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Study on the indexes of basic sanitation and human development in the state of Minas Gerais, Brazil: a panorama in the context of the new sanitation framework

In 2020, the sanitation framework was updated by the Brazilian Federal Law nº 14,026/2020 to advance the sanitation sector throughout the country. This study aims to evaluate and correlate the indices related to basic sanitation with indexes of economic and social development of the municipalities of the state of Minas Gerais, Brazil. The consultation and collection of data on the treatment and distribution of drinking water were carried out from the government databases. They were correlated with the various human and sanitation indicators to perform the present work. It was obtained that the mean and standard deviation of the data of the index of attendance with Wastewater Treatment Plant (WWTPs) evaluated (2013-2035) are, respectively, 92.02% and 0.13%. It was possible to conclude that there is a tendency to increase the percentage values of the population with piped water with the quality-of-life indices of the population.

Keywords: Basic sanitation; Legal framework; Universalization.

Estudo sobre os índices de saneamento básico e desenvolvimento humano no estado de Minas Gerais, Brasil: um panorama no contexto do novo quadro de saneamento

Em 2020, o quadro de saneamento foi atualizado pela Lei Federal Brasileira nº 14.026/2020 para avançar o setor de saneamento em todo o país. Este estudo tem como objetivo avaliar e correlacionar os índices relacionados ao saneamento básico com os índices de desenvolvimento econômico e social dos municípios do estado de Minas Gerais, Brasil. A consulta e coleta de dados sobre tratamento e distribuição de água potável foram realizadas a partir dos bancos de dados governamentais. Eles foram correlacionados com os diversos indicadores humanos e de saneamento para a realização do presente trabalho. Obteve-se que a média e o desvio padrão dos dados do índice de atendimento com Estação de Tratamento de Efluentes (ETEs) avaliados (2013-2035) são, respectivamente, 92,02% e 0,13%. Foi possível concluir que há uma tendência de aumento dos valores percentuais da população com água encanada com os índices de qualidade de vida da população.

Palavras-chave: Saneamento básico; Enquadramento jurídico; Universalização.

Topic: **Engenharia Sanitária**

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INTRODUCTION

Although it is recognized as a fundamental human right, universal access to basic sanitation still faces many challenges globally, including in Brazil (CUNHA et al., 2018). According to Dantas et al. (2012), Brazil faces a significant challenge concerning basic sanitation, especially about sewage collection and treatment. According to the authors, although the investments provided by the Growth Acceleration Program (PAC, in Portuguese) were intended to improve all sanitation in Brazil, there was a concern of municipalities in ensuring access to drinking water. Consequently, sewage treatment did not receive a precise dimension of the investments to be made.

According to the Brazilian National Sanitation Information System (BRAZIL, 2019), in its last Diagnosis of Water and Sewage Services - 2018, launched in December 2019, 83.6% of the population is served by a water supply network, and only 53.2% is served by sewage collection. Concerning the sewage generated that is treated, only 46.3% of the population is served with this service. In this scenario, more than 50% of the sewage generated in Brazil is released *in nature* into the water bodies (BRASIL, 2019).

The National Basic Sanitation Survey (PNSB, in Portuguese) was published by the Brazilian Institute of Geography and Statistics (IBGE, in Portuguese) in 2020 and addressed the rates of drinking water supply and sewage through the survey conducted in the 1989/2017 period. According to PNSB, there was an advance in drinking water supply rates in Brazilian municipalities, while the care related to sanitary sewage remains below expected. The proportion of municipalities with sewage services increased from 47.3% in 1989 to 60.3% in 2017. The water supply service increased from 95.9% in 1989 to 99.6% in 2017 (IBGE, 2020).

Minas Gerais is a Brazilian state with a population of 18,886,672 inhabitants. It is the state with the largest number of municipalities in the country, with 853 according to the most recent census conducted by IBGE in 2010 (IBGE, 2020). According to Minas Gerais (2020), this state has a high urban population served by sewage collection, of approximately 16,216,463 inhabitants, which corresponds to 85.86% of the population of Minas Gerais. However, the same is not the case in the sewage treatment scenario, where only 49.45% (about 9,339,577 inhabitants) of the urban population is served.

In Brazil, the competent legislation in sanitation had as its initial milestone in the 1970s. The National Sanitation Plan (PLANASA, in Portuguese) and the Sanitation Financial System (SFS, in Portuguese) were created. Both policies were managed at this time by the National Housing Bank (BNH, in Portuguese), with resources from the Service Time Guarantee Fund (FGTS), and intended to provide sanitation services to sanitation companies since they had access to BHN loans (NOZAKI, 2007).

Since the creation of the Ministry of Cities, Brazil has resumed investments and restructured the country's sanitation area. However, it was only in 2007 the legal framework for the definition and implementation of basic sanitation services in the country, with the enactment of Law Nº. 11,445 of January 5, 2007, called the "Basic Sanitation Law", establishing national guidelines for the provision and management of services (BRAZIL, 2007).

To ensure the availability of quality water to present and future generations, Law Nº. 9,433 (Water

Law) (BRAZIL, 1997) was approved on January 8, 1997, establishing the National Water Resources Policy and creating the National Water Resources Management System (SINGREH, in Portuguese).

Internationally, the United Nations (UN) proposed a new sustainable development agenda in 2015 to its member countries for the next 15 years, the 2030 Agenda, composed of the 17 Sustainable Development Goals (SDGs). Among these SDGs, SDG 6 is defined as "Ensuring the availability and sustainable management of water and sanitation for all".

The update of the Legal Framework of Basic Sanitation was sanctioned on July 15, 2020, by Federal Law Nº. 14026/2020, aiming at the universalization of basic sanitation in Brazil (BRASIL, 2020). In addition, this law aimed to enabling and ensuring the universalization of services until 12/31/2033, serving 99% of the population with drinking water and 90% with sewage collection and treatment (BRAZIL, 2020).

Some authors analyzed the relation between society's quality of life and basic sanitation. For example, to investigate the effect of dependence on natural resources on access to water and sanitation, Tadadjeu et al. (2020) and Ndikumana et al. (2017) used an empirical model based on the dynamic framework. The authors used two versions of a baseline model. The first version of the model, used by Ndikumana et al. (2017), related the total income from natural resources to the percentage of the population (total, rural and urban, alternatively) with access to improved water sources or sanitation facilities. The second version used by Tadadjeu et al. (2020), who carried out a study with 44 countries in Africa from 1995 to 2017, seeks to study the effect of total incomes from natural resources on the urban-rural gap in access to water and sanitation, respectively.

Tadadjeu et al. (2020) concluded by analyzing the baseline models that there is a negative relationship between total incomes from natural resources and access to water and sanitation, both for the entire population and for urban and rural areas. Although theoretically, natural resource rents provide governments with a continuous source of income necessary for investments in the provision of social services such as electricity, water, sanitation, education and health care.

Ndikumana et al. (2017) investigated whether targeting external aid to the water and sanitation sector can help achieve the goal of expanding access to water and sanitation services in Africa through data estimation. The authors suggest that the increase in aid directed to water supply and sanitation is associated with increased access to these services, although the relationship is not linear.

METHODOLOGY

We have performed the consultation and collection of data on the treatment and distribution of drinking water in a government database to perform the present work, such as: The Brazilian National Water Agency (*Agência Nacional das Águas*, ANA) - The Sewer Atlas (ANA, 2020); Atlas of Human Development of Municipalities of UNDP/Brazil (UNDP/Atlas) (BRAZIL, 2020); The Brazilian Institute of Geography and Statistics (IBGE).

In this study, the various human and sanitation indicators were correlated to verify Brazil's basic sanitation framework. We used the Microsoft® Excel® tools to correlate data in a linear function. For simple statistical analysis, we used the free software Paleontological Statistics Software Package for Education and Data Analysis - PAST4.03 (HAMMER, 2001).

Then, the cities from Minas Gerais were subdivided into classes. The study was carried out on the variables investments in collection and treatment of sewage per capita (R$/hab$_{2035}$) versus the population served estimated in 2035 versus the index of care with WWTPs evaluated (2013-2035) (C): up to 5,000 inhabitants; from 5 001 to 10 000 inhabitants; from 10 001 to 20 000 inhabitants; from 20 001 to 50 000 inhabitants; from 50 001 to 100 000 inhabitants; from 100 001 to 500 000 inhabitants; and more than 500 000 inhabitants.

RESULTS AND DISCUSSION

Figure 1 shows the correlation between the percentage parameters of the population with piped water *versus* life expectancy at birth.

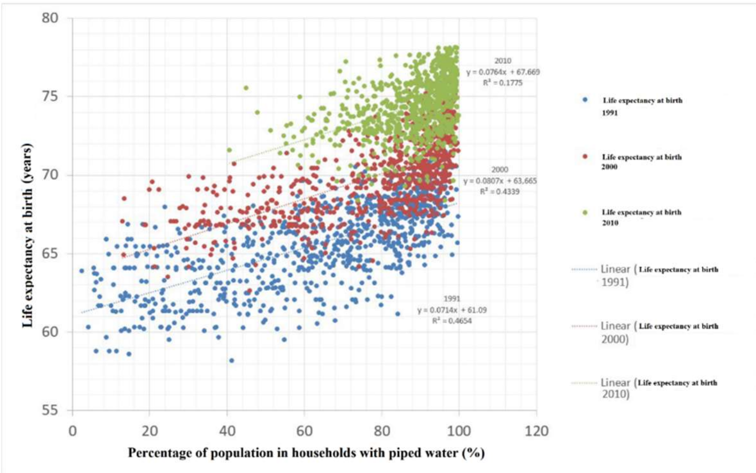

Figure 1: Percentage of the population with piped water *versus* life expectancy at birth.

The values obtained from the statistical analysis of the variables presented in Figure 1 using the *software* PAST® are described in Table 1.

Table 1: Results of statistical analysis among the percentage variables of the population with piped water *Versus* life expectancy at birth in 1991, 2000 and 2010.

Results of statistical analysis			
1991			
Ordinary least squares regression: A*-B**			
Slope to:	0,071421	Standard error to:	0,0026256
T:	27,202	p (slope):	$1,0410^{-117}$
Intercept b:	61,09	Standard error b:	0,18272
95% initialized confidence intervals (N=1999):			
Slope to:	(0,06603, 0,076749)		
Intercept b:	(60,705, 61,473)		
correlation:			
R:	0,68219		
r2:	0,46539		
T:	27,202		
p (uncorr.):	$1,0410^{-117}$		
Permutation p:	0,0001		

2000			
Ordinary least squares regression: A*-B**			
Slope to:	0,080692	Standard error to:	0,0031616
T:	25,523	p (slope):	$4{,}0710^{-107}$
Intercept b:	63,665	Standard error b:	0,26194
95% initialized confidence intervals (N=1999):			
Slope to:	(0,074244, 0,086825)		
Intercept b:	(63.146; 64.194)		
correlation:			
R:	0.65868		
r2:	0.43386		
T:	25.523		
p (uncorr.):	$4.07 . 10^{-107}$		
Permutation p:	0.0001		
2010			
Ordinary least squares regression: A*-B**			
Slope to:	0.076441	Standard error to:	0.0056431
T:	13.546	p (slope):	$5.40 . 10^{-38}$
Intercept b:	67.669	Standard error b:	0.50191
95% initialized confidence intervals (N=1999):			
Slope to:	(0.064808; 0.086913)		
Intercept b:	(66.738; 68.725)		
correlation:			
R:	0.42136		
r2:	0.17755		
T:	13.546		
p (uncorr.):	$5.40 . 10^{-38}$		
Permutation p:	0.0001		
*A: Percentage of the population with piped water			
**B: life expectancy at birth			

In the graph of Figure 1, which addresses the percentage of the population with piped water *versus* life expectancy at birth, there is a tendency to increase the percentage values of the population with piped water and life expectancy at birth regarding the years 1991, 2000, and 2010. The obtained linear correlation coefficients between the variables for the years 1991, 2000, and 2010 resulted in low values, respectively, of 0.4654, 0.4339, and 0.1775 due to data dispersion. Moreover, it is noted that when compared to 1991, 2010 presents higher rates of care of the population in households treated with piped water and higher life expectancy at the population's birth, evidencing the proportionality of the indexes. It is observed that over the years 1991, 2000, and 2010 the improvement in the rates of service with piped water supply caused higher rates of life expectancy at birth, with the years 1991 and 2010 being the lowest and the highest rate of care, respectively.

As shown in Table 1, the linear correlation values (R^2) resulted from 1991, 2000, and 2010, respectively, of 0.46539, 0.43386, and 0.17755. These values are very close to those obtained in the analysis of Figure 1. Table 2 shows the values obtained in Pearson's linear correlation test, performed in the *software* PAST®. In bold, the r-Pearson values corresponding to the percentage of the population and life expectancy at the birth of the respective year are highlighted.

Table 2: Linear test results r – Pearson.

	A[1]	B[2]	C[3]	D[4]	E[5]	F[6]
A[1]		$3.745.10^{-320}$	$1.63.10^{-83}$	$\mathbf{1.04.10^{-117}}$	$5.82.10^{-130}$	$5.73.10^{-113}$
B[2]	0.90629		$1.24.10^{-108}$	$1.83.10^{-93}$	$\mathbf{4.07.10^{-107}}$	$1.43.10^{-90}$
C[3]	0.59732	0.66218		$1.13.10^{-33}$	$1.22.10^{-37}$	$\mathbf{5.40.10^{-38}}$

D[4]	**0.68219**	0.62488	0.39772		$2.39.10^{-277}$	$3.96.10^{-119}$
E[5]	0.70689	**0.65868**	0.4195	0.8802		$5.11.10^{-166}$
F[6]	0.67194	0.61714	**0.42136**	0.68519	0.76707	
[1]A: percentage of the population with piped water 1991; [2]B: percentage of the population with piped water 2000; [3]C: percentage of the population with piped water 2010; [4]D: life expectancy at birth 1991; [5]E: life expectancy at birth 2000; and [6]F: life expectancy at birth 2010.						

Figure 2 shows the relationship between the percentage of the population with piped water *Versus* MHDI - Longevity dimension. The values obtained from the statistical analysis among the variables mentioned above are presented in Table 3.

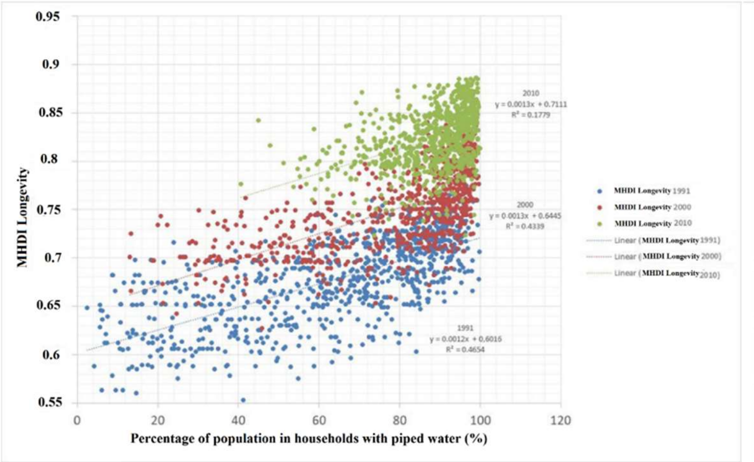

Figure 2: Percentage of the population with piped water versus MHDI - Longevity Dimension.

Table 3: Results of statistical analysis among variables percentage of the population with piped water *Versus* HDI-M Longevity Dimension in 1991, 2000 and 2010.

Results of statistical analysis			
1991			
Ordinary least squares regression: A-B			
Slope to:	0.00119	Standard error to:	$4.37 . 10^{-05}$
T:	27.201	p (slope):	$1.06.10^{-117}$
Intercept b:	0.60164	Standard error b:	0.0030438
95% initialized confidence intervals (N=1999):			
Slope to:	(0.0011005; 0.0012824)		
Intercept b:	(0.59487; 0.608)		
correlation:			
R:	0.68218		
r2:	0.46537		
T:	27.201		
p (uncorr.):	$1.06 . 10^{-117}$		
Permutation p:	0.0001		
2000			
Ordinary least squares regression: A-B			
Slope to:	0.080692	Standard error to:	0.0031616
T:	25.523	p (slope):	$4.07 . 10^{-107}$
Intercept b:	63.665	Standard error b:	0.26194
95% initialized confidence intervals (N=1999):			
Slope to:	(0.074508; 0.086729)		
Intercept b:	(63.171; 64.174)		
correlation:			
R:	0.65868		
r2:	0.43386		
T:	25.523		
p (uncorr.):	$4.07 . 10^{-107}$		

Permutation p:	0.0001		
2010			
Ordinary least squares regression: A-B			
Slope to:	0.001315	Standard error to:	9.49E-05
T:	13.856	p (slope):	$1.67 . 10^{-39}$
Intercept b:	0.70752	Standard error b:	0.0084421
95% initialized confidence intervals (N=1999):			
Slope to:	(0.0011435; 0.0014899)		
Intercept b:	(0.69187; 0.72314)		
correlation:			
R:	0.42966		
r2:	0.1846		
T:	13.856		
p (uncorr.):	$1.67 . 10^{-39}$		
Permutation p:	0.0001		
A: Percentage of the population with piped water			
b: HDI-M Longevity Dimension			

From the analysis of the values in Table 2, it can be observed that the values from the relationship between the percentage of the variable of the population with piped water and life expectancy at birth have a moderate positive association. These values are 0.68219, 0.65868, and 0.42136 for the years 1991, 2000, and 2010. Despite this relationship, it cannot be concluded that changes in one variable cause changes in another variable based only on correlation. When changing the position variables, leaving on the x-axis the life expectancy data at birth and on the y axis the percentage of the population with piped water, the respective values are already very low (1,04.10-117, 4.07.10-107, and 5.40.10-38).

The graph from Figure 2 on the percentage of the population with piped water versus MHDI – Longevity Dimension presents the same trend as the graph in Figure 1. There is a tendency to increase the percentage values of the population with piped water and also the MHDI - Longevity Dimension, from the years 1991 to the year 2000 and 2010. It can be affirmed, despite the linear correlation coefficients, r^2, between the variables for the years 1991, 2000, and 2010, of 0.4654, 0.4339, and 0.1779, respectively. It is observed that over the years 1991, 2000, and 2010 the improvement in the rates of service with piped water supply caused higher values for the MHDI - Longevity Dimension. In addition, it is observed that over the years, the rates of piped water care have improved and concentrated on better rates. Values from Table 3 present the linear correlation coefficients (R^2) between the variables for the years 1991, 2000, and 2010. They were close to the values of the correlations obtained by the *Microsoft® Excel®* 0.4654; 0.4339 and 0.1846. Table 4 presents the values obtained in the r-Pearson linear correlation test. In bold, the r-Pearson values corresponding to the percentage of the population with piped water and MHDI of the respective years are highlighted.

Table 4: Linear Test Results r – Pearson.

	A[1]	B[2]	C[3]	D[4]	E[5]	F[6]
A[1]		$3.5117.10^{-319}$	6.31E-87	$\mathbf{2.39.10^{-117}}$	$5.63.10^{-130}$	$9.44.10^{-113}$
B[2]	0.90617		$2.00.10^{-113}$	$3.03.10^{-93}$	$\mathbf{4.35.10^{-107}}$	$1.76.10^{-90}$
C[3]	0.60764	0.67353		$1.20.10^{-34}$	$3.24.10^{-38}$	$\mathbf{1.67.10^{-39}}$
D[4]	**0.68201**	0.62487	0.40364		$6.82.10^{-277}$	$4.74.10^{-119}$
E[5]	0.70749	**0.65919**	0.42298	0.88033		$2.84.10^{-166}$
F[6]	0.67204	0.61746	**0.42966**	0.6856	0.768	
[1]A: Percentage of the population with piped water 1991;						

	A[1]	B[2]	C[3]	D[4]	E[5]	F[6]
[2]B: percentage of the population with piped water 2000; [3]C: percentage of the population with piped water 2010; [4]D: HDI-M Longevity Dimension 1991; [5]E: HDI-M Longevity Dimension 2000; and [6]F: HDI-M Longevity Dimension 2010.						

Figure 3 shows the bubble chart relationship between the percentage of the variable of the population with piped water, life expectancy at birth, and MHDI Dimension Longevity for the years 1991 (Figure 3a), 2000 (Figure 3b), and 2010 (Figure 3c).

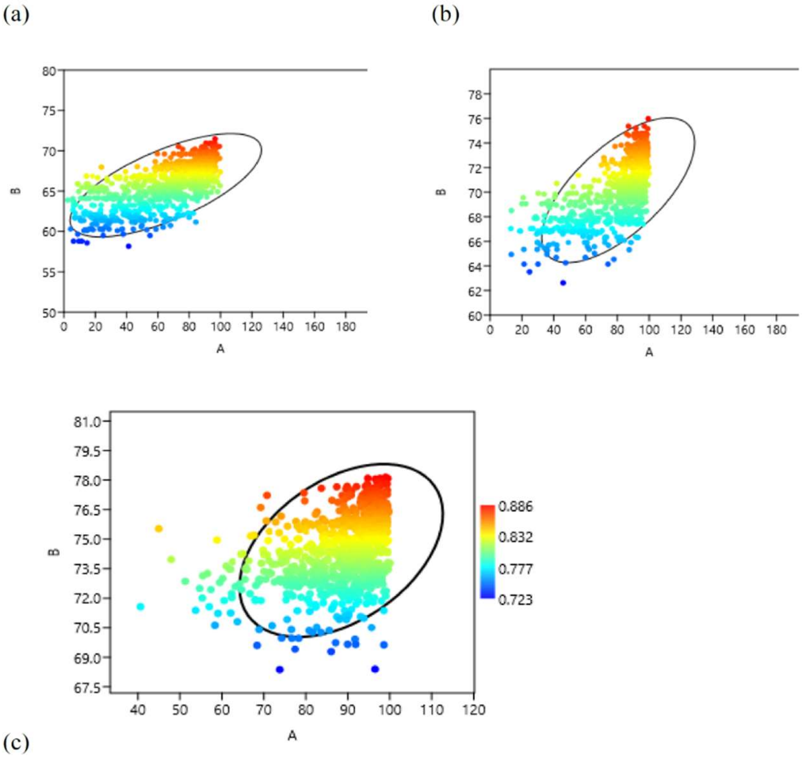

Figure 3: Bubble chart ratio between the variables (A) percentage of the population with piped water, (B) life expectancy at birth and MHDI Longevity Dimension for the years: a) 1991 (upper right), 2000 (upper left) and 2010 (lower).

Figure 4 shows the linear correlation between an increase in the index of WWTPs evaluated (2013-2035) *versus* the amount to be achieved by investments in sewage collection and treatment per capita for an estimated population in the state of Minas Gerais in 2035 (R$/$hab_{2035}$). In other words, this variable estimates how much should be invested (in reais, R$) for each inhabitant in 2035, aiming at the universalization of access to the collection and treatment of sanitary sewage in Minas Gerais.

From the values presented in Table 4, it can be observed that the relationship between the percentage of the variable of the population with piped water and HDI-M Longevity Dimension have a moderate positive relationship, respectively 0.68201; 0.65919 and 0.42966 for the years 1991, 2000, and 2010. Despite this relationship, it cannot be concluded that changes in one variable cause changes in another variable based only on correlation. When changing the position variables, leaving on the x-axis the MHDI values and the y-axis the percentage of the population with piped water, the respective values are very low ($2,39.10^{-117}$, $4,35.10^{-107,}$ and $1,67.10^{-39}$).

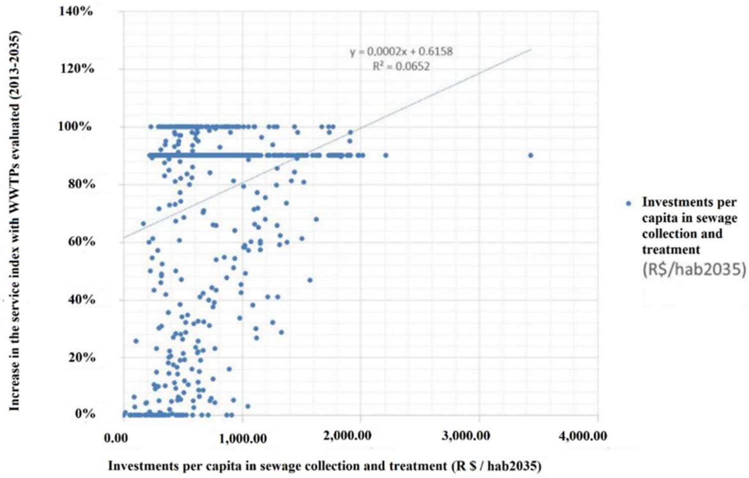

Figure 4: Linear correlation between the variables investments in collection and treatment per capita (R$/hab2035) *versus* increase in the index of WWTPs scare rate evaluated (2013-2035).

The graph in Figure 3 shows data within the ellipse that represent 95% of the data and the ratio of the population to piped water (A) *versus* life expectancy at birth (B) *versus* MHDI Longevity Dimension. It is verified that there is a tendency to increase the percentage values of the population with piped water, life expectancy at birth, and MHDI Longevity Dimension for the years 1991, 2000 and finally, 2010. The higher the percentages of the piped water population, the higher the values of life expectancy at birth and the higher the HDI-M Longevity Dimension, respectively.

The graph analysis in Figure 4 shows a low linear correlation coefficient between the variables investments in per capita sewage collection and treatment (R$/hab2035) *versus* an increase in the index of care with evaluated WWTPs (2013-2035), whose value is 0.0652.

Figure 5 shows the bubble chart between variables population served estimated in 2035 (obtained through the database) (A), index of care with ETEs evaluated (2013-2035) (B) *versus* investments in sewage collection and treatment per capita (R$/hab2035) (C).

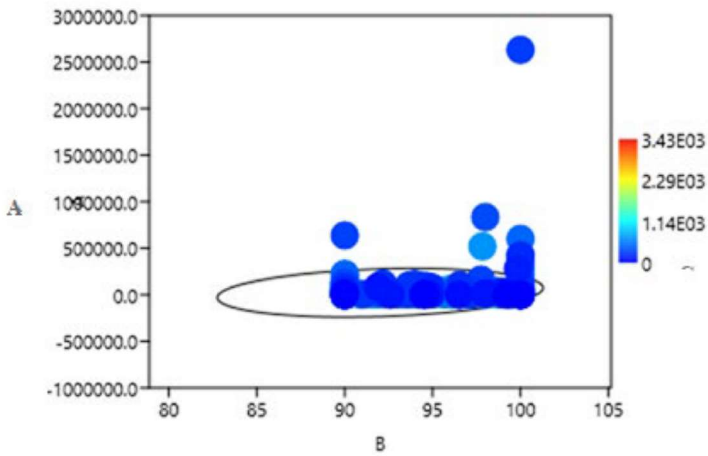

Figure 5: Bubble graph among variables population served estimated in 2035 (A), investments in sewage collection and treatment per capita (R$/hab2035) (B) *Versus* index of service with WWTPs evaluated (2013-2035) (C).

Table 5 presents the statistical results among the variables population served estimated in 2035 (obtained through the database) (A), index of care with ETEs evaluated (2013-2035) (B) and investments in collection and treatment of sewage per capita (R$/hab2035) (C). Table 6 shows the results of the linear test r - Pearson for the same variables presented in Figure 5.

Table 5: Statistical results.

	A	B	C
N	853	853	853
Min	482	90	0
max	2631460	100	3432,86
sum	$1.95.10^{+07}$	78493.5	588910.1
average	22880.23	92.02051	690.3987
Standard error	3646.323	0.1294338	14.55429
variance	$1.13.10^{+10}$	14.29039	180688.7
Deviation - Standard	106495.1	3.780264	425.075
Media	5702	90	573.04
25th percentile	3017	90	407.005
75th percentile	13721	90	852.6
Skewness	18.59526	1.468896	1.514007
Kurtosis	430.1626	0.3193424	2.918655
Geometric mean	7232.667	91.94589	0
Mr. Coef. Var	465.4459	4.108066	61.56949
A: Population Served Estimated in 2035			
B: Index of Service with ETEs Evaluated (2035)			
C: Investments in Collection and Treatment per capita (R$/hab$_{2035}$)			

Table 6: Linear Test Results r – Pearson.

	A	B	C
A		$3.40.10^{-09}$	0.0029076
B	0.20063		$2.30.10^{-05}$
C	-0.10183	-0.1444	
A: Population Served Estimated in 2035			
B: Index of Service with ETEs Evaluated (2035)			
C: Investments in Collection and Treatment per capita (R$/hab2035)			

In the graph presented in Figure 5, the values within the ellipse represent 95% of the data, mainly constituting small cities in which investments in sewage collection and treatment do not generally exceed the value of about 1,140.00 R$/hab2035.

By analyzing the data in Table 5, it is verified that in 2035 the population will be more than 19 million, and the average rate of service with WWTPs in 2035 will be 92%, while the maximum investment value is R$ 3,432.86 per inhabitant. These values, concerning the collection and treatment of sanitary sewage, are in agreement with Art. 11-B of Law Nº. 14026/2020 (BRASIL, 2020), of the legal framework of sanitation. It is defined as a goal of universalizing the following values: 99% of the population with drinking water and 90% of the population with sewage collection and treatment by December 31, 2033. However, the planning of the goals described for 2035 should be adapted to the law mentioned above for 2033.

By analyzing the data in Table 6, it is verified that the data Population Serviced Estimated in 2035 *versus* Index of Service with WWTPs Evaluated (2035) and Population Attended Estimated in 2035 *versus* Investments in Collection and Treatment per capita (R$/hab2035) are directly proportional. On the other hand, analyzing the Index of Service with WWTPs Evaluated (2035) versus Investments in Collection and Treatment per capita (R$/hab2035) is inversely proportional. In other words, the higher the rates of care with WWTPs, the lower the investments in collection and per capita treatment required. As for the results of the linear test r - Pearson, very low values are observed for all combinations between the variables as mentioned above. We analyzed various indicators of quality of human life with the subdivision into classes of municipalities by the size of the population. Figure 6 presents the correlations for the MHDI are analyzed *versus* population classes for the years 1991, 2000, and 2010, respectively.

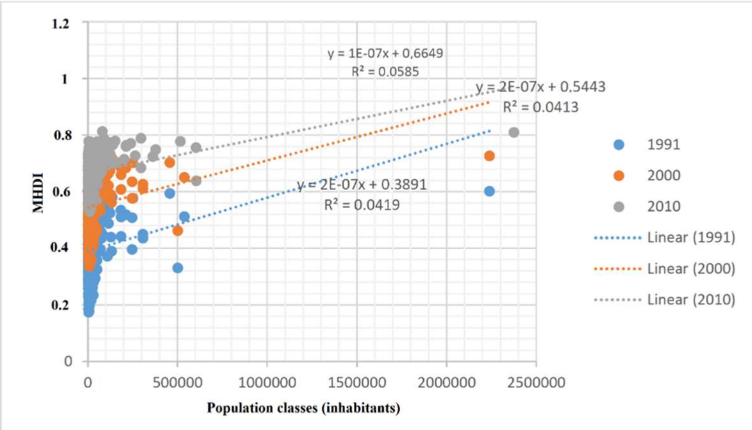

Figure 6: MHDI *versus* population classes.

Table 7 shows the r-Pearson values for the data presented in Figure 6. In bold the r-Pearson values corresponding to the population and the MHDI of the respective years are highlighted.

Table 7: R-Pearson values for the population and MHDI relationship.

	A[1]	B[2]	C[3]	D[4]	E[5]	F[6]
A[1]		**0.000523**	1.1510^{-195}	$2.17.10^{-09}$	$6.66.10^{-190}$	$5.82.10^{-11}$
B[2]	**0.11873**		$3.86.10^{-07}$	$3.14.10^{-07}$	$1.35.10^{-07}$	$5.19.10^{-12}$
C[3]	0.80641	0.17294		**0.001921**	0	$1.88.10^{-10}$
D[4]	0.20353	0.17425	**0.10626**		0.00075	$6.33.10^{-15}$
E[5]	0.79949	0.17953	0.99914	0.1154		**$3.99.10^{-11}$**
F[6]	0.22225	0.2336	0.21626	0.26295	**0.22398**	

[1]A: Population 1991
[2]B: MHDI 1991
[3]C: Population 2000
[4]D: MHDI 2000
[5]E: Population 2010
[6]F: MHDI 2010

Figure 6 shows low values for linear correlation (R^2) equal to 0.0585; 0.0413 and 0.0419. In other words, there is a low linear correlation between the analyzed parameters. It appears that the MHDI was high during the analyzed scenarios, with the classes of smaller cities having the highest concentrations of the lowest MHDI; in addition, it appears that the largest cities have higher MHDI.

The r-Pearson values are presented in Table 7. There is a positive relationship between population and the respective MHDI variables, respectively 0.000523, 0.001921, and $3.99.10^{-11}$, for 1991, 2000, and 2010. Despite this relationship, it cannot be concluded that changes in one variable cause changes in another variable based only on correlation. When changing the position variables, leaving on the x-axis the MHDI values and on the y-axis the population class, the respective values also result in low (0,11873, 0.10626, and 0.22398).

By correlating life expectancy data at birth *versus* population classes, we obtained the graph shown in Figure 7. Table 8 shows the r-Pearson values for the data presented in Figure 7. In bold the r-Pearson values corresponding to the population and life expectancy at birth of the respective years are highlighted.

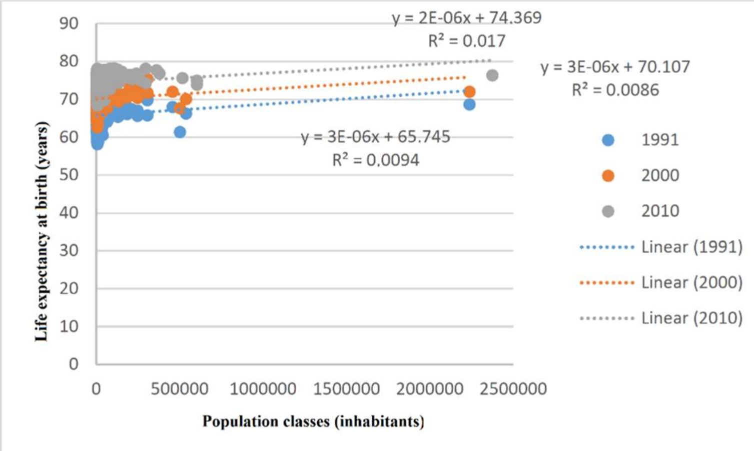

Figure 7: Life expectancy at birth *versus* population classes.

Table 8: R-Pearson values for the population versus life expectancy at the birth relationship.

	A[1]	B[2]	C[3]	D[4]	E[5]	F[6]
A[1]		**0.004914**	$3.96.10^{-196}$	0.025518	$2.34.10^{-190}$	0.007259
B[2]	**0.096276**		$3.71.10^{-05}$	0.001738	$4.15.10^{-05}$	$3.87.10^{-05}$
C[3]	0.80642	0.14082		**0.006892**	0	0.000236
D[4]	0.076562	0.1072	**0.092508**		0.005291	$9.56.10^{-05}$
E[5]	0.7995	0.13994	0.99914	0.095462		**0.000136**
F[6]	0.091971	0.14057	0.12565	0.13334	**0.13036**	

[1]A: Population 1991
[2]B: Life expectancy at birth 1991
[3]C: Population 2000
[4]D: Life expectancy at birth 2000
[5]E: Population 2010
[6]F: Life expectancy at birth 2010

By correlating the percentage of hospitalizations for diseases related to inadequate environmental sanitation *versus* population classes, the graph shown in Figure 8 was obtained.

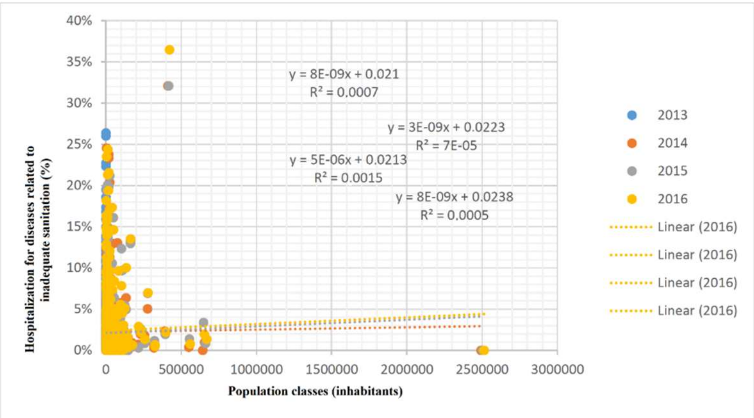

Figure 8: Percentage of hospitalizations for diseases related to inadequate environmental sanitation *versus* population classes.

Table 9 presents the analysis of r-Pearson values of the data shown in Figure 8, in bold. The r-Pearson values corresponding to the population and the percentage of hospitalizations for diseases related to inadequate environmental sanitation of the respective years are highlighted in bold.

Table 9: R-Pearson values for the relationship between population *versus* percentage hospitalizations for diseases related to inadequate environmental sanitation.

	A[1]	B[2]	C[3]	D[4]	E[5]	F[6]	G[7]	H[8]
A[1]		**0.61199**	0	0.80871	0	0.4588	0	0.51293
B[2]	**0.017402**		0.60697	$2.05.10^{-21}$	0.60222	$6.26.10^{-11}$	0.59764	$1.86.10^{-05}$
C[3]	1	0.017648		**0.80284**	0	0.4533	0	0.50694
D[4]	0.008306	0.31738	**0.008566**		0.79676	$1.04.10^{-17}$	0.79209	$3.22.10^{-08}$
E[5]	0.99999	0.017881	1	0.008836		**0.44811**	0	0.50121
F[6]	0.025413	0.22138	0.025726	0.28728	**0.026022**		0.44357	$8.07.10^{-29}$
G[7]	0.99997	0.018107	0.99999	0.009044	1	0.026283		**0.49618**
H[8]	0.022445	0.146	0.022765	0.18769	0.023073	0.36804	**0.023345**	

[1]A: Total population 2013
[2]B: % of hospitalizations for diseases related to inadequate environmental sanitation 2013
[3]C: Total population 2014
[4]D: % of hospitalizations for diseases related to inadequate environmental sanitation 2014
[5]E: Total population 2015
[6]F: % of hospitalizations for diseases related to inadequate environmental sanitation 2015
[7]G: Total population 2016
[8]H: % of hospitalizations for diseases related to inadequate environmental sanitation 2016

Low linear correlation values were obtained through the analysis of Figure 7, being equal to 0.017, 0.0094, and 0.008, i.e., there is no linear correlation between the evaluated parameters. However, it is verified that life expectancy at birth increased over the years, indicating better conditions and quality of life of the population and led to higher life expectancy rates at birth.

Table 8 shows the r-Pearson analysis. It is verified that the relationship between the variables is positive, being equal to 0.004914, 0.006892, and 0.000136 for the years 1991, 2000, and 2010 respectively. When the axes are reversed, the coefficients equal to 0.096276 are obtained; 0.092508 and 0.1306 for 1991, 2000 and 2010, remaining a positive relationship between the variables.

Figure 8 shows low linear correlation values, equal to 0.007, 0,0015, 0.0005, and $7.10^{-05,}$ indicating no linear correlation between the variables. However, it is verified that the most populated cities have the lowest percentages of hospitalization, while the less populated cities are the most heterogeneous, with higher and lower hospitalization rates.

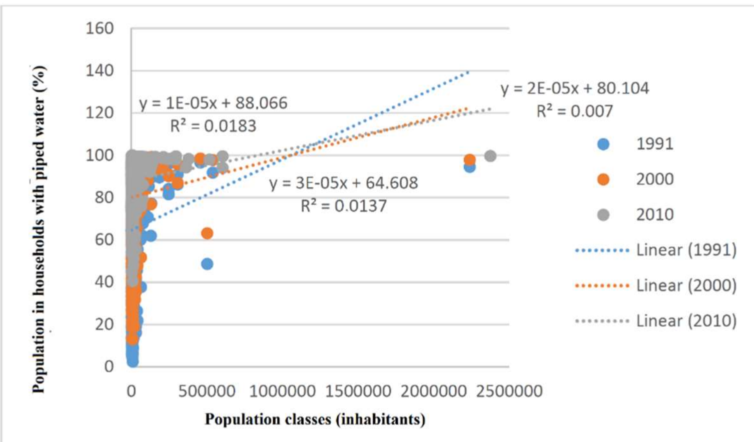

Figure 9: Percentage of population with piped water *versus* population classes.

As shown in Table 9, when performing the analysis of r-Pearson values, it is verified that these are positive relationships and analyzed population *versus* percentage of hospitalizations for diseases related to inadequate environmental sanitation and the inverse of the relationship. When studying the correlation between the percentage of the population in households with running water *versus* the population classes, we obtained the graph as shown in Figure 9.

From the analysis of the graph of Figure 9, there are low values of linear correlation (R^2), being equal to 0.007, 0.0183, and 0.0137, indicating that there is a very low linear correlation between the analyzed parameters. However, it is verified that the most populated mining cities have higher percentages of care for the years 1991, 2000, and 2010, respectively. Moreover, it is evident that over the time analyzed (1991 to 2010), there is an increase in the rate of the population that has piped water in less populated cities. Moreover, the lowest population rates with piped water are found in less populated cities.

Table 10 shows the r-Pearson values for the percentage of the population with running water versus classes of population in bold. The r-Pearson values corresponding to the relationship for the respective years are highlighted.

Table 10: R-Pearson values for the population versus population relationship percentage of the population with piped water.

	A[1]	B[2]	C[3]	D[4]	E[5]	F[6]
A[1]		**0.000446**	$6.76.10^{-196}$	0.018618	$3.67.10^{-213}$	0.000688
B[2]	**0.12011**		$1.03.10^{-07}$	0.018357	$2.33.10^{-08}$	0.042357
C[3]	0.80641	0.1812		**0.014834**	$2.34.10^{-190}$	0.000136
D[4]	0.08065	0.080829	**0.083447**		0.000329	0.06094
E[5]	0.82556	0.19	0.7995	0.12276		**$2.69.10^{-09}$**
F[6]	0.1162	0.069646	0.13042	0.064266	**0.20214**	

[1]A: Population in 1991
[2]B: % population with piped water 1991
[3]C: Population in 2000
[4]D: % population with piped water 2000
[5]E: Population in 2010
[6]F: % population with piped water 2010

As shown in Table 10 by the analysis of r-Pearson values, it is verified that the population relationship *versus* percentage of the population in households with piped water values equal to 0.000446; 0.014834, and $2.69.10^{-09}$. Although they are relatively low values, this is a positive relationship between the parameters. The same also occurs when reversing the axes, obtaining values equal to 0.12011, 0.083447, and 0.20214.

CONCLUSIONS

The present study aimed to evaluate and correlate data from drinking water supply statistically and sewage collection and treatment, with quality of life indexes of the population of the state of Minas Gerais aiming at universalization to basic sanitation services, having as background Law Nº. 14026/2020 (BRASIL, 2020), sanctioned in the country.

It is verified through the data obtained that there is a tendency to increase the percentage values of the population with piped water and also the life expectancy at birth of the years 1991, 2000, and 2010. These numbers also indicated that there was an improvement in the rate of care over time t.

There is also a trend of increasing percentage values of the population with piped water *Versus* MHDI – Longevity dimension, concerning the years 1991, 2000, and 2010. It was observed that over the observed periods, there was an increase in the rates of care and MHDI. It is noted that higher rates of care with water supply to the population provide better indicators of quality of life of the population, such as higher rates of life expectancy at birth and MHDI.

The analyses showed a low coefficient of linear correlation between the investments in sewage collection and treatment per capita (R$/hab2035) variables *versus* an increase in the index of WWTPs evaluated (2013-2035).

In the joint analysis between variables investments in sewage collection and treatment per capita (R $ / hab2035) *versus* the population served estimated in 2035 *versus* the rate of service with evaluated WWTPs (2013-2035), it appears that most cities (95 % within the ellipse) are small cities. Therefore, investments in sewage collection and treatment do not generally exceed the value of about 1,140.00 R$/hab2035 (average of 690.40 R$/hab2035 with a standard deviation of 425.08 R$/ hab2035).

The amounts to be achieved by investments in sewage collection and treatment per capita (R$/hab2035) seek universal access to sewage collection and treatment in Minas Gerais, from 90-100% of the population to be served (average of 92.02% and standard deviation of 0.13%). Concerning the collection and treatment of sanitary sewage, these values are in line with Art. 11-B of Law N. 14026/2020 (BRAZIL, 2020), of the legal framework of sanitation (universalization goals that guarantee the attendance of 90% of the population with sewage collection and treatment until December 31, 2033). However, the planning of the goals that have been described for 2035 must conform to the aforementioned law, for 2033.

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