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Analysis of the Cases of Covid-19 and Environmental Health for 14 Municipalities of the UGRHIs Baixo Pardo/Grande and Pardo

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SUMMARY

Safety protocols emerged to minimize the spread of Covid-19 and are in force 20 months after the disease exists in Brazil. The occurrence of SARS-CoV2 can be analyzed by the local Environmental Health Indicator (ISA). The objective of this study was to analyze the mortality rate caused by Covid-19 about environmental and sanitary conditions in 14 municipalities in the state of São Paulo, located in the Baixo Pardo/Grande and Pardo UGRHIs. Data from covid-19 (total cases and deaths) were obtained by SEADE (2021) and research by Rezende (2021) and Alvares (2021) provided the ISA parameters. The municipalities were grouped by demographic density and those with up to 50 thousand inhabitants were selected. The fatality rate was obtained as the ratio of the number of deaths to the accumulated cases of Covid-19. Of the 14 selected municipalities, 57,1% met the research hypothesis (municipalities with higher ISA have a mortality rate at covid-19 below the national average) and seven of them are below 20 thousand inhabitants with mortality rates below 2,4 %. Studies based on data from Covid-19, socio-environmental parameters (schooling, income, age group) and social vulnerability conditions can contribute to a better interpretation of environmental health in the pandemic.

KEYWORDS: Covid-19. Environmental Health. Indicator.

1 INTRODUCTION

Covid-19 is a disease caused by SARS-CoV-2, transmitted mainly by nasal secretions and droplets expelled by infected people. Most people who become infected can have mild to moderate flu-like symptoms and recover without the need for special treatments. However, elderly people with preexisting comorbidities, such as cardiovascular disease, diabetes, chronic respiratory diseases, cancer, among others, are more susceptible to developing severe symptoms when infected by the virus (WHO, 2021).

Hand and object hygienization is, among others, one of the core recommendations of the World Health Organization (WHO) to prevent the virus spreading (WHO, 2021). In this sense, the guarantee of drinking water and adequate sanitary conditions for hand hygiene is of fundamental importance for the prevention of Covid-19 transmission (RUTERE *et* al., 2020).

The importance of basic sanitation and environmental conditions as relevant factors to prevent coronavirus transmission was highlighted by Odih *et* al. (2020); Gonzaga and Alves (2020); Scherchan *et* al. (2020); Mangla, Pathak and Sahoo (2020), and Silva *et* al. (2020).

Federal Law Number 11.445/2007 defines basic sanitation as a set of public services, infrastructure and operational installations for water supply, sanitary sewage, urban cleaning and solid waste management and drainage and rainwater management (BRAZIL, 2007).

In this aspect, 92,8% of the Brazilian urban population has access to water, 60,9% has access to sewage collection, 98,8% has access to household solid urban waste collection. Regarding rainwater, 79,4% of Brazilian municipalities have some type of drainage system (MINISTÉRIO DO DESENVOLVIMENTO REGIONAL, 2021).

Environmental health, in turn, corresponds to the environmental quality capable of preventing or preventing the spread of diseases transmitted by the environment, improving the mesological conditions that promote the health of the urban and rural population (PIZA, 2000).

In this context, it is essential to establish the relationship between the cases of Covid-19 with the sanitary and environmental conditions of the municipalities.

1.1 Sanitation, Environment and Coronavirus

Areas where there is deficiency or inexistence of water supply systems, or sanitary sewage systems are more susceptible to contamination by the virus, mainly in places with high population density (ODIH *et* al., 2020). The transmission of SARS-CoV-2 through water, especially in wastewater, is a real concern and requires further research attention, especially in terms of cold climate regions (CARDUCCI *et* al., 2020).

There is no scientific evidence on the oral-fecal contamination of the virus, however, it is a factor that cannot be ruled out. The release of raw sewage into water bodies impacts the quality of water sources and enables the indirect transmission of the virus, due to the contact of individuals with contaminated water (GONZAGA and ALVES, 2020).

Wastewater contaminated by SARS-CoV-2, which comes into contact with clean water or even with water used for public supply, poses risks to populations that use it (PURNAMA and SUSANNA, 2020).

In North America, the first study to detect the presence of SARS-CoV-2 RNA in wastewater was the one by Scherchan *et* al. (2020), developed in Louisiana, United States of America. In the research, water samples were collected on 4 occasions from January to April 2020. Of the total of 15 samples, 2 of them presented the RNA of SARS-CoV-2.

Studies were carried out to assess the relationship of sewage and water supply with the presence of SARS-Cov2, as Silva *et* al. (2020) and Mangla, Pathak and Sahoo (2020).

Silva *et* al. (2020) studied the rates of basic sanitation and cases of Covid-19 in Brazilian municipalities. They identified that the water supply coverage index and fecal coliform index obtained outside the standard in the supplied water exert a direct influence on the spread of Covid-19. About sanitary sewage, municipalities with lower levels of sewage collection and treatment had a higher incidence of mortality due to Covid-19.

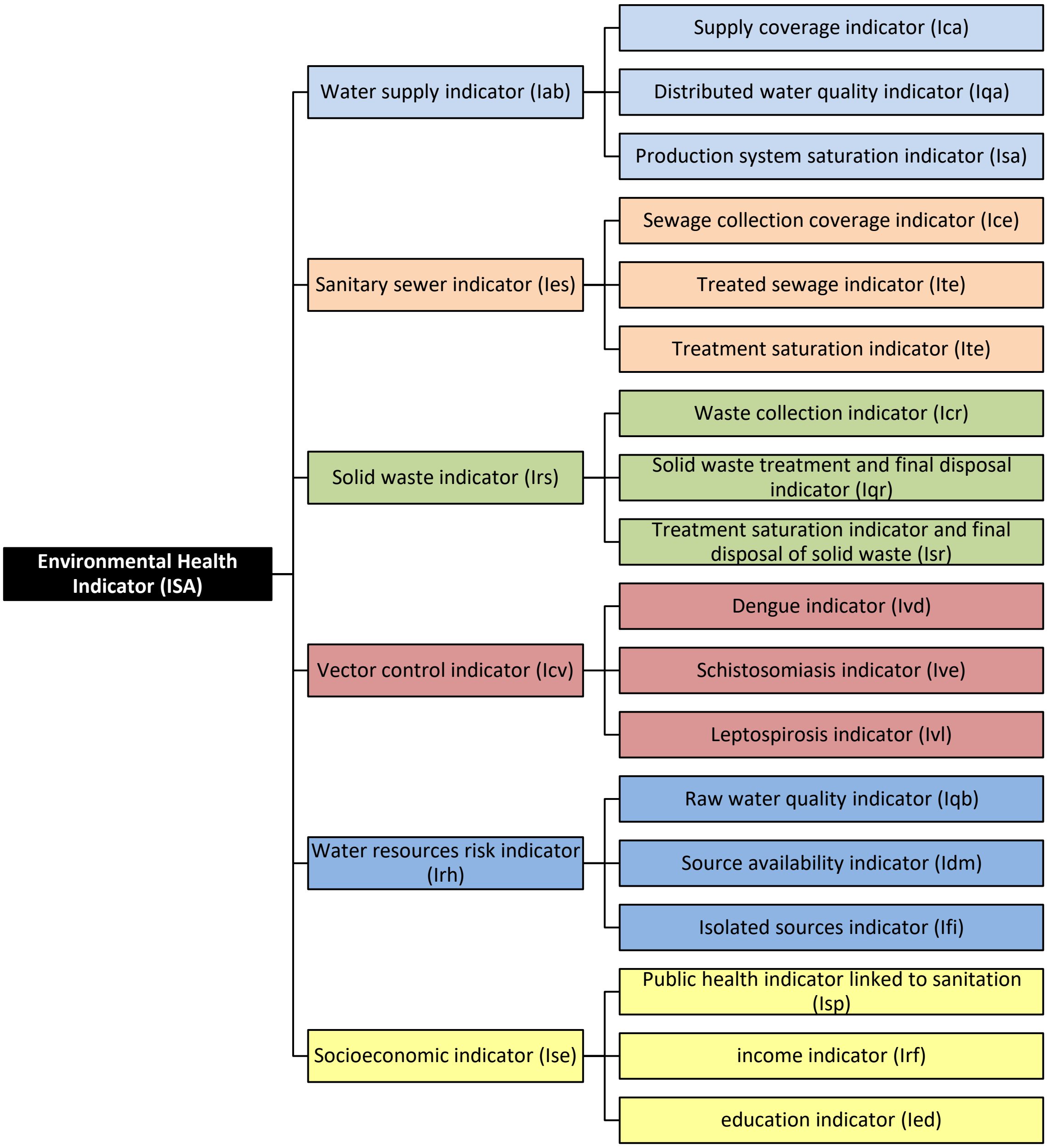
Mangla, Pathak and Sahoo (2020) investigated the relationship between environmental indicators (air pollutants and meteorological parameters of temperature, humidity, wind speed and rainfall) with Covid-19, in Delhi, India. The indicators that showed incompatible results were i) the temperature that directly influenced the spread of the virus and, on the other hand, ii) the air humidity, which established adverse health effects and favored viral contamination. Thus, environmental indicators depend on the healthy conditions of the environment, which highlights the importance of research linking environmental factors with Covid-19.

1.2 Environmental Health Indicator

In 1999, the State Sanitation Council (CONESAN) of the State of São Paulo developed the Environmental Health Indicator (ISA), whose objective is to measure the sanitary and environmental conditions of municipalities, places or regions (PIZA, 2000). This indicator contributes to the recommendations of Federal Law Number 11.445/2007, which determines the identification of infrastructure causes by sanitary, epidemiological, environmental and socioeconomic indicators that point out the causes of detected deficiencies (BRAZIL, 2007).

The ISA is called the primary indicator, formed by the secondary indicators Iab, Ies, Irs, Icv, Irh and Ise (Figure 1), which are composed of other indicators, called tertiary indicators.

Figure 1: Composition of the environmental health indicator



Source: Organized by the authors, based on PIZA (2000).

The ISA calculation is performed by Equation 1, and it is possible to make adaptations to the method.

$$ISA = 0{,}25\ Iab + 0{,}25\ Ies + 0{,}25\ Irs + 0{,}10\ Icv + 0{,}10\ Irh + 0{,}05\ Ise \quad [Eq.\ 1]$$

Being: Iab = water supply indicator; Ies = sanitary sewer indicator; Irs = solid waste indicator; Icv = vector control indicator; Irh = water resources risk indicator; and Ise = Socioeconomic indicator

Secondary and tertiary indicators are calculated according to Chart 1.

Chart 1: Calculation of secondary and tertiary indicators

Indicador Secundário e Método de Cálculo	Cálculo do Indicador Terciário e Método de Cálculo
Iab = Water supply indicator Iab = (Ica + Iqa + Isa) / 3	Ica = Supply coverage indicator Ica = (Dua/Dut) x 100(%)
	Iqa = Distributed water quality indicator Iqa= K x (Naa/Nar) x 100(%)
	Isa = Production system saturation indicator Isa: n= log {CP/[VP.(K2/K1)]} Log (1 + t)
Ies = Sanitary sewer indicator Ies = (Ice + Ite + Ise) / 3	Ice = Sewage collection coverage indicator Ice= (Due/Dut) x 100(%)
	Ite = Treated sewage indicator Ite = Ice x (VT/VC) x 100(%)
	Ise = Treatment saturation indicator Ise: n = [log (CT/VC)] / [log (1 + t)]
Irs = Solid waste indicator Irs = (Icr + Iqr + Isr) / 3	Icr = Waste collection indicator Icr = (Duc/Dut) x 100(%)
	Iqr = Solid waste treatment and final disposal indicator Iqr = based on the score given by CETESB
	Isr = Treatment saturation indicator and final disposal of solid waste Isr: n = log {[CA x t/VL) + 1 log (1 + t)
Icv = Vector control indicator Icv = {[(Ivd + Ive) / 2] + Ivl} / 2	Ivd = Dengue indicator Ivd = function of disease occurrence data
	Ive = Schistosomiasis indicator Ive = function of disease occurrence data
	Ivl = Leptospirosis indicator Ivl = function of disease and flood occurrence data
Irh = Water resources risk indicator Irh = (Iqb + Idm + Ifi) / 3	Iqb = Raw water quality indicator
	Idm = Source availability indicator Idm = Disp / Dem
	Ifi = Isolated sources indicator Ifi = (Naa / Nar) x 100
Ise = Socioeconomic indicator Ise = (Isp + Irf + Ied) / 3	Isp = Public health indicator linked to sanitation Isp = 0,7 x Imh + 0,3 x Imr
	Irf = Income indicator Irf = 0,7 I2s + 0,3 Irm
	Ied = Education indicator Ied = 0,6 Ine + 0,4 Iel

Legend:
Dua: homes served; Dut: total urban households; K: number of samples taken/minimum number of samples; Naa: amount of samples considered to be drinking water related to colimetry, chlorine and turbidity (monthly); Nar: number of samples taken (monthly); n = number of years the system will be saturated; CP: production capacity; VP: production volume to serve 100% of the population; K2: predicted loss for 5 years; K1: current loss; t: average annual growth rate of growth; Due: urban households served by collection; Ice = collected sewage index; VC: collected volume; VT= treated volume; CT = treatment capacity; Duc: urban households served by garbage collection; Dut: total urban households; Iqr: home solid waste landfill quality index – CETESB; VL: collected volume of garbage; CA: remaining landfill capacity; Disp: availability, treatable water for supply; Dem = demand; Imh = indicator related to infant mortality (0 to 4 years) linked to waterborne disease; Imr: indicator related to the average infant mortality (0 to 4 years) and elderly (over 65 years) linked to respiratory diseases; I2s: income distribution indicator less than 3 minimum wages; Irm: average income indicator; Ine: no education indicator; Iel: education indicator up to 1st grade.
Source: PIZA, 2000.

The method includes 18 indicators, which are organized into the main thematic axes (Figure 1), whose class varies in high health (100,00 to 75,51), medium health (75,50 to 50,51), low health (50,50 to 25,51) and unhealthy conditions (25,50 to 0,00), according to Piza (2000).

Teixeira, Prado Filho and Santiago (2018) carried out a study to analyze the State of the Art of research with the ISA in Brazil. From 1999 to 2016, 60 studies on this topic were identified.

2 PURPOSE

The main objective was to analyze the relationship between the incidence of Covid-19 and environmental health in the municipalities included in the Water Resources Management Unit (UGRHI) 12 – Baixo Pardo/Grande and in the northwest portion of UGRHI 4 – Pardo.

3 METHODOLOGY

The research methodology was organized in four Steps (Chart 2).

Chart 2: Steps developed for this research

Step	Description	Purpose
Step 1	Selection of municipalities	Present selection criteria for municipalities
Step 2	Environmental Health Assessment	Illustrate environmental health with indicators for water supply, sanitary sewage, urban solid waste, vector control, water resources risks, socioeconomic and environmental health
Step 3	Identification of covid-19 cases in selected municipalities	Get data on covid-19
Step 4	Integrated analysis of covid-19 cases with the environmental health of municipalities	Associate covid-19 cases with the Environmental Health Indicator (ISA)

Source: Own authorship.

Stages 1 and 2: Alvares (2021) and Rezende (2021) supported, respectively, the data collection for the municipalities in the Baixo Pardo/Grande basin and the northwestern portion of the Pardo basin (Chart 3).

Chart 3: Municipalities covered in this study

Basin	Municipalities					
Baixo Pardo / Grande (UGRHI 12)	Altair	Barretos	Bebedouro	Colina	Colômbia	Guaraci
	Icém	Jaborandi	Morro Agudo	Orlândia	Terra Roxa	Viradouro
Pardo (UGRHI 4)	Altinópolis	Brodowski	Cravinhos	Jardinópolis	Ribeirão Preto	Serrana

Source: Own authorship.

Step 3: To search for data on Covid-19, the SEADE database (2021) was considered as the reference source for all municipalities. The data collection period for covid-19 was between Jul 2th 2020 and Jun 2th 2021.

Step 4: The accumulated cases of the disease were organized in an electronic spreadsheet, together with the indicators from Step 1. Due to the discrepancy between the number of inhabitants, it was necessary to group the municipalities by population group (Table 1). Municipalities with more than 50 thousand inhabitants were not included in this analysis, as small municipalities (< 50 thousand inhabitants) were prioritized. Thus, of the 18 municipalities indicated in Chart 3, 14 were selected for this research.

Table 1: Grouping of municipalities by population group

Group	Population Range (inhab.)	Municipalities				
I	0 < p ≤ 10.000	Altair	Colômbia	Jaborandi	Icém	Terra Roxa
II	10.000 < p ≤ 20.000	Altinópolis	Colina	Guaraci	Viradouro	---
III	30.000 < p ≤ 40.000	Cravinhos	M. Agudo	----	---	---
IV	40.000 < p ≤ 50.000	Jardinópolis	Orlândia	Serrana	---	---

Source: Own authorship.

The main hypothesis of this research was "municipalities with medium and high environmental health have a lower mortality rate for Covid-19 than the national average", considering that environmental conditions are relevant factors in the spread of the disease, as pointed out by Odih *et* al. (2020); Gonzaga and Alves (2020); Scherchan *et* al. (2020); Mangla, Pathak and Sahoo (2020), and Silva *et* al. (2020).

4 RESULTS

The results are presented by methodological step (items 4.1 to 4.3).

4.1 Environmental Health Indicator (ISA) by Selected Municipality

The characterization of the municipalities is detailed in the studies by Alvares (2021) and Rezende (2021), and their boundaries and locations in relation to the UGRHIs are shown in Figure 2. The order of municipalities was organized according to population size (Table 1). It is observed that the municipalities of Barretos, Bebedouro, Brodowski and Ribeirão Preto are not included (Table 2), according to the criteria defined in item 3 of this article.

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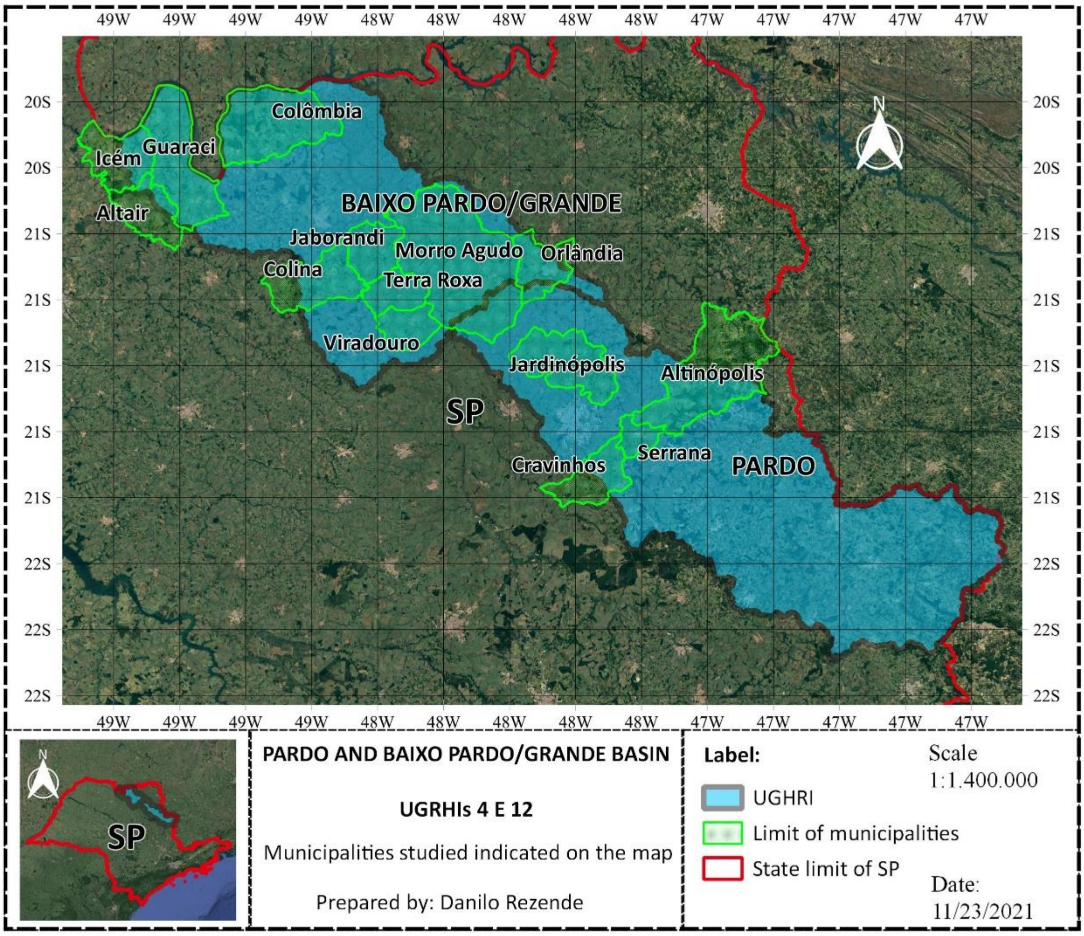
Figure 2: Delimitations of municipalities and locations in relation to UGRHIs



Source: Own authorship.

Table 2: Population, Area and Environmental Health Indicator by Municipality

Municipality	Pop. (hab) ¹	Area (km²)¹	DD (inhab. /km²)¹	Iab	Ies	Irs	Icv	Irh	Ise	Idu	ISA
1-Altair	4.036	313,01	12,89	66,67	98,64	100,00	81,25	50,00	58,96	-	**82,40**
2-Colômbia	6.046	728,65	8,30	66,67	98,99	83,33	81,25	50,00	49,78	-	**77,86**
3-Jaborandi	6.677	273,44	24,42	62,42	100,00	83,33	81,25	50,00	64,62	-	**77,79**
4-Icém	8.032	362,36	22,17	66,67	91,43	66,67	81,25	50,00	44,67	-	**71,55**
5-Terra Roxa	9.121	221,54	41,17	62,28	100,00	66,67	81,25	50,00	48,37	-	**72,78**
6-Guaraci	10.978	641,50	17,11	64,07	85,22	83,33	81,25	50,00	57,44	-	**74,15**
7-Altinópolis	16.184	928,96	16,74	60,66	66,67	100,00	81,25	100,00	50,67	36,00	**72,76**
8-Colina	17.603	422,30	41,68	64,81	66,67	66,67	81,25	50,00	49,65	-	**65,15**
9-Viradouro	18.347	217,73	84,26	65,81	54,97	66,67	81,25	50,00	55,15	-	**62,75**
10-M. Agudo	32.332	1.388,13	23,29	64,07	85,22	83,33	81,25	50,00	57,44	-	**72,40**
11-Cravinhos	35.292	311,42	110,55	68,45	66,67	75,00	18,75	100,00	52,00	5,00	**60,42**
12-Orlândia	42.266	291,77	144,86	66,62	92,42	100,00	81,25	50,00	43,43	-	**80,06**
13-Jardinópolis	44.380	501,87	86,19	69,58	33,33	75,00	43,75	50,00	57,67	0,30	**51,35**
14-Serrana	45.107	126,05	352,51	44,19	33,33	75,00	43,75	100,00	53,33	17,20	**51,48**

(1) Inhabitants. (2) Demographic Density (inhabitants per km2) obtained by SEADE (2021).
Definitions:
Iab: water supply indicator; **Ies**: Sanitary sewer indicator; **Irs**: solid waste indicator; **Icv**: vector control indicator; **Irh**: water resources risk indicator; **Ise**: socioeconomic indicator; **Idu:** urban drainage indicator.

Environmental health conditions (class/score): high health (100,00 a 75,51), average health (75,50 a 50,51), low health (50,50 a 25,51) and unhealthy conditions (25,50 a 0,00), according to Piza (2000).
Source: Organized by the authors based on Alvares (2021), Rezende (2021) and SEADE (2021).

Rezende (2021) proposed changes to the Piza (2000) method, including the replacement of indicators and changes in Equation 1 (item 1). Alvares (2021), in turn, made other adaptations, different from Rezende (2021). The results in Table 2 were analyzed only with the cases of Covid-19 by the municipality, based on the hypothesis established in the methodology.

4.2 Occurrences of Covid-19 Cases in the Studied Municipalities

The cases of Covid-19 for the 14 municipalities are listed in Table 1. It can be seen that the national lethality was 2,4% on 2/27/2021 (BRAZIL, 2021). With this, it is observed that the municipality of Altair is the least populous and has practically 3 times the mortality rate in the country (2,4%). This identifies that SARS-CoV2 contamination in Altair is extremely high for the municipality with 4.036 inhabitants (Table 2).

In much smaller proportions, there is the municipality of Cravinhos (2,6%) which has an order of magnitude similar to the national lethality (2,4%). The other municipalities have a lethality rate below 1,8% (Table 3).

Table 3: covid-19 data for selected municipalities between 2/07/2020 to 2/06/2021.

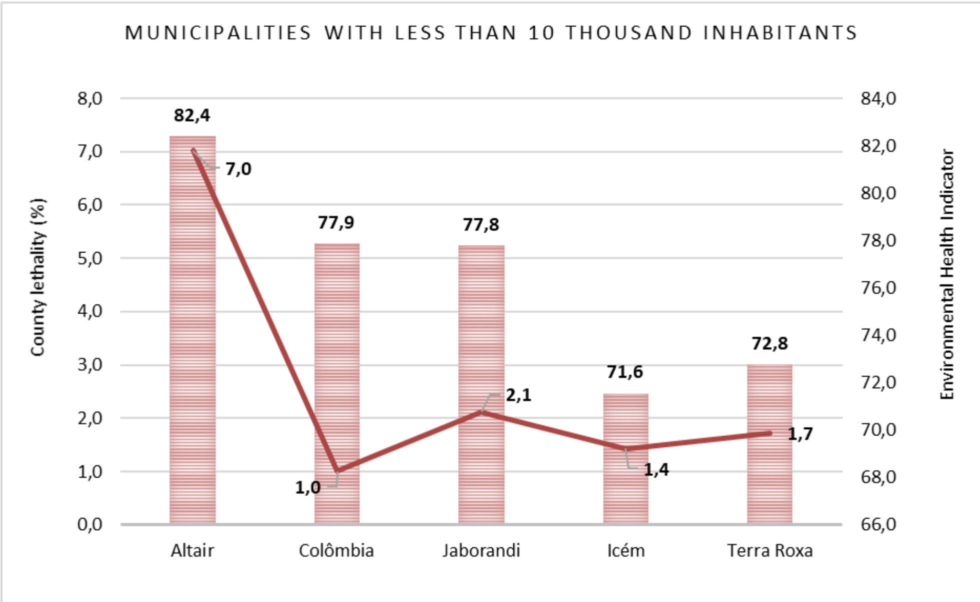
Municipalities	Cases of covid-19	covid-19 cases per 100.000 inhabitants	Deaths from covid-19	Lethality (%) [1]	City Lethality / Brazil Lethality [2]
Altair	57	1.670	4	7,0	2,9
Colômbia	199	4.382	2	1,0	0,4
Jaborandi	236	3.722	5	2,1	0,9
Icém	351	5.041	5	1,4	0,6
Terra Roxa	347	5.473	6	1,7	0,7
Guaraci	395	3.872	8	2,0	0,8
Altinópolis	429	3.006	11	2,6	1,1
Colina	477	2.843	18	3,8	1,6
Viradouro	754	4.234	14	1,9	0,8
Morro Agudo	1.921	6.087	28	1,5	0,6
Cravinhos	692	2.040	43	6,2	2,6
Orlândia	1.780	4.323	51	2,9	1,2
Jardinópolis	1.474	3.469	61	4,1	1,7
Serrana	1.637	3.705	52	3,2	1,3

(1) Local lethality is the ratio between the number of deaths/total confirmed cases by municipality
(2) Ratio between local lethality and national lethality (2,4%)
Source: SEADE, 2021.

4.3 Environmental Health and Lethality by Covid-19 in Selected Municipalities

The results obtained for **Group I (up to 10 thousand inhabitants)** are shown in Figure 3. It can be seen that the municipalities with the lowest lethality about the country have ISA in high health conditions (Colombia and Jaborandi) and medium health conditions (Icém and Terra Roxa). The only municipality with the contamination of Covid-19 in an accelerated way and that, therefore, did not meet the expected standard is the municipality of Altair, contrary to the hypothesis of this research. Thus, these causes has deserved in-depth studies.

Figure 3: Covid-19 lethality and ISA for Group I municipalities in February 2021



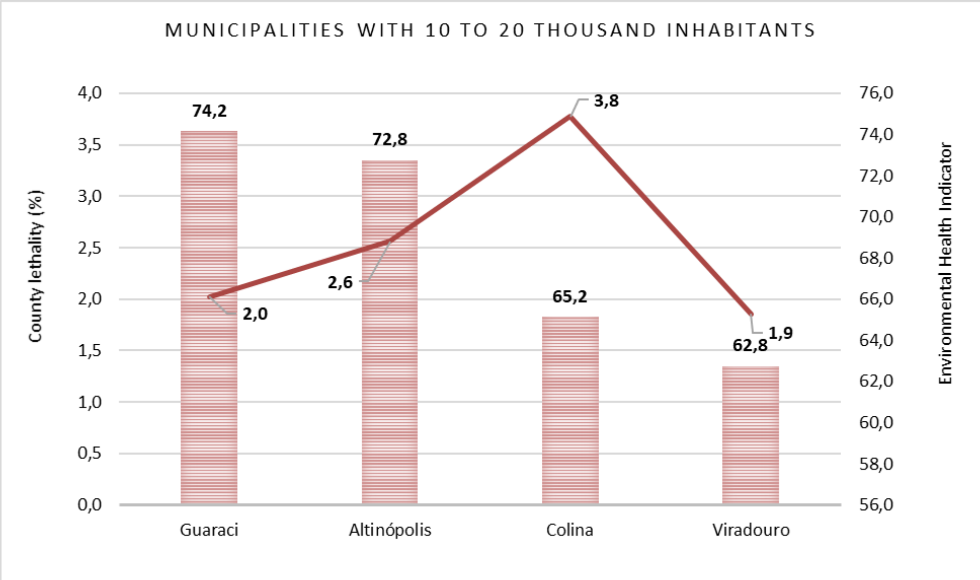
Source: Own authorship.

The results obtained for **Group II (10,000 to 20,000 inhabitants)** are shown in Figure 4. It can be seen that all municipalities were classified as having average health conditions (75,50 to 50,51).

The municipalities of Altinópolis (2,0%) and Guaraci (2,6%) had a fatality rate similar to the country; Colina, in turn, had 3,8% lethality, reaching a value above the national average (2,4%). It is worth noting that Viradouro, despite having the lowest ISA value (62,8), was the municipality with the lowest mortality rate (1,9%), as shown in Figure 4.

For Group II, only the municipality of Colina did not reach the defined hypothesis.

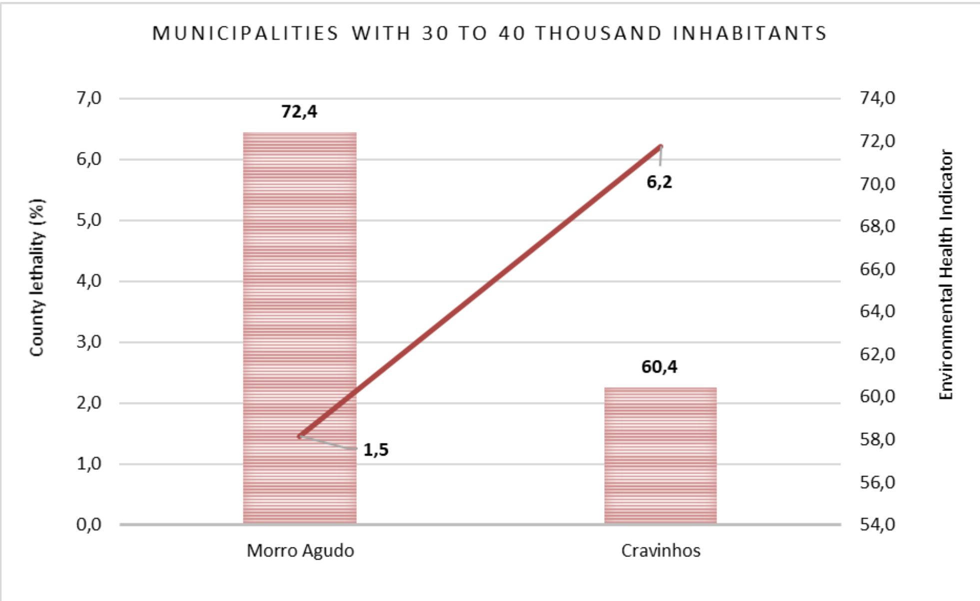
Figure 4: Covid-19 lethality and ISA for Group II municipalities in February 2021



Source: Own authorship.

The results obtained for **Group III (30 thousand to 40 thousand inhabitants)** are shown in Figure 5. Both municipalities presented medium health conditions (75,50 to 50,51).

Figure 5: Lethality by Covid-19 and ISA for Group III municipalities in February 2021



Source: Own authorship.

The municipality of Morro Agudo had a low mortality rate (1,5) in Brazil (2,4%), with high health conditions (100,00 to 75,51).

However, Cravinhos, even guaranteeing average health conditions (75,50 to 50,51), recorded a high mortality rate (6,2%), contrary to the established hypothesis.

Figure 6 illustrates the representation of the municipalities in **Group IV (40 thousand to 50 thousand inhabitants)**. All municipalities had a fatality rate above the national lethality rate.

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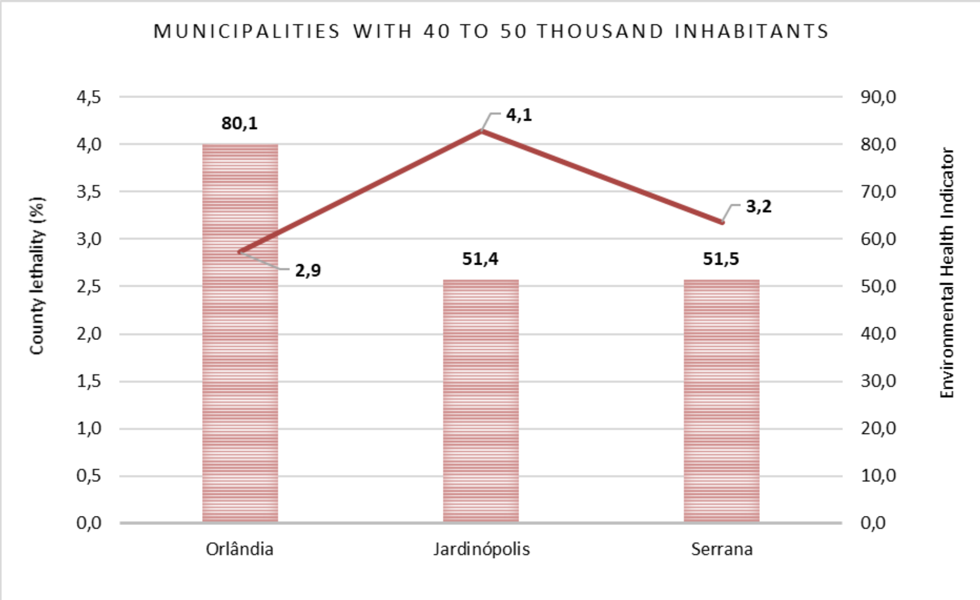
It should be noted that Orlândia (Figure 6) showed high environmental health (100,00 to 75,51) and a fatality rate (2,9%) slightly higher than that observed in Brazil (2,4%). Therefore, it did not meet the criteria of this research.

The municipalities of Jardinópolis (4,1%) and Serrana (32%) were classified as having medium healthiness, and the observed indices were very close to the upper limit of low healthiness (50,50 to 25,51), reinforcing the need for improvements in sanitation, health and environmental control to raise these rates. These municipalities did not meet the criteria defined in the hypothesis of this research (Figure 6).

Figure 6: Lethality by Covid-19 and ISA for Group IV municipalities in February 2021



Source: Own authorship.

Thus, the research included covid-19 data for 4 groups of municipalities, divided into **Group I (up to 10 thousand inhabitants), Group II (10 thousand to 20 thousand inhabitants), Group III (30 thousand to 40 thousand inhabitants)** and **Group IV (40 thousand to 50 thousand inhabitants)**.

In summary, when comparing the local lethality rate with that observed in the country and associating it with the result of the ISA of the 14 municipalities (total analyzed), 8 (57.1%) of them met the hypothesis of this research:

- **Group I** (28,6% of the total): Colombia, Jaborandi, Icém, Terra Roxa;
- **Group II** (21,4% of the total): Altinópolis, Guaraci, Viradouro;
- **Group III** (7,1% of the total): Morro Agudo.

The other municipalities (6: 42,8% of the total) did not meet the research hypothesis.

5 CONCLUSION

After 20 months of the first Covid-19 case in Brazil (Jun 26, 2020), p.reventive measures and, above all, the conduct adopted by the population (isolation and social distance; use of masks and use of alcohol gel >70%) guarantee a reduction in the risk of the disease. It should be noted that the existence of more restrictive public policies and protocols that encourage restrictions on the movement of people, such as Lockdown, can contribute to this reduction, if developed in an integrated manner with the WHO measures.

In this context, environmental health measures physical infrastructure and socio-environmental and public health factors in each municipality, whose method was conceived in 1999 and, since then, no other changes have been consolidated, including for pandemic events.

The hypothesis of this research (municipalities with higher ISA have a lethality rate below the national average) was confirmed in 57,1% of the analyzed cities, and seven of them are below 20 thousand inhabitants with lethality rates below 2,4%.

Studies based on accumulated Covid-19 cases can correlate the use of population data (education, income, age group) with the conditions of social vulnerability and apply geoprocessing techniques to better interpret the sanitary and environmental conditions in each municipality, and thus, contribute to the analysis of environmental health in the pandemic.

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