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Profile of air pollution by PM_{10} in the province of Kadiogo, Burkina Faso

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ABSTRACT

PM_{10} are one of the major air pollutants. There is a paucity of air quality data in Burkina Faso. The present study aimed at assessing the profile of air pollution by PM_{10} in the province of Kadiogo. Districts of Ouagadougou and rural communes of the province of Kadiogo were the subject to four campaigns of PM_{10} level measurement in the air, between November 15, 2016, and February 15, 2017, using DUSTMATE series DM 11932 (Turnkey, Cheshire, UK). Measurements of PM_{10} concentrations revealed high levels in districts 2, 5, and 6 while intermediate levels were observed in districts 4, and 11. For the rural communes, Koubri presented the lowest level of PM_{10} (86.80 µg/m^3). The commune of Komsilga presented the highest maximum level (6469,43 µg/m^3). The largest standard deviation (2532.65) was found in the rural commune of Koubri. Our results revealed that PM_{10} levels were higher than the WHO defined standards both in Ouagadougou and rural communes of Pabre, Koubri and Komsilga. Further investigations are therefore required to determine in addition to PM_{10}, $PM_{2.5}$, the levels of PM_1, $PM_{0.1}$ and TSP and their mechanisms of toxic action as well as their impacts on the health of the populations in Burkina Faso.

Keywords: PM_{10}, air pollution, Ouagadougou, rural area, Burkina Faso.

INTRODUCTION

The London smog with its 12,000 deaths in 1952 marks a milestone in air pollution history (Dooley, 2002). More than 91% of the world's population breathes polluted air (WHO, 2016). Air pollution is defined as the introduction into the atmosphere by humans, directly or indirectly,

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of substances or energy having a harmful action that could disorder the human organism" (Tiwary and Nirala, 2018; UNICEF, 2019). The pollutants are therefore of a different nature. They are gaseous pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NOx), Volatile Organic Compounds (VOC), carbon monoxide (CO), carbon dioxide (CO_2), ozone (O_3), and various sized particulate pollutants (WHO, 2021a). Particulate matter is a complex mixture of small solid particles and liquid droplets. They have a varied chemical composition (Eghomwanre et al., 2022). Suspended particles are grouped into several classes: Total Suspended Particulate (TSP) (Jangirh et al., 2022), PM_{10}, les $PM_{2.5}$, and $PM_{0.1}$ (Benabed and Boulbair, 2022). The classes of particles are based on their aerodynamic diameter.

Well-conducted and well-organized studies on air quality monitoring in industrialized countries contrast with the lack of political will and the absence of air quality monitoring in sub-Saharan African countries (Jackson, 2009a; Amegah and Agyei-Mensah, 2017; Abera et al., 2021; McElroy et al., 2022). This same region was declared the most polluted region in the world in 2006 at the Nairobi conference (Schwela, 2012). It is a region where poverty and rapid urbanization are combined, not insignificant factors in the deterioration of air quality (Arku et al., 2008; Abera et al., 2021). Ouagadougou, the capital of Burkina Faso, is not excluded from this situation. It is located in the heart of the Sahel and, in addition to the factors mentioned above, is experiencing a growing fleet with very old and poorly maintained vehicles and an increase in anthropogenic activities (Zoma, 2022). Thus, it is a prime target of environmental pollution.

In the current study we describe the profile of air pollution by PM_{10} in various districts of Ouagadougou city as well as the rural communes of Koubri, Pabre and Komsilga between 15 November 2016 and 15 February 2017.

MATERIALS AND METHODS

Study framework

Ouagadougou is the capital and largest city of Burkina Faso with a dynamic population of 2.5 million inhabitants located in 12 districts (INSD, 2020). Ouagadougou is characterized by horizontal spatial sprawl of the city, a growing fleet of cars dominated by two-wheelers, and inadequacies in the transport system which are all factors associated with air pollution (Zoma, 2022).

The peri-urban commune of Koubri is part of the province of Kadiogo in Burkina Faso. It is located 15 km south of Ouagadougou and covers an area of about 555 km². The population is made up of 30,235 women and 30,567 men, whose main activities are agriculture, livestock and fishing (Dahani and Compaore, 2021).

The commune of Pabre is one of six rural communes in the province of Kadiogo located in the central region. It is located 22 km from Ouagadougou on the Ouagadougou-Kongoussi axis, covering an area of 411.3 km^2 with 22 villages and a population of 20,102 men and 20,611 women.

The rural commune of Komsilga is a commune in the province of Kadiogo located approximately 120 km south of the city of Ouagadougou. It is made up of 36 villages and 101,193 inhabitants counted in 2019. The rural commune of Komsilga is facing the pressure of urbanization with a progressive installation of anthropogenic activities such as "agro-businessmen" and some administrative services of Ouagadougou. All of these factors are a risk of pollution for the commune of Komsilga (INSD, 2020).

Measurement of PM_{10} level in the air

Districts of Ouagadougou and rural communes of the province of Kadiogo were the subject of a measurement of PM_{10} level in the air, between November 15, 2016 and February 15, 2017, a period marked by the Harmattan wind, a factor of high environmental pollution by PM (Marticorena et al., 2010; Nana et al., 2012). Average points were identified and used as measurement points (Figure 1 and Figure 2) in districts 2

and 5 (center), 3 and 6 (pericenter) and 4 and 11 (periphery) and the rural communes of Koubri, Pabré and Komsilga.

PM_{10} was collected at the different sampling points for 24 hours. Four measurement campaigns were carried out at the rate of one campaign per month. The instrument used for the measurements was a particle counter: DUSTMATE series DM 11932 (Turnkey, Cheshire, UK). The particle concentration measurement data were recorded on a computer using the software provided by the manufacturers of the device.

Statistical analysis

The raw data recorded on the computer made it possible to express the minimum, maximum, daily averages, and standard deviation per campaign for each measurement point. Thus, a table was designed with the characteristics of the PM_{10} level. The different districts and rural municipalities were classified according to the PM_{10} profile into three categories (high PM_{10} above 2200 µg/m^3, intermediate PM_{10} between 1700 and 2200 µg/m^3, low PM_{10} below 1700 µg/m^3). This allowed the mapping of PM_{10} pollution in the city of Ouagadougou. Finally, a comparison of the average PM_{10} levels was carried out. Statistical analyzes and graphs were performed with GraphPad Prism 5.0 software using ANOVA parametric test followed by a multiple comparison test with Dunnett's correction. The results were expressed as mean ± standard deviation. Differences were considered significant when $p < 0.05$ (*), $p < 0.01$ (**), $p < 0.001$ (***).

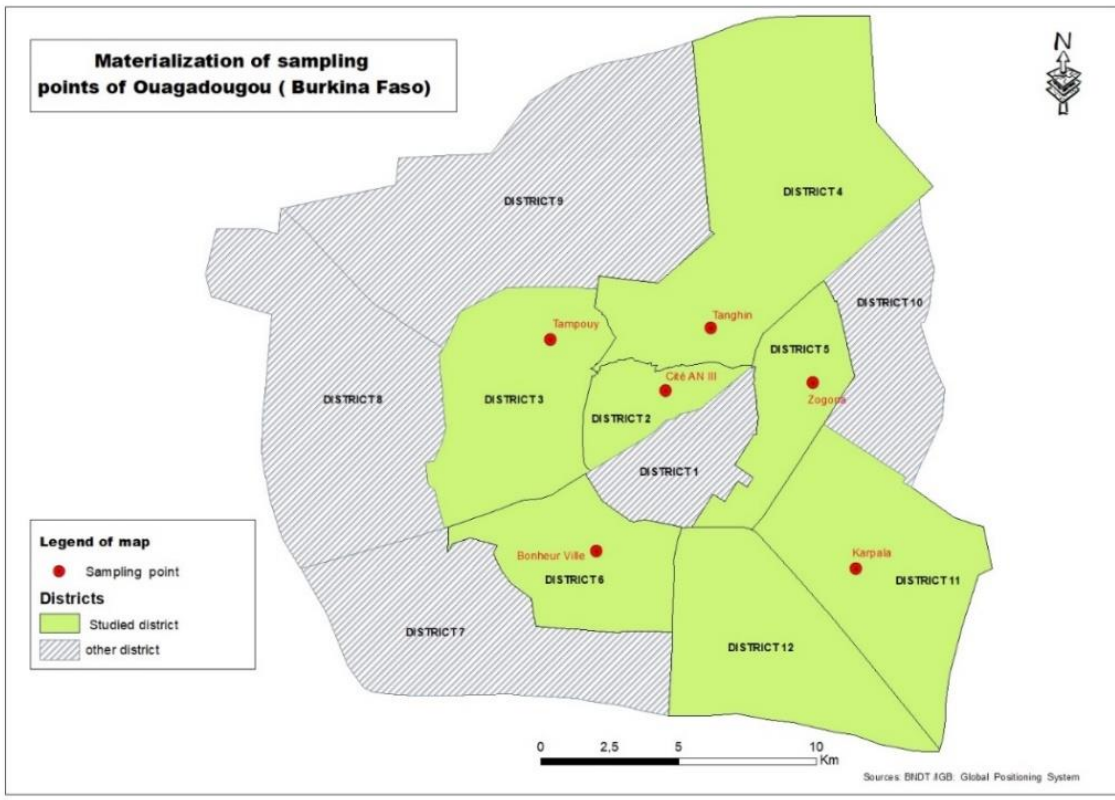

Figure 1: Data collection sites and measurement points in the districts of Ouagadougou.

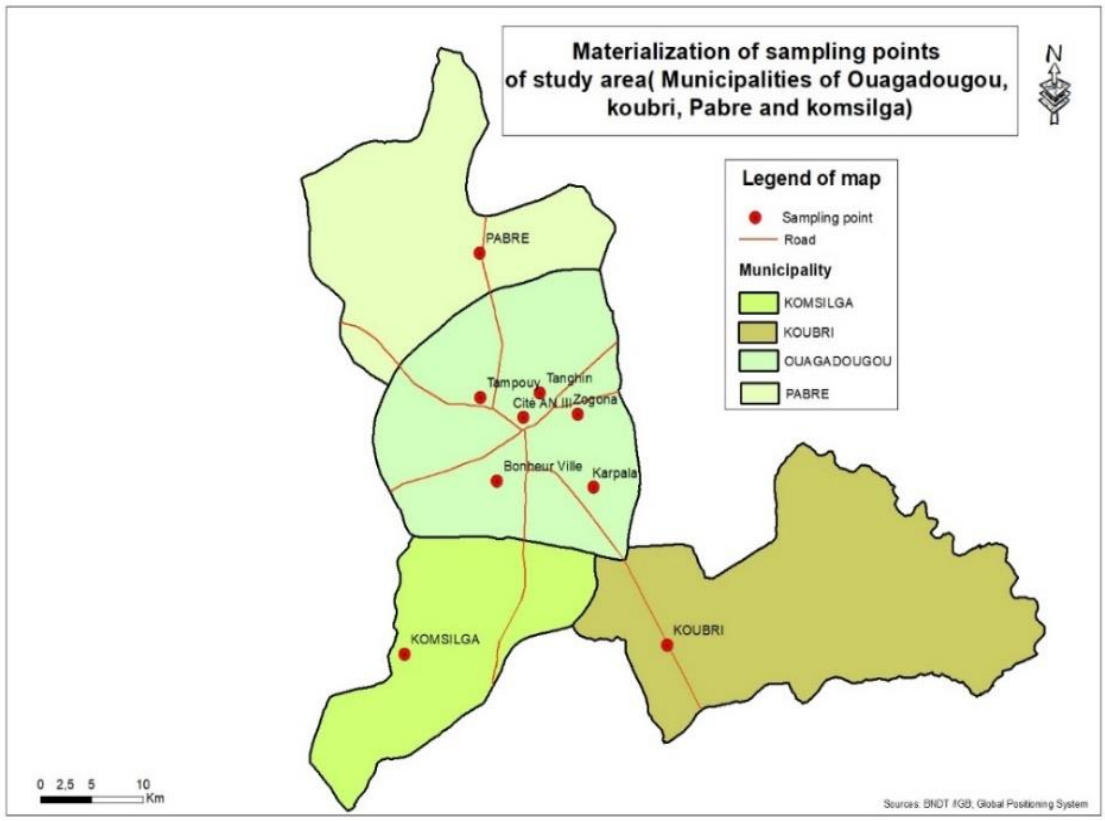

Figure 2: Data collection sites and measurement points in the rural communes of Komsilga, Koubri and Pabre.

RESULTS

The level of PM_{10} in the air varies according to the district of Ouagadougou

The presence and level of PM_{10}, is an indicator for assessing air quality. Measurements of PM_{10} concentrations in the present study revealed high levels in districts 2, 5, and 6 while intermediate levels were observed in districts 4, and 11. District 6 showed the highest PM_{10} level in our study with an average of 3111.21 µg/m^3 while the lowest level (1438.48 µg/m^3) was recorded in District 3 (Figure 3).

Variation of the mean level of PM_{10}

The mean level of PM_{10} differed from one measurement point to another. The lowest mean was found in district 3 with 1438.48 µg/m^3 and the highest in Komsilga commune with 3276.90 µg/m^3 (Figure 4).

The discrepancies observed in the different measurements throughout the four campaigns were significant. For the rural communes, Koubri presented the lowest level of PM_{10} with 86.80 µg/m^3. The commune of Komsilga presented the highest maximum level with 6469.43 µg/m^3. The largest standard deviation (2532.65) was found in the rural commune of Koubri (Table 1). In the city of Ouagadougou, district 4 had the lowest PM_{10} level with 189.62 µg/m^3 while the highest level was recorded in district 5 (6524.65 µg/m^3). The greatest variation between the different measurements was observed in district 5 with a standard deviation of 2521.70.

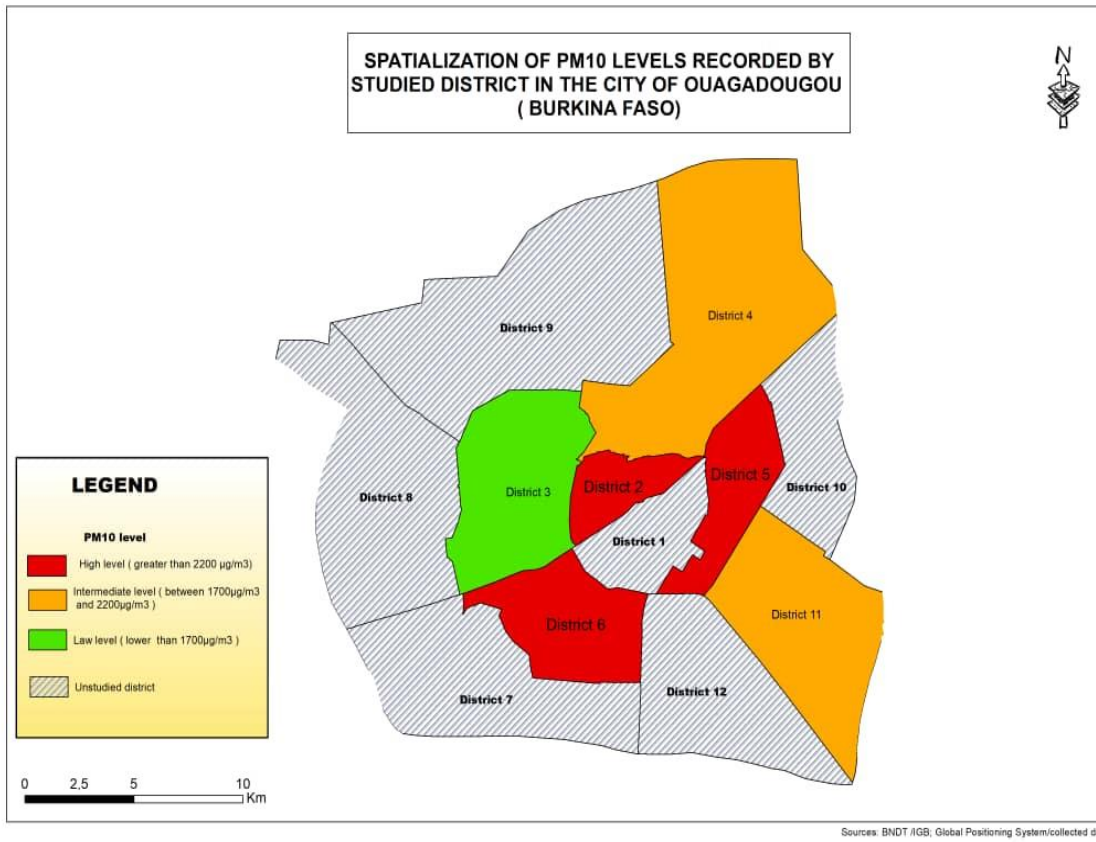

Figure 3: PM_{10} level in the districts of Ouagadougou.

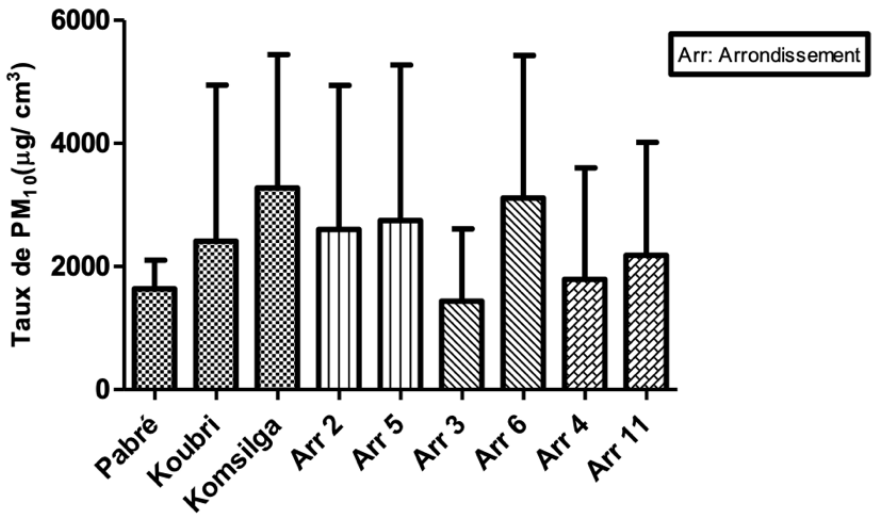

Figure 4: Mean level of PM_{10} in the districts of Ouagadougou and the communes of Komsilga, Koubri and Pabre.

Table 1: Variations of PM_{10} level in the districts of Ouagadougou and the rural communes.

PM_{10} level	Location	Minimum (µg/m³)	Maximum (µg/m³)	Standard deviation
High	Komsilga	1712,48	6469,43	2167,20
	District 6	1651,87	6524,65	2317,29
	District 5	332,58	5983,14	2521,70
	District 2	701,22	5646,02	2339,16
	Koubri	86,80	6005,82	2532,65
Intermediate	District 11	324,61	4707,12	1836,25
	District 4	189,62	4356,38	1813,77
Low	Pabré	1235,17	2286,01	465,19
	District 3	522,18	3144,38	1172,16

DISCUSSION

The level of PM_{10} collected over the entire study area exceed the WHO recommended guideline values of 45 µg/m³, but also the intermediate targets of 150 µg/m³, 100 µg/m³, 75 µg/m³ and 50 µg/m³ over a 24-hour period (WHO, 2021b; WHO, 2022). This observation had already been made in previous studies on air quality monitoring in Ouagadougou (Eliasson et al., 2008; Boman et al., 2009; Lindén et al., 2012; Nana et al., 2012).

The level of PM_{10} found in our study also exceed the standards established in Burkina Faso, although these are not specific to PM_{10}. The PM_{10} level recorded are not proportional to the population density. Indeed, in the commune of Ouagadougou, district 6 with 320 inhabitants/km² presented the highest PM_{10} rate with 3111.21 µg/m³. However, district 3 with the highest density of 480 inhabitants/km² presented the lowest PM_{10} level: 1438.48 µg/m³. Other factors should be considered to justify this situation. The geographical situation of the districts could explain the high levels found in some districts. Indeed, districts 2 and 5 located in the heart of the city have high levels of PM_{10}. This is the area where the most administrative and commercial activities take place.

This area includes equipment that generates and receives displacements. These various elements foster anthropic activity, which is a significant factor in air pollution. Districts 3 and 6 are located in the pericenter. District 6 has a high level of PM_{10} in contrast to district 3 which has an area of 32.116 km² while District 6 covers an area of 20.028 km² (MTMUSR, 2017). The neighborhoods in district 6 are much older than those in district 3. PM_{10} is a heterogeneous mixture of several elements including road wear, tire wear, clutch brake linings containing some asbestos fibers and exhaust (Piscitello et al., 2021). The district 6 and its roads, asphalt roads existing long before the district 3, the sources of PM_{10} considering the wear of the road and tires could explain the high levels of PM_{10} observed compared to the district 3. In addition, pollution sources such as: cooking methods (cooking on wood fires and traditional barbecues) would be worth considering more carefully (Jackson, 2009b; WHO, 2022).

As for districts 4 and 11, they extend to the outskirts of the city. The districts of the periphery are essentially characterized by their

living quarters. They have few developed and organized markets. These two districts have higher levels of PM_{10} than district 3. The peripheral districts of the commune of Ouagadougou are experiencing rapid urbanization, an important factor in the degradation of air quality (Arku et al., 2008).

The particularity of the district 4 requires considering the existence of the water point which would limit the dispersion of PM_{10} in the atmosphere. Indeed, the presence of the industrial site, an important source of PM_{10}, in this area would suggest the collection of a higher level of PM_{10} (Baby et al., 2010; Pekey et al., 2010). However, for the rural communes, the PM_{10} gradient seems to be a function of population density. Pabré with the lowest density 93 inhabitants/km^2 had a PM_{10} level of 1636.97 µg/m^{3}and Komsilga with the highest density 269 inhabitants/km^2 recorded a PM_{10} level of 3276.90 µg/m^3. High density would suggest high anthropogenic activity.

Comparing the urban and rural areas, Komsilga with the highest PM_{10} had a little asphalt road length. Indeed, the length of asphalt roads differed. It was 203.4 km for Ouagadougou, 5.3 km for Komsilga, 9.24 km for Koubri and 8.3 km for Pabré (MTMUSR, 2017). One-point PM_{10} level variances could be enormous. The installation of the Harmattan, period during which the high levels of particulate matter are observed could explain it (De Graaf et al., 2010). The PM_{10} levels recorded in our study are significantly higher than those noted in February 2007 during a study on air quality in Ouagadougou. A maximum of 1000 µg/m^3 in 2007 for the high traffic sites compared to 5646.02 µg/m^3 and 5983.14 µg/m^3 respectively for districts 2 and 5 in our research (Nana et al., 2012). This difference could be explained by the accentuation of the factors favoring pollution. Indeed, in the central regions, urban sites, air pollution is mainly due to traffic. In ten years, the number of cars and two-wheeled vehicles has increased considerably (Mama et al., 2013).

A study conducted in Bamako (capital of Mali, a country bordering Burkina Faso), found an average of 210 ± 93 µg/m^3 during the period from November 2012 to May 2013 (Garrison et al., 2014). These results are much lower than those found in the present study. Assumptions could be made to explain this difference. The results found in Bamako are four years prior to the results of our study.

During this period, the sources of pollution were able to develop and expand (population growth, anthropogenic activities, development of road transport, and expansion of the city). A second assumption could be that Ouagadougou is much closer to the desert region of Africa than Bamako. It is therefore more vulnerable to particles transported from this region.

Conclusion

Our results revealed that PM_{10} levels were higher than the WHO defined standards both in the urban center of Ouagadougou and in the rural communes of Pabré, Koubri and Komsilga. The increase in anthropogenic activities with various sources of pollution suggests a progressive increase in PM_{10} levels recorded in our study area. Further investigations are therefore necessary to determine in addition to PM_{10}, $PM_{2.5}$, the levels of PM_1, $PM_{0.1}$ and TSP and their mechanisms of toxic action as well as their impacts on the health of the populations in Burkina Faso.

COMPETING INTERESTS

The authors declare that they have no competing interests

AUTHORS' CONTRIBUTIONS

JNG, JS and JS conceived and designed the study. JNG, AKO and IB, SK were involved in data generation, collection, and assembly. JNG, AKO, IB, JS and JS were

involved in data extraction, analysis, and interpretation. JNG, AKO, IB, SK, JS and JS were involved with drafting or revising the manuscript. JS and JS provided administrative, technical, and material support. Supervision of the study was made by JS and JS. All authors critically revised and approved the final version of this publication.

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