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Impact of COVID-19 Response Measures on Physicochemical Parameters of Surface Waters in Yaoundé City

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Abstract

The widespread use of disinfectants and various medications in response to the COVID-19 pandemic has raised concerns about their potential impact on the characteristics of natural waters. To assess the effect of the COVID-19 response on surface waters in Yaoundé, various physicochemical parameters of three rivers (Mfoundi, Tongolo, and Mingoa) were examined over 8 months. The selection of these rivers was based on their proximity to hospitals involved in COVID-19 patient management. Physico-chemical parameters were measured following standard protocols, and their spatiotemporal variations and the influence of various factors, were examined. The results revealed that, during the study period, the values for temperature (23˚C to 30˚C), dissolved oxygen (14% to 90%), pH (6.2 to 9.5), electrical conductivity (100 to 662 µS/cm), oxidability (0.19 to 42.19 mg/l), and suspended solids (1 to 725 mg/l) exhibited variations, except for total dissolved solids (30 to 470 mg/l), whose levels remained within the recommended limit (<1000 mg/l). The oxidability and pH were negatively impacted by the COVID-19 response measure. Compared to previous studies, the water quality for these parameters in certain rivers deteriorated. The incidence of COVID-19 cases was positively correlated ($r_s = 0.812$, $P = 0.014$) with oxidability levels in the Tongolo river. The COVID-19 response measures had a limited negative effect on the surface waters of Yaoundé during the study period. This could be attributed to the disproportionate application of hygiene measures among the city's populations. Additionally, the lack of flow observed in certain rivers requires particular attention from authorities and the populations to safeguard the city's ecosystems.

Keywords

COVID-19, Environmental Health, Watercourses, Physicochemical Parameters, Cameroon

1. Introduction

In December 2019, China reported the emergence of a novel respiratory disease, Coronavirus Disease 19 (COVID-19), caused by the SARS-CoV-2. This highly infectious pathogen primarily targets the human respiratory tract, inducing symptoms similar to those of common influenza (Zhou et al., 2020). The rapid global spread of SARS-Cov2 led to over 170,000 reported cases and approximately 6,500 deaths. The World Health Organization (WHO) declared a Public Health Emergency of International Concern on January 30, 2020, and elevated it to a pandemic on March 11, 2020 (WHO, 2020).

Cameroon confirmed its first case on March 6, 2020, and the disease's progression in country can be divided into three distinct periods. The initial exponential increase in cases from March 25 to May 26, 2020, was followed by a significant decline from June 25, 2020, to January 25, 2021. However, a resurgence was observed in February 2021 with over 3,000 new cases recorded within a week (from March 3 to 7, 2021). By October 13, 2021, 100,289 cases were reported (Anonymous, 2021). Yaoundé, due to its high population density and mobility (Nsegbe et al., 2023), has been a significant urban center of COVID-19 spread in Cameroon. The peak of confirmed cases was recorded in May 2020 (Placard, 2021).

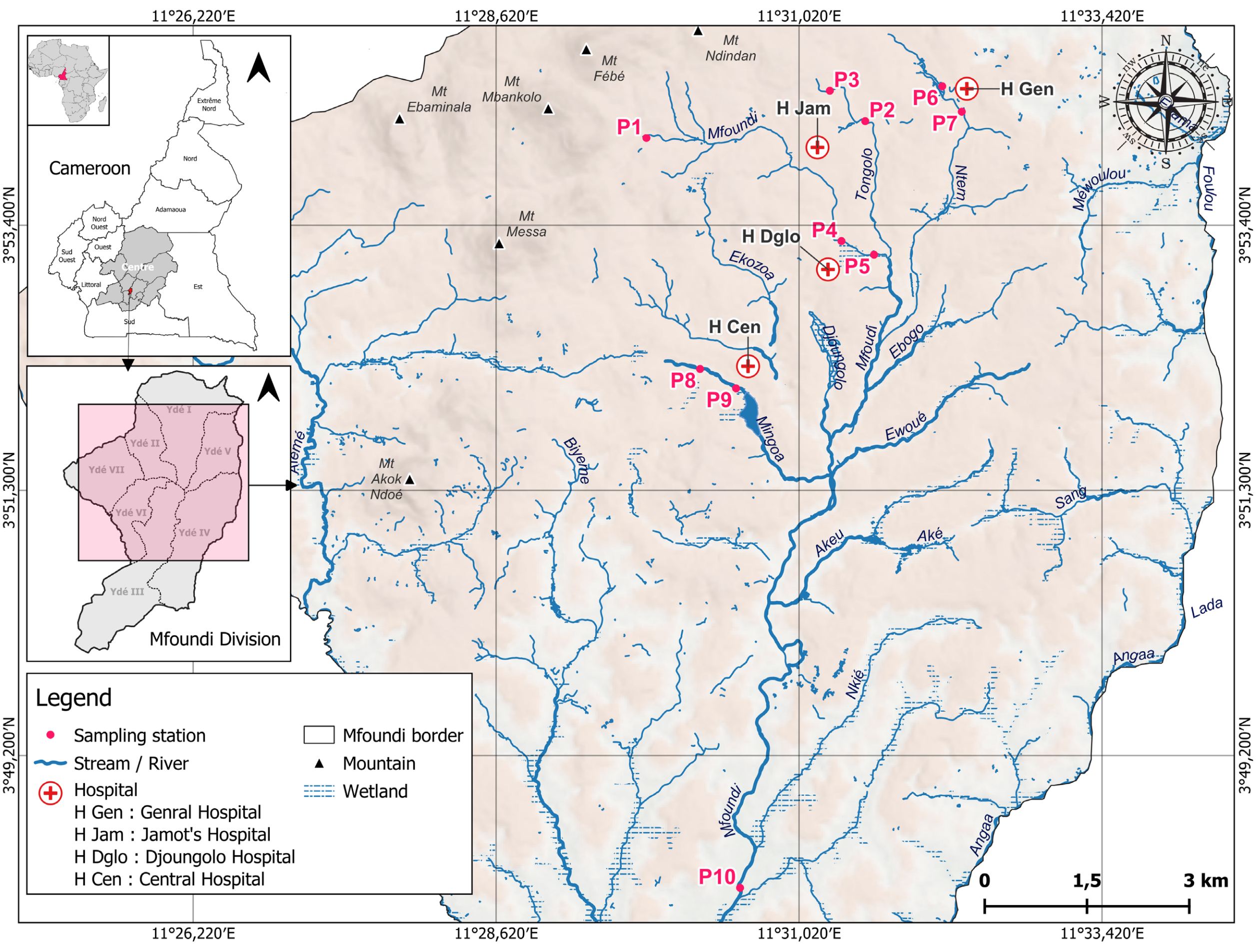
The measures deployed to fight against the pandemic, including individual and collective protection, have a significant impact on water quality. These measures include "barrier" gestures, enhanced hygiene practices leading to the widespread use of disinfectants and antiseptics, the use of protective tools like face masks, and the administration of various medications (Poschet et al., 2020). These materials could potentially enter access natural waters and exacerbate existing pollution (Mimouni, 2020; Moussima et al., 2020), particularly given the inadequacies in urban waste management system (Ajeagah et al., 2018). Contamination of water resources with chemical components poses severe environmental and health concerns. For instance, water with a pH outside the normal range can lead to nutritional imbalances and hinder the growth and development of aquatic life (Kouame, 2021). The integrity of water thus depends on various physicochemical parameters and their concentrations. To evaluate the effect of the COVID-19 response on the physico-chemical parameters of surface waters in Yaoundé, we monitored various parameters over 8 months period.

2. Material and Methods

2.1. Description of Study Area and Sampling Stations

Yaoundé, the capital of Cameroon, covers an area of about 400 km^2. It is located approximately 200 km from the Atlantic coast, between 3˚5' North latitude and 11˚31' East longitude (Yogo, 2005). The climate is equatorial, characterized by two dry seasons and two rainy seasons, with an average temperature of 23.5˚C and an annual rainfall of 2000 mm (Suchel, 1972). The soil is lateritic, acidic (pH < 5) and the vegetation is of the intertropical type with a predominance of southern rainforest (Wéthé, 2001). The hydrographic network includes the Mfoundi River and its tributaries, which drain the main watercourse, and its tributaries, which drain runoff and surface waters. The Mfoundi flows into the Méfou, which in turn flows into the Nyong River, the main source of drinking water supply in Cameroon. Permanent streams, rivers, lakes, and ponds complete the hydrographic network.

Three health facilities belonging to the same health district and involved in the management of COVID-19 were selected: The Central Hospital, the Jamot Hospital, and the Djoungolo Hospital. Three rivers, the Mfoundi and two of its tributaries, the Tongolo and Mingoa (Figure 1), were selected based on their hydrographic network, proximity to the hospitals, accessibility, and uses of water. Eight points were selected and described in Table 1. With the aim of understanding the effect of the Covid-19 health crisis on water, for each health facility, two sampling points, one upstream and the other downstream, were chosen along the watercourse (tableau 1). Thus, the upstream and downstream points of the Djoungolo, Jamot, and Central hospitals were respectively coded P4/P5, P2/P3, and P8/P9. Two additional points (P1, located at the highest level, and P10 at the lowest level) serving as controls (not directly influenced by a health facility) were also chosen on the Mfoundi, the main watercourse of the city.



SOURCES : OpenStreetMap (OSM) 2023. SCR : EPSG4326 - WGS 84. Logiciel : QGIS 3.28.0. Edition : Stéphane A. NOAH. Fait le : 29-05-2023.

Figure 1. Map of the hydrographic network of the Yaoundé city indicating the watercourses and the sampling sites selected.

Table 1. Description of sampling points.

waters course	Sampling points	Geographical coordinats	Location	Pollution's Sources	Using
Mfoundi	P_1	N 03˚54'05.5" E 011˚29'48.7" 3m GPS	Club Bastos: most heightest point on the river	Household waste	None
Tongolo	P_2	N 03˚54'13.6" E 011˚31'32.7" 3m GPS	In front of the Bafia, Bafoussam travel agency); point upstream from Jamot's Hospital	Trash bins, Latrines, Household waste	Vehicle wash
	P_3	N 03˚53'21.7" E 011˚31'16.8" 3m GPS	Nkol-eton Market: point downstream from Jamot's Hospital	Latrines, Household waste water	None
Mfoundi	P_4	N 03˚53'16.5" E 011˚31'21.4" 3m GPS	Bata-Nlonkak: behind the Bunker Hotel, upstream from the Djoungolo Hospital	Household waste water, garbage bins	Washing clothes
	P_5	N 03˚53'10.0" E 011˚31'36.9" 3m GPS	New ETOA MEKI road, behind the stadium? and the laundry; point downstream from Djoungolo hospital	Household waste water, garbage bins	Cloth Washing, Plant watering.
Mingoa	P_8	N 03˚52'15.7" E 011˚30'14.2" 3m GPS	Public works road (YEYAP camp); point upstream from Central Hospital	Household wastewater from SIC Messa coumpound, after the Abiergue/Mingoa confluence	Cloth Washing, bath
	P_9	N 03˚52'06.5" E 011˚30'31.3" 3m GPS	Before the municipal lake; point downstream of Central Hospital	Discharges from the sic Messa camp, from the laundry wastewater treatment	Washing clothes, bath.
Mfoundi	P_{10}	N 03˚48'09.1" E 011˚30'33.2" 3m GPS	Second Mvan interchange: Lowest point on the watercourse	Building and construction works, brewery effluents, in general all city drains.	Plant watering.

2.2. Physicochemical Analysis of Water

2.2.1. Water Sampling

Water samples were collected monthly from July 2020 to June 2021 between 6:00 am and 11:00 am ± 1 hour. A 500 ml sterile polyethylene bottle was immersed 30 cm deep and filled by opening it in the opposite direction of the flow. The bottle was recapped before removal, and all collected samples were maintained at 4˚C in a cooler and transported to the laboratory for analysis within two hours (Rodier et al., 2005).

2.2.2. Measurements

The temperature was measured in situ using a pre-calibrated thermometer, in accordance with the manufacturer's recommendations. The value of the temperature corresponding to the height of mercury migration was directly read and expressed in degrees Celsius (˚C) (Affholder & Valiron, 2001). Dissolved oxygen, pH, electrical conductivity, and total dissolved solids were measured in situ using a HANNA multi-parameter device, model HI-9829. Suspended solids (SS) and oxidability were measured in the laboratory. The first by spectrophotometry using the HACH DR/2800 spectrophotometer. The second by volumetry by determining the amount of potassium permanganate consumed for the oxidation of organic matter present in the sample (Norme ISO 5813: 1983) (Hasumoto et al., 2006).

2.3. Determining the Influence of Various Factors

To determine the influence of certain factors (space, incidence of Covid-19 cases) on the measurements obtained in this study, the Mann Whitney test was performed to compare for each parameter the difference in value between the upstream and downstream points of each selected hospital on one hand, and between P1 and P10 of the Mfoundi course on the other hand. The Spearman correlation coefficient "Rs" was determined with the aim of evaluating the influence of the incidence of Covid-19 cases on the parameters. These two non-parametric tests were applied because most of the measurements did not follow a normal distribution. It is important to specify that the incidence of Covid-19 cases was obtained through the weekly and monthly reports from the Ministry of Public Health. All statistical tests were performed using SPSS version 20 software.

3. Results

3.1. Physicochemical Characteristics of the Studied Watercourses during the Study

The measurements of the physicochemical parameters obtained in this study are presented in Table 2. Except for TDS (30 to 470 mg/l) whose water content were within the recommended limit (<1000 mg/l) during the study, the values for

Table 2. Physicochemicals parameters values.

		Mfoundi				Tongolo		Mingoa	
		P1	P4	P5	P10	P2	P3	P8	P9
Temperature (˚C)	Average	24.15	24.22	24.43	25.82	25.07	24.1	23.97	24.15
	Min-Max	23 - 25.3	23.5 - 26.5	23.5 - 27.5	23 - 30	24 - 27	23.6 - 24.5	23.3 - 24.5	23 - 25.5
pH	Average	7.3	7.17	7.21	7.75	7.27	7.41	7.50	7.39
	Min-Max	6.5 - 7.8	6.3 - 8.08	6.2 - 8.11	6.9 - 9.5	6.6 - 7.91	6.57 - 7.61	6.9 - 8.25	6.7 - 8.19
Dissolved O_2 (%)	Average	62.12	58.02	69.69	52.89	49.35	72.45	63.45	63.62
	Min-Max	35 - 81	20.87 - 81.25	49.09 - 80	33 - 63.31	30 - 75	61 - 81.92	43 - 88	56 - 71
Conductivity (µS/cm)	Average	187.8	203.8	193.1	325	212.52	193.17	381.12	431.25
	Min-Max	130 - 292	110 - 259	100 - 365	200 - 428	110 - 266	120 - 272	100 - 662	239 - 553
TDS (mg/l)	Average	125.07	115.06	125.52	183.47	122.88	119.4	224.17	200.26
	Min-Max	81 - 250	50 - 220	86 - 240	62 - 390	30 - 210	80 - 220	81 - 410	71 - 276
MES (mg/l)	Average	78.5	98.62	80.62	11.5	84	92.87	182.75	79.87
	Min-Max	8 - 522	3 - 700	2 - 554	2 - 42	3 - 559	5 - 640	1 - 725	4 - 529
Oxidability (mg/l O_2)	Average	10.26	6.62	3.96	7.11	4.20	7.30	7.72	8.10
	Min-Max	2.96 - 42.19	2.3 - 19.75	1.18 - 11.06	0.98 - 29.98	0.19 - 9.48	2.17 - 13.23	1.72 - 6.86	2.3 - 26.98

Max: maximum value; Min: minimum value.

temperature (23˚C to 30˚C), dissolved oxygen (14 to 90%), pH (6.2 to 9.5), electrical conductivity (100 to 662 µS/cm), oxidability (0.19 to 42.19 mg/l), and suspended solids (1 to 725 mg/l) varied. For all these parameters, no statistically significant difference ($P > 0.05$) was observed between the upstream and downstream points of each hospital, except between points (P2 and P3) of Jamot Hospital for temperature and dissolved oxygen. Between these points, the highest average temperature (25.07˚C) was recorded at P2. Conversely, the highest average dissolved oxygen rate was observed at P3. In the Mfoundi River, significant differences were observed between the highest (P1) and the lowest (P10) point for temperature ($P < 0.05$), electrical conductivity (100 to 662 µS/cm), and suspended solids. For the first two parameters, the average values were higher (25.82˚C and 325 µS/cm) at P10 compared to P1. For the last, it was the opposite (Table 3).

Table 3. Comparison of parameter values between upstream and downstream points of selected hospitals using Mann-Whitney test.

Parameters	Values of Mann-Whitney Test	Hospitals						Highest Upstream Point of Mfoundi	Lowest Downstream Point of Mfoundi
		Jamot Hospital		Djoungolo Hospital		Central Hospital			
		P2	P3	P4	P5	P8	P9	P1	P10
Temperature (˚C)	Average	25.07	24.1	24.22	24.43	23.97	24.15	24.15	25.82
	Sign assympt. bil	**0.030***		0.822		0.620		**0.05***	
MES (mg/l)	Average	84	92.87	98.62	80.62	182.75	79.87	78.5	11.5
	Sign assympt. bil	0.269		0.343		1.00		**0.035***	
Dissolved oxygen (%)	Average	49.35	72.45	58.02	69.69	63.45	63.62	62.12	52.89
	Sign assympt. bil	**0.004***		0.247		0.599		0.058	
pH	Average	7.27	7.41	7.17	7.21	7.50	7.39	7.3	7.75
	Sign assympt. bil	0.752		0.832		0.560		0.269	
Oxydability (mg/l d'O_2)	Average	4.20	7.30	6.62	3.96	7.72	8.10	10.26	7.11
	Sign assympt. bil	0.314		0.102		0.874		0.206	
Electrical Conductivity (µS/cm)	Average	212.52	193.17	203.8	193.1	381.12	431.12	187.8	325
	Sign assympt. bil	0.399		0.345		0.753		**0.003***	
TDS	Moyenne	122.88	119.4	115.06	125.52	224.17	200.26	125.07	183.47
	Sign assympt. bil	0.248		0.713		0.793		0.59	

Sign assympt. bil: Significance assymptote (bilateral) *The mean difference is significant at the 0.05 level, ddl = 8.

3.2. Effect of the Response on pH and Oxidability

Comparison of These Parameters with Those of Some Previous Studies

Table 4 presents some results of the characteristics of pH and oxidability of the studied waters before and during the study. Regarding pH, it reveals changes in the upstream part of the Mfoundi (Mf 1), Tongolo, and Mingoa rivers. Indeed, in the latter, the waters changed from slightly acidic from 2002 to 2020 to slightly basic between 2020 and 2021. Regarding oxidability, compared to previous studies, during this study an inversion of the distribution of its levels was noted between the upstream part (Mf 1) and the downstream part (Mf 3). In previous studies, these levels were higher in the downstream part than in the upstream part.

Table 4. Characteristics of studied watercourses before and during the study.

	pH					Oxidability (mg/l d'O_2)				
	Mfoundi			Tongolo	Mingoa	Mfoundi			Tongolo	Mingoa
	Mf 1	Mf 2	Mf 3			Mf 1	Mf 2	Mf 3		
Lami (2002)	6.45	7.02	7.31	6.71	6.99	17	271	46	14.7	101
Menye et al. (2012)	6.9	6.8	7	/	/	4.1	14.7	22.1	/	/
Tombedi et al.	7.3	7.19	7.7	7.23	7.44	10.26	5.29	7.11	5.75	7.91

Mf 1: upstream part of the Mfoundi; **Mf 2**: middle part of the Mfoundi (P4/P5); **Mf 3**: downstream part of the Mfoundi.

3.3. Incidence of COVID-19 Cases on Oxidability

The incidence of COVID-19 cases impacted the oxidability levels in the Tongolo River. Indeed, the correlation test between the two was positive ($r_s = 0.812$) and statistically significant ($P = 0.014$) at 95%, ddl = 8. Which means that in the water of Tongolo, during periods of increasing Covid-19 cases, the levels of oxidability also rose (**Figure 2**).

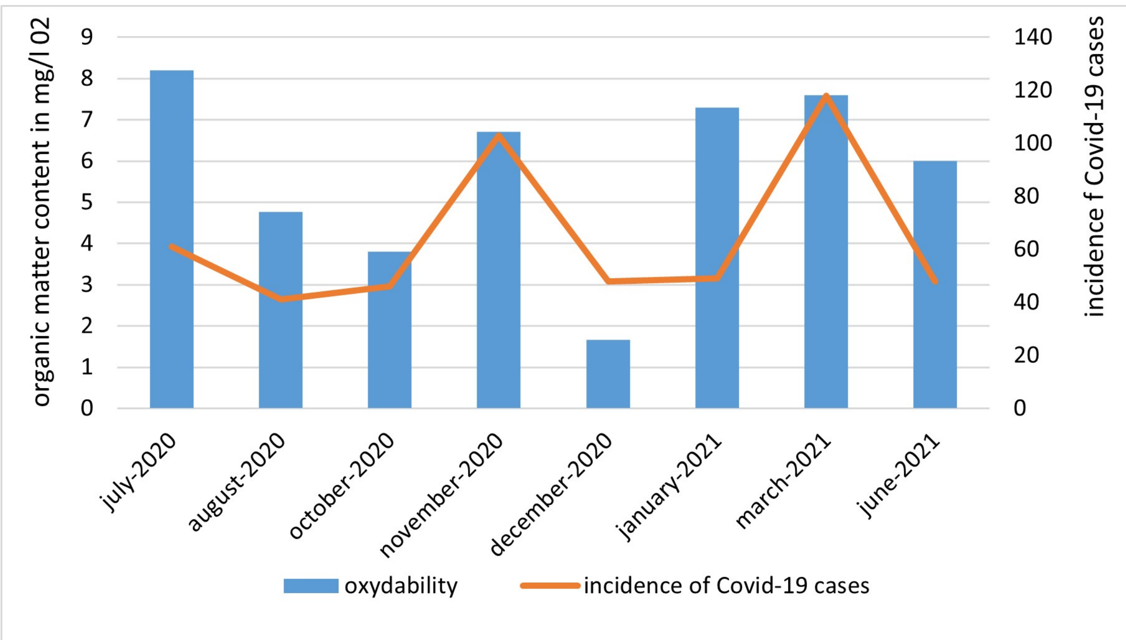


Figure 2. Evolution of organic matter content in Tongolo water in relation to the incidence of Covid-19 cases.

4. Discussion

To assess the impact of the widespread use of disinfectants and various medication in response to COVID-19 on the surface waters of Yaoundé, various physico-chemical parameters were measured in four rivers during an 8 months period.

Temperature plays a crucial role in the distribution and development of aquatic fauna and flora (Chauhan, 2013). According to WHO (2002), the required temperatures range for a healthy aquatic ecosystem is between 15˚C to 25˚C. In this study, they ranged from 23˚C to 30˚C; however, they were comparable to those reported by Ajeagah et al. (2018), Awawou et al. (2021) (26.2˚C), and Zogning (2017) (27˚C) in their studies on the Mingoa and Mfoundi, respectively. The temperature of a river is primarily determined by the thermal regime and solar radiation. The P10 and P2 points showed the highest average temperatures. This could could be justified by the sampling hours, which were fixed between 6 am ± 1 hour and 11 am ± 1 hour, with the last sampling at 10:30 am - 11 am. However, temperatures above 25°C could pose a threat to the life of many aquatic organisms, particularly aerobic ones, due to the reduction in dissolved oxygen levels (Walaa, 2018).

The levels of dissolved oxygen saturation varied during the study. Its values ranged from 33 to 81.25% in Mfoundi, 30 to 81.92% in Tongolo, and 43 to 88% in Mingoa. Compared to the values obtained by Ajeagah et al. (2018) (25%) in the Mingoa and by Lami (2002) (22.83% ± 17.15%) in the Tongolo, the values reported in our study for the same courses have slightly improved. This could indicate a decrease in mineralization activity by microorganisms in these environments due to a lesser input of organic pollutants. Indeed, in order to limit the spread of SARS-CoV-2, several restrictive measures were enacted during the Covid-19 health crisis by the Cameroonian government. These have led to the cessation (closure of public and private training institutions) or the slowdown (temporary closure of markets, bars, restaurants…) of numerous economic activities. Which would have favored the reduction of their pollution in these courses. This result has been found by Edward et al. (2021) in their study in the gulf Mannar. The difference observed between P3 and P2 of Jamot Hospital (Tongolo) could be justified by a drainage issue. Indeed, unlike P3, the water flow at P2 is heavily obstructed by the solid waste present there. Baok (2007) emphasizes in this regard that the oxygen content of the environment can only be enriched by the circulation of water in contact with air on one hand, and by the photosynthetic activity of its flora on the other. The difference between P1 (highest point) and P10 (lowest point) of Mfoundi was not statistically significant ($P > 0.05$). Which is contrary to the findings of Tanawa et al. (2003) who report that the state of the water in the Mfoundi river gradually deteriorates from upstream to downstream and worsens particularly at the P10 level (known as interchange no. 1 on the heavy axis Yaoundé-Douala). The similarity between the two points in this study would indicate a greater involvement of households in the pollution of this stream during the crisis.

The pH allows for the evaluation of the acid-base balance of water (Nkeng, et al., 2020). On average, it varied from 7.3 upstream to 7.7 downstream of the Mfoundi, it was 7.23 in Tongolo and 7.44 in Mingoa. No statistically significant difference ($P > 0.05$) was detected between the values recorded at points along the same watercourse during the study. The results obtained in this work at the Mfoundi and Mingoa sites differ from those obtained by INS-BGR (2013), Menye et al. (2012), Tanawa et al. (2003) at the first site and by Ajeagah et al. (2018), Kouam (2004) at the second. Indeed, regarding the Mfoundi, these authors reported slightly acidic (6) to basic (9) pH levels from upstream to downstream of the course. At the Mingoa level, the reported values for this parameter were slightly acidic (<7). Which was not the case in our study. This difference reveals, compared to previous studies, a change in environmental conditions. This change could be related to the increase in households' adherence to hygiene rules, particularly due to the increased use of soaps and detergents recommended during the crisis. Covid-19. These products, due to the failure of the waste sanitation system in most households, ended up in natural waters and caused an increase in their pH. The INS-BGR (2013) emphasizes that the pH of surface waters increases in accordance with the input of wastewater rich in alkaline detergents (soaps) and toilet wastewater. Moreover, this modification could also be related to the presence of azithromycin in the waters, a basic nature antibiotic (Parnham et al., 2014) widely used during the health crisis to combat the coronavirus. Indeed, in their study on the water bodies of the city of Yaoundé, Scaccia et al. (2022) highlighted the presence of this antibiotic in trace amounts. The standard values required for water use would be between 6.5 and 9.2 (WHO, 2011). The values recorded in P4 (6.3), P5 (6.2), and P10 (9.5) would indicate intense microbial degradation activities of organic matter (Kouame, 2021) resulting from point source pollution. It is noted that an increase in the pH of the waters, as observed in this study, could promote the scaling of the channels and a poor effectiveness of chlorine during treatment, exposing users to risks of ocular and skin irritations during swimming and also being harmful to aquatic fauna. Zakaria (2020), in his work on the coast of Mostaganem, emphasizes that basic pH levels would increase ammonia concentrations, which would be toxic to fish.

The incidence of Covid-19 cases was positively ($rs = 0.812$) and significantly ($P = 0.014$) correlated with oxidability in the Tongolo course. This result could be an indirect consequence of the psychosis generated by the outbreaks of Covid-19 cases in the city of Yaoundé. Indeed, during the outbreaks, this psychosis would have led the residents along this course to become more aware of the meticulous application of preventive measures, such as cleaning their environment, particularly the Nkoleton market located about 10 meters upstream from P3. The wastewater enriched with organic substances from these cleanings could thus have contributed to the pollution of this watercourse. The observed inversion of oxidability levels between P1 (10.26 mg/l of O_2) and P10 (7.11 mg/l of O_2) of the Mfoundi course during this study is contrary to the results reported by Tanawa et al. (2003), Menye et al. (2012) in the same course. This change could be related to the increase in domestic wastewater discharges due to the implementation of hygiene measures. Mimi Coultas et al. (2020), in their work titled Compendium on Handwashing in Resource-Poor Contexts, indicate that the chemical substances contained in soaps and alcohol-based hand gels could potentially harm the environment.

Electrical conductivity measures the ability of water to conduct electricity. It depends on the concentration of ions in the water (Hajjar, 1997). The results obtained in this study for this parameter remained consistent across all courses when compared to those published in earlier studies for the same courses. The difference observed between P1 and P10 of the Mfoundi corroborated the results of Lami (2002), Tanawa et al. (2003), and Menye et al. (2012). This could be justified by the scattered application of preventive measures such as handwashing during the COVID-19 response (Sop et al., 2022), it would have limited the risks of water pollution in the city.

5. Conclusion

The widespread use of detergents, disinfectants, and antibiotics in response to COVID-19 in Yaoundé has had a profound impact on the water quality of city's rivers. Specifically, the oxidability and pH levels at certain points of the rivers selected for the study have deteriorated compared to previous studies. Furthermore, a positive correlation ($r_s = 0.812$, $P = 0.014$) was observed between the incidence of COVID-19 cases with oxidability levels in Tongolo river, suggesting that the crisis has had a direct impact on the water quality. However, it is worth noting that the disproportionate application of hygiene measures among the populations of Yaoundé during the crisis has mitigated the effects of this deterioration. Despite these efforts, the lack of water flow observed in the beds of some rivers poses a significant threat to the integrity of the aquatic ecosystems in Yaoundé. Therefore, it is crucial that public authorities and the populations living along these rivers take action to address this issue and ensure the long-term sustainability of these ecosystems.

Conflict of interest

The authors declare no conflict of interest regarding the publication of this paper.

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