waste management plants [44] [45].

Finally, the use of public spaces as clandestine dumps and the deterioration of the urban landscape affect the perception of security, collective identity and social cohesion, since these environments are often associated with marginality and state abandonment. Environmental education, when applied from a territorial and participatory approach, can reverse this perception and empower communities as agents of transformation [46] [47]. Table 1 shows the environmental, social and economic impacts of inadequate solid waste management and its relationship with environmental education.

C. Economic Impacts

From the economic point of view, inadequate solid waste management represents high direct and indirect costs for local governments, businesses, and society in general. In the first place, the inefficient operation of collection, transportation and final disposal systems, as a result of low separation at the source and lack of citizen education, implies a greater volume of waste to be treated, which increases operating costs and reduces the useful life of sanitary landfills [48].

In addition, large volumes of usable materials such as paper, cardboard, plastics and organic materials are lost, which could be reincorporated into circular value chains, generate green jobs and boost local economies. This loss of economic value occurs due to the lack of knowledge of recycling and composting practices, both at the household and institutional levels [49]. Several studies estimate that the costs of correcting the ecological and social damage resulting from poor waste management are several times higher than those of preventive investment in environmental education and inclusive recycling systems [50].

Finally, the failure to exploit the potential of environmental education as a management tool generates a prolonged dependence on linear and unsustainable systems, slowing progress towards more resilient, sustainable and inclusive economic models [51].

D. Political Impacts

Inefficient solid waste management generates various political impacts that deteriorate citizen confidence in institutions, affect the legitimacy of the State, and limit territorial governance. One of the main effects is the loss of credibility in local administrations when they fail to provide an efficient sanitation service, when landfills overflow, when open dumps proliferate, or when environmental regulations are not complied with. This situation gives rise to social tensions, community protests and governance conflicts, particularly in peripheral areas that have historically been neglected by the state [45].

In addition, the absence of comprehensive and participatory public policies on solid waste reflects weaknesses in environmental planning and decision making with a territorial approach. The lack of environmental education as a structural policy limits social appropriation of management strategies, reduces citizen participation and hinders the implementation of schemes such as circular economy or separation at source [52].

Another relevant political impact is clientelism or corruption in the contracting of collection and final disposal services, as well as the granting of environmental licenses without prior consultation or adequate technical studies. This perpetuates inefficient models, weakens transparency and encourages a short-term vision of waste management [53].

Likewise, inequity in the distribution of environmental impacts, such as the concentration of landfills in vulnerable territories or excluded communities, can generate environmental and political conflicts, violating principles of environmental justice and affecting territorial cohesion [54].

Finally, inadequate waste management compromises the climate agenda and international commitments acquired by States in the framework of agreements such as the Paris Agreement or the SDGs, due to the increase in greenhouse gas emissions from the decomposition of organic waste in uncontrolled dumps [55].

E. Policies and Regulatory Aspects of Solid Waste Management in Colombia

Solid waste management in Colombia is governed by a set of policies, laws, decrees and resolutions that have evolved with the objective of promoting integrated, sustainable and inclusive management. However, despite regulatory advances, significant challenges persist related to implementation, control and citizen participation.

One of the most important regulatory milestones in Colombia is the enactment of Law 142 of 1994, also known as the Household Public Services Law, which establishes the legal framework for the provision of public sanitation services, including the collection, transportation, treatment, and final disposal of solid waste [56]. This law introduced the concept of business efficiency; however, it left gaps in terms of environmental sustainability and community participation in the management of the service.

Subsequently, Decree 1713 of 2002 defined the guidelines for the integrated management of solid waste, establishing obligations for the providers of the sanitation service and promoting the use of waste as a mandatory component. Decree 1077 of 2015, which compiles the regulations of the housing, city and territory sector, and consolidates provisions for the development of Integrated Solid Waste Management Plans (PGIRS), that must be adopted by all municipalities and districts in the country [57].

In the area of social inclusion, Colombia became a pioneer in Latin America by formally recognizing the work of waste pickers as part of the public sanitation service, through Ruling T-291 of 2009 and other subsequent rulings of the Constitutional Court. These decisions prompted the issuance of Resolution 0754 of 2014, which includes and regulates waste collection activities and requires the inclusion of organized recyclers as service providers [58].

In terms of public policy, the country has the National Policy for Integrated Solid Waste Management (PNGIRS), initially adopted in 1998 and updated in 2016. This policy promotes a preventive approach, based on the management hierarchy (reduction, reuse, recycling, treatment, and final disposal), as well as interinstitutional articulation and the strengthening of citizen culture [11]. Despite its integrative approach, its implementation has been uneven among municipalities, and is often limited to reactive actions or quantitative goals poorly articulated with educational or community processes.

A key aspect in the Colombian context is the transition to the circular economy, promoted by the 2019 which seeks to close production cycles and valorize materials through eco-design, responsible consumption and technological innovation. However, this strategy requires a National Circular Economy Strategy (ENEC) that

deeply transforms the productive, educational and institutional dynamics, which implies significant challenges for local governments with limited technical and budgetary capacities [49].

Despite the robust regulatory framework, the main problems lie in the weak control and surveillance capacity of the environmental authorities, the low articulation between levels of government and the scarce compliance with the PGIRS in municipalities of category 5 and 6. In addition, inadequate disposal practices persist, such as the existence of more than 200 open dumps in the country, a situation that contradicts the principles of environmental sustainability and calls into question the effectiveness of the current regulations [48].

Environmental education, although mentioned in sectoral policies, has not been prioritized as a transversal axis in waste management.. Its incorporation in the National Environmental Education Policy (PNEA) and in the PGIRS Guidelines is still weak and fragmented, which limits its transformative impact on citizenship and community waste management [46].

F. The importance of environmental education in proper solid waste management

Environmental education is a strategic pillar to achieve an integrated and sustainable management of solid waste, since it allows transforming individual and collective behaviors, fostering ecological awareness and promoting the active participation of citizens in the solution of urban environmental problems. In contexts such as Colombia's, where there are still high levels of informality, inadequate disposal practices and a low culture of separation at the source, environmental education is not only a complement, but a necessary condition for the success of any public policy in this field.

Several studies have shown that educational programs have a direct impact on the reduction of waste generated and on the increase in recovery rates, by encouraging practices such as reduction, reuse, recycling and composting [59]. Environmental education acts as a transforming tool by generating awareness and training processes that go beyond information and aim to modify consumption and disposal habits, consistent with the principles of the circular economy and sustainability [60].

In Colombia, although the National Environmental Education Policy (PNEA) and the Integrated Solid Waste Management Plans (PGIRS) recognize the importance of education as a transversal axis, its implementation has been weak and fragmented, often limited to specific campaigns without continuity or inter-institutional articulation [46]. This limits their structural impact and reduces their scope to informative activities, without a clear evaluation of results.

One of the main contributions of environmental education in waste management is that it empowers the community as an agent of change, allowing them to understand the social, health and ecological implications of inadequate disposal. In addition, it facilitates the appropriation of institutional programs such as separation at the source, payment per generation and the inclusion of recyclers, promoting a more active, critical and co-responsible citizenship [61].

From a pedagogical perspective, environmental education allows the integration of scientific knowledge with local knowledge, strengthening values such as responsibility, solidarity and respect for the environment. This is especially relevant in vulnerable or rural communities, where the lack of infrastructure for waste management can be partially addressed through educational strategies based on the environment and self-management [62].

Additionally, environmental education is key to overcoming cultural and perception barriers that impede the success of technological or regulatory innovations. For example, resistance to recycling or composting in many urban households is due more to ignorance or disinterest than to a real lack of skills, which demonstrates the need for constant educational interventions, adapted to the context and with participatory approaches [63] [61].

Finally, environmental education helps to ensure the long-term sustainability of waste management strategies by building a solid social base that legitimizes and supports institutional decisions. Without a profound cultural change, any investment in infrastructure, regulations or technology runs the risk of failure due to lack of social appropriation. Therefore, environmental education should be understood as a structural and not a complementary strategy to the solid waste policy, articulated with the education, health, environment and territorial development sectors [42].

G. Successful experiences of environmental education for the proper management of solid waste worldwide.

Waste Separation Program in Seoul, South Korea:

Description and success. Since the 1990s, South Korea implemented a Volume-Based Waste Fee System along with an intensive environmental education campaign that includes school education, media campaigns, citizen participation and mandatory labeling of waste bags. This system has led to more than 50% of the waste generated in Seoul being recycled [64].

Educational importance. The success is due in part to the implementation of educational programs in schools and neighborhoods that teach how to properly separate waste and why it is important. In addition, community centers have been developed where citizens receive constant training in recycling and composting practices, which encourages ownership of the system.

Zero Waste Program in San Francisco, USA:

Description and success. San Francisco is recognized for its ambitious "Zero Waste" goal, based on a robust selective collection system, mandatory composting and a strong educational component. More than 80% of the solid waste generated in the city is diverted from landfills [65].

Educational importance. Educational campaigns are ongoing and include multilingual materials, community trainings, workshops in schools, and waste audits in companies. Citizen engagement has been promoted through

alliances between the government, NGOs and private companies, making education a cross-cutting issue in public policy.

EcoSchools in Latin America (Program of the Foundation for Environmental Education - FEE):

Description and success. The EcoEscuelas program is an international initiative implemented in more than 60 countries. In Spain, it has been adopted in more than 500 schools. It promotes comprehensive environmental education with a focus on waste, energy, water and biodiversity [66].

Educational importance. Participating schools prepare an environmental diagnosis, form a school environmental committee, and develop an action plan involving teachers, students, parents, and administrative staff. The process culminates with “Green Flag” certification, which generates institutional pride and improves the environmental culture of the environment.

Zero Garbage” Program in the city of Rosario, Argentina:

Description and success. The “Zero Waste” Law 1854 in Rosario, Argentina, establishes progressive goals for the reduction of waste sent to final disposal. This policy is complemented by educational strategies that include community workshops, school programs and mobile green points [67] [68].

Educational importance. The inclusion of urban recyclers (cartoneros) as educational agents in neighborhood campaigns stands out. These actors not only recover materials, but also teach communities about separation, reduction and reuse, promoting the circular economy based on social justice.

“Karo Sambhav” in India - E-recycling education:

Description and success. Karo Sambhav is an initiative that promotes responsible e-waste recycling in India through an educational approach in schools and communities. The program has reached over 1,000 schools and collected tons of e-waste [69].

Educational importance. The educational component includes training teachers, providing teaching materials, and carrying out school projects focused on the life cycle of electronic products. Environmental education is combined with values such as innovation, responsibility and conscious consumption.

Let’s Do It World” - Global Mass Cleanup Movement:

Description and success. Started in Estonia in 2008, this movement promotes massive community cleanups, accompanied by solid waste education days. In 2018, the global event achieved the participation of more than 17 million people in 157 countries in a single day [70].

Educational importance. The strategy is not limited to garbage collection, but seeks to generate environmental awareness through educational campaigns, workshops, social networks and collaborative work. Its success lies in mobilizing citizens from a logic of collective empowerment, inspiring cultural transformations.

CONCLUSIONS

From an environmental perspective, it is concluded that environmental education is fundamental to mitigate the negative impacts of inadequate waste management, such as soil, water and air pollution, loss of biodiversity and overloading of ecosystems. Environmental education contributes to raising awareness about the life cycle of products, the principle of extended consumer responsibility and the reduction of unsustainable consumption, thus promoting a more harmonious relationship between human activities and natural systems. In addition, the articulation of educational programs with circular economy policies can enhance the regeneration of natural resources and significantly reduce the ecological footprint of cities.

In the social sphere, it should be noted that inclusive and contextualized environmental education can reduce information and inequality gaps in solid waste management, especially in vulnerable communities. This approach encourages the active participation of citizens, dignifies the work of waste pickers, and promotes environmental justice through processes of knowledge appropriation, community empowerment and co-responsibility. By strengthening the social fabric around waste management, it fosters cooperative relationships, respect for the environment and intergenerational solidarity, key pillars for sustainability.

Economically, environmental education represents a strategic investment that can reduce the costs associated with the final disposal of waste, improve the efficiency of recycling systems and stimulate the development of green businesses and circular economy models. An environmentally educated citizenry tends to generate less waste, sort better and consume more consciously, which optimizes the use of resources and reduces pressure on public sanitation budgets. Likewise, strengthening human capital through environmental training boosts innovation and the generation of sustainable jobs in sectors such as recycling, composting and technological waste management. From the political approach, it is concluded that environmental education is key to strengthening governance in solid waste management. It contributes to legitimize public policies, promote regulatory compliance and consolidate participatory planning processes and citizen control. The absence of a solid environmental culture limits the effectiveness of legal instruments and hinders the articulation between institutional and social actors. Therefore, environmental education should be incorporated as a mandatory component in integrated solid waste management plans (PGIRS) and in the formulation of public policies, guaranteeing its integration with other sectors such as health, education and urban planning.

In terms of regulations and management policies, Colombia has a broad but dispersed legal framework that needs to be strengthened through a national environmental education strategy focused on solid waste, with a territorial approach and clear follow-up mechanisms. The implementation of the Color Code, the recognition of recyclers and the guidelines of the National Policy on Integrated Solid Waste Management (PNGIRS) are important

advances, but insufficient if they are not articulated with continuous training processes, pedagogical accompaniment and impact evaluation. It is necessary that public policies not only promote technical waste management, but also cultural transformation through a robust, critical and long-term environmental education. Finally, the research shows that environmental education constitutes a transversal and strategic axis in the sustainable management of solid waste, not only as a training tool, but also as a catalyst for cultural, institutional and structural changes. Its coherent, systematic and territorialized implementation allows not only to improve the indicators of waste separation, reduction and use, but also to strengthen an environmentally active and aware citizenry, capable of influencing decision making and demanding effective public policies. The educational approach must go beyond mere awareness-raising to become a critical, participatory and transformative process involving all social actors.

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