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Environmental Education, Waste Exposure, and Potential Microbial or Genetic Health Risk Indicators in a Peri-Urban Peruvian Community

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ABSTRACT

The study analyzed the relationship between environmental education and sustainable practices in solid waste management in the community of Quebrada Verde, district of Pachacámac, during the year 2025. Using a quantitative, applied, and non-experimental design, 120 residents participated in a structured survey of 24 items validated by experts (V de Aiken = 0.91; $\alpha = 0.89$). The data processed using SPSS version 25 software and Spearman's test ($p < 0.05$) showed a positive and significant correlation ($r = 0.726$) between both variables. The results reveal that strengthening environmental knowledge, attitudes, and practices has a direct impact on the adoption of sustainable behaviors aimed at responsible waste management. It is understood that environmental education is a fundamental basis for promoting sustainability in the area and compliance with SDG 12 on responsible production and consumption.

Keywords: *environmental education, sustainable practices, solid waste, sustainability, SDG 12.*

INTRODUCTION

Improper waste accumulation has become one of the major environmental problems for local governments in Latin America, where population growth, rapid urbanization, and poor municipal management skills have negative effects on public health and the environment (Pan American Health Organization [PAHO], 2023). In Peru, it is estimated that there are more than 23,000 tons of waste per day, less than half of which receives adequate treatment or disposal (Ministry of the Environment [MINAM] 2023). This situation highlights the need to implement sustainable strategies that integrate education as a way to change people's attitudes toward the environment (United Nations Environment Programme [UNEP], 2022).

From a quantitative perspective, environmental education is seen as a factor that helps people understand ecological actions, which can be measured through mental, emotional, and behavioral aspects (Leal et al., 2021). Recent studies show a strong correlation between environmental knowledge and the use of sustainable products in large and small towns (Cárdenas and García, 2023). Thus, measuring knowledge

and attitudes about the environment with real data reveals whether this education has a significant effect on waste management, which is key to making local laws more effective (Gonzales et al., 2024).

Solid waste management is a technical and social process that involves the collection, transport, treatment, recycling, and final disposal of waste, based on criteria of efficiency and sustainability (Bolaños et al., 2022). In the Peruvian context, municipalities are responsible for implementing waste management programs, but their actions are limited without the active and educated participation of the population (MINAM, 2023). Therefore, environmental education not only raises awareness but can also quantitatively generate variations in indicators of source separation, recycling, and responsible disposal (Cruz and Gutiérrez, 2022).

In the district of Pachacámac, and particularly in the community of Quebrada Verde, the problem of solid waste is exacerbated by a lack of infrastructure, infrequent collection, and low levels of environmental awareness. These conditions justify the application of a quantitative, descriptive-correlational study aimed at measuring the relationship between environmental education and sustainable waste management practices. This type of analysis allows us to obtain statistical evidence on the degree of influence of the educational variable on the environmental behavior of the inhabitants, through the use of validated instruments and reliable measurement scales (Hernández and Mendoza, 2023).

This study seeks to determine the extent to which environmental education is related to sustainable practices in solid waste management in Quebrada Verde, Pachacámac – 2025. Through structured surveys applied to the residents of the sector, indicators such as environmental knowledge, ecological attitudes, recycling habits, and final waste disposal will be analyzed. The data will be statistically processed using correlation coefficients and hypothesis tests in order to establish significant relationships between the variables and test the general hypothesis.

The results of this research will provide relevant quantitative information to strengthen municipal environmental policies, guide evidence-based environmental education programs, and promote informed community participation. In this way, the study will contribute to the fulfillment of Sustainable Development Goal 12, which refers to responsible production and consumption, and to the strengthening of a local environmental culture based on measurement and empirical evidence.

METHODOLOGY

This quantitative, applied, non-experimental, cross-sectional, and correlational study aimed to objectively measure the relationship between environmental education and sustainable practices in solid waste management in the community of Quebrada Verde, district of Pachacámac, during the year 2025. A census population of 120 residents was surveyed using a structured questionnaire with 24 items, validated by experts (V de Aiken = 0.91) and with high reliability ($\alpha = 0.89$). The data were processed using SPSS version 25 software, applying Spearman's correlation test ($p < 0.05$), whose results demonstrated a direct and significant relationship between both variables, concluding that strengthening environmental education promotes responsible behavior in solid waste management and provides empirical evidence for the design of local community sustainability policies and strategies.

RESULTS

Analysis of Figure 1 shows that, in the Knowledge dimension, 63% of Quebrada Verde residents have an average level, while 37% are at a low level and 46% at a high level. These results show that most residents have basic information on environmental issues, although gaps remain in their deep understanding of ecological and sustainability concepts. This suggests the need to strengthen environmental education through awareness-raising and ongoing training programs in the community.

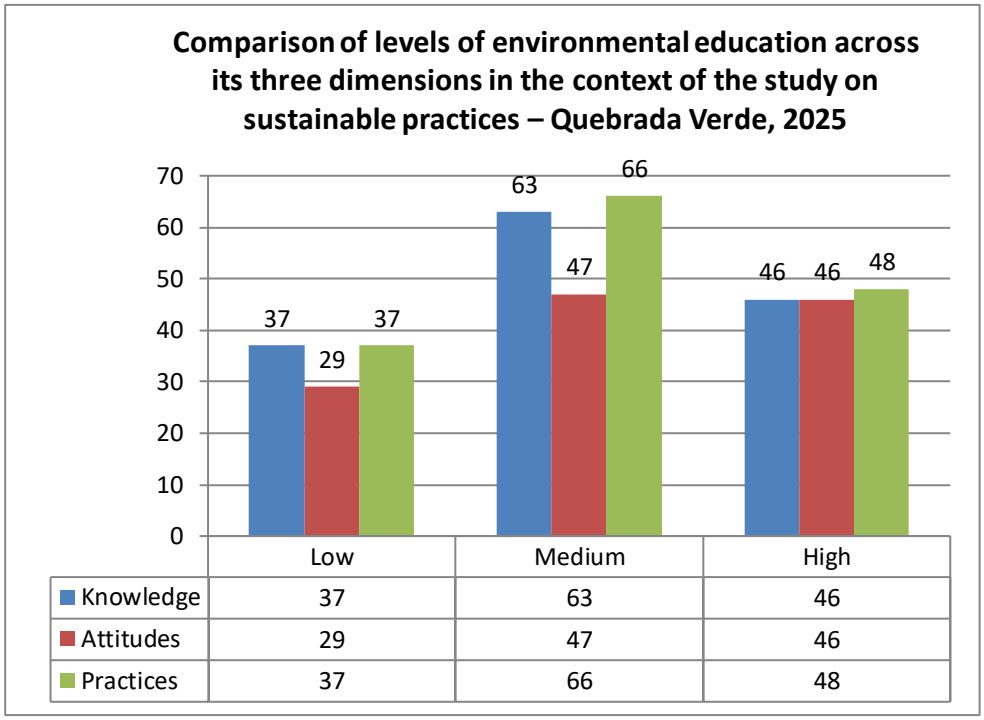

Figure 1: Levels of Environmental Education according to the dimensions of Knowledge, Attitudes, and Practices among the residents of Quebrada Verde, Pachacámac – 2025
Note: data obtained from a survey of residents in the area.

A similar trend can be observed in the Attitudes and Practices dimensions: 47% and 66% of respondents, respectively, are at an intermediate level, while 46% and 48% are at a high level. This indicates a favorable disposition toward caring for the environment, but with a still limited degree of practical application. Overall, the results reflect that the residents of Quebrada Verde have an environmental awareness that is in the process of consolidation, where the knowledge acquired has not yet been fully translated into sustainable and permanent actions in solid waste management.

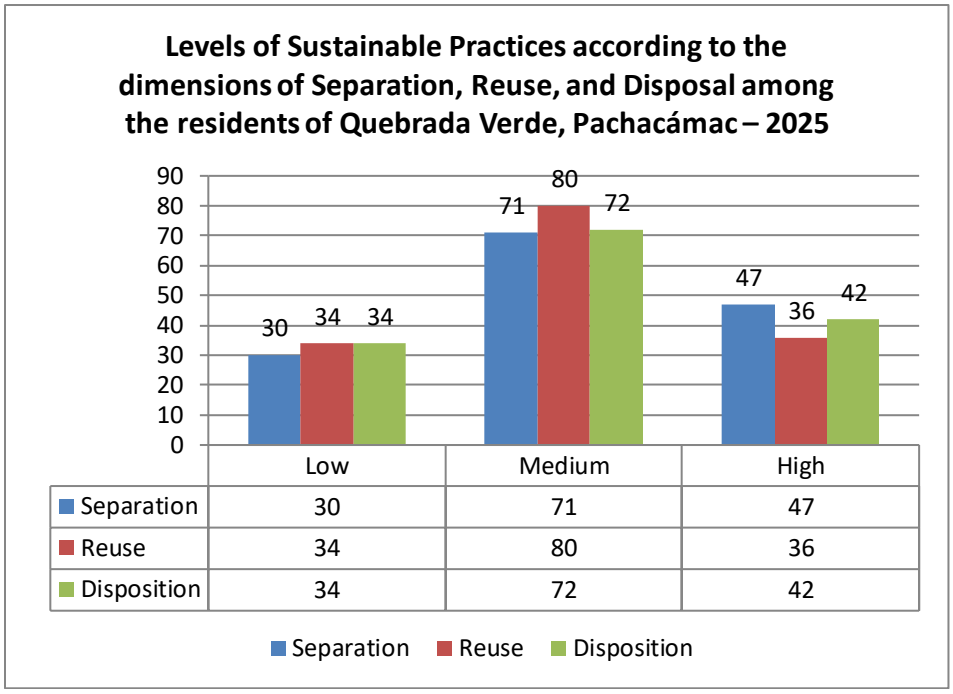

Figure 2: Levels of Sustainable Practices according to the dimensions of Separation, Reuse, and Disposal among the residents of Quebrada Verde, Pachacámac – 2025

Note: data obtained from a survey of residents in the area.

The results show that in the Sustainable Practices variable, most residents of Quebrada Verde are at the medium level in the three dimensions evaluated. In waste separation, 71% of participants are at a medium level, while 30% are at a low level and 47% at a high level, reflecting partial participation in proper waste sorting. In reuse, 80% reached a medium level, 34% a low level, and 36% a high level, indicating that material reuse is not yet a consistent practice.

In terms of final waste disposal, 72% are at an intermediate level, 34% at a low level, and 42% at a high level, showing that, although there is environmental awareness, limitations in proper waste management persist. Overall, the results show that sustainable practices in the community are in the process of consolidation, and it is necessary to strengthen education and citizen participation to achieve a more solid and permanent environmental commitment.

Table 1: Relationship between Environmental Education and Sustainable Practices among the residents of Quebrada Verde, Pachacámac – 2025

Level of Environmental Education	**Level of Sustainable Practices**			**Total**
	Low	Medium	High	
Low	18 (15%)	7 (6%)	2 (2%)	27 (23%)
Medium	10 (8%)	42 (35%)	18 (15%)	70 (58%)
High	3 (2%)	9 (7%)	11 (9%)	23 (19%)
Total	31 (26%)	58 (48%)	31 (26%)	120 (100%)

Note: data obtained from a survey conducted among residents of the area.

Analysis of the table shows that there is a clear trend between the level of environmental education and the sustainable practices of the residents of Quebrada Verde. Fifty-eight percent of participants with an average level of environmental education also have an average level of sustainable practices, while 19% with a high level of environmental education achieve a high level of sustainable practices. In contrast, residents with a low level of environmental education (23%) also show low levels of sustainable practices (15%), demonstrating a direct correlation between the two variables.

The results obtained in the research show that environmental education has a direct and significant influence on the sustainable practices of the residents of Quebrada Verde, reflecting that strengthening ecological knowledge, attitudes, and behaviors translates into a greater commitment to responsible solid waste management. Most respondents fall in the middle range for both variables, demonstrating significant progress, although still insufficient to consolidate a solid environmental culture. These findings confirm the need to continue promoting educational programs and local policies aimed at sustainability, capable of transforming everyday practices into permanent actions of environmental care and community participation.

DISCUSSION

The research results show a clear and significant relationship between environmental education and the sustainable behaviors of Quebrada Verde members, which is consistent with what is seen in Latin America. The actual evidence indicates that greater knowledge and a positive attitude toward nature lead to greater participation in separating, reusing, and properly disposing of waste. This data is in line with what Cárdenas and García (2023) believe: Ecology in Andean highland communities causes positive and lasting changes, as ecological learning improves the relationship with the environment. In this sense, it is clear that environmental education plays an important role in promoting actions that are good for the environment, because it changes what people know, feel, and do. Real et al. (2021) say that learning about what does not harm the planet is like a change that helps us understand how nature works and motivates us to make informed decisions to care for the world. In the case of Quebrada Verde, the high presence of average levels of knowledge, thinking, and action on ecology shows a growing awareness that needs more teaching and support from the social group to reinforce lasting green behaviors.

In parallel with the above, Gonzales et al. argue that in Lima, those who know more about the environment use better ways to recycle and reduce waste, which is consistent with the findings of the current study; Spearman's coefficient ($r = 0.726$; $p < 0.05$) shows a strong and clear connection between these variables. This data supports the idea that environmental education generates effective social action for sustainable local management.

Likewise, Bolaños and his team (2022) note one fact: solid waste management is not enough if it is not combined with environmental education and local interventions. Despite progress, there is still a need for ongoing educational processes that promote environmental responsibility in all areas, from public services to recycling processes. In this sense, the results of this study are very similar to the rules created by the Ministry of the Environment (MINAM, 2023) and the United Nations Environment Programme (UNEP, 2022). These rules show the great need to initiate educational programs based on participation and research, to reduce the gap between what we know about the environment and its actual use. In this regard, the study has shown that local environmental education programs in Pachacámac can be an important center for sustainable management, strengthening citizens' skills and improving ways to recycle and dispose of waste properly.

Finally, the results show that environmental education is a very important tool for achieving the Sustainable Development Goals (SDGs), especially SDG 12, which addresses responsible consumption and production. As the Pan American Health Organization (PAHO, 2023) states, reducing waste requires not only official

rules but also cultural change. Thus, the Quebrada Verde initiative shows that a group with a high level of environmental awareness can put sustainable practices into action, which contributes to participatory environmental management and the strengthening of a local green culture.

CONCLUSION

The results of this study show that environmental education strengthens the link between what we know and what we do for the good of the earth, thus creating a positive effect on how we manage solid waste at the neighborhood level. The experience in Quebrada Verde shows that environmental education not only improves our knowledge of ecology but also causes us to change our behavior in clear ways that help make the place where we live more sustainable. As Tilbury and Cooke (2022) say, environmental education can change citizens' actions by promoting critical thinking and an ecological ethic focused on the common good, which can be seen in groups that are moving towards a responsible way of caring for their resources.

Above all, the research clearly shows the value of combining knowledge about the environment with the active participation of the people. According to UNESCO (2023), sustainability is achieved when this knowledge about the environment leads to joint actions that strengthen the local group in the face of ecological challenges. In this case, the community of Quebrada Verde can become an example of good collective management where technical expertise is combined with civic responsibility, promoting wise consumption and reducing waste.

The study also shows that environmental education plans must always be adapted to the local situation and involve various groups. New research indicates that learning projects focused on ecology have greater impact when supported by governments and civil society organizations (Vega and Espinoza, 2024; Jiménez et al., 2022). This means that the town of Pachacámac could improve its environmental policy by replicating community workshops, reporting methods, and constantly monitoring the impact of good actions, ensuring lasting environmental change.

The conclusion is that environmental education around the world is key to achieving development goals that will last over time. In particular, SDG 12 on how to use and carry out ecological activities in a careful manner. As Leicht et al. (2022) show, educational methods that incorporate sustainability greatly help to create more equitable, resilient communities that understand the value of their natural environment. Therefore, it is suggested that local organizations, schools, and municipalities maintain a constant union that combines study, teaching, and environmental care, ensuring that what is studied becomes a green lifestyle forever.

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