RIMA
Revista Interdisciplinar e do Meio Ambiente
Interdisciplinary and Environment Journal
v.6, n.1, 2024, DOI: 10.52664/rima.v6.n1.2024.e230

# Correlation between waste generation, population and GDP of cities in Sergipe, Brazil

## *Correlación entre la generación de residuos, la población y el PIB de las ciudades de Sergipe (Brasil)*

*Carlos Gomes da Silva Júnior*[1], *Zacarias Caetano Vieira*[2], *Eliglesia Maria Caldas dos Santos*[3], *Wanderson Lucas dos Santos Barros*[4] & *Alejandro Luis Machado Hussain*[5]

**Abstract:** The problem of solid waste (garbage or rubble) is a global problem that affects the environment, public health, and the quality of life of people all over the world. In this work, a literature review and quantitative research were carried out on the websites of the Institute of Water and Sanitation and Dataviva of the Federal University of Minas Gerais, to collect the data needed to verify whether or not there is a correlation between population size, waste generation and gross domestic product (GDP) per capita. This work used the correlation coefficient, which is widely used to measure the relationships between variables and what they represent, and is important for drawing up overviews in studies with many related variables so that it is possible to understand how the variability of one affects the other. The results show that population size and per capita waste generation showed a weak positive correlation and GDP per capita and per capita waste generation showed a very weak negative correlation. It can be concluded that economic and population aspects can influence the total volume of waste generated, but that they did not emerge as determining factors in isolation, showing that different populations (in terms of age structure, household arrangement structure, and cultural habits, among others) practice different consumption patterns, generating different amounts of solid waste.
**Keywords:** *Relationship; Coefficients; Sustainability; Awareness.*

**Resumen:** El problema de los residuos sólidos (basura o escombros) constituye una dificultad global que afecta al medio ambiente, a la salud pública y a la calidad de vida de las personas en todo el mundo. En este trabajo, se realizó una revisión bibliográfica y una investigación cuantitativa en los sitios web del Instituto de Agua y Saneamiento y Matavia de la Universidad Federal de Minas Gerais, con el fin de recopilar los datos necesarios para verificar la existencia o no de una correlación entre el tamaño de la población , la generación de residuos y el producto interno bruto (PIB) per cápita. En este trabajo se utilizó el coeficiente de correlación, ampliamente utilizado para medir las relaciones entre variables y lo que representan. Son importantes para trazar panoramas en estudios con muchas variables relacionadas, ya que así es posible comprender cómo la variabilidad de una afecta a la otra. Los resultados muestran que el tamaño de la población y la generación de residuos per cápita presentan una correlación positiva débil y que el PIB per cápita y la generación de residuos per cápita presentan una correlación negativa muy débil. Se concluye que aspectos económicos y poblacionales pueden influenciar el volumen total de residuos generados, pero que aisladamente no surgieron como factores determinantes, mostrando que poblaciones diferentes (en estructura de edad, estructura de arreglo doméstico, hábitos culturales, entre otros) practican patrones de consumo diferentes, generando residuos sólidos en grandes cantidades.
**Palabras clave:** *Relación; Coeficientes; Sustentabilidad; Concientización.*

*Author for correspondence
Received for publication on 2024/04/04; approved on 2023/10/25.
[1] Student, Federal Institute of Sergipe, cgomes.aju2016@gmail.com, https://orcid.org/0000-0001-6383-9629 *;
[2] Professor, Federal Institute of Sergipe, zacariascaetano@yahoo.com.br, https://orcid.org/0000-0001-5019-0971;
[3] Student, Federal Institute of Sergipe. eliglesia.caldas021@academico.ifs.edu.br, https://orcid.org/0000-0001-8552-6594;
[4] Student, Federal Institute of Sergipe. wanderson.barros107@academico.ifs.edu.br, https://orcid.org/0009-0006-4553-9060;
[5] Student, Federal Institute of Sergipe. alejandro.hussain981@academico.ifs.edu.br, https://orcid.org/0009-0002-6103-571X.

## INTRODUCTION

It was only after the Industrial Revolution that waste began to gain importance, especially for public health; however, it was from the 1970s onwards that waste really gained environmental weight, both nationally and internationally, and was widely discussed at major world meetings, such as the Stockholm conferences in 1972 and ECO 92 in Rio de Janeiro (Velloso, 2008; Wilson, 2007).

The importance of waste collection and management is related to the reduction of environmental impacts due to consumption, because when we separate waste (or what is left over from what we consume), we make it much easier to deal with and reduce the chances of harmful impacts on the environment and the health of life on the planet, including human life.

In urban areas, incorrect waste can accumulate in inappropriate places, becoming breeding grounds for disease vectors. Another aspect to consider is that wind and rain can transport this waste, hence the importance of urban cleaning and correct management. Such actions play an important role in reducing the exploitation of natural resources, as they contribute to increasing recycling and the circular economy (Ecycle, 2023).

As reported by Godecke, Naime, and Figueiredo (2012), population growth and the concentration of this contingent in urban areas have increased the use of ecosystem services, whose depletion occurs both through use for production and consumption, and through the damage resulting from the return of waste to nature after its use by man.

Knowledge of the factors that interfere with this generation of waste is extremely important to develop actions that promote its reduction.

Because of the above, this article aims to analyze the magnitude of the correlation between population size, Gross Domestic Product (GDP), and the amount of waste generated in the cities of Sergipe.

## THEORETICAL BACKGROUND

### Solid Waste

According to the National Solid Waste Management Information System (SINIR), Municipal Solid Waste (MSW) is that which originates from domestic activities in urban residences (household waste), industrial activities, street cleaning, and other urban cleaning services (urban cleaning waste) (Brasil, 2023).

Also, according to SINIR, Law No. 14.026/2020 (New Legal Framework for Sanitation), which establishes national guidelines for basic sanitation, article 3-C states that waste originating from

commercial, industrial, and service activities whose responsibility for management is not attributed to the generator may, by decision of the public authorities, be considered urban solid waste (Brazil, 2023).

**Solid waste issues**

The issue of municipal solid waste (MSW) today is a major challenge for the management of cities towards sustainability. However, the phenomena and impacts related to the prevention, generation, collection, disposal, and reuse of MSW have been dealt with on a sectoral basis, in a disjointed manner, obstructing a systemic view of the problem and reflected in fragmented public policies. For public managers around the world, solid waste management has become an issue of concern in recent decades (Dias, 2022).

**Challenges and implications**

**Public Health:** Poorly managed solid waste can attract various disease proliferators, such as rats, flies and mosquitoes, which can spread diseases to humans. The adverse effects of municipal solid waste on the environment, collective health, and individual health are recognized by several authors (Accurio et al, 1998; Anjos et al, 1995; Cantanhede, 1997; Diaz et al, 1997; Ferreira, 1997; Leite & Lopes, 2000; Maglio, 2000; Robazzi et al, 1992; Velloso, 1995; Zepeda, 1995), who point to deficiencies in the collection and final disposal systems and the absence of a public policy to protect workers' health as the main factors generating these effects.

**Depletion of natural resources:** The various economic activities and current lifestyles have caused various environmental impacts, including the depletion of natural resources and an increase in the amount of waste. Much of this waste is disposed of in inappropriate places, causing serious problems for the environment and the population (Baron; Reimman; Mori, 2010).

**Environmental pollution:** Environmental concern is a growing issue throughout society, as the environment and its preservation directly affect the quality of life and human health. Population growth and the acceleration of urbanization over time have changed the dynamics of the relationship between man and nature. Souza, Costa, and El-Deir (2017) & Odum (1988) consider that these factors, especially since the 20th century, have promoted changes on the planet more than any other anthropogenic activity.

**Climate change:** The Carbon Footprint (CF) is defined as a measure of the amount of carbon dioxide emissions directly and/or indirectly caused by an activity, or accumulated throughout the manufacturing phases of a product. The CP proposal vividly reveals the effect of human behavior on climate change and provides an effective tool for scientifically measuring carbon emissions (Shi; Yin, 2021). In this context, the population is primarily responsible for contributing to the emission of large quantities of GHGs,

through excessive consumption of energy, water, and the volume of domestic solid waste generated, the collection and treatment of which also contributes to greenhouse gas (GHG) emissions. This leads to accelerated climate change and increases global warming.

**Gross Domestic Product (GDP):** According to the Brazilian Institute of Geography and Statistics (IBGE), GDP is the sum of all final goods and services produced by a country, state, or city, usually in one year. All countries calculate their GDP in their respective currencies. In Brazil in 2022, for example, the GDP was R$9.9 trillion. In the last quarter released (1st quarter 2023), the figure was R$2,556.5 billion (IBGE, 2023).

## METHODOLOGY

### Study Area

According to the Mundo Educação website, in the year 2023, the state of Sergipe is one of the nine states located in the Northeast region of Brazil and is the smallest in territorial extension in Brazil. Its capital and most populous city is Aracaju. Sergipe's geography is made up of a humid coastline and a dry interior, characterized by the semi-arid climate of the Northeast. The economy is geared towards primary activities, especially the extraction of oil and natural gas, and its infrastructure is made up of a transportation network, especially the local airport.

According to information obtained from the website of the Brazilian Institute of Geography and Statistics (IBGE, 2023), in 2022 the state of Sergipe had an estimated population of 2,209,558 people, spread over 75 municipalities. The area of the state's territorial unit in 2022 was 21,938.188 km² (square kilometers) and the urbanized area in 2019 was 461.84 km² (square kilometers). The demographic density is approximately 100.72 inhabitants per square kilometer.

### Graphs and correlation coefficients

Correlation coefficients are statistical methods for measuring the strength of relationships between variables and what they represent. What correlation seeks to understand is how one variable behaves in a scenario where another is varying, to identify whether there is any relationship between the variability of the two. Although it does not imply causality, the correlation coefficient expresses this relationship in numbers, in other words, it quantifies the strength of the relationship between the variables. In scientific research, correlation coefficients are very important for drawing up overviews in studies with many related variables, as this makes it possible to understand how the variability of one affects the other (Oliveira, 2019).

According to Oliveira (2019), the linear or Pearson correlation coefficient (r), also called linear correlation or Pearson's r, is a degree of relationship between two quantitative variables and expresses the degree of correlation through values in a range between -1 and 1.

When the correlation coefficient is close to 1, there is an increase in the value of one variable when the other also increases, i.e. there is a positive linear relationship. When the coefficient is close to -1, it is also possible to say that the variables are correlated, but in this case, when the value of one variable increases, that of the other decreases.

This is what is known as a negative or inverse correlation. A correlation coefficient close to zero indicates that there is no relationship between the two variables, and the closer they are to 1 or -1, the stronger the relationship. Santos (2007) proposes the following classification of linear correlation:

**TABLE 01**: Linear Correlation Classification.

| Correlation Coefficient | Correlation |
|---|---|
| r = 1 | Perfect Positive |
| 0,8 ≤ r < 1 | Strong Positive |
| 0,5 ≤ r < 0,8 | Moderate Positive |
| 0,1 ≤ r < 0,5 | Weak Positive |
| 0 < r < 0,1 | Positive |
| 0. | Nil |
| -0,1 < r < 0 | Minimal Negative |
| -0,5 < r ≤ -0,1 | Weak Negative |
| -0,8 < r ≤ -0,5 | Moderate Negative |
| -1 < r ≤ -0,8 | Strong Negative |
| r = -1 | Perfect Negative |

**SOURCE:** Santos (2007).

## Methodological procedures

Initially, a literature review was carried out on the concepts that were important to the research. Next, the urban population and the mass of household and public waste collected per capita about the urban population (MRPU) in kg/inhabitant/day, with data for 2021, were surveyed on the website of the Water and Sanitation Institute, and then graphs were generated in an Excel spreadsheet to assess the correlation between these two pieces of information.

Meanwhile, on the DataViva platform of the Federal University of Minas Gerais, the GDP per capita of each city was obtained and a graph was generated in the Excel spreadsheet to assess whether there is any correlation between GDP per capita and waste generation.

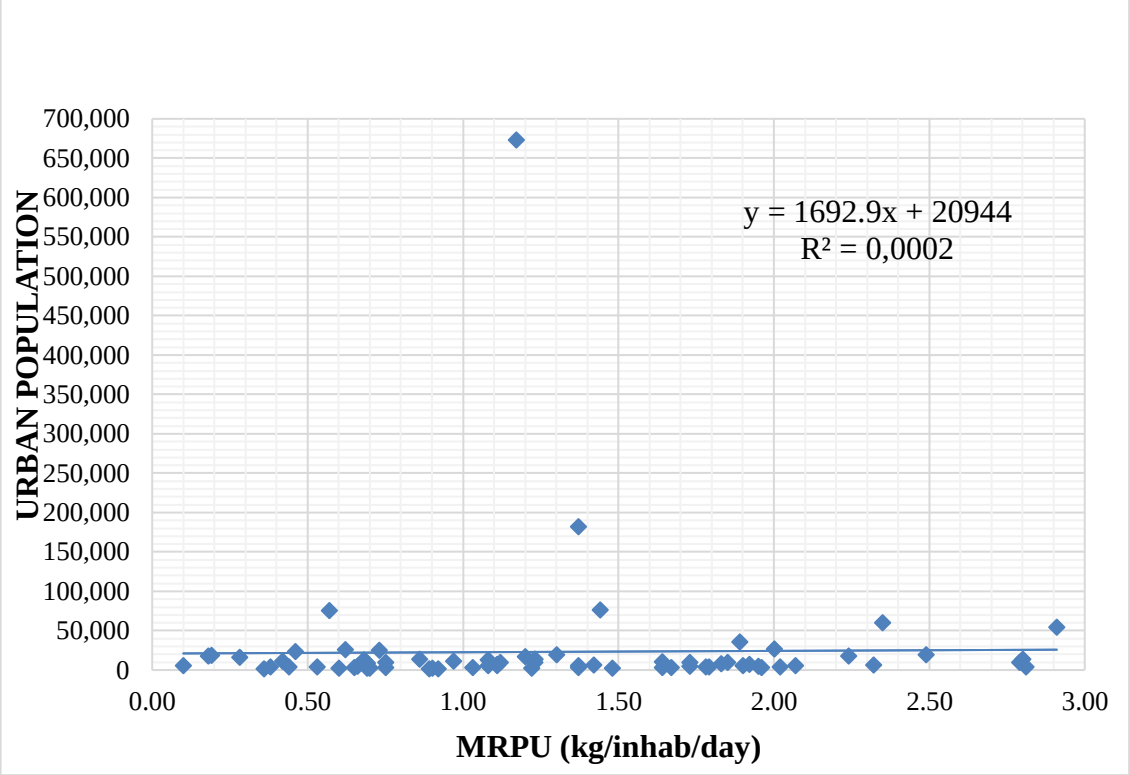
## RESULTS AND DISCUSSION

### Correlation between population size and waste generation

Graph 01 shows that, according to Santos (2007), there is a weak positive correlation, with an $R^2$ coefficient of determination of 0.0002. The city with the largest population is Aracaju (672,614 inhabitants) and the smallest is Pedra Mole (1,200 inhabitants).

Concerning the mass of household and public waste collected per capita by the urban population, the values ranged from 0.10 kg/inhabitant/day (Cedro de São João) to 2.91 kg/inhabitant/day (Lagarto).

**GRAPH 01:** Population x Waste Generation.




| | |
|---|---|
| **0,0147** | **Correlation Coefficient R** |
| **0,02%** | **Correlation Coefficient $R^2$** |

**SOURCE:** Research data (2023).

**TABLE 01:** Data Analysis Population

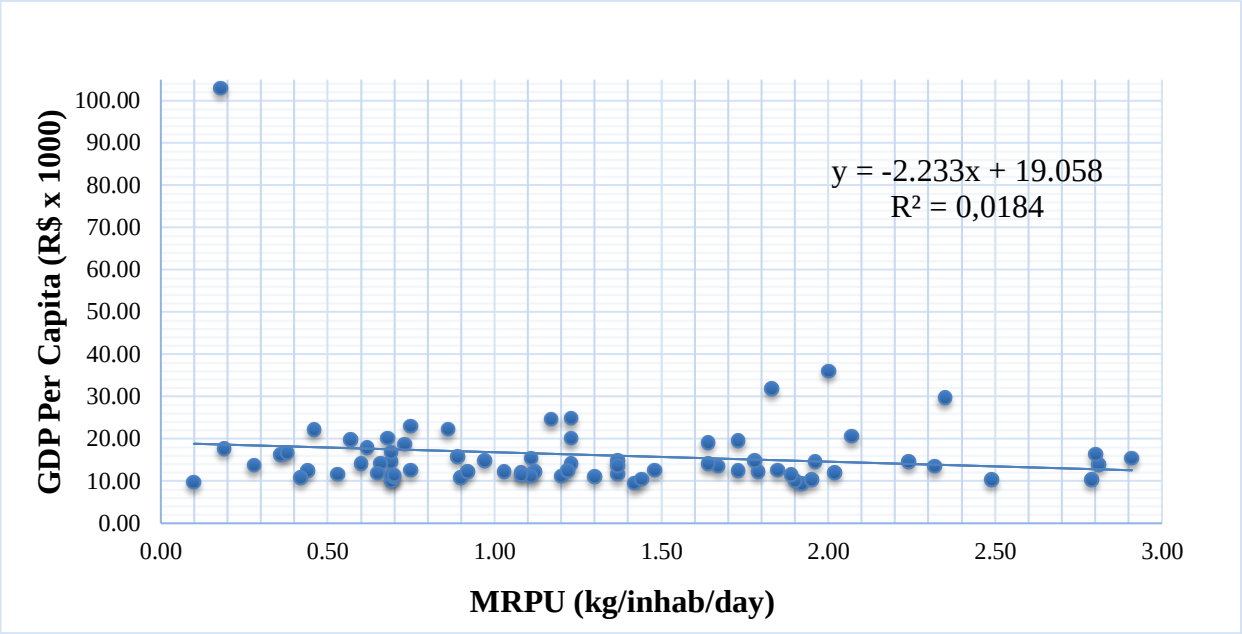
| *Regression statistics* | |
|---|---|
| Multiple R | 0,139162641 |
| R-Squared | 0,019366241 |
| Adjusted R-squared | 0,005554498 |
| Standard error | 11,52363855 |
| Observations | 73 |

**SOURCE:** Authors (2023).

**Correlation between Gross Domestic Product (GDP) and Waste Generation**

Graph 02 shows that, according to Santos' classification (2007), there is a very weak negative correlation, with an $R^2$ determination coefficient of 0.0184. Regarding GDP per capita, the values ranged from 9.3 (Pedrinhas) to 103.0 (Canindé de São Francisco).

**GRAPH 02:** Gross Domestic Product (GDP) x Waste Generation.




| | |
|---|---|
| **-0,1358** | **Correlation Coefficient R** |
| **2%** | **Correlation Coefficient $R^2$** |

**SOURCE** : Survey data (2023).

**TABLE 02:** Data Analysis GDP

| *Regression statistics* | |
|---|---|
| Multiple R | 0,011266798 |
| R-Squared | 0,000126941 |
| Adjusted R-squared | -0,013955778 |
| Standard error | 81543,22292 |
| Observations | 73 |

**SOURCE:** Authors (2023).

Socioeconomic and demographic differences play a significant role in defining the volume of waste generated, but the size of the resident population per area evaluated in the study was not a determining factor, which shows that different populations (in terms of age structure, household arrangement structure, cultural habits, among others) practice different consumption patterns, generating solid waste in different ways and quantities (MARTER, et.al, 2018).

## CONCLUSIONS

Based on the results obtained, it can be concluded that:

a) The data analyzed did not show a significant correlation between population size and per capita solid waste generation, demonstrating that population size interferes with the total amount of waste generated in cities, however, it does not show a linear relationship with per capita waste generation,

b) The data analyzed did not show a significant correlation between population size and GDP per capita, demonstrating that the increase in solid waste generation may be proportional to the increase in the population's GDP per capita, but not as a rule;

c) Efficient solid waste management in urban areas in Sergipe must take into account not only population size and GDP but also a series of interconnected and independent variables, such as environmental education, collection infrastructure, waste treatment, incentives for recycling, and public awareness, among others.

d) The great variation in per capita waste generation between the cities of Sergipe should be studied in greater depth, to understand the reason for such a discrepancy, and thus guide the implementation of public policies aimed at reducing waste generation, especially in the cities with the highest values.

## REFERENCES

[1] ACCURIO, G.; ROSSIN, A.; TEIXEIRA, P. F. & ZEPEDA, F. Diagnóstico de La Situación del Manejo de Residuos Sólidos Municipales em América Latina y El Caribe, 1998. Organización Panamericana de la Salud/Organización Mundial de La Salud, Serie Ambiental no 18. Washington, DC: Organización Panamericana de la Salud/Organización Mundial de La Salud.

[2] ANJOS, L. A.; BARROS, A. A.; FERREIRA, J. A.; OLIVEIRA, T. C. E.; SEVERINO, K. C.; SILVA, M. O. & WAISSMANN, W. Gasto Energético e Carga Fisiológica de Trabalho em Coletores de Lixo Domiciliar no Rio de Janeiro: Um Estudo Piloto, 1995. Relatório de Pesquisa. Rio de Janeiro: Centro de Estudos da Saúde do Trabalhador e Ecologia Humana, Escola Nacional de Saúde Pública, Fundação Oswaldo Cruz.

[3]BRASIL. Sistema Nacional de Informações sobre a Gestão dos Resíduos Sólidos. Ministério do Meio Ambiente. Resíduos Sólidos Urbanos. 2023. Disponível em: https://sinir.gov.br/informacoes/tipos-de-residuos/residuos-solidos-urbanos. Acesso em: 06 set. 2023

[4] BARON, V; REIMMAN, D; MORI, P. R. Licenciamento Ambiental para Centrais de Triagem de Resíduo Sólido Urbano. Relatório da disciplina de Laboratório de Arquitetura e Urbanismo. Universidade de Caxias do Sul. Caxias do Sul, 2010.

[5] CANTANHEDE, A. Experiences from the Pan- American Centre of Sanitary Engineering & Environmental Sciences – Difficulties and possibilities. 1997. In: LATIN AMERICAN-SWEDISH

SEMINAR ON SOLID WASTE MANAGEMENT, PROCEEDINGS, pp. 163-168. Rio de Janeiro: Associação Brasileira de Engenharia Sanitária e Ambiental/Lund University.

[6] DIAS, Sylmara Gonçalves. O desafio da gestão de resíduos sólidos urbanos. GV-executivo, v. 11, n. 1, p. 16-20, 2012.

[7] DIAZ, L. F.; SAVAGE, G. M. & EGGERTH, L. L. Managing solid wastes in developing countries, 1997. Wastes Management, 10:43-45.

[8] ECYCLE. A importância da coleta de resíduos está relacionada com a redução dos impactos ambientais do consumo. Disponível em: https://www.ecycle.com.br/coleta-seletiva/. Acesso em 24 ago de 2023

[9] FERREIRA, J. A. Lixo Hospitalar e Domiciliar: Semelhanças e Diferenças – Estudo de Caso no Município do Rio de Janeiro, 1997. Tese de Doutorado, Rio de Janeiro: Escola Nacional de Saúde Pública, Fundação Oswaldo Cruz.

[10] GODECKE, M. V.; NAIME, R. H.; FIGUEIREDO, J. A. S. O consumismo e a geração de resíduos sólidos urbanos no Brasil. Revista Eletrônica em Gestão, Educação e Tecnologia Ambiental, Santa Maria, v. 8, n. 8, p. 1700-1712, 2012.

[11] INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). Panorama das cidades. Disponível em: <https://cidades.ibge.gov.br/brasil/se/panorama>. Acesso em 24 ago de 2023.

[12] INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). Produto Interno Bruto. Disponível em: <https:// https://www.ibge.gov.br/explica>. Acesso em 24 ago de 2023.

[13] LEITE, V. D. & LOPES, W. S. Avaliação dos Aspectos Sociais, Econômicos e Ambientais Causados pelo Lixão da Cidade de Campina Grande, 2000. In: IX SIMPÓSIO LUSO-BRASILEIRO DE ENGENHARIA SANITÁRIA E AMBIENTAL, Anais, CD-ROM IV. Porto Seguro: Associação Brasileira de Engenharia Sanitária e Ambiental.

[14] MAGLIO, I. C. Gestão Ambiental dos Resíduos Sólidos – O Papel dos Municípios, 2000. In: 9º SIMPÓSIO LUSO-BRASILEIRO DE ENGENHARIA SANITÁRIA E AMBIENTAL, Anais, CD-ROM VI. Porto Seguro: Associação Brasileira de Engenharia Sanitária e Ambiental.

[15] MARDER, M.; HASAN, C.; BEZAMA, A.; KONRAD, O.; HENKES, J. A.; ROSSATO, I. F. Análise da influência do Produto Interno Bruto (PIB) e da população urbana na geração per capita de resíduos sólidos em municípios do interior do RS, Brasil. Revista Gestão & Sustentabilidade Ambiental, [S.L.], v. 7, n. 3, p. 21, 3 out. 2018. Anima Educação. http://dx.doi.org/10.19177/rgsa.v7e3201821-35.

[16]MUNDO EDUCAÇÃO. Sergipe - Dados Gerais. Disponível em: https://mundoeducacao.uol.com.br/geografia/sergipe.htm Acesso em 24 ago de 2023.

[17] ODUM, Eugene. Ecologia. 434 pp. 1988.

[18]OLIVEIRA, B. Coeficientes de Correlação. Disponível em: < https://statplace.com.br/blog/coeficientes-de-correlacao/>.2019. Acesso em: 27 ago 2023.

[19] ROBAZZI, M. L. C.; MORIYA, T. M.; FÁVERO, M. & PINTO, P. H. D. Algumas considerações sobre o trabalho dos coletores de lixo, 1992. Revista Brasileira de Saúde Ocupacional, 20:34-40.

[20] SANTOS, C. Estatística Descritiva - Manual de Autoaprendizagem. Lisboa, Edições Silabo, 2007.

[21] SOUZA, A. L.; COSTA, Amanda Rodrigues Santos; EL-DEIR, Soraya Giovanetti. 1.1. Indicadores de Sustentabilidade como auxílio na Gestão de resíduos Sólidos Urbanos; um estudo de caso da pegada ecológica. Para a gestão integrada, p. 7, 2017.

[22] SHI, S.; YIN, J. Global research on carbon footprint: a scientometric review. Environmental Impact Assessment Review, [S.L.], v. 89, p. 106571, jul. 2021. Elsevier BV. http://dx.doi.org/10.1016/j.eiar.2021.106571.

[23] VELLOSO, M. P. Processo de Trabalho da Coleta de Lixo Domiciliar da Cidade do Rio de Janeiro: Percepção e Vivência dos Trabalhadores, 1995. Dissertação de Mestrado, Rio de Janeiro: Escola Nacional de Saúde Pública, Fundação Oswaldo Cruz.

[24] VELLOSO, M.P. Os restos na história: percepções sobre resíduos. Ciência & Saúde Coletiva v. 13, n. 6, p. 1953-1964, 2008.

[25] WILSON, D.C. Development drivers for waste management. Waste Management & Research v. 25, n.3, p. 198-207, 2007.

[26] ZEPEDA, F. El Manejo de Residuos Sólidos Municipales em America Latina y El Caribe, 1995. Washington, DC: Organización Panamericana de la Salud.