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Anthropogenic activities and COVID-19 effects on natural water bodies: Arroyo Seco's case

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Abstract

Concerns about pollution in Arroyo Seco, an important natural water body in the Monterrey Metropolitan Area, have been reported due to possible wastewater discharges and solid waste mismanagement, turning the river into a potential public health hazard in the context of the COVID-19 pandemic. As a result, a volunteer clean-up campaign denominated "Arroyo Vivo" has been promoted by Distrito Tec and the Campana-Altamira initiative. To aid in the efforts, ammonium, nitrates, nitrites, and sulfate concentrations, total solids, and total organic matter were measured in parallel with SARS-CoV-2 detection and quantification in river water samples. Compared with applicable regulations (NOM-001-SEMARNAT-2021, NOM-127-SSA1-2021), total suspended solid levels (55-365 mg/L) were found above the maximum limit (84 mg/L), while ammonium (0.0175-0.198 mg/L), nitrite (0.0585-0.169 mg/L), nitrate (1.065-3.285 mg/L), sulfate (91.2-111 mg/L), and chemical oxygen demand (16.95-43.1 mg/L) were consistently below the maximum limits (0.50, 0.90, 11.00, 84.00, 400.00, and 100.00 mg/L, respectively), showing that no large-scale wastewater discharges had taken place in Arroyo Seco. However, SARS-CoV-2 genetic material was detected at three sampling sites, indicating some degree of sewage leakage and inadequate management of solid waste containing respiratory fluids of infected patients. While reports indicate that water bodies are not sources of SARS-CoV-2 infection in surrounding populations, it proves that waste disposal policies must be enforced more strictly to ensure water quality and environmental protection towards sustainable development. Nonetheless, continued efforts to screen concerning contaminants are still needed to fully assess the environmental status of the stream and propose relevant public policy.

Keywords: Water pollution, anthropogenic activities, viral gene, SARS-CoV-2, water quality, increased total suspended solids

INTRODUCTION

The establishment, development and growth of human settlements is highly dependent on water availability, with urbanization often revolving around surface water bodies such as rivers[1]. However, anthropogenic activities such as industry, agriculture, transportation, municipal waste, livestock production, cemeteries, the discharge of industrial and domestic wastewater[2,3], fish farming, mining and solid waste disposal[4-6] are common sources of pollutants that often end up in natural water bodies, including nitrogen[7-10], microplastics[11-15], persistent compounds[16-20], metals[4-6], and pathogens[21-24], limiting water quality and availability, which in turn decreases quality of life and hinders sustainable development[25].

Furthermore, pollution in surface water bodies originating from pharmaceuticals (active compounds), illicit drugs, personal care-related compounds, endocrine disruptors, and pathogens, among others, poses a major risk for public health as direct contact may lead to several concerning health effects[26] including endocrine disruption[27], poisoning, and alterations in the gut microbiota[28]. In the same way, masks used as protective equipment by the population during the pandemic can be a source of contamination, including microplastics and potential viral particles, as studies have already confirmed that traces of the COVID virus can persist on the external surface of face masks for up to 7 days[29]. Notably, the presence of antibiotics in water bodies due to widespread misuse and improper disposal has often been regarded as a relevant factor in the development of antibiotic-resistant bacterial strains, which pose a significant challenge for global healthcare systems[30].

The presence of high concentrations of contaminants such as nitrogen and phosphorus in aquatic ecosystems, often originating from fertilizers and similar pollutants, can lead to severe environmental disruptions through eutrophication, which manifests as abhorrently increased proliferation of algae and plankton in the surface that limits the availability of light and oxygen in the rest of the body of water, compromising its ability to support ecological communities[31,32]. To assess the risk of eutrophication in a given body of water, a comprehensive nutritional status index [TLI (Σ)] is calculated through physicochemical analysis; using this parameter, total nitrogen and total phosphorus have been identified as the main factors driving eutrophication processes[33].

Additionally, sewage leakage and inadequate waste management and its impacts on water quality in streams and rivers may also be representative of public health status in surrounding population centers, as a vast array of molecules can be directly linked to human activities, an approach that has previously proven successful in wastewater-based epidemiology (WBE) studies[34]. Among other uses, WBE has been used to track pathogens such as Hepatitis E[35], Norovirus[36], enteric viruses[37] and, most notably, SARS-CoV-2[38]. In the context of the COVID-19 pandemic, our research group developed a wastewater surveillance system for SARS-CoV-2 in the Monterrey Metropolitan Area and found it to be widespread in the sewage system during the most critical stages of the emergency[39]. Furthermore, viral genetic material was detected in groundwater, rivers and dams across the city and successfully correlated its presence with wastewater leakage and faulty sewage infrastructure[40], although more detailed studies on the environmental impacts of human disease outbreaks in the area are still needed.

Such observations indicate that current regulatory frameworks may be insufficient to ensure the quality of the water in rivers, streams, and lagoons[41]. As a result, specific studies of the effects of inadequate waste management and bad practices in water administration in urban water bodies are still needed to guide evidence-based decision-making and develop responsible policies.

In the Monterrey Metropolitan Area in northeastern Mexico, this need becomes apparent in the case of Arroyo Seco, which is one of the few natural surface water bodies available in the south of the city. The stream was subjected to a waste remediation and recycling campaign denominated "Arroyo Vivo", promoted by DistritoTec and the Campana-Altamira initiative, which seeks to contribute to the regeneration of the ecosystem around it, part of the aquifers in the Bravo basin shared by Mexico and the USA, through volunteering clean-up crews to remove solid waste such as plastics and rubble from the riverbed[42]. To aid in the effort, this study aims to evaluate the quality of water samples taken before the campaign by analyzing their physicochemical quality in terms of nutrients (N-NH_4^+, N-NO_3^-, N-NO_2^- and S-SO_4^-) and organic matter, measured as total and dissolved chemical oxygen demand (COD), as well as tracing genetic materials from the SARS-CoV-2 virus in different sampling locations along the Arroyo Seco steam to understand the impact of waste mismanagement in urban water bodies and potentially detect clandestine or illegal wastewater discharge based on the characteristics of the stream.

EXPERIMENTAL METHODS

Sample collection and preservation

The present study was conducted in the Monterrey Metropolitan Area, located in the state of Nuevo León, México, and focused on Arroyo Seco, a 9.73 km long river beginning at coordinates 25.627728, -100.340174 and ending at 25.653431, -100.272023 [Figure 1]. Eleven sampling sites along the stream, shown in Figure 1, were chosen due to their proximity to residential, commercial, and industrial areas, as well as the presence of sufficient water levels to make sampling feasible. In accordance with the procedures outlined in the Norma Mexicana PROY-NMX-AA-003-SCFI-2019, Análisis de agua.- Muestreo de aguas residuales y residuales tratadas[43], duplicate, 2 L samples were collected at each point using high-density polyethylene (HDPE) bottles, placed in disposable insulator boxes containing ice and gel bags to maintain the samples at 4 °C to prevent degradation and transported to the laboratories at Tecnológico de Monterrey, Campus Monterrey, where they were stored at 4 °C until characterization. Samples manipulation and conservation until characterization was performed in concordance with the Norma Mexicana PROY-NMX-AA-003-SCFI-2019 guidelines[43].

Due to time and resource constraints, samples were managed differently in each characterization process: for SARS-CoV-2 viral load quantification, all eleven samples were tested and evaluated separately for the presence of SARS-CoV-2 genetic material, while physicochemical analysis was conducted using five composed samples (pools), prepared as shown in Table 1, as sampling sites were close to each other and were representative of similar land uses (residential, commercial and industrial) and related anthropogenic activities, for these reasons mentioned below, the pools comprise sampling points that represent similar anthropogenic activities and that are areas geographical close to each other.

Table 1. Samples mixed in each pool were selected according to similarities in the source or close anthropogenic activities to each point

Pool	Mixed sample points
Pool 1	1
Pool 2	2, 3, 4
Pool 3	5, 6
Pool 4	7, 8
Pool 5	9, 10, 11

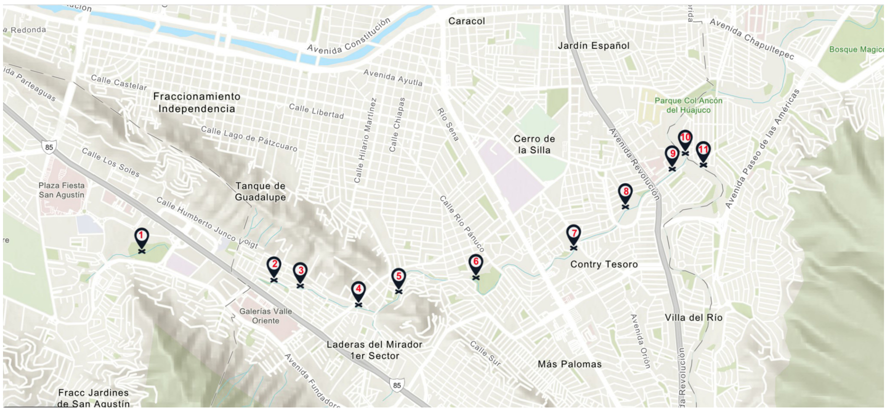

Figure 1. Arroyo Seco river maps, (a) Shows an estimation of its length measured by Google Maps tool; (b) Sample points enumerated from 1 to 11 and marked in Google Maps screenshot. 1 at 25.644377, -100.328755, 2 at 25.641689, -100.314972, 3 at 25.641165, -100.312228, 4 at 25.639355, -100.306084, 5 at 25.640616, -100.301948, 6 at 25.641883, -100.2938385, 7 at 25.644673, -100.283639, 8 at 25.648561, -100.278192, 9 at 25.652101, -100.273304, 10 at 25.653576, -100.271975, and 11 at 25.652479, -100.270110 (Río la Silla).

Virus detection and quantification: SARS-CoV-2 genetic material

SARS-CoV-2 genetic material was concentrated using a method based on the one reported by Sapula *et al.*[44]. Briefly, two aliquots of 35 mL were taken from each sample and centrifuged at 5,000 g for 5 min to precipitate solids. Supernatants were transferred into new Falcon tubes containing polyethylene glycol 8000 and NaCl solution, homogenized thoroughly and further centrifuged at 12,000 g for one hour and forty-five minutes. Pellets were serially resuspended in 300 µL of Milli-Q water and stored at -20 °C until further processing to avoid degradation of viral genetic materials.

Nucleic acid extraction was performed using the Water DNA/RNA Magnetic Bead Kit (IDEXX, Westbrook, Maine) according to the supplier's instructions adapted for a KingFisher™ Flex automated system (Thermo Fisher, Waltham, Massachusetts). Eluted genetic materials were recovered and stored at -20 °C until analysis.

SARS-CoV-2 genetic material was detected and quantified through RT-qPCR using the SARS-CoV-2 RT-PCR Test kit for wastewater samples (IDEXX, Westbrook, Maine) on a QuantStudio 5 system (Applied Biosystems, Waltham, Massachusetts). Reactions consisted of 5 µL of SARS-CoV-2 mix (containing N1 and N2 primers and probes), 5 µL of RNA Master Mix (reverse transcriptase, hot-start polymerase, and a reference dye), and 5 µL of extracted genetic material. Positive and negative controls were set alongside the assays. The RT-qPCR program consisted of an initial hold for 15 min at 50 °C and 1 min at 95 °C, followed by 45 cycles of 95 °C for 15 s and 60 °C for 30 s.

Water physicochemical characterization

Physicochemical characterization of water on the Arroyo Seco stream was performed using the five pooled samples as described previously. Physicochemical characterization was carried out considering the most usual parameters followed in the different wastewater sectors, due to their frequency and relevance in the environment. The parameters considered in this study included Total and Total Suspended Solids (TS and TSS, respectively), Nitrate ($N\text{-}NO_3^-$), Nitrite ($N\text{-}NO_2^-$), Ammonium ($N\text{-}NH_4^+$), Sulfate ($S\text{-}SO_4^{2-}$), and total and soluble Organic Matter COD.

TS and TDS were determined by duplicate using the gravimetric method according to standard methods published by the APHA[45]. In accordance with the HATCH Colorimetric methods outlined in Table 2, COD was quantified in both total and soluble phase, while the rest of the parameters ($N\text{-}NO_3^-$, $N\text{-}NO_2^-$, $N\text{-}NH_4^+$ and $S\text{-}SO_4^{2-}$) were quantified in soluble phase only after passing water samples through a 1.5 µm pore membrane filter, and all measurements for each compound was developed using HACH kits (HACH, CO, US) described in table 2 and following manufacturer's guidelines.

RESULTS AND DISCUSSION

Physicochemical characterization was performed to characterize pollutants related to the inadequate discharge of wastewater in natural bodies of water and its effects on water quality in order to identify potential hazardous effects of human contact with the source. Additionally, the detection and quantification of SARS-CoV-2 genetic materials further proved the potential consequences of inadequate wastewater and solid urban waste management for public health in the context of a global sanitary emergency.

Physicochemical characterization

Relevant physicochemical parameters for each pooled sample and comparisons with their maximum permissible limits, determined by official norms, are presented in Table 3. When it comes to pollution in water and natural water bodies, normative applicable in Mexico are presented in NOM-001-SEMARNAT-2021, which regulates the maximum concentration of pollutants in water discharges into natural bodies[46], and NOM-127-SSA1-2021, which establishes the maximum concentration of pollutants in potable waters[47], respectively, as wastewater discharges are considered one of the main sources of contamination in surface water bodies such as Arroyo Seco and any human contact with untreated water originating from the stream might represent a health risk.

Based on the experimental results, there is no evidence of large-scale discharge of untreated wastewater into the river, so actual levels of pollution are likely related to sewage leakage due to faulty infrastructure, natural phenomena, or mismanagement of other kinds of waste. Furthermore, the only parameter that exceeds concentrations established in the normative is Total Suspended Solids, which can be related to the levels of salts and other inorganic compounds that are not considered in the present study.

Nevertheless, it is important to note that the normative mentioned so far was not designed to assess the quality of the water in streams or rivers and many relevant parameters were not considered. In fact, most regulations regarding water quality are focused on the presence of organic matter in wastewater discharges and heavy metals and organic compounds in drinking water, despite the fact that evidence shows that nutrients, which are not as strictly regulated, can cause significant environmental effects in natural water bodies and surrounding population centers. In Mexico, there are currently two reference values for superficial water stream quality, the "Criterios de calidad de agua [Water Quality Criteria (WQC)]" and the *"Indice de calidad del agua"* [Water Quality Index (WQI)], both published by the SEMARNAT. It is important to mention that both parameters are not a regulatory norm, but rather are indicators used to

Table 2. List of methods for quantification of physicochemical quality

Parameter	HACH method
$N\text{-}NH_4^+$	Salicylate method 10205 TNT plus 830
$N\text{-}NO_2^-$	Method 10207 TNT plus 839
$N\text{-}NO_3^-$	Dimethylphenol method 10206 TNT plus 835
$S\text{-}SO_4^{2-}$	Method 10227 TNT plus 864
COD	Method 8000 TNT plus 821

COD: Chemical oxygen demand.

Table 3. Physicochemical characterization and Mexican regulations comparison

Parameter ($mg \cdot L^{-1}$)	Pool 1	Pool 2	Pool 3	Pool 4	Pool 5	NOM-001-SEMARNAT-2021	NOM-127-SSA1-2021	WQC (SEMARNAT, 1998)
$N\text{-}NH_4^+$	-	0.039 ± 0.03	-	0.017 ± 0.01	0.198 ± 0.01		0.50	0.06
$N\text{-}NO_2^-$	-	0.163 ± 0.06	0.058 ± 0.00	0.169 ± 0.00	0.1245 ± 0.00		0.90	
$N\text{-}NO_3^-$	1.42 ± 0.01	2.8 ± 0.11	3.285 ± 0.07	1.065 ± 0.06	2.165 ± 0.05		11.00	6.00
TS	370 ± 0.000	770 ± 0.001	500 ± 0.001	325 ± 0.00	350 ± 0			
TSS	155 ± 0.001	365 ± 0.00	-	-	-	84.00		4.00
$S\text{-}SO_4^{2-}$	103 ± 0.0	106 ± 5.66	111 ± 4.24	101.8 ± 3.11	91.2 ± 2.40		400.00	
COD (total)	31.25 ± 7.00	43.1 ± 5.23	16.95 ± 1.77	39.75 ± 3.75	25.3 ± 0.42	100.00		6.00
COD (soluble)	31.5 ± 3.53	27.5 ± 1.98	16.25 ± 1.06	19.55 ± 3.041	25.9 ± 1.98			

The value on the Mexican regulations are the maximum levels permitted in the water bodies. COD: Chemical oxygen demand; $mg \cdot L^{-1}$: milligrams per liter; TS: total solids; TSS: total suspended solids; WQC: water quality criteria.

monitor the quality of the waters. The WQC establishes the maximum concentration of different parameters required to maintain the ecological interactions according to the natural balance in freshwater ecosystems, considering 18 parameters including COD, Phosphorous as Phosphates, Nitrogen as Ammonium, Nitrates and Nitrites, suspended solids, among others. According to the maximum levels published in the WQI, all the sampling points exceed the COD concentration limits, pools one, two and five exceed TSS, and pool five ammonium [Table 3]; hence, the natural equilibrium is compromised. On the other hand, the WQI takes the parameters of the WQC and gives them specific weights that are used to determine the quality of the superficial waters. Moreover, despite the fact that WQC is the reference used for WQI, the final concentrations allowed in the WQI are higher than the ones in the WQC, and the main parameters for the determination of the quality of the water are Biological and Chemical Oxygen Demand, Total Suspended Solids, Dissolved Oxygen and Coliforms. In these limits, it is considered that superficial water with an acceptable quality should not exceed a COD and TSS concentration higher than 40 $mg \cdot L^{-1}$ and 150 $mg \cdot L^{-1}$, respectively. In this context, only pools one and two are above the mentioned concentrations and it could be said that water quality at this point is poor. A study carried out by Mora *et al.* in the Atoyac River in central Mexico, one of the most polluted water bodies in the country, showed COD levels significantly higher (18-1,100 $mg \cdot L^{-1}$) than those reported in the present study (16-43 $mg \cdot L^{-1}$) associated with unregulated discharge of wastewater flows originated from dense population centers and industrial areas[48]. Moreover, reported ammonium ($N\text{-}NH_4^+$) levels (0.40-102 $mg \cdot L^{-1}$) were mostly above the maximum allowed by NOM-127-SSA1-2021 (0.50 $mg \cdot L^{-1}$) and significantly higher than those reported in the present study

(0.02-0.20 mg·L^{-1}), nitrate (N-NO_3^-) levels (0.45-12 mg·L^{-1}) were mostly under the allowed limits (11 mg·L^{-1}) but higher than those reported in the present study (1.06-3.28 mg·L^{-1}), and nitrite (N-NO_2^-) levels (0.07 mg·L^{-1}) were comparable to those reported here (0.05-0.17 mg·L^{-1}) and were within permissible limits (0.90 mg·L^{-1}). In the same study[48], it was observed that NH_4^+ and NO_3^- levels are associated with the availability of dissolved oxygen as a result of nitrification and algae blooms[48]. Ammonium nitrification is a process carried out by microorganisms. It has been reported that in superficial waters, water bodies have an aerobic superior layer, in which ammonium nitrogen is transformed to nitrite and then nitrite to nitrate; this sequence of transformations is known as the nitrification process, which has a stoichiometric oxygen requirement of three oxygen molecules for each nitrogen molecule involved. It was reported that at least half of the nitrate identified in waters originates from ammonium nitrogen; hence, it is considered that ammonium has an effect on dissolved oxygen due to its involvement in the nitrification process[49].

Nevertheless, while the presence of high concentrations of nitrogen in water can cause eutrophication phenomena, previous studies have shown that they are not delimited to any specific nitrogen concentration. In Mexico, elevated nutrient concentrations in rivers, streams, and other natural water bodies have been associated with harmful algal blooms along the Mexican coast[50]. In this regard, a study by Crisóstomo-Vázquez *et al.* monitored nitrogen concentrations and the proliferation of phytoplankton in a Mexican lagoon over a year; total nitrogen concentrations ranged from 0.50 to 1.60 mg·L^{-1}, leading to the growth of ten different algae groups[51]. The authors calculated the mean trophic index for the lagoon at 64.84, classifying it as a eutrophic with a high biological activity associated with elevated nutrient concentrations. Compared to this report, nitrogen levels in Arroyo Seco were three times lower; however, Davidson *et al.* concluded that while there is an association between water quality and the frequency and intensity of algae blooms as a response to eutrophication, a direct correlation to punctual presence or absence of nitrogen in water remains elusive[52].

Nonetheless, despite the present study not showing any significant violations of the current regulatory framework for water quality in Arroyo Seco, it is still unclear whether the presence of pollutants may pose any potential threats to the environment or public health in the Monterey Metropolitan Area and further physicochemical characterization is needed to obtain more information on the negative effects of human activities and waste mismanagement in the stream, which would be highly valuable for the development of robust, responsible policies and regulations.

Virus detection and quantification of SARS-CoV-2 genetic material

As shown in Table 4, SARS-CoV-2 genetic material was detected in three samples originating from sites 5, 7 and 10. This indicates that the river entered into contact with one or more contamination sources during its course. RNAse-P served as an internal control of human cell contamination.

Sewage leakage has been extensively reported as a source of contamination for water in urban environments, including rivers, streams, and aquifers, as demonstrated by the detection of biomarkers for microbiological pathogens commonly associated with sewage, including viruses, bacteria, and protozoa[53,54]. Moreover, as previously reviewed by Tran *et al.*, traces of SARS-CoV-2 nucleic acids have been reported in sludges from water treatment plants, municipal sewage, and wastewater from medical facilities, cruise ships, and passenger aircraft, likely due to contact with feces or face masks worn by infected individuals[55]. In a prior study by our research group[39], SARS-CoV-2 genetic material was detected in wastewater samples from the Monterrey Metropolitan Area during the COVID-19 pandemic, further indicating that the presence of viral contamination observed in the river water samples could have arisen from contact with sewage systems. In this line, a previous study by Mahlknecht *et al.* had reported the presence of viral genetic

Table 4. Results of the RT-qPCR test in sample points of Arroyo Seco for SARS-CoV-2 detection

Sample ID	Ct SARS-CoV-2	Ct RNAse-P	SARS-CoV-2 genomic copies/L
1A	Undetermined	Undetermined	0
1B	Undetermined	Undetermined	0
2A	Undetermined	Undetermined	0
2B	Undetermined	Undetermined	0
3A	Undetermined	Undetermined	0
3B	Undetermined	Undetermined	0
4A	Undetermined	36.541	0
4B	Undetermined	Undetermined	0
5A	Undetermined	34.063	0
5B	36.385	33.031	10,410
6A	Undetermined	38.05	0
6B	Undetermined	36.25	0
7A	35.991	Undetermined	13,257
7B	Undetermined	Undetermined	0
8A	Undetermined	36.196	0
8B	Undetermined	Undetermined	0
9A	Undetermined	37.112	0
9B	Undetermined	36.777	0
10A	Undetermined	36.629	0
10B	35.940	Undetermined	13,676
11A	Undetermined	Undetermined	0
11B	Undetermined	Undetermined	0

material remnants in groundwater, rivers and dams across the Monterrey Metropolitan Area and successfully related it to sewage leakage, as viral loads showed a significant correlation with the presence of *E. coli* and sucralose, common population markers used for WBE applications[40]. In any case, it must be noted that previous studies detecting SARS-CoV-2 in wastewater and rivers have concluded that traces of viral genetic materials are not infectious due to contact with high temperatures, organic matter, and antagonistic microorganisms[56,57], but can be detected as a way to detect contamination in natural water bodies and as a complementary mechanism in pandemic surveillance and containment, in parallel with wastewater-based epidemiology approaches.

However, as physicochemical parameters from the samples show no evidence of large-scale untreated wastewater discharges, it is possible that other contaminants, such as plastic bottles, face masks or disposable paper towels and tissues that were in contact with oral and respiratory fluids from sick individuals or subclinical carriers could have played a role in the presence of SARS-CoV-2 traces in the river, as viral shedding in saliva, mucus, and sputum has been reported and are commonly used samples for diagnostic assays[58-60]. Given that high amounts of solid waste and trash were reported during cleaning efforts at Arroyo Seco, SARS-CoV-2 may have gotten into the water as a result of inappropriate waste management although, as observed in a similar study by Guerrero-Latorre *et al.*, its effect is often minor[61]. Therefore, sewage leakage into the stream should not be fully discarded.

Study limitations and future outlook

The main focus of this study was to aid in the efforts of the "Arroyo Vivo" campaign by studying the overall water quality in the Arroyo Seco stream and detecting the presence of SARS-CoV-2 genetic materials, as there was contact with wastewater during the cleanup activities. As such, the data presented here are only prospective and must be extended in future research efforts. While this study used samples representing the entire course of the stream across population centers, sampling was conducted only once, so no comparisons between different times can be made at the moment. Additionally, to report whether or not Arroyo Seco was subjected to untreated wastewater dumping in a timely manner to the campaign organizers, the number of physicochemical characterization assays that were conducted using the samples obtained were limited to parameters that could be directly compared to limits established in the applicable regulations.

In order to fully assess the current state of Arroyo Seco and its possible effects on surrounding population centers, more exhaustive sampling and physicochemical characterization procedures must be performed to integrate the vast arrange of concerning chemicals, such as metals, microplastics, pathogenic microorganisms, pharmaceuticals, illicit drugs, personal care-related compounds, and endocrine disruptors, among others, and generate relevant insights to guide public policy and strengthen current regulatory frameworks to ensure water quality and sustainable development in the Monterrey Metropolitan Area. Moreover, surveillance efforts must continue to understand the origins of pollutants that end up in Arroyo Seco, their dynamics across time, and to evaluate the long-term effects of environmental policy on water quality and public health. Further efforts to understand the impact of human disease outbreaks in natural water bodies should also be conducted, in parallel to current WBE studies, as a time and resource-efficient strategy for epidemiological preparedness, surveillance and containment, as proven in the context of the COVID-19 pandemic.

CONCLUSIONS

Arroyo Seco, one of the most important natural water bodies in the south of the Monterrey Metropolitan Area, was recently subjected to a clean-up campaign as concerns over untreated wastewater discharge and inadequate solid waste disposal have been reported as threats to the environmental health of the city. In order to aid with cleanup efforts, basic physicochemical characterization detection of SARS-CoV-2 genetic materials was conducted on samples obtained from representative sites along the stream course. Of all parameters tested, only Total Dissolved Solids (155-365 mg/L) were above the maximum limits established by the applicable normative (84 mg/L), indicating that large-scale dumping of untreated wastewater into the stream is unlikely. However, remnants of SARS-CoV-2 genetic materials were detected at sampling points 5, 7, and 10, pointing to contamination as a result of sewage leakage, likely due to faulty public infrastructure, or solid waste containing traces of respiratory fluids of infected patients, such as plastic bottles, face masks or tissues. While viral detection can be related to public health status in the context of the COVID-19 pandemic, as proven by previous WBE efforts conducted by our research group, previous reports indicate that it is unlikely that virus-contaminated water bodies could become an infection source in surrounding populations.

Although levels of ammonium, nitrates, nitrites, sulfate and organic matter were consistently below the limits established by the current, relevant normative across all sampling sites, previous studies warn that eutrophication and other environment-disrupting phenomena may arise even under conditions previously thought of as safe, indicating that continued, case by case surveillance is crucial to ensure water quality and environmental health in population centers such as the Monterrey Metropolitan Area. Analytical assays applied in the area must also be expanded to encompass a vast array of concerning pollutants and markers of anthropogenic activities that may damage environmental conditions to gain significant insights to draw public policy and strengthen regulatory frameworks in the country. For this, extensive cooperation between research centers and local governments will be vital.

Overall, the present study has successfully aided in the cleanup efforts of the "Arroyo Vivo" campaign for the benefit of the inhabitants of the Monterrey Metropolitan Area and laid the foundations for future sustained surveillance efforts, which are crucial for ensuring water quality and environmental health; however, to achieve its ultimate goals, this cooperative network must be expanded. Although no comparisons with specific regulations for natural water bodies could be drawn, results are still indicative of environmental and public health risks in the area and should not be underestimated.

DECLARATIONS

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Conflicts of interest

All authors declared that there are no conflicts of interest.

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Not applicable.

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