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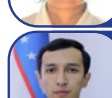
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SPATIOTEMPORAL TRENDS IN WATER QUALITY ALONG THE TASHKENT URBAN REACH OF THE CHIRCHIK RIVER: A PAIRED MONITORING ANALYSIS FOR 2017–2024

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Abstract: This study evaluates spatial and temporal changes in water quality along the Tashkent urban reach of the Chirchik River based on paired upstream and downstream monitoring observations conducted during 2017–2024. Annual mean values derived from quarterly observations were analyzed for total suspended solids (TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD₅), ammonium nitrogen (NH₄-N), nitrite nitrogen (NO₂-N), nitrate nitrogen (NO₃-N), and phosphate. Spatial enrichment was assessed from the difference between downstream and upstream mean values, while temporal trends were evaluated using the Mann–Kendall statistic and Sen’s slope. The strongest spatial signals were observed for COD and phosphate: mean downstream COD was approximately 59% higher than upstream, while phosphate concentrations were about 5.2 times higher. Downstream NO₂-N showed a significant increasing trend (Sen’s slope $\approx +0.0109$ mg/L/year; Kendall $\tau \approx 0.79$; $p \approx 0.006$), and phosphate also increased significantly ($\approx +0.0149$ mg/L/year; $\tau \approx 0.69$; $p \approx 0.018$). COD exhibited a positive downstream slope of about $+0.75$ mg/L/year, although it did not reach statistical significance over the eight-year period. TSS showed an episodic pattern: a significant increase was observed upstream, whereas the 2022 downstream maximum reflected a short-term sediment event rather than a sustained monotonic trend. The results indicate that organic matter and phosphorus provide the clearest signals of enrichment within the urban reach, while nitrogen species exhibit contrasting transformation pathways. Therefore, paired-site trend analysis provides more diagnostic information than evaluating individual concentrations or isolated exceedances in particular years.

Keywords: Chirchik River; water quality; urban river; COD; nutrients; phosphate; nitrite; Mann–Kendall; Sen’s slope.

Annotatsiya: Ushbu tadqiqot 2017–2024-yillarda yuqori va quyi oqimda olib borilgan juft monitoring kuzatuvlari asosida Chirchiq daryosining Toshkent shahar uchastkasida suv sifatining makoniy va vaqt bo'yicha o'zgarishlarini baholaydi. Har chorak kuzatuvlaridan hisoblangan yillik o'rtacha qiymatlar umumiy muallaq moddalar (TSS), kislorodga kimyoviy ehtiyoj (COD), kislorodga biokimyoviy ehtiyoj (BOD₅), ammoniy azoti (NH₄-N), nitrit azoti (NO₂-N), nitrat azoti (NO₃-N) va fosfat bo'yicha tahlil qilindi. Makoniy boyish quyi va yuqori oqimdagi o'rtacha qiymatlar farqi, vaqt tendensiyalari esa Mann–Kendall statistikasi va Sen qiyaligi yordamida baholandi. Eng kuchli makoniy signallar COD va fosfatda kuzatildi: quyi oqimdagi

o'rtacha COD yuqori oqimdagidan qariyb 59% yuqori, fosfat miqdori esa taxminan 5,2 baravar katta bo'ldi. Quyi oqimdag $\text{NO}_2\text{-N}$ sezilarli o'suvchi trendni ko'rsatdi (Sen qiyaligi $\approx +0,0109$ mg/L/yil; Kendall $\tau \approx 0,79$; $p \approx 0,006$), fosfat ham sezilarli oshdi ($\approx +0,0149$ mg/L/yil; $\tau \approx 0,69$; $p \approx 0,018$). COD quyi oqimda $+0,75$ mg/L/yil ijobiy qiyalikni ko'rsatgan bo'lsa-da, sakkiz yillik davrda statistik ahamiyatlilikka yetmadi. TSS epizodik xususiyatga ega bo'lib, yuqori oqimda sezilarli oshdi, quyi oqimdag 2022-yil maksimumi esa qisqa muddatli cho'kindi hodisasini aks ettirdi. Natijalar organik moddalar va fosfor shahar uchastkasidagi boyishning eng yaqqol signallari ekanini, azot shakllari esa turlicha transformatsiya yo'llarini namoyon etishini ko'rsatdi. Shu sababli juft kuzatuv punktlari bo'yicha trend tahlili alohida konsentratsiyalar yoki ayrim yillardagi me'yor oshishlariga qaraganda ko'proq diagnostik axborot beradi.

Kalit so'zlar: Chirchiq daryosi; suv sifati; shahar daryosi; COD; biogen moddalar; fosfat; nitrit; Mann–Kendall; Sen qiyaligi.

Аннотация: В данном исследовании на основе парных мониторинговых наблюдений, проведённых в верхнем и нижнем течении в 2017–2024 гг., оцениваются пространственные и временные изменения качества воды на городском участке реки Чирчик в пределах Ташкента. На основе квартальных наблюдений были проанализированы среднегодовые значения общего содержания взвешенных веществ (TSS), химического потребления кислорода (COD), биохимического потребления кислорода (BOD_5), аммонийного азота ($\text{NH}_4\text{-N}$), нитритного азота ($\text{NO}_2\text{-N}$), нитратного азота ($\text{NO}_3\text{-N}$) и фосфатов. Пространственное обогащение оценивалось по разнице средних значений между нижним и верхним течением, а временные тенденции — с использованием статистики Манна–Кендалла и наклона Сена. Наиболее выраженные пространственные сигналы выявлены для COD и фосфатов: среднее значение COD в нижнем течении было примерно на 59% выше, чем в верхнем, а содержание фосфатов — примерно в 5,2 раза выше. В нижнем течении $\text{NO}_2\text{-N}$ показал значимый возрастающий тренд (наклон Сена $\approx +0,0109$ мг/л/год; Kendall $\tau \approx 0,79$; $p \approx 0,006$), также значительно увеличивалась концентрация фосфатов ($\approx +0,0149$ мг/л/год; $\tau \approx 0,69$; $p \approx 0,018$). COD в нижнем течении демонстрировал положительный наклон около $+0,75$ мг/л/год, однако за восьмилетний период наблюдений этот тренд не достиг статистической значимости. Изменения TSS носили эпизодический характер: в верхнем течении отмечался значительный рост, тогда как максимум 2022 года в нижнем течении отражал кратковременное событие, связанное с наносами. Полученные результаты показывают, что органическое вещество и фосфор являются наиболее выраженными индикаторами обогащения городского участка, тогда как формы азота характеризуются различными путями трансформации. В связи с этим трендовый анализ по парным пунктам наблюдений даёт более информативную диагностическую оценку, чем анализ отдельных концентраций или единичных случаев превышения нормативов.

Ключевые слова: река Чирчик; качество воды; городская река; COD; биогенные вещества; фосфат; нитрит; Манн–Кендалл; наклон Сена.

INTRODUCTION

Rivers passing through urban areas can undergo substantial changes in hydrological regime and water quality under the combined effects of urbanization, municipal and industrial wastewater, agricultural drainage, and sediment transport [1,2,3]. Organic pollution is reflected in chemical oxygen demand (COD) and biochemical oxygen demand (BOD_5), whereas nitrogen and phosphorus inputs can increase nutrient concentrations and eutrophication pressure. Total suspended solids (TSS), in turn, are closely linked to discharge, erosion, and sediment remobilization [4,5].

Transformations of nitrogen species are particularly important in urban rivers. Ammonium nitrogen ($\text{NH}_4\text{-N}$) entering with wastewater may be oxidized to nitrite ($\text{NO}_2\text{-N}$) and subsequently to nitrate ($\text{NO}_3\text{-N}$), while dilution, biological uptake, and denitrification simultaneously modify their spatial distribution [5]. Consequently, a combined assessment of TSS, COD, BOD_5 , nitrogen species, and phosphate provides a more complete representation of hydrochemical conditions than interpretation of a single indicator [6,7,8].

The Chirchik River is an important water resource of the Tashkent Region and supports water supply, irrigation, industry, and aquatic ecosystems [9]. Because the basin passes through intensively urbanized, industrial, and agricultural areas, anthropogenic pressure can increase in its middle and lower reaches [10,11]. Previous studies have reported pronounced spatial and temporal differences in BOD, COD, ammonium, nitrite, and nitrate along the Chirchik River, including higher levels of nitrogen compounds and organic pollution downstream of industrialized and urbanized areas [12].

The aim of this study is to evaluate spatial and temporal changes in water quality along the Tashkent urban reach of the Chirchik River using paired upstream and downstream monitoring data for 2017–2024. TSS, COD, BOD_5 , $\text{NH}_4\text{-N}$, $\text{NO}_2\text{-N}$, $\text{NO}_3\text{-N}$, and phosphate were analyzed, and differences between the two sites were combined with Mann–Kendall trend testing and Sen's slope estimation. Particular attention was given to the interconnected transformation pathway $\text{NH}_4\text{-N} \rightarrow \text{NO}_2\text{-N} \rightarrow \text{NO}_3\text{-N}$.

REVIEW OF LITERATURE ON THE SUBJECT

The literature on urban streams consistently shows that water-quality changes are controlled by both external

inputs and in-stream processes. The “urban stream syndrome” framework describes recurring hydrochemical and ecological responses to urban development [1], while research on nonpoint phosphorus and nitrogen pollution emphasizes the importance of diffuse watershed inputs [2]. Studies of urban nitrogen fluxes further demonstrate that retention and transformation within the river network can substantially modify the signal measured at a monitoring point [3].

Methodological studies also show that COD, BOD, and nitrogen indicators respond differently to organic matter composition and biogeochemical conditions [4], whereas TSS can be strongly influenced by event-scale sediment hysteresis and hydrological variability [5]. Recent work on nitrogen dynamics in point-source-influenced streams confirms that observed ammonium, nitrite, and nitrate concentrations reflect a balance among source inputs, oxidation, uptake, and dilution [6]. Regional studies in Central Asia and Uzbekistan similarly emphasize the need to interpret water quality together with basin-scale hydrological and anthropogenic conditions [7,11].

However, the paired comparison of water entering and leaving the Tashkent urban reach over the same observation period has received less attention. Such a design can characterize the cumulative signal of the urban reach, but it cannot by itself attribute the observed difference to one source because wastewater discharges, tributaries, collectors, dilution, biological processes, sediment interactions, and discharge variability may all contribute. Combining this spatial comparison with a long-term nonparametric trend analysis provides a way to distinguish persistent tendencies from isolated anomalous events [13, 15]. This combined paired-site and trend-based diagnostic approach defines the focus of the present study.

RESEARCH METHODOLOGY

Water-quality observations were obtained from two official monitoring points located upstream and downstream of the Tashkent urban reach of the Chirchik River (Figure 1). The upstream point is located at 69.375083°E, 41.262167°N, and the downstream point at 69.231866°E, 41.168635°N. Seasonal observations are available for 2017–2024, including water temperature, TSS, COD, BOD₅, NH₄-N, NO₂-N, NO₃-N, and phosphate. The present analysis focuses on hydrochemical differences and recent temporal tendencies rather than repeating a separate meteorological trend analysis for the basin (Figure 1).

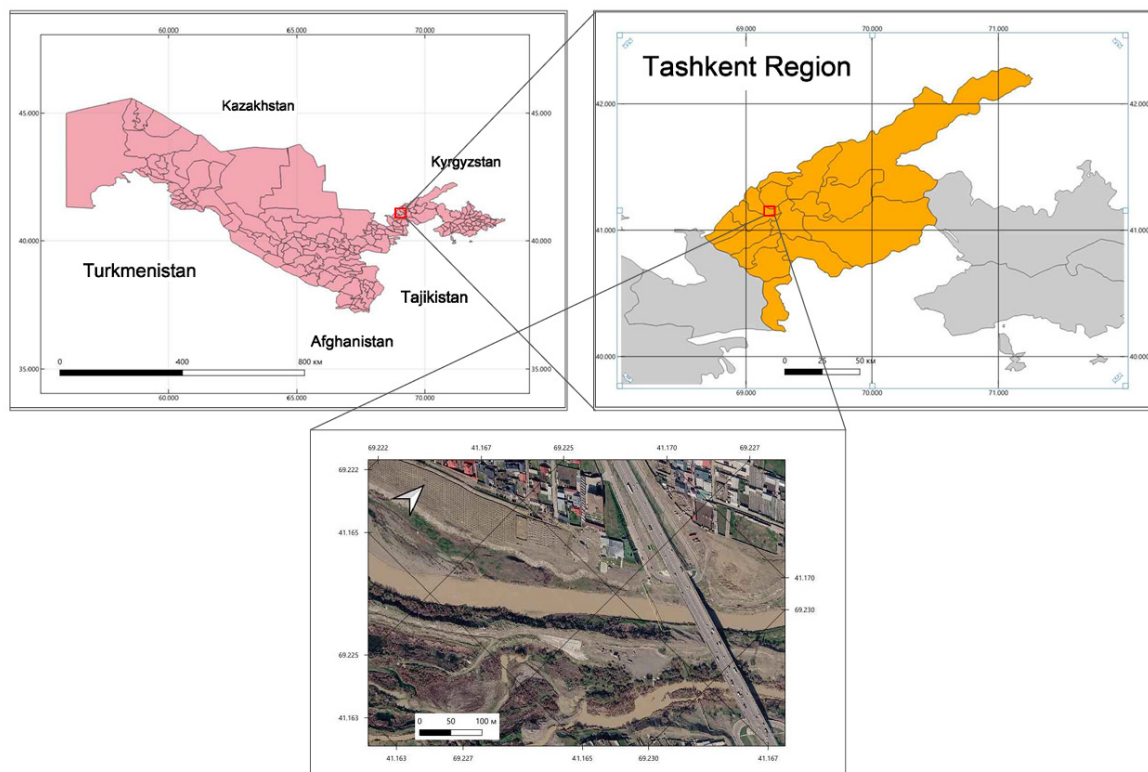


Figure 1. Upstream and downstream monitoring points on the Chirchik River¹

Measurements were available by season (winter, spring, summer, and autumn). For each component and site,

¹ Source: Author's own work.

the source dataset contained annual mean, minimum, and maximum values derived from the seasonal observations. Annual means were used as the common temporal unit to provide a consistent eight-year comparison. Missing seasonal observations were not artificially imputed; the annual statistics were retained in the form reported in the source data. Seven indicators were included in the quantitative analysis, while water temperature was treated as contextual information because the principal objective was hydrochemical rather than meteorological (Table 1).

Table 1. Mean spatial differences between upstream and downstream sites, 2017–2024 (concentration, mg/L)²

Parameter	Upstream mean	Downstream mean	Δ Downstream–Upstream	Relative change
TSS	65.600	62.537	–3.062	–4.7%
COD	5.880	9.363	+3.482	+59.2%
BOD ₅	1.674	1.725	+0.051	+3.1%
NH ₄ –N	0.461	0.261	–0.200	–43.4%
NO ₂ –N	0.096	0.078	–0.018	–19.1%
NO ₃ –N	1.646	1.548	–0.099	–6.0%
PO ₄	0.013	0.069	+0.056	+421.7%

For each parameter, spatial enrichment at the downstream site was characterized using the eight-year site means:

$$R = 100 \cdot (C_{\text{down}} - C_{\text{up}}) / C_{\text{up}} \quad (1)$$

where C_{up} and C_{down} are the upstream and downstream mean concentrations, respectively. Positive R indicates enrichment downstream, whereas negative R indicates a lower mean downstream concentration. This metric is descriptive and does not independently identify a causal source because tributaries, collectors, in-stream transformations, sediment dynamics, and measurement variability may also contribute to the observed difference.

Monotonic temporal trends were evaluated using Kendall rank correlation between year and concentration, which for a simple time series is equivalent in interpretation to the Mann–Kendall trend test. The magnitude of the trend was estimated with Sen's slope as the median of all pairwise annual slopes:

$$\beta = \text{median} [(C_j - C_i) / (t_j - t_i)], \quad j > i \quad (2)$$

The significance level was set at $\alpha = 0.05$. Because each record contained only eight annual values, p -values were interpreted cautiously and considered together with trend direction, magnitude, differences between sites, and the original seasonal minimum–maximum information. This robust nonparametric approach is preferable to a simple least-squares slope when isolated values, such as the 2022 TSS event, can strongly influence a linear regression.

ANALYSIS AND RESULTS

COD provides the clearest indicator of the difference in organic load between the paired sites. The eight-year mean increased from 5.88 mg/L upstream to 9.36 mg/L downstream, corresponding to a mean difference of 3.48 mg/L or approximately 59% (Table 1). The two series were relatively similar in 2017–2018, but from 2019 onward the downstream series became distinctly higher. Downstream annual mean COD reached 11.9 mg/L in 2021, 10.3 mg/L in 2022, and 12.6 mg/L in 2023, whereas upstream values generally remained within 4.8–7.0 mg/L. Seasonal maxima downstream reached 15.6 mg/L in both 2022 and 2023, showing that annual means can conceal short periods of elevated organic load (Figure 2).

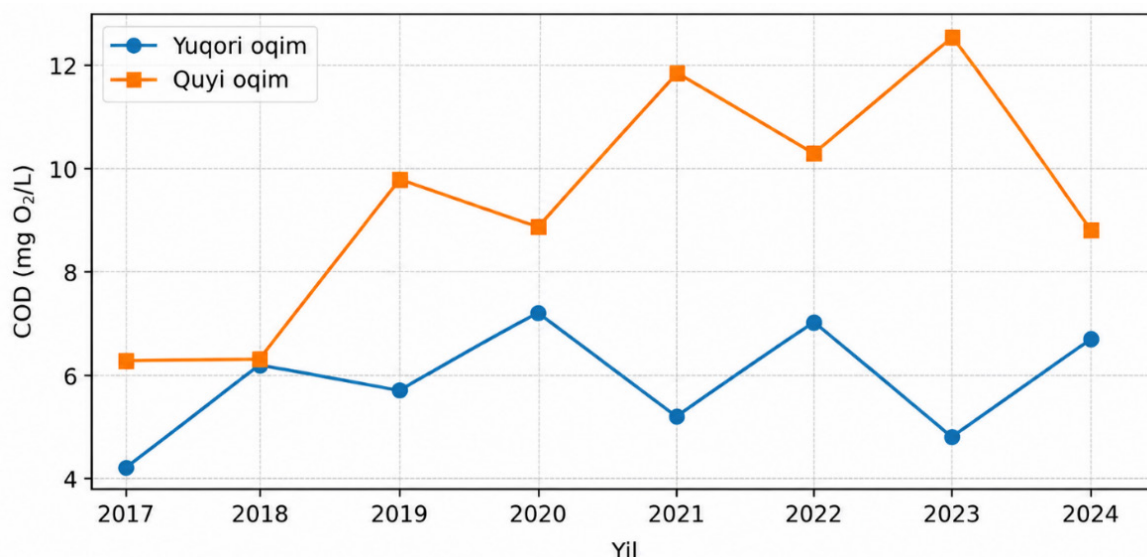


Figure 2. Annual mean COD at the upstream and downstream monitoring points, 2017–2024³

The downstream COD trend was positive, with Sen's slope of approximately +0.75 mg/L/year and Kendall $\tau \approx 0.47$, but the p-value ($p \approx 0.105$) did not meet the $\alpha = 0.05$ significance criterion. It should therefore be described as an increasing tendency rather than a statistically confirmed monotonic trend. The short eight-year series and the decrease from 12.6 mg/L in 2023 to 8.8 mg/L in 2024 reduce formal statistical significance despite the persistent spatial difference between sites.

BOD₅ was considerably more stable. Mean values were approximately 1.67 mg/L upstream and 1.73 mg/L downstream, a difference of only about 3%. During 2017–2023, annual means at both sites were generally around 1.5–1.7 mg/L; the principal deviation occurred in 2024, when the upstream and downstream means increased to approximately 2.29 and 2.40 mg/L, respectively. The small spatial difference indicates that the urban-reach signal for oxygen-demanding substances is expressed more clearly by COD than by BOD₅, because COD includes a broader fraction of oxidizable organic and inorganic matter (Table 2).

Table 2. Summary of organic-load indicators and downstream trend statistics⁴

Parameter	Upstream mean	Downstream mean	Downstream Sen's slope	Kendall p
COD	5.88	9.36	+0.750 mg/L/year	0.105
BOD ₅	1.67	1.73	+0.010 mg/L/year	0.111

The divergence between COD and BOD₅ is diagnostically important. An increase in COD without a comparable increase in BOD₅ may indicate a larger contribution of less readily biodegradable organic compounds, additional chemically oxidizable substances, or differences in dilution and transformation conditions downstream. Direct source attribution would require more detailed indicators such as dissolved organic carbon, industrial tracers, and continuous dissolved-oxygen observations; nevertheless, the paired monitoring data identify COD as a priority variable for downstream surveillance.

Phosphate showed the largest proportional downstream enrichment among all analyzed components. The eight-year mean was approximately 0.013 mg/L upstream and 0.069 mg/L downstream, corresponding to a concentration ratio of about 5.2 and a relative increase of approximately 422%. The temporal separation between sites became particularly clear after 2019 (Figure 3).

³ Source: Author's own work.

⁴ Source: Author's own work.

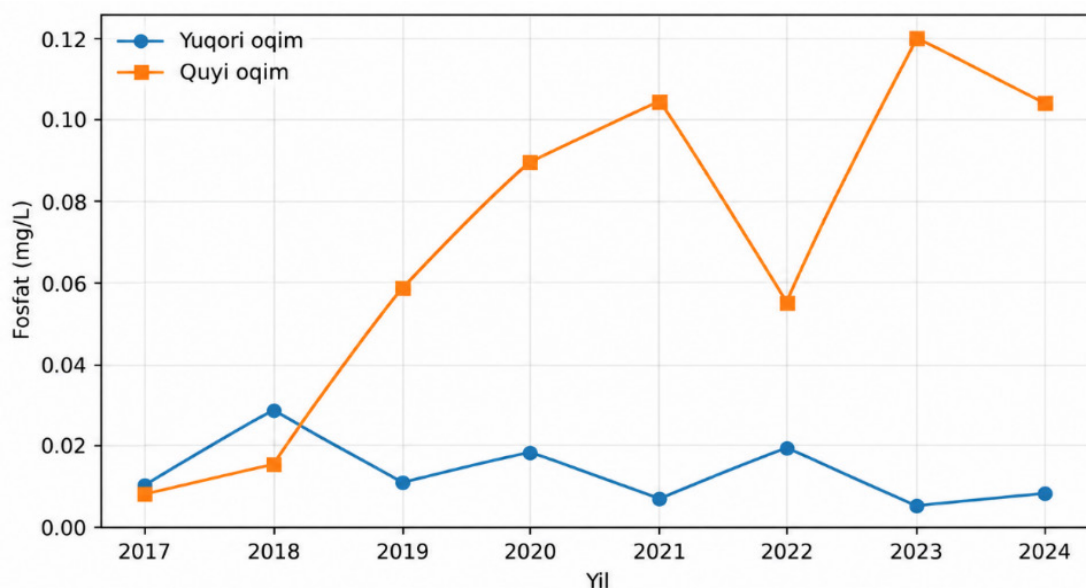


Figure 3. Annual mean phosphate concentration at the paired monitoring points⁵

Downstream annual mean phosphate increased from 0.058 mg/L in 2019 to 0.089 mg/L in 2020 and 0.104 mg/L in 2021. After a temporary decrease in 2022, it reached 0.121 mg/L in 2023 and remained high at 0.104 mg/L in 2024, while upstream means remained very low. The downstream phosphate series showed a statistically significant increasing trend, with Sen's slope $\approx +0.0149$ mg/L/year, Kendall $\tau \approx 0.69$, and $p \approx 0.018$. Seasonal records support this result: downstream phosphate reached 0.178 mg/L in winter 2021 and values of approximately 0.153 mg/L were recorded in 2023–2024. The dataset does not include chlorophyll-a or algal biomass and therefore cannot demonstrate that algal blooms occurred; however, the persistent spatial contrast and significant upward trend justify treating phosphorus as a priority ecological-monitoring parameter.

Nitrogen species exhibited contrasting spatial behavior. Mean $\text{NH}_4\text{-N}$ was lower downstream (0.261 mg/L) than upstream (0.461 mg/L), and mean $\text{NO}_3\text{-N}$ was also slightly lower downstream (1.55 versus 1.65 mg/L). In contrast, $\text{NO}_2\text{-N}$ displayed an important temporal shift. During 2017–2020, downstream means were below upstream values, but from 2021 the two series converged, and by 2024 downstream $\text{NO}_2\text{-N}$ reached 0.109 mg/L while the upstream value was approximately 0.01 mg/L (Figure 4).

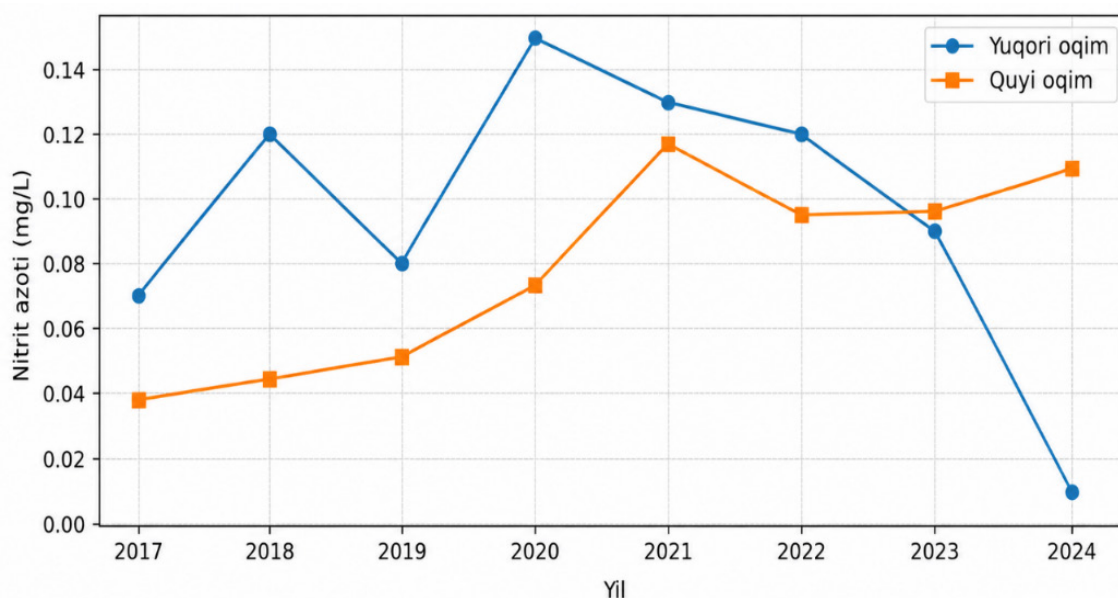


Figure 4. Annual mean nitrite nitrogen ($\text{NO}_2\text{-N}$) at the upstream and downstream sites⁶

⁵ Source: Author's own work.

⁶ Source: Author's own work.

The downstream $\text{NO}_2\text{-N}$ trend was the strongest statistically confirmed signal among the nitrogen indicators: Sen's slope $\approx +0.0109$ mg/L/year, Kendall $\tau \approx 0.79$, and $p \approx 0.006$. No significant trend was observed upstream. This divergence is consistent with changing conditions of nitrogen transformation within the urban reach, where ammonium oxidation can generate nitrite and subsequent oxidation can convert nitrite to nitrate. The balance is influenced by dissolved oxygen, temperature, residence time, and substrate availability, none of which can be fully resolved from annual means alone (Table 3).

Table 3. Mean concentrations of nitrogen species and downstream trend statistics⁷

Parameter	Upstream mean	Downstream mean	Downstream Sen's slope, mg/L/year	p
$\text{NH}_4\text{-N}$	0.461	0.261	+0.0300	0.061
$\text{NO}_2\text{-N}$	0.096	0.078	+0.0109	0.006
$\text{NO}_3\text{-N}$	1.646	1.548	-0.0064	0.615

The lower downstream mean of $\text{NH}_4\text{-N}$ may indicate transformation or dilution rather than the absence of nitrogen loading. Similarly, the lack of a strong nitrate increase does not contradict active nitrification because nitrate may also be affected by dilution, plant uptake, tributary inflows, and seasonal flushing. The source records show a downstream nitrate maximum of approximately 3.05 mg/L in summer 2021, while most annual means remained near 1–2 mg/L. Nitrogen status should therefore be interpreted as an interconnected system of NH_4 , NO_2 , and NO_3 rather than as three independent indicators.

From a management perspective, the $\text{NO}_2\text{-N}$ series demonstrates why temporal trends and spatial means must be evaluated together. Early low downstream values keep the eight-year downstream mean below the upstream mean, but the time series nevertheless contains a strong and significant positive trend. A long-period mean alone would therefore obscure the recent direction of change.

TSS showed the greatest interannual variability and is the most difficult indicator to interpret through a simple urban-reach gradient. The eight-year means were similar—65.6 mg/L upstream and 62.5 mg/L downstream—but they combined very different temporal patterns. A major downstream event occurred in 2022, with an annual mean of 164.7 mg/L and a seasonal maximum of 560 mg/L; downstream annual means subsequently fell to 36.6 mg/L in 2023 and 33.5 mg/L in 2024. In contrast, upstream TSS rose sharply in the last two years, reaching 118.2 mg/L in 2023 and 176.6 mg/L in 2024, with a 2024 maximum of 624.5 mg/L (Figure 5).

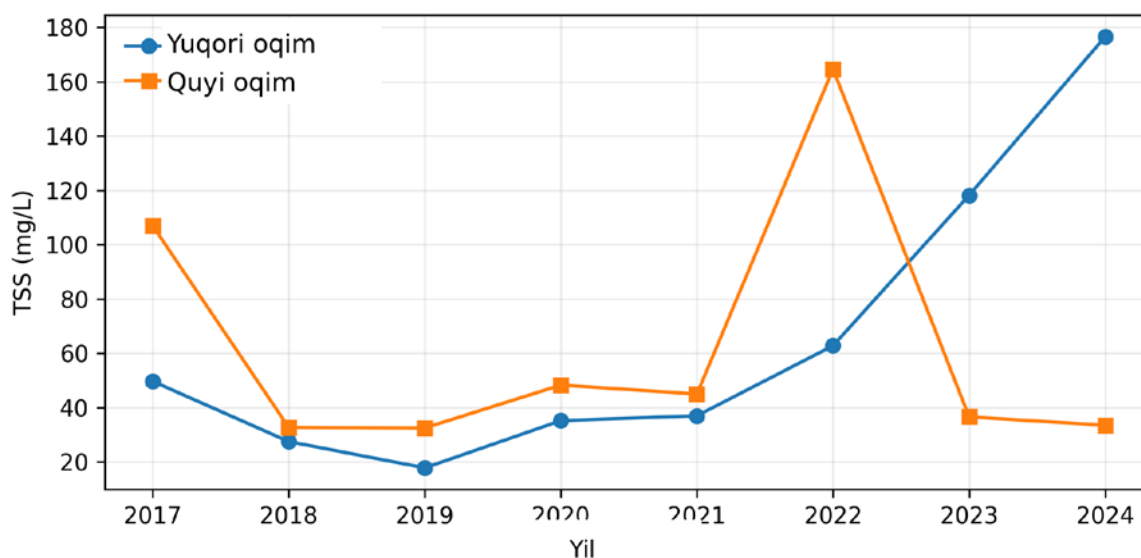


Figure 5. Annual mean TSS at the upstream and downstream monitoring points⁸

The upstream TSS series had a significant positive monotonic trend (Sen's slope $\approx +16.2$ mg/L/year; Kendall $\tau \approx 0.64$; $p \approx 0.031$), whereas the downstream series showed almost no monotonic trend (Sen's slope ≈ -1.7 mg/L/year; $p \approx 0.905$). This contrast demonstrates that TSS cannot be used as a simple proxy for wastewater influence in this reach. Suspended sediment responds strongly to erosion, rainfall and snowmelt, tributary sediment inputs, channel

⁷ Source: Author's own work.

⁸ Source: Author's own work.

works, and changes in flow transport capacity. The 2022 downstream maximum is therefore better interpreted as an event-scale signal rather than evidence of continuous deterioration. Future analysis should combine TSS with daily discharge, high-frequency turbidity measurements, and sediment-rating relationships to distinguish hydrologically driven sediment transport from point-source solids.

An integrated spatial comparison separates the analyzed indicators into three functional groups. The first group shows strong downstream enrichment: phosphate (+422%) and COD (+59%). The second group is comparatively stable on the eight-year mean scale: BOD₅ (+3%), TSS (−5%), and nitrate (−6%). The third group has lower downstream long-term means—ammonium (−43%) and nitrite (−19%)—but the long-term average for nitrite masks its recent significant upward trend. This classification shows that “urban impact” is not a single direction of change, but the combined outcome of source inputs and in-stream transformations (Figure 6).

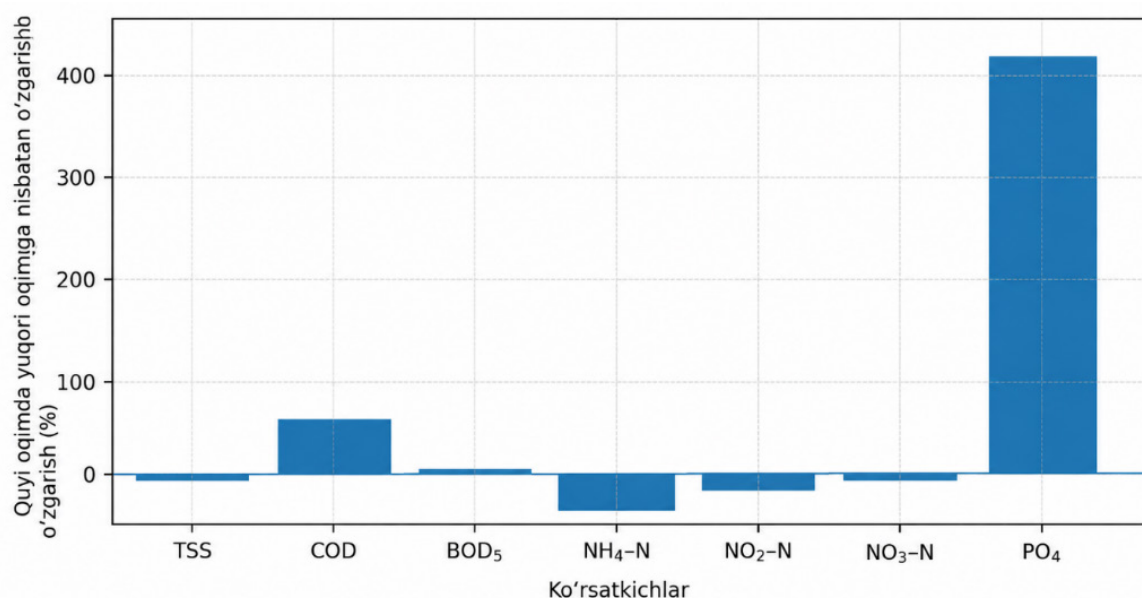


Figure 6. Relative change in the eight-year downstream mean compared with the upstream mean⁹

Phosphate is the clearest indicator of persistent nutrient enrichment because both its mean concentration and temporal trend increase strongly downstream. COD provides the strongest signal of organic loading because its downstream mean is persistently elevated even though the short trend record does not reach formal significance. Nitrite provides a different warning: the long-term mean does not indicate enrichment, but the time series shows a significant upward direction. Together, these three indicators represent complementary dimensions of water-quality change—level, spatial contrast, and temporal direction.

The paired-site design also helps reduce the risk of misinterpreting natural hydrological variability. If sediment concentrations rise simultaneously at both sites during a high-sediment period, the change is more likely to reflect basin-scale or flow-related processes than a source confined to the urban reach. Conversely, if downstream phosphate increases while upstream phosphate remains near background levels, the likelihood of a local contribution within the reach becomes greater. Formal source apportionment would still require discharge-weighted loads, tributary and collector monitoring, and land-use information, but the paired design provides an effective screening basis for prioritizing those investigations.

Normalizing Sen's slopes by the mean concentration highlights indicators changing rapidly relative to their typical level. Downstream phosphate and nitrite are particularly prominent, while COD shows a moderate positive tendency. The pattern is scientifically consistent with the source dataset: nutrient and organic inputs may respond to wastewater composition and urban drainage, while nitrate and BOD₅ are simultaneously modified by biological processing. However, the eight-year record is too short to justify linear extrapolation of these rates into the future (Figure 7).

9 Source: Author's own work.

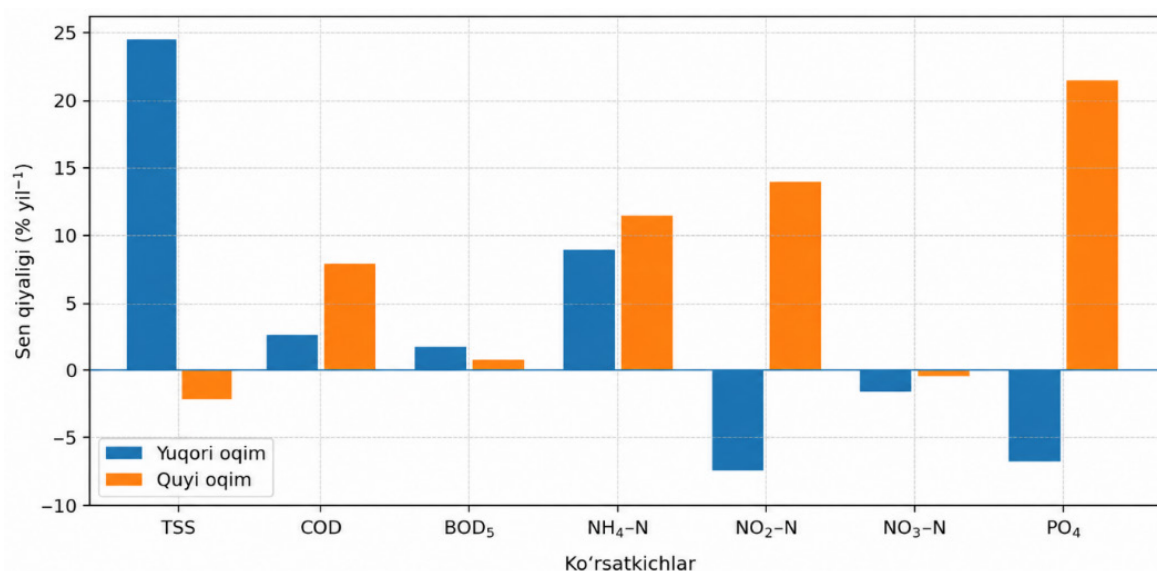


Figure 7. Sen's slopes normalized by the mean concentration at each monitoring site (%/year)¹⁰

The results also emphasize the difference between concentration and pollutant load. Concentration may increase because pollutant mass input rises, river discharge falls, or both occur simultaneously; conversely, stronger dilution can keep concentration stable even when mass loading increases. The available source records do not contain simultaneous site-specific discharge measurements for each chemical observation, so a load-based trend analysis could not be performed. Synchronizing chemical sampling with discharge measurements is therefore an important requirement for future work.

A further limitation is monitoring frequency. Quarterly sampling is sufficient to identify broad seasonal and annual contrasts but can miss short-lived pollution events and make annual means sensitive to individual observations. The TSS series illustrates this limitation directly. Higher-frequency monitoring would also improve interpretation of nitrogen transformation because ammonium, nitrite, and nitrate may change over much shorter time scales as oxygen and temperature vary. Continuous sensing of dissolved oxygen, electrical conductivity, turbidity, and temperature, combined with monthly laboratory nutrient analysis, would substantially improve process attribution.

Despite these limitations, two conclusions are robust within the available data. First, the downstream site shows a persistent signal of organic and phosphorus enrichment relative to the upstream point. Second, downstream nitrite and phosphate show significant recent increasing trends that are not mirrored upstream. These results support targeted investigation of urban and collector inflows and low-flow periods, while also cautioning against attributing episodic sediment anomalies directly to wastewater sources.

CONCLUSIONS AND SUGGESTIONS

Paired monitoring of the Chirchik River upstream and downstream of Tashkent during 2017–2024 revealed distinct patterns of change in organic matter, nutrients, and suspended sediment. The strongest spatial enrichment was observed for phosphate: the downstream mean was approximately 5.2 times the upstream mean. Mean downstream COD was about 59% higher than upstream, providing a persistent urban-reach signal that was not similarly evident in the BOD₅ or nitrate means.

Nonparametric trend analysis added an important temporal dimension. Downstream NO₂-N increased significantly at approximately +0.0109 mg/L/year, and downstream phosphate increased at approximately +0.0149 mg/L/year. COD also showed a positive downstream tendency of +0.75 mg/L/year, although the eight-year record was insufficient for conventional statistical significance. TSS behaved differently: a significant upward trend occurred upstream, while the downstream series was dominated by a major 2022 event rather than by a persistent monotonic tendency. The combined spatial and temporal approach therefore separates persistent hydrochemical enrichment from episodic sediment dynamics more effectively than a single concentration-based assessment.

For management of the Tashkent urban reach, COD, phosphate, and nitrite should receive the highest analytical priority, particularly during low-flow periods when dilution is limited. Additional sampling is recommended after major runoff events. TSS should be monitored together with high-frequency turbidity and discharge data to

¹⁰ Source: Author's own work.

distinguish basin-derived sediment pulses from local solid discharges. Because downstream phosphate repeatedly reached levels associated with increased eutrophication potential, future monitoring should also include biological-response indicators such as chlorophyll-a, diel dissolved-oxygen cycles, and periphyton where feasible.

Future studies should integrate simultaneous river discharge measurements, discharge-weighted pollutant loads, continuous dissolved-oxygen and turbidity records, and source-specific monitoring of municipal, industrial, tributary, and collector inflows. Such integration would extend the present concentration-based diagnostic approach toward a quantitative pollutant mass balance and a more defensible separation of causal source contributions.

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