

Annual monitoring of physicochemical parameters and phenolic contamination along the Tirana River, Albania

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ABSTRACT

Tirana River is an important urban water body of Tirana city but it is affected by increasing anthropogenic pressure associated with urbanization and wastewater inputs. The aim of this study was to evaluate the selected physicochemical parameters and total phenolic compounds in the Tirana River over a one-year monitoring period. Water samples were collected from seven sampling stations distributed along the river, from Tufina in the upstream section to Rinas in the downstream section, during six sampling campaigns conducted between October 2025 and September 2026. Dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC), pH and total phenolic compounds were determined. DO concentrations ranged from 6.80 to 11.80 mg/L, while TDS varied from 227.00 to 414.00 mg/L. Electrical conductivity ranged from 385 to 784.82 $\mu\text{S}/\text{cm}$, whereas pH values ranged from 7.17 to 9.12. Total phenolic concentrations varied between 3.205 and 55.210 $\mu\text{g}/\text{L}$, with the highest concentration recorded at Laknas in October 2025. The downstream stations shown increase in TDS, electrical conductivity and phenolic concentrations, accompanied by a decrease in dissolved oxygen. These fact is connected with increasing anthropogenic influence shown the influence of hydrological conditions, runoff, dilution and temporal changes in pollutant inputs. The results demonstrate the presence of phenolic contamination in the Tirana River regardless of the station or the time of analysis. Continued monitoring and source-oriented investigations are recommended for the institutions, particularly in downstream urbanized areas, to support effective management and protection of the river ecosystem.

Keywords: Tirana River, physicochemical parameters, dissolved oxygen, electrical conductivity, total dissolved solids, phenols, water quality, urban pollution.

INTRODUCTION

Surface water quality is strongly influenced by natural processes and anthropogenic activities, particularly in urbanized areas where domestic wastewater, industrial discharges, urban runoff and other diffuse sources may introduce a complex mixture of organic and inorganic contaminants into aquatic ecosystems. Continuous monitoring of physicochemical characteristics and chemical pollutants is therefore essential for evaluating changes in river water quality and identifying areas subjected to increased anthropogenic pressure.

The European Water Framework Directive (WFD) establishes an integrated approach for the protection of European water bodies and requires assessment of both chemical and ecological status. Chemical status is evaluated using Environmental Quality Standards (EQS) for priority substances, while additional river-basin-specific pollutants may also contribute to the assessment of ecological status (European Commission, 2026).

Physicochemical parameters such as dissolved oxygen (DO), pH, electrical conductivity (EC), total dissolved solids (TDS), etc. provide important information about the general condition of aquatic

systems. Changes in these parameters may reflect variations in hydrological conditions, organic loading, mineralization, runoff and anthropogenic inputs. In particular, dissolved oxygen is an important indicator of the biological and chemical processes occurring in rivers, while EC and TDS can provide useful information on the concentration of dissolved ionic material and the influence of wastewater and urban runoff (Kucaj et al., 2022; Giakoumatos et al., 2024; gjeci et al., 2025).

The presence of phenolic compounds in aquatic environments is of particular environmental concern. Phenols and their derivatives originate from both natural processes and anthropogenic activities, including petroleum refining, production of resins and polymers, dyes, pesticides, pharmaceuticals and other chemical industries. Urban and industrial wastewater can therefore represent important pathways for their introduction into surface waters (Yan et al., 2018; Mohd, 2022). Phenolic compounds are also environmentally relevant because several phenols and their derivatives may exhibit toxic effects on aquatic organisms. Their toxicity is influenced by the chemical structure of individual compounds and by environmental conditions such as temperature, dissolved oxygen and water chemistry (Yan et al., 2018). Recent reviews have demonstrated that numerous phenolic compounds have been detected in surface and other water matrices worldwide, although the occurrence and concentrations vary substantially among locations and pollution sources (Rahman et al., 2021; Mohd, 2022; Ndwabu et al., 2023; Rodrigues et al., 2024).

The Tirana River is an important urban watercourse crossing the city of Tirana and receiving the influence of densely populated and highly modified areas along its course. Previous investigations have documented variations in physicochemical parameters and nutrient concentrations in the river and have emphasized the influence of domestic wastewater, urban activities and runoff on its water quality (Hoxha et al., 2022). More recently, phenolic contamination has been investigated in several surface-water ecosystems of the Tirana area using UV–Vis spectrophotometry, demonstrating the relevance of phenols as indicators of organic pollution in the region (Shehi et al., 2025). In addition, recent monitoring of the Tirana River has identified BTEX compounds, polycyclic aromatic hydrocarbons and n-alkanes, confirming the presence of different groups of organic contaminants and the importance of

continued assessment of this urban river system (Nuro et al., 2026).

Relatively limited information is available on the combined spatial and seasonal variability of physicochemical parameters and total phenolic compounds along the Tirana River during a complete annual monitoring period. The objective of the present study was to evaluate the selected physicochemical parameters (Temperature, DO, TDS, EC and pH), together with total phenolic compounds in water samples collected from seven stations along the Tirana River during six sampling campaigns between October 2025 and September 2026. This investigation represents the first annual monitoring program combining physicochemical parameters and phenolic contamination along seven stations of the Tirana River using HPLC-DAD determination of phenols over six seasonal campaigns. The study provides an updated assessment of the river's water-quality conditions and contributes to the existing information required for long-term environmental monitoring and management of this important urban aquatic ecosystem.

MATERIALS AND METHODS

Study area and water sampling in Tirana River

Tirana River, one of the main urban water bodies in the Tirana city, was selected for the assessment of some physicochemical parameters and phenolic compounds. Seven sampling stations were selected in the most populated part of the river, extending from the upstream area of Tufina to the downstream section near Rinas. Sampling were performed every two months between October 2025 and September 2026, resulting in six monitoring periods (October 2025, December 2025, February 2026, April 2026, June 2026 and September 2026) during the study period. Note that, the Tirana River originates from Dajti Mountain; however, this section of the river was not taken into account because the river's gradient is higher, and the population, as well as industrial and agricultural activities, are minimal. Data regarding the station coordinates are presented in Table 1. The distances between selected stations were approximately 2 km from Tufina to the Instituti Bridge, and 3 km apart between the Instituti Bridge and Rinas.

Physicochemical parameters (pH, dissolved oxygen, electrical conductivity and total dissolved solids) were measured in situ using a calibrated portable multiparameter model HANNA, HI9829 (Hanna Instruments, Woonsocket, RI, USA). Prior to each sampling campaign, the instrument was calibrated according to the manufacturer's instructions using certified calibration solutions. For the determination of phenol, 1 liter of surface water samples (until 25 cm depth) were collected in glass bottles, based on ISO 5667-3:2018 Method. Samples were transported under refrigerated conditions, and stored at +4 °C until analysis (Figure 1).

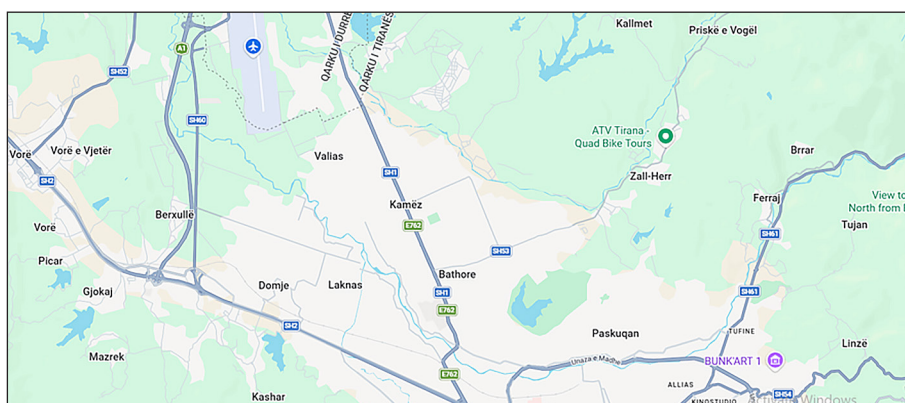
Determination of physicochemical parameters

The physicochemical parameters of the water samples, including temperature, dissolved oxygen, pH, total dissolved solids, and electrical conductivity, were measured in situ immediately after sample collection using a portable

multimeter apparatus (model HANNA HI 9829) manufactured by Hanna Instruments (USA). Field measurements were performed at each sampling location (three parallel measurements were done at each stations) to minimize potential alterations in water quality characteristics associated with sample storage and transport. Prior to each monitoring campaign, the instrument was calibrated according to the manufacturer's instructions using certified standard solutions. Water temperature, dissolved oxygen concentration (mg/L), pH, electrical conductivity ($\mu\text{S cm}^{-1}$), and total dissolved solids (mg/L) were recorded directly at each sampling station. Measurements were performed in triplicate, and the average values were used for subsequent statistical analysis.

Determination of phenol in water samples

Phenol compounds were determined using solid-phase extraction (SPE) followed by high-performance liquid chromatography with



diode-array detection (HPLC-DAD). The equipment model Agilent Infinity 1260 Series II (Waldbronn, Germany) was used. Prior to extraction, water samples were acidified to pH 2 using phosphoric acid. Solid-phase extraction was performed using cartridges model Oasis HLB (500 mg, 6 mL, Waters Corporation, Milford, MA, USA) with polymeric phase (N-vinylpyrrolidone/divinylbenzene copolymer) previously conditioned with methanol and ultrapure water. After sample loading (100 mL), the cartridges were clean-up with ultrapure water and dried under vacuum. The phenols were eluted with 10 mL methanol, and concentrated under a gentle stream of nitrogen. Prior to chromatographic analysis, all extracts were filtered through 0.45 µm membrane filters and transferred into HPLC vials. Chromatographic separation was performed on a C18 reversed-phase analytical column (model Zorbax Eclipse XDB-C18, 15 cm × 4.6 mm, 5 µm). The mobile phase consisted of water and acetonitrile under isocratic conditions at 30 °C. 20 µL of

sample were injected for each sample. The mobile phase flow was 1.5 mL/min. The run time was selected for 20 minutes. Detection was carried out using a diode-array detector operating at 270 nm, corresponding to the maximum absorption wavelength of phenol. Quantification was performed by the external standard method using calibration curves prepared from phenol reference standards [7,8,18,19]. Phenol analytical standard (PES-TANAL®, Product No. 35952, CAS No. 108-95-2) was purchased from Sigma-Aldrich (Merck KGaA, Darmstadt, Germany). Stock standard solution (1000 mg/L) was prepared in HPLC-grade methanol and stored at 4 °C. Calibration standards were prepared at following concentration levels: 0; 0.1; 0.25; 0.5; 1; 2.5; 5; 10; 20; 50; and 100 µg/L (Table 2, Figure 2).

The quality control results for the determination of phenol using HPLC-DAD technique, are summarized in Table 3. Recovery experiments conducted at three spiking levels (1, 5 and 25 µg/L) demonstrated satisfactory extraction efficiency within the acceptable range for trace organic analysis (Figure 3, Table 4). Procedural blanks analysed with each analytical

Table 2. Phenol concentrations used for calibration curve

Concentration of phenol (µg/L)	Area (Hz)
0	0
0.1	4.12
0.25	12.98
0.5	26.11
1	49.65
2.5	99.75
5	117.3
10	231.9
25	539.55
50	1178.1

Table 3. Quality assurance and quality control parameters for phenol determination

Parameter	Result
Calibration range	0.1–100 µg/L
Correlation coefficient (R ²)	0.9984
LOD	0.013 µg/L
LOQ	0.040 µg/L
Blank concentration	< LOD
Precision (%RSD)	<5%
Repeatability (%RSD)	<5%

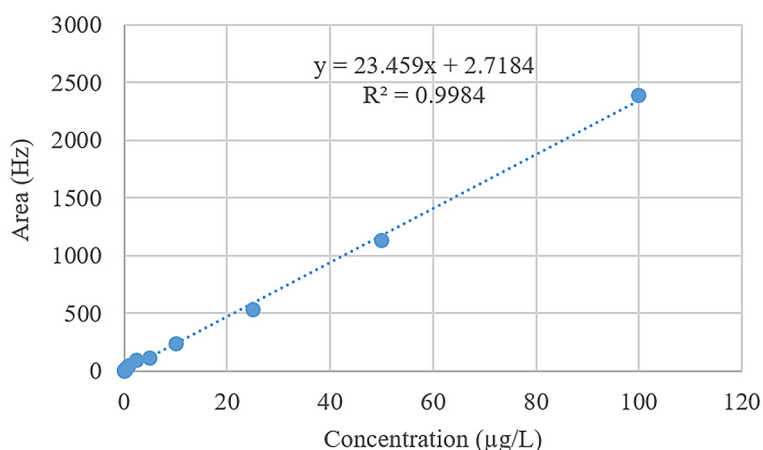


Figure 2. Calibration curve for phenol

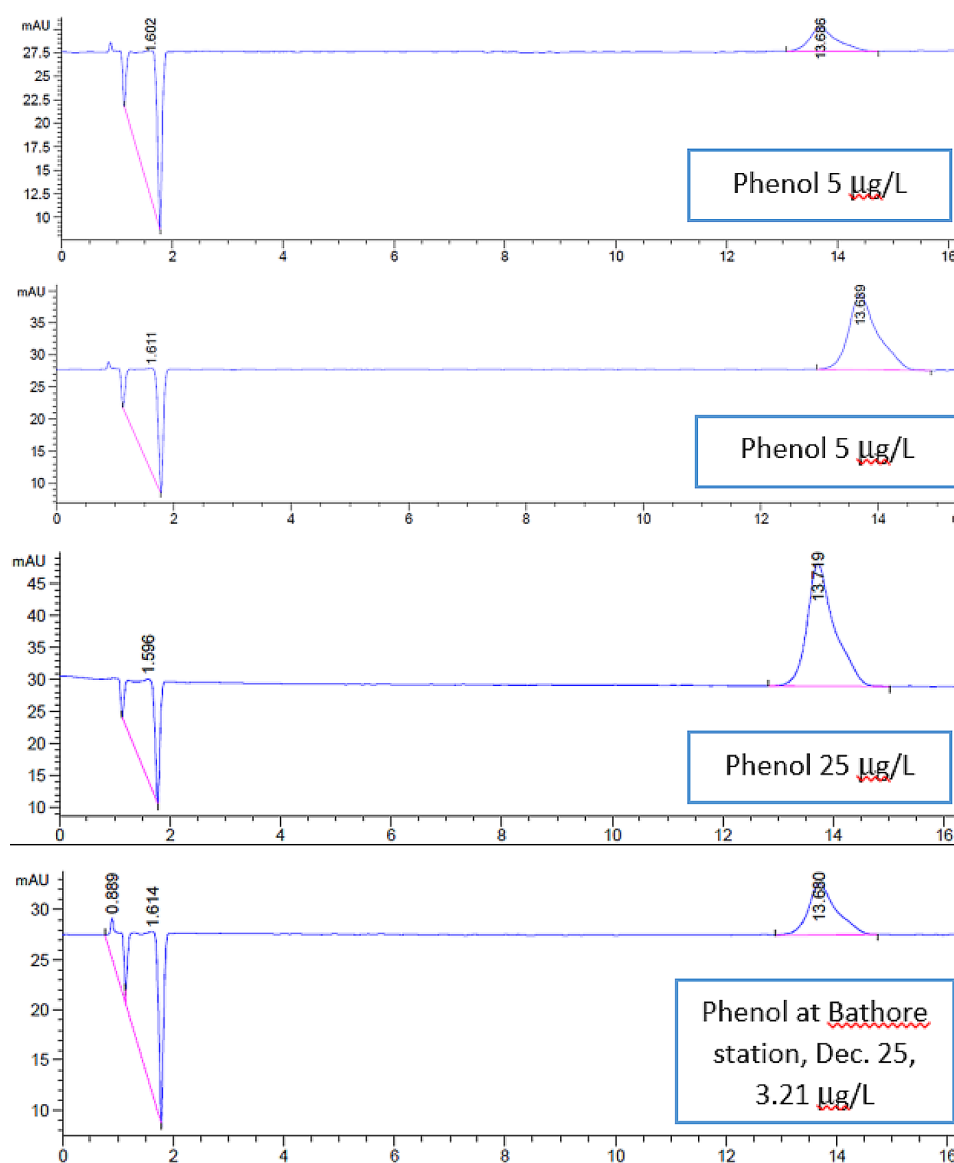


Figure 3. Chromatogram for standards of phenol at concentrations 1, 5 and 25 µg/l, and for the phenol at water samples of Tirana River

Table 4. Recovery study and QA/QC performance

Spike level (µg/L)	Measured concentration (µg/L)	Recovery (%)	RSD (%)
1.0	0.94	94.0	4.2
5.0	4.89	97.8	3.6
25.0	24.1	96.4	2.8

Table 5. Data for the blank procedure

Parameter	Result
Number of procedural blanks	12
Phenol detected	Not detected
Concentration	< LOD
LOD	0.013 µg/L

batch showed phenol concentrations below the method detection limit (<0.013 µg/L), indicating the absence of laboratory contamination (Table 5). Instrument performance was verified using calibration verification standards and duplicate analyses throughout the monitoring period.

RESULTS AND DISCUSSION

Data interpretation for physicochemical and phenol levels

This study shows the first annual monitoring program combining physicochemical parameters and phenolic contamination along the Tirana River using HPLC-DAD determination of phenols over six seasonal campaigns. The physicochemical data of the Tirana River water samples shown notable differences during the one-year monitoring period from October 2025 to September 2026. Seven sampling stations were investigated along the river course, from Tufina in the upstream section to Rinas in the downstream section. The monitored parameters included temperature, DO, TDS, EC, and pH (Table 6).

River water temperature is primarily linked to the season in which the measurements were taken. Values range from 13.02 in February to 26.62 in September 2026. Overall, there are only minor variations in water temperature between the stations, given their distribution along a stretch of approximately 20 km.

The pH values ranged from 7.17 to 9.12, with an overall mean of 8.24, indicating predominantly neutral to moderately alkaline conditions. The maximum pH value (9.12) was recorded at Tufina in April 2026, while the minimum value (7.17) occurred at both Paskuqa 2 and Ura e Institutit in September 2026. The relatively high pH values observed during April and June 2026, with mean values of 9.06 and 8.74, respectively, may be associated with increased biological activity and photosynthetic uptake of dissolved CO₂. Conversely, the lower values observed in September may reflect changes in hydrological conditions and biological activity. Although the pH remained within a generally alkaline range, the relatively wide seasonal variation indicates that the river chemistry is influenced by both natural processes and anthropogenic inputs.

Dissolved oxygen concentrations ranged from 6.80 to 11.80 mg/L, with an overall mean of approximately 9.69 mg/L. The lowest value (6.80 mg/L) was recorded at Ura e Institutit in October 2025, whereas the highest value (11.80 mg/L) occurred at Tufinë in September 2026. A clear spatial tendency was observed, with mean DO decreasing from approximately 11.18 mg/L at Tufinë to 8.63 mg/L at Rinas. This downstream decrease may reflect increasing anthropogenic

influence and organic loading along the urbanized part of the river. DO values classify the water of the Tirana River as good/moderate for surface waters (NEA/AKM, 2019). The same general pattern has been reported in previous investigations of the Tirana River, where deterioration of water quality downstream was associated with urban and wastewater inputs. Hoxha et al. (2022) similarly identified anthropogenic discharges as an important factor affecting the physicochemical characteristics of the river. Seasonal variation was also evident. The lowest average DO concentration occurred in October 2025 (8.17 mg/L), whereas values increased during December 2025 and February 2026, reaching average concentrations of 10.20 and 10.34 mg/L, respectively. The relatively high concentrations observed during the colder months are consistent with the higher solubility of oxygen in colder water. In contrast, the lower values observed at several downstream stations may additionally indicate increased oxygen consumption associated with organic matter and wastewater inputs.

TDS values varied between 227.00 and 414.00 mg/L, with an overall mean of approximately 308.34 mg/L. The highest value was measured at Rinas in October 2025, whereas the lowest was recorded at Tufinë in February 2026. The data indicate an overall increase in dissolved solids in the downstream direction, with mean values increasing from approximately 263 mg/L at Tufinë to 361 mg/L at Rinas. The downstream increase in TDS suggests increasing inputs of dissolved substances along the river. These may originate from domestic wastewater, urban runoff, small commercial activities, soil erosion, and other anthropogenic sources. The temporal pattern was also pronounced, with the highest mean TDS concentration occurring in June 2026 (366.15 mg/L), while the lowest occurred in February 2026 (271.29 mg/L). The relatively elevated TDS values during spring and summer may be associated with flow reduction, water evaporation and greater contribution from urban and diffuse sources. All TDS values, regardless of the sampling station or time of analysis, are below 1000 mg/L, classifying this water body as suitable (Good) based on this parameter (NEA/AKM, 2019).

Electrical conductivity shows the same pattern with TDS. EC values ranged from 385 to 784.82 µS/cm, with a mean value of 562.59 µS/cm. The lowest value was observed at Bathore in February

Table 6. Physicochemical and phenol data for the Tirana River, October 2025 – September 2026

Parameter	Sampling period	Stations of Tirana River							Mean	STDEV
		Tufine	Bathore	Paskuqan 1	Paskuqan 2	Ura institutit	Laknas	Rinas		
Temperature (°C)	Oct. 2025	23.84	23.89	23.94	24.01	24.09	24.07	24.12	23.99	0.11
	Dec. 2025	15.85	15.90	15.95	16.02	16.10	16.08	16.13	16.00	0.11
	Feb. 2026	12.80	12.90	12.80	13.00	13.10	13.10	13.40	13.01	0.21
	Apr. 2026	17.73	17.79	17.85	17.92	18.01	17.99	18.05	17.91	0.12
	Jun. 2026	24.14	24.21	24.29	24.39	24.52	24.49	24.56	24.37	0.16
	Sep. 2026	25.12	26.42	26.62	26.82	26.92	27.12	27.32	26.62	0.73
PH	Oct. 2025	8.04	7.95	7.88	7.72	7.63	7.74	8.11	7.87	0.18
	Dec. 2025	8.15	8.06	8.07	8.11	8.07	8.09	8.14	8.10	0.04
	Feb. 2026	8.21	8.26	8.24	8.17	8.16	8.13	8.26	8.20	0.05
	Apr. 2026	9.12	9.02	9.03	9.07	9.03	9.05	9.11	9.06	0.04
	Jun. 2026	8.81	8.70	8.71	8.76	8.71	8.73	8.79	8.74	0.04
	Sep. 2026	7.97	7.87	7.27	7.17	7.17	7.27	7.67	7.48	0.34
DO ppm	Oct. 2025	10.40	9.50	8.40	7.80	6.80	7.10	7.20	8.17	1.35
	Dec. 2025	11.20	11.00	10.80	10.20	9.60	8.90	9.70	10.20	0.85
	Feb. 2026	11.50	11.20	10.50	10.20	9.80	9.70	9.50	10.34	0.77
	Apr. 2026	11.40	10.80	10.60	10.20	9.90	9.40	9.10	10.20	0.81
	Jun. 2026	10.80	10.50	10.10	9.70	9.30	8.80	8.10	9.61	0.96
	Sep. 2026	11.80	10.20	9.80	9.50	9.20	8.40	8.20	9.59	1.21
TDS (ppm)	Oct. 2025	261.00	284.00	334.00	308.00	256.00	316.00	414.00	310.43	53.89
	Dec. 2025	254.00	258.00	294.00	301.00	311.00	335.00	324.00	296.71	30.99
	Feb. 2026	227.00	229.00	241.00	283.00	275.00	301.00	343.00	271.29	42.51
	Apr. 2026	284.20	288.68	328.96	336.79	347.98	374.83	362.52	331.99	34.68
	Jun. 2026	313.44	318.37	362.80	371.43	383.77	413.39	399.82	366.15	38.25
	Sep. 2026	239.03	257.50	264.68	273.92	265.71	291.36	322.13	273.48	26.67
Electrical conductivity (µS/cm)	Oct. 2025	489.00	553.00	627.00	619.00	511.00	657.00	748.00	600.57	90.08
	Dec. 2025	448.00	476.00	492.00	535.00	574.00	582.00	636.00	534.71	66.87
	Feb. 2026	392.00	385.00	387.00	388.00	394.00	425.00	628.00	428.43	89.06
	Apr. 2026	501.27	532.60	550.50	598.61	642.25	651.20	711.62	598.29	74.82
	Jun. 2026	552.83	587.38	607.13	660.19	708.32	718.19	784.82	659.84	82.52
	Sep. 2026	431.90	487.30	524.23	537.57	588.87	637.08	668.89	553.69	83.50
Phenol (ug/l)	Oct. 2025	9.740	13.640	34.250	36.950	40.510	55.210	52.470	34.68	17.52
	Dec. 2025	3.333	3.205	3.974	4.615	4.038	7.949	11.859	5.57	3.20
	Feb. 2026	10.192	10.705	11.154	11.859	14.359	15.192	17.564	13.00	2.75
	Apr. 2026	4.133	3.974	4.928	5.723	5.007	9.857	14.705	6.90	3.97
	Jun. 2026	10.277	12.615	13.657	15.975	24.602	34.427	44.468	22.29	12.89
	Sep. 2026	4.323	5.254	6.012	6.238	6.810	12.303	19.897	8.69	5.57

2026, while the maximum was recorded at Ura e Institutit in June 2026. A progressive increase in mean conductivity was observed from upstream to downstream, from approximately 469 µS/cm at Tufina to 696 µS/cm at Rinas. The positive correspondence between TDS and EC indicates that the station differences in conductivity were largely associated with changes in the concentration of dissolved ionic material. The elevated

conductivity observed in the lower part of the river is consistent with increased anthropogenic influence. Almost for all samples, the EC value ranges from 300 to 700 µS/cm, classifying the waters as moderate with respect to this parameter (NEA/AKM, 2019). Similar values has previously been reported for the Tirana River, where water quality was affected by domestic wastewater and other discharges associated with the densely populated

river corridor (Hoxha et al., 2022). Note, that this investigation represents the first annual monitoring program along seven stations of the Tirana River over six seasonal campaigns.

The physicochemical results indicate a clear longitudinal gradient along the Tirana River, characterized by decreasing DO and increasing TDS and EC toward the downstream stations. This pattern is particularly relevant because the downstream section from Paskuqa toward Laknas and Rinas is more strongly influenced by urban activities. Previous investigations have also identified anthropogenic wastewater and urban discharges as important factors affecting the Tirana River.

Phenolic compounds were detected at all investigated stations and during all six sampling campaigns, indicating their widespread in the Tirana River. Concentrations ranged from 3.205 to 55.210 $\mu\text{g/L}$, with a mean value of 15.19 $\mu\text{g/L}$. The lowest concentration was recorded at Bathore in December 2025, whereas the maximum concentration occurred at Laknas in October 2025. A pronounced temporal variation was observed. The highest mean concentration of phenols was recorded in October 2025 (34.68 $\mu\text{g/L}$), followed by June 2026 (22.29 $\mu\text{g/L}$). The lowest mean concentration occurred in December 2025 (5.57 $\mu\text{g/L}$), followed by April 2026 (6.90 $\mu\text{g/L}$). The October 2025 results are particularly noteworthy because phenol concentrations increased markedly along the river course, from 9.74 $\mu\text{g/L}$ at Tufinë to 55.21 $\mu\text{g/L}$ at Laknas, followed by a slightly lower value of 52.47 $\mu\text{g/L}$ at Rinas. This pattern is also consistent with the physicochemical evidence of increasing anthropogenic influence toward the downstream stations. Phenolic compounds can enter aquatic systems from a variety of sources, including domestic and industrial wastewater, petroleum-related activities, production of resins and polymers, dyes, pharmaceutical activities, pesticides and degradation of natural organic matter. Their relatively high water solubility also facilitates their transport within aquatic systems. The observed concentrations in the Tirana River are higher than the concentrations generally reported for uncontaminated natural waters. Shehi et al. (2025) reported that natural waters may contain approximately 0.01–2.0 $\mu\text{g/L}$ phenol, while concentrations in unpolluted waters are often below 0.02 mg/L (20 $\mu\text{g/L}$). Their study of surface-water ecosystems in the Tirana area also demonstrated widespread phenol occurrence and associated the contamination primarily

with urban wastewater. Phenolic concentrations in the present study were substantially lower than the very high concentrations reported for heavily contaminated industrial surface waters (Yan et al., 2018). The detected concentrations indicate a water body contaminated with phenols and suggest continued monitoring for this group of organic pollutants. Phenol and related compounds can affect aquatic organisms, although toxicity depends strongly on the individual compound, exposure duration, species and environmental conditions. Available experimental data show considerable variation in toxicity thresholds among aquatic organisms. It is also important to note that phenol itself is not currently listed as an EU Water Framework Directive priority substance with a specific EQS in Annex I of Directive 2008/105/EC.

The connection between physicochemical data and phenol concentrations

The heatmap revealed a clear spatial gradient along the Tirana River. The lowest values of EC, TDS, and phenol concentrations were observed at the upstream station (Tufina), whereas the highest values occurred at the downstream stations of Laknas and Rinas (Figure 4). Electrical conductivity increased from approximately 469 $\mu\text{S cm}^{-1}$ at Tufina to 696 $\mu\text{S cm}^{-1}$ at Rinas, while TDS increased from approximately 263 mg/L to 361 mg/L. A similar arrangement was observed for phenol concentrations, which increased from an annual average of approximately 7 $\mu\text{g/L}$ at Tufina to more than 26 $\mu\text{g/L}$ at Rinas. These results indicate progressive accumulation of dissolved substances and phenolic contaminants along the river course and suggest increasing anthropogenic influence in the urban and industrialized sections of the watershed.

The correlation matrix demonstrates strong positive relationships between EC, TDS, and phenol concentrations. Phenol levels showed a strong positive association with both EC and TDS, indicating that phenolic contamination increased simultaneously with dissolved ionic and solid loads. Conversely, dissolved oxygen exhibited negative correlations with EC, TDS, and phenol concentrations, suggesting deterioration of water quality in areas affected by higher pollutant inputs. These relationships support the fact that phenolic contamination is associated with increasing anthropogenic pressures along the river (Figure 5).

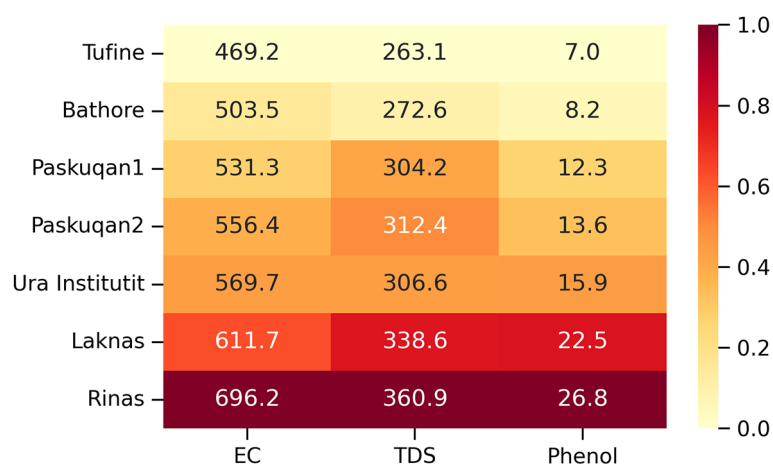


Figure 4. Heatmap illustrating the spatial distribution of EC, TDS, and phenol concentrations at the seven monitoring stations along the Tirana River for one year measurements

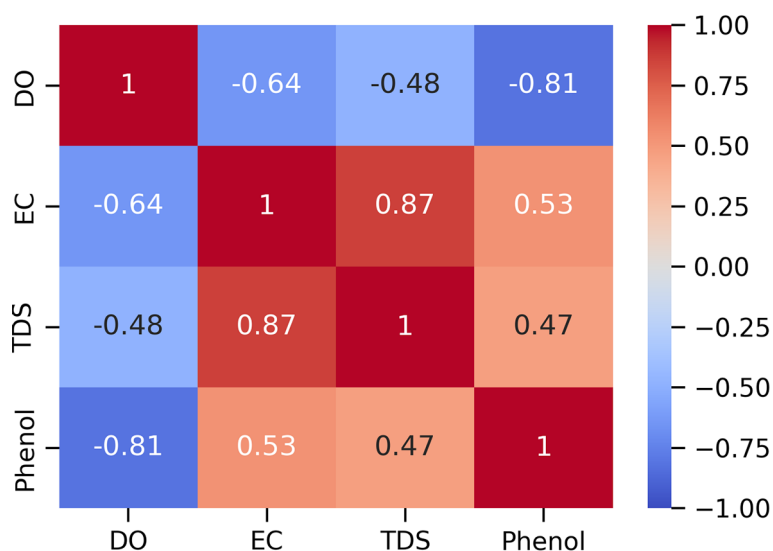


Figure 5. Pearson correlation matrix for dissolved oxygen, electrical conductivity, total dissolved solids, and phenol concentrations measured along the Tirana River

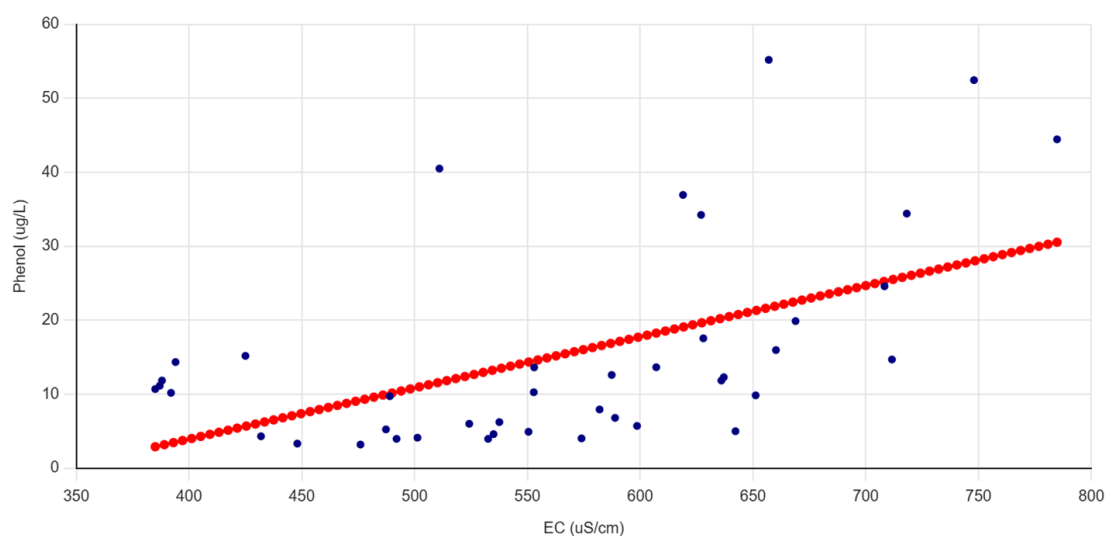


Figure 6. Relationship between phenol concentration and electrical conductivity

A positive relationship was observed between electrical conductivity and phenol concentrations. Phenol levels tended to increase with increasing EC values, indicating that areas characterized by elevated ionic content also exhibited higher phenolic contamination. The coefficient of determination (R^2) demonstrates the proportion of variability in phenol concentrations explained by conductivity values. This relationship suggests that conductivity may serve as a useful indicator of pollution intensity and anthropogenic impact within the Tirana River catchment (Figure 6).

CONCLUSIONS

The one-year monitoring study demonstrated the variability in the physicochemical characteristics and phenolic contamination of the Tirana River. Dissolved oxygen concentrations ranged from 6.80 to 11.80 mg/L, while TDS, and electrical conductivity varied between 227.00–414.00 mg/L and 385–784.82 $\mu\text{S}/\text{cm}$, respectively. The pH values ranged from 7.17 to 9.12, indicating predominantly neutral to moderately alkaline conditions throughout the investigated period. The differences between stations were characterized generally by decreasing dissolved oxygen and increasing TDS and electrical conductivity toward the downstream stations. This pattern suggests increasing influence of anthropogenic inputs along the river course, particularly in the Laknas–Rinas section. This fact indicates the influence of hydrological conditions, runoff and seasonal changes in the transport of suspended material. Total phenolic concentrations were detected at all investigated stations and during all sampling campaigns, ranging from 3.205 to 55.210 $\mu\text{g}/\text{L}$. The highest concentration was recorded at Laknas (downstream) in October 2025, while relatively high concentrations were also observed in the downstream section (Laknas and Rinas) during June 2026. The frequent downstream enrichment of phenols, together with increasing TDS and conductivity and decreasing dissolved oxygen, indicates a broader pattern of anthropogenic pressure rather than an isolated contamination event. These results show that the Tirana River is subject of intense pollution. Continued monitoring is recommended for the institutions, particularly in the Laknas–Rinas section, together

with source-oriented investigations. Future studies should include analyses of other compounds, hydrocarbons, pesticides, nutrients and other priority contaminants to provide a more comprehensive assessment of the river's ecological and chemical status.

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