# Spatial analysis of COVID-19 and inequalities in Mexico City

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## Abstract

The 2019 coronavirus disease (COVID-19) has caused over 300,000 deaths worldwide. Currently, in Mexico City, one of the largest urban centers in the world, the number of people infected and the deaths due to de COVID-19 is still increasing. The distribution of COVID-19 is likely to be shaped by both environmental conditions and social processes related to the city's unplanned growth and social inequalities. Here we present a descriptive, spatially explicit account of the distribution of the COVID-19 for the 7th of January to 13th of May of 2020 period, that considers patterns of distribution of COVID-19 and whether or not it was affected by water availability as well as household overcrowding. Understanding the distribution patterns' of the number of confirmed cases of COVID-19 in Mexico City is relevant for future urban planning and health policy making, both aspects related to the Sustainable Development Goals 2030.

**Keywords**: COVID-19; spatial analysis; water availability; household overcrowding.

## *Introduction*

Mexico City is a megacity with 8,918,653 inhabitants (INEGI, 2010) located within the Mexico City Metropolitan Area (MCMA) that is inhabited by more than 20 million people (OECD, 2015). As most megacities in the developing world, Mexico City is characterized by rapid and generally unplanned urbanization in the peripheries (Baeza et al., 2018). The concentration of people and services in such a built environment creates a high vulnerability to diverse shocks (Tellman et al., 2018), such as the pandemic of coronavirus disease 2019 (COVID-19). Therefore, understanding the distribution patterns' of the number of confirmed cases of COVID-19 in Mexico City is relevant for future urban planning and health policy making.

Currently, the number of people infected and the deaths due to de COVID-19 in Mexico City is still increasing, while the pandemic has already caused over 300,000 deaths worldwide (WHO, 2020), the majority of them in urban areas, where now days most of the global population and the urban poor live. In this context, the fulfillment of the United Nations Sustainable Development Goals (SDGs) could be seriously jeopardized (Zhou et al., 2020). In particular the SDG 3 that aims to ensure healthy lives and promote well-being for all, at all ages, and more specifically the SDG 3.3, which by 2030,  aims to end epidemics of AIDS, tuberculosis, malaria and overlooked tropical diseases, as well as fighting hepatitis, water-borne diseases and other communicable diseases (UNDP, 2015). Thus, under conditions of global environmental change and a growing majority of the world's population living in cities, urban planning and the design of health policies are a key to achieve the SDGs.

In this work we present a descriptive, spatially explicit account of the distribution of the COVID-19, few days after reaching the predicted peak of cases in Mexico City[1], and its relation to both environmental conditions and social processes that shape the epidemiological vulnerability of the city. In particular, we analyzed the total number of confirmed cases and the COVID-19 prevalence by municipalities within the city[2],  based on which we  looked for patterns or relations between the distribution of the COVID-19 prevalence and the availability of water the one hand, and the relations between prevalence and the level of houses´ overcrowding on the other. Understanding the patterns of distribution of COVID-19 and whether or not it is affected by water

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[1] On May 18, 2020.

hard infrastructure –the built infrastructure (Eakin et al., 2017; Tellman et al., 2018)– or socio-economic factors such as household overcrowding and access to health services, might offer some useful insights for the design of effective health and urban policies.

## *Methods*

We used official data from the Ministry of Health (available at https://coronavirus.gob.mx/datos/#DownZCSV) from where we obtain the confirmed cases of COVID-19 in the 16 municipalities of Mexico City, for period of January 7 to May 13, 2020. Data on water hard infrastructure, and in particular, water availability in Mexico City were obtained from the results of the study of López-Guerrero's (2016) on territorial inequalities related to the provision, o distribution, coverage and access to water in Mexico City. We gathered information on household overcrowding from the 2015 municipality Marginalization index developed by the National Population Council (CONAPO, 2016), while the access to health services was derived from the urban marginalization index (CONAPO, 2011) and from Mexico City's government open data portal (https://datos.cdmx.gob.mx/explore/dataset/).

To establish the categories of COVID-19 prevalence per 100,000 people (COVID-19 prevalence, hereafter), we used the classification method of geometrical intervals. In particular, we followed the approach proposed by Bojórquez-Tapia and colleagues (2009) based on the Weber-Fechner Law, a well-established principle of psychophysics, that allows to define significant intervals between categories, that establishes the logarithmic relationship between the magnitude of a stimulus and the intensity of its perception– so that category cuts are defined by modifying the "progression factor", $(1 + r)$, which determines the stimulus/perception relationship. In particular, we applied $1 < (1 + r) \leq 2$ to establish the intervals of the categories of COVID-19 prevalence. Using this method, we explored different possible intervals between categories, aiming to identify significant limits that satisfied the postulates of the precautionary principle, applied to the prevalence of COVID-19 in Mexico City. Based on the results of this procedure, it was possible to graphically classify the municipalities with COVID-19 prevalence corresponding to the categories: very high, high, and moderate.

In order to calculate the population by municipality without access to health services, we used the statistics of the 2010 urban marginalization index developed by the National Population Council (CONAPO, 2011). For the analysis of those municipalities with lands within the Protected Area of Mexico City[3], we gathered the data by census blocks, but the information was aggregated according to the size of the municipalities in order to relate it with the COVID-19 prevalence. The remaining variables were categorized using the classification method of natural breaks. In this categorization each category cut has a maximum variance between categories but the smallest variance within each category.

## Results

We compared two typologies on the presence of COVID-19 in Mexico City: the distribution of the number of confirmed cases of COVID-19 in the 16 municipalities of the city during the period January 7, 2020 to May to13, 2020 (Fig. 1) and the prevalence of the pandemic in the same municipalities . First there is no clear pattern of distribution the number of cases of COVID-19 in the city (Fig. 1-A). The municipality of Iztapalapa, on the east of the city, presented the highest number of cases whereas Cuajimalpa de Morelos, on the south-west presented the lowest numbers. Most of the municipalities (10 out of 16) felt either in the moderate or low categories (i.e. with less than 709 confirmed cases). However, population size of the different municipalities varies greatly within the city, with Iztapalapa being the most populated of them (1,815,551 people) and Milpa Alta the less populated municipality (139,371 people) with a population thirteen times smaller than Iztapalapa. Thus we analyzed the prevalence of COVIT-19 in each of the 18 municipalities in relation to their population sizes (Fig. 1-B). In this new estimate it was possible to observe marked distribution changes, with the municipalities in the south-east of the city with the largest prevalence of COVIT-19 cases (the prevalence there was very high, high and moderate) and the municipalities in south-west area with very low COVID-19 prevalence, even if most of these municipalities are located in the peripheral areas  of Mexico City. Nonetheless, Milpa Alta in the south-east side, and Iztacalco in the east side were the municipalities with higher prevalence. Both of them with less than 400,000 people, a substantially lower population than the municipality of Iztapalapa.
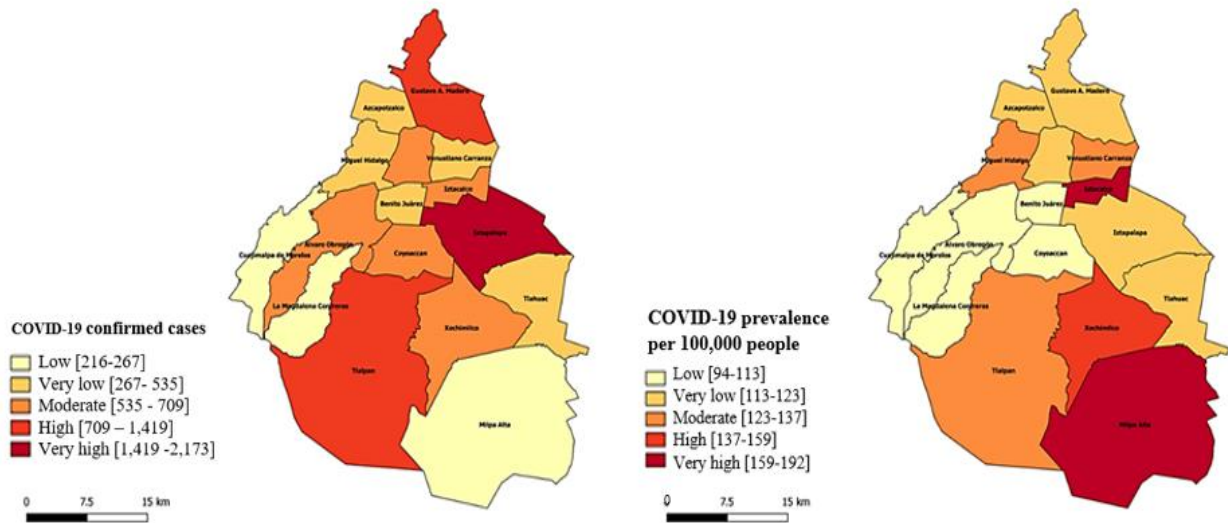
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[33] Around 66% of the land of Mexico City is formally devoted to conservation.

Health services in Mexico City comprise 87 public and private hospitals (Figure 2-A), two-thirds of them (68%) in municipalities with low and very low COVID-19 prevalence. Only five hospitals (6%) are located in municipalities with high and very high COVID-19 prevalence, while the remaining hospitals (26%) are localized in municipalities s with moderate COVID-19 prevalence (Fig. 2-A).
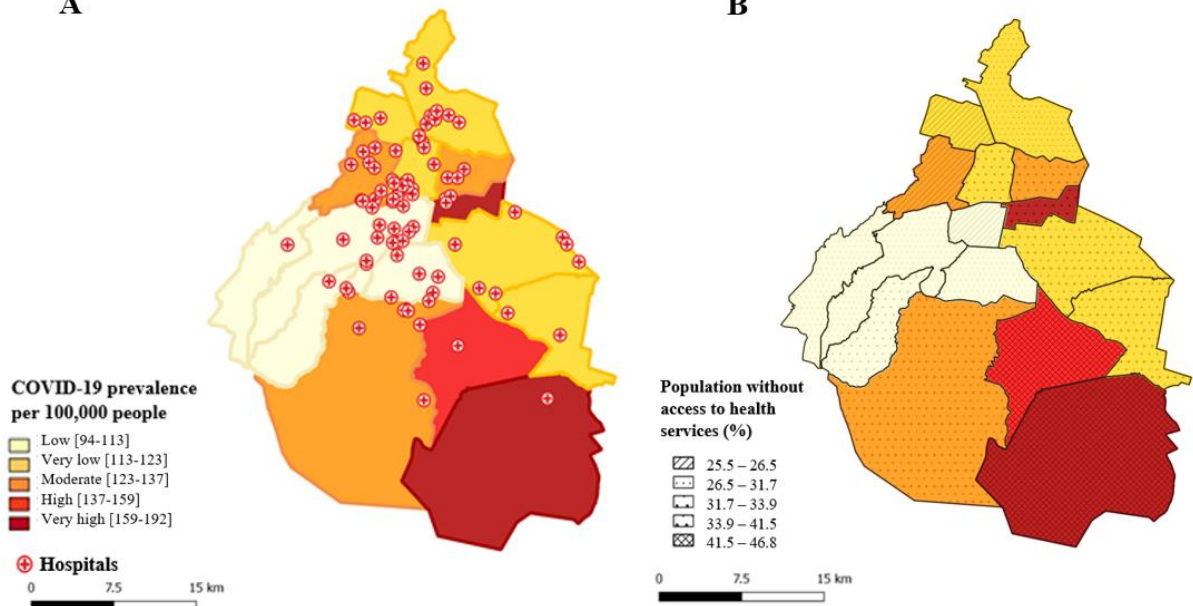
**A**

**B**



**COVID-19 confirmed cases**

- ☐ Low [216-267]
- ☐ Very low [267- 535]
- ☐ Moderate [535 - 709]
- ■ High [709 – 1,419]
- ■ Very high [1,419 -2,173]

0    7.5    15 km

**COVID-19 prevalence per 100,000 people**

- ☐ Low [94-113]
- ☐ Very low [113-123]
- ☐ Moderate [123-137]
- ■ High [137-159]
- ■ Very high [159-192]

0    7.5    15 km

**Figure 1.** Distribution of confirmed cases of COVID-19 in Mexico City. A) Total number of COVID-19 confirmed cases by municipality, B) COVID-19 prevalence per 100,000 people in each municipality.

**A**

**B**



**COVID-19 prevalence per 100,000 people**

- ☐ Low [94-113]
- ☐ Very low [113-123]
- ☐ Moderate [123-137]
- ■ High [137-159]
- ■ Very high [159-192]

⊕ **Hospitals**

0    7.5    15 km

**Population without access to health services (%)**

- ▨ 25.5 – 26.5
- ⊡ 26.5 – 31.7
- ▭ 31.7 – 33.9
- ▱ 33.9 – 41.5
- ⊠ 41.5 – 46.8

0    7.5    15 km

**Figure 2.** Access to health services in Mexico City. A) Public and private hospitals in Mexico City and COVID-19 prevalence by town hall, B) Percentage of the population without access to health services and COVID-19 prevalence by town hall.
We also looked at the population without access to health services by district (CONAPO, 2011).

Our results show that the south-east municipalities of Mexico City have a higher percentage of population without access to public health services (Fig. 2-B). In particular, Milpa Alta and Xochimilco, two of the municipalities with very high and high COVID-19 prevalence, had the highest percentage of population without access to health services of the city (Table 1).

**Table 1.** Percentage of population without access to health services in municipalities of Mexico City's (CONAPO, 2011).

| Town Hall | Population | Population without access to health services (%) |
|---|---|---|
| Álvaro Obregón | 726,551 | 30.6 |
| Azcapotzalco | 414,711 | 25.5 |
| Benito Juárez | 385,439 | 26.5 |
| Coyoacán | 620,416 | 30.8 |
| Cuajimalpa de Morelos | 183,528 | 31.7 |
| Cuauhtémoc | 528,212 | 33.6 |
| Gustavo A. Madero | 1,173,152 | 31.5 |
| Iztacalco | 384,029 | 33.3 |
| Iztapalapa | 1,791,672 | 39.2 |
| La Magdalena Contreras | 238,431 | 33.5 |
| Miguel Hidalgo | 372,101 | 25.5 |
| Milpa Alta | 113,716 | 46.8 |
| Tláhuac | 356,085 | 40.6 |
| Tlalpan | 639,795 | 41.5 |
| Venustiano Carranza | 430,927 | 33.9 |
| Xochimilco | 398,692 | 44.4 |

Access to water is another major problem in Mexico City, also with significant differences within municipalities (Mazari-Hiriart et al., 2018). Hence, we analyzed the availability of water in the city, a fundamental resource to prevent the spread of COVID-19. López-Guerrero (2016)

classified the city's water districts according to the quantity and type of problems faced by households (Fig. 3-A). The main water access problems identified by this study were lack of access, leaking, intermittent access, and alternate supply.
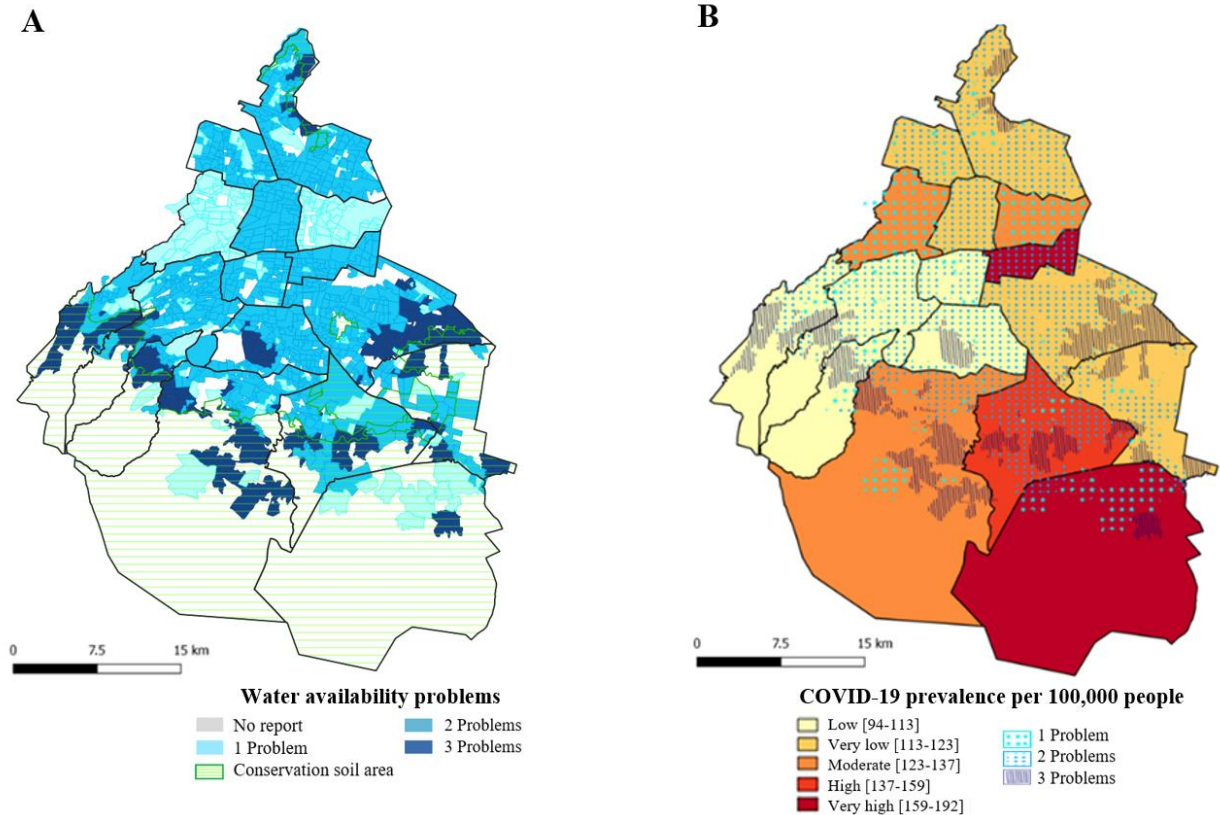


**Figure 3.** Water availability and the distribution of confirmed cases of COVID-19 in Mexico City. A) Number of problems affecting household's availability of water by municipalities (modified from López-Guerrero, 2016), B) Water availability and COVID-19 prevalence in municipality.

Although López-Guerrero (2016) study does not provide specific information on water availability for 14% (256 water districts) of the 1,812 Mexico City's water districts, his results revealed that of the remaining 1,556 districts: 17% (299 districts) presented one water access; 58% (1,053 water districts) presented two water access problems (both types of water districts located in the municipalities of the city center) while 11% of them (204 water districts) had three major water access problems. More than half of the water districts (52%) are placed in o the municipalities in the peripheries of the city, those with more problems of water availability (i.e. three or two problems affecting households´ availability of water). Moreover, most of these water districts are located within the lands of Mexico City's Protected Area (Fig. 3-A). This Protected

Area covers about two thirds of the city and is allocated to conservation purposes and provides important environmental services to the metropolitan area, among them food production and contribution to water capture and quality, hence, supposedly no constructions or housing is allowed (Aguilar y Escamilla, 2013). Yet, many of the census blocks that comprise these water districts are irregular settlements that, overall, cover 26% of the Soil Conservation Area, paradoxically with poor access to water

We then looked for potential patterns of relation between the availability of water and COVID-19´s distribution in the city (Fig. 3-B) we found that while some districts with the worst water availability are located in municipalities with very high and high COVID-19 prevalence, 1,224 districts (79%) with water distribution problems where located in municipalities with very low COVID-19 prevalence. For instance, Iztapalapa had a low COVID-19 prevalence (but high numbers of COVID), yet the majority of its water districts (88%) have water distribution problems. However, Xochimilco (also a semi-rural municipality as Milpa Alta[4]) had a high COVID-19 prevalence and most of the households located in its water districts (88%) face serious problems of water availability.

Population density varies considerably between municipalities of Mexico City. The relation between population density houses´ overcrowding and COVID-19 was another source of inquiry. (Fig. 4).

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[44] With more tan 15% of the Economically Active Population working on agriculture.
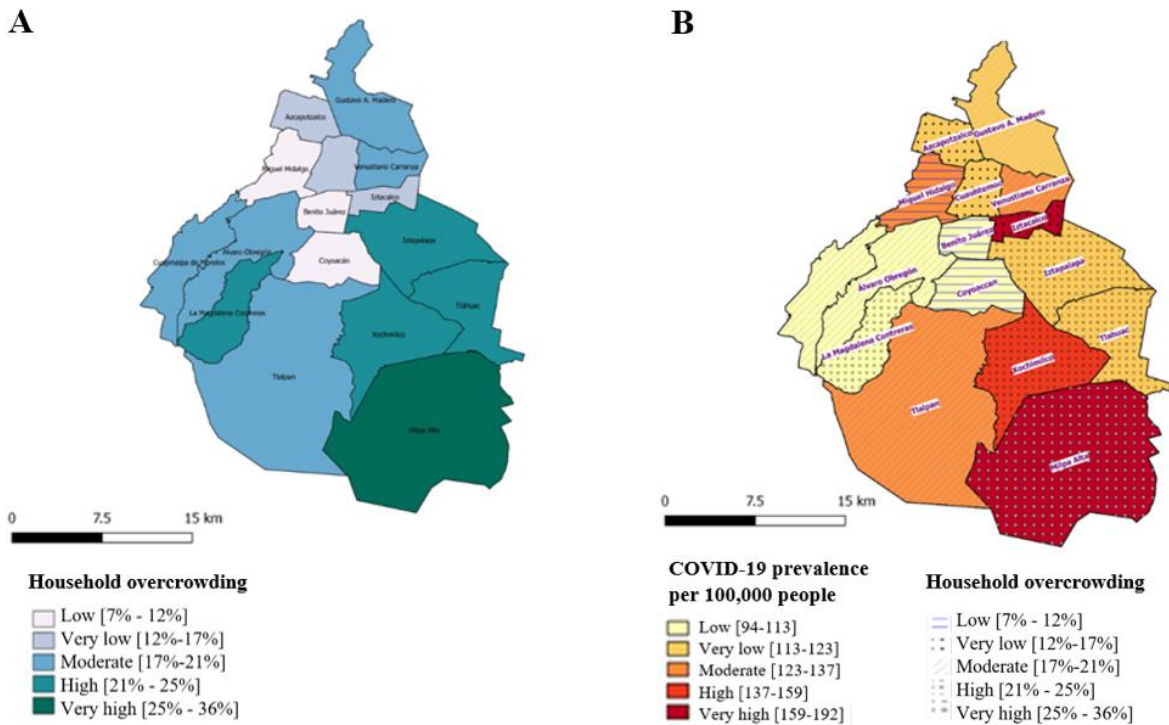
**Figure 4.** Houses overcrowding and the distribution of confirmed cases of COVID-19 in Mexico City. A) houses overcrowding by municipalities, B) Houses overcrowding and COVID-19 prevalence by municipality.

Paradoxically Milpa Alta, a semi-rural municipalities with the lowest population density has a very high level of houses overcrowding (and poverty) and COVID-19, this is also the case for Xochimilco, with high houses overcrowding and high COVID prevalence. For the rest of the municipalities this relation is not clear, which express the multifactorial nature of the process of COVID-19 expansion. In the majority of the municipalities, houses´ overcrowding was high (four out of 16 municipalities) or moderate (five municipalities); low overcrowding is found in the more affluent municipalities of the center of the City. (Fig 4-A). Apart of Milpa Alta and Xochimilco we did not find a clear relation pattern between house overcrowding and COVID-19 prevalence (Fig. 4-B). For instance, Iztacalco had very high COVID-19 prevalence but low house overcrowding (Fig. 4-B) whereas Magdalena Contreras had very low COVID-19 prevalence but high house overcrowding. Moreover, Miguel Hidalgo had very low house overcrowding but had a moderate COVID-19 prevalence; in fact, it was the fourth town hall in terms of COVID-19 prevalence in the city.

## Discussion and conclusions

We presented a descriptive t account of the distribution of the COVID-19 in Mexico City between January 7 and of May 13, 2020 considering some environmental conditions and social processes that could shape the epidemiological vulnerability of Mexico City. We looked for patterns of distribution of COVID-19 and their potential relation with access to water and houses´ overcrowding. Our results show that COVID-19 distribution around Mexico City was dissimilar with no general patterns of relation between the numbers of those affected by the pandemic and a problems of water access and houses´ overcrowding.

The initial assumption that those municipalities with more water access problems (more people being unable to wash their hands and prevent the infection and dissemination of the disease) would be those with the highest numbers of cases of COVID-19, was not proven. However we found that municipalities with households facing more problems of water access are located in the irregular settings on the lands of the City´s Protected Area: Milpa Alta (with 100% of its lands in the PA), Xochimilco and Tlalpan[5] (85% of its land in the PA), where the city's government, aiming to tackle further urbanization, does not provide basic water and sanitation services, because of their irregular nature (SMA-PAOT, 2012). However, we did not find any clear pattern between water availability and the distribution of confirmed cases of COVID-19. Although it is to be said that during the pandemic period Mexico City's Water Authority (Sistema de Aguas de la Ciudad de México, SACMEX) has made a great effort to guarantee the availability of water even where the availability of water is usually more troublesome, including the irregular settlements in the PA, which comprises 30% of Mexico City´s urban area.

House´s overcrowding and prevalence of COVIT-19 seem to be related in Milpa Alta and Xochimilco, and to a lesser extent in Tlalpan, nevertheless other cases, such as Iztacalco with a very high COVID-19 prevalence but low houses´ overcrowding, and Miguel Hidalgo with moderate COVID-19 prevalence, but very low houses´ overcrowding. Here other factors such as

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[5] With high leve lof water access problems, moderate houses´ overcrowding and also a moderate level of COVID-19 prevalence.

the income level and the economic possibility to follow the quarantine mandated by the authorities are up to now, strong explaining factors.

Notwithstanding it, there are a few useful insights arising from the outcomes of this study. First, by looking at the total number of COVID-19 confirmed cases in Mexico City it might seem that town halls from the north of the city were doing worst. However, many of these municipalities, such as Iztapalapa and Gustavo A. Madero, are actually the most populated ones (with over one million people). Thus, it seems reasonable that these two municipalities had the highest number of COIVID-19 cases. Consequently, we looked at the COVID-19 prevalence, so that the number of confirmed cases was relative to the size of population. Opposite of what we found with the raw numbers of total cases by town halls, the COVID-19 prevalence analysis shows that Milpa Alta and Iztacalco were in fact the municipalities s with very high prevalence. In particular, Milpa Alta had a COVID-19 prevalence that was almost double –specifically, 1.6 times higher– than the COVID-19 prevalence of Iztapalapa. Also, when we analyzed access to health services in Mexico City, we found that the three municipalities s with the highest COVID-19 prevalence were those with the least hospitals (five out of 87 hospitals) and have also have significant water supply problems. These findings point out that attention must be paid to these three municipalities: Milpa Alta, Iztacalco and Xochimilco.

However, further exploration should be provided based on new data that comes out of the pandemic in Mexico City, and the analysis should be expanded to the larger Mexico City Metropolitan Area in order to understand the spread of the pandemic in the megacity. Finally, even though we did not find clear patterns between COVID-19 prevalence and environmental conditions and social processes, there are great inequalities within the Mexico City in terms of access to health services, house overcrowding and water availability that cannot be overlooked to ensure the fulfillment of the SDGs in this megacity and development of resilience capacities to face unexpected future shocks, that tend to affect unproportionally those already vulnerable.

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