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SEASONAL ASSESSMENT OF KORANG RIVER SURFACE WATER QUALITY USING WATER QUALITY INDEX (WQI) AND GIS-BASED SPATIAL ANALYSIS

[1]Muhammad Bilal, [*2]Muhammad Taimoor Mustafa, [3]Khayam Shahzad, [4]Muhammad Saad Ali, [5]Muhammad Ali Raza, [6]Muhammad Ishtiaq

[1]Supervisor & Lecturer, Department of Civil Engineering, HITEC University, Taxila, 47808, Pakistan.
[2]Co-supervisor & Lecturer, Department of Civil Engineering, HITEC University, Taxila, 47808, Pakistan.
[3]Undergraduate Student, Department of Civil Engineering, HITEC University, Taxila, 47808, Pakistan.
[4]Undergraduate Student, Department of Civil Engineering, HITEC University, Taxila, 47808, Pakistan.
[5]Undergraduate Student, Department of Civil Engineering, HITEC University, Taxila, 47808, Pakistan.
[6]Undergraduate Student, Department of Civil Engineering, HITEC University, Taxila, 47808, Pakistan.
[1]engineerbilal408@gmail.com, [*2]taimoor.mustafa@hitecuni.edu.pk,
[3]khayamshahzad840@gmail.com, [4]saadalimughal1641@gmail.com, [5]ar665740@gmail.com,
[6]muhammadishtiaqm527@gmail.com,

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Corresponding Author: *

Muhammad Taimoor Mustafa

Abstract

Water quality of fresh water basins in Pakistan is being degraded because of human actions. Surface water quality at Baroha, Shahpur and Korang Road which are the main tributaries of river Korang and Rawal Lake were investigated during December and April and compare with (NSDWQ 2010). And then Water quality index was calculated and analyze using GIS base spatial analysis. 18 Physico-chemical parameters were analyzed during both seasons. The study showed that the pollution level increases at Shahpur and Korang road as compared to baroha because of discharge of domestic wastes, poultry waste, agricultural activities and solid waste dumping directly into the sites. Turbidity was found to be higher in the april due to runoff after rainfall. On the other hand, EC, TDS and alkalinity decreased gradually due to the dilution effect. Dissolved oxygen was found low at other two sites then baroha in December and remain within the permissible in April suggesting pollution stress at those reaches. WQI values indicated Baroha Bridge as Good in water quality and Shahpur and Korang Road as Poor to Very Poor water quality areas. GIS based mapping of stations revealed that pollution hotspots towards downstream.

1-INTRODUCTION

Water is one of the most vital natural resources, fundamental to human health, food security, socio-economic well-being, and the sustenance of all life on Earth [1]. Fresh water resources are among the most valuable assets of any human civilization, playing a basic role in the overall economy of a country due to the certain demand of water in all sectors of life. Rivers are a significant component of the natural environment, having many values such as economic, aesthetic, and ecological, as well as serving as sources for water consumption and conveying wastewater discharges. However, the declining water quality of these ecological systems has threatened their sustainability [2].

Freshwater resources in developing countries are facing escalating pressure from rapid urbanization, industrialization, agricultural expansion, and improper disposal of domestic and solid wastes [3]. The presence of contaminants in natural fresh water continues to be one of the most important environmental issues in many areas of the world, particularly in developing countries where several populations are far away from potable water supply [4]. Surface water is a vibrant system containing living as well as non-living, organic, inorganic, soluble, and insoluble substances, so its quality is likely to change day by day [5]. Any change in quality will disturb the natural equilibrium and render it unfit for designated uses [6].

Natural processes and anthropogenic activities both influence surface water quality [7]. Aquatic resources, owing to their capacity to dilute and detoxify contaminants, are being used as dumping sites for sewage, industrial, and domestic waste [8]. Effluents of low quality are discharged unchecked into natural water bodies, resulting in further degradation of their water quality, threatening human health and crop yields in many cases [9]. Pollution of rivers first influences their physico-chemical characteristics, then affects the aquatic community, disturbs the food web, and ultimately proves harmful to human health [10]. Water quality of natural rivers and streams is becoming poor due to the mixing of large quantities of untreated wastewater, making it obligatory to investigate and formulate policies for water quality management that maintain acceptable standards for irrigation and community usage [11].

In Pakistan, the quality of rivers draining both urban and peri-urban catchments have deteriorated significantly over recent decades, raising serious concerns regarding public health, aquatic biodiversity, and the long-term sustainability of drinking-water supplies [12]. The major sources of surface water contamination include toxic chemicals, elevated nutrients from geogenic processes such as atmospheric deposition, rock weathering and erosion, as well as anthropogenic inputs such as urban waste, industrial effluents, and agricultural activities [7]. Farm chemicals and heavy metals further affect water quality, which is also deteriorated by unscientific waste disposal and improper waste management [13].

The Korang River is one of the most significant tributaries feeding Rawal Lake — the principal drinking-water reservoir serving the twin cities of Islamabad and Rawalpindi [14]. Originating in the Margalla Hills, the Korang River accumulates water from several small streams and nullahs traversing its catchment before draining into Rawal Lake. Pollution in the Korang River therefore has a direct bearing on Rawal Dam water quality, downstream aquatic ecosystems, and the broader catchment, all of which play a critical role in regional water management, irrigation, and biodiversity conservation [15].

Apart from surface water degradation, the entire Rawalpindi District is also experiencing serious groundwater depletion with studies showing that only 39.36% of the District has high to very high recharge potential, mainly in the central and north-eastern alluvial regions, and the rapid urbanization and impermeable land cover is also affecting the natural replenishment of groundwater [16].

The Water Quality Index is a widely accepted and effective tool that aggregates multiple physico-chemical parameters into a single numerical value, providing a holistic representation of water quality [17]. It reflects the composite influence of different water quality parameters and defines the feature of water in the form of an index number for any intended use. Several WQI formulations have been proposed in the literature, including the Weighted

Arithmetic Index method, which provides a straightforward and interpretable framework for assessment [18]. WQIs have been frequently used in the estimation of potable water quality, though very limited studies have been carried out to evaluate water for agricultural purposes [19].

Coupled with the WQI, Geographic Information Systems provide a powerful platform for visualizing, mapping, and interpreting spatial patterns of water quality across a river catchment [20]. Tools such as ArcGIS are increasingly used in environmental studies to map pollution gradients and identify hotspots of degraded water quality, enabling decision-makers to visualize complex datasets in an intuitive manner [21].

The specific objective of this study was to assess the key physico-chemical parameters of water quality in dry and wet seasons along the Korang River, compute Water Quality Index at each sampling station and classify the water quality status, compare the observed water quality parameters with the National Standards for Water Quality of Drinking Water of Pakistan, and analyze the spatial variation of water quality along the river corridor by ArcGIS techniques and determine the pollution hotspots along the river corridor.

2-STUDY AREA

The study area covers an approximately 21 km stretch of the Korang River, extending from Baroha Bridge upstream down to Rawal Lake. Three sampling stations were selected to capture upstream-to-downstream variation in water quality:

Table 1: *Overview of selected sampling stations along the Korang River study area.*

Station ID	Longitude	Latitude	Location	Administrative Area
S1	73°14'31.87"E	33°48'5.72"N	Baroha Bridge	Near Murree, Rawalpindi District
S2	73°12'1.47"E	33°44'55.08"N	Shahpur Barakahu	Islamabad
S3	73° 9'45.82"E	33°43'11.18"N	Korang Road	Islamabad

Figure 1 Station Point 1 (S1): Baroha Bridge (Near Murree in the Rawalpindi District)

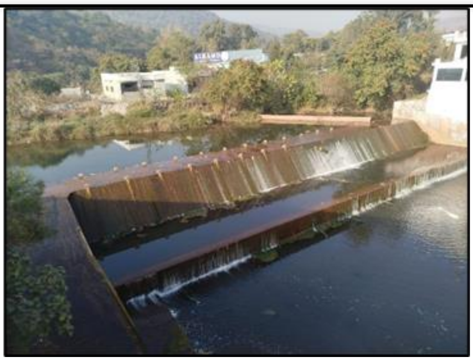


Figure 2 Station Point 2 (S2): Shahpur Barakahu Islamabad.

Figure 3 Station Point 3 (S3): Korang Road Islamabad.

This is a particularly important stretch as it represents the transition from the relatively pristine hill catchment to a heavily urbanized corridor leading up to the river's discharge into Rawal Lake. The river runs along the northern boundary of the Islamabad Capital Territory, draining agricultural lands, peri-urban settlements and industrial and domestic activities in pockets. Intensive poultry farming along the catchment's banks, agricultural runoff in the monsoon and post-monsoon season, and the constant discharge of untreated domestic sewage from nearby settlements all affect the catchment.

3-MATERIALS AND METHODS

3.1-Sample Collection

Surface water samples were collected from the three sampling stations during two distinct seasons:

- **Dry Season**: December
- **Wet Season**: April

Samples were collected in clean 1.5 liter plastic bottles following standard grab-sampling protocols, properly labeled, preserved, and transported to the laboratory for analysis within the recommended holding times.

3.2-Selection and Analysis of Parameters

A total of Eighteen physico-chemical parameters were analyzed to characterize the surface water quality during both seasons. The parameters included:

Table 2: ***Physico-chemical parameters analyzed for surface water quality characterization and their corresponding reference methods.***

Parameter	Reference Methods
Color	Sensory Evaluation
Electrical Conductivity	Standard Method 2510-B, APHA, 24th Edition
pH	Standard Method 4500-H^+ B, APHA, 24th Edition
Turbidity	Standard Method 2130B, APHA, 24th Edition
Alkalinity (as $CaCO_3$)	Standard Method 2320-B, APHA, 24th Edition

Bicarbonates	Standard Method 2320-B, APHA, 24th Edition
Calcium	Standard Method 3500-Ca^{2+}-B, APHA, 24th Edition
Carbonates	Standard Method 2320-B, APHA, 24th Edition
Chlorides	Standard Method 4500-Cl--B, APHA, 24th Edition
Total Hardness	Standard Method 2340-C, APHA, 24th Edition
Magnesium	Standard Method 3500-Mg^{+2}-B, APHA, 24th Edition
Potassium	Standard Method 3500-K-B, APHA, 24th Edition
Sodium	Standard Method 3500-Na-B, APHA, 24th Edition
Sulphate	Standard Method 4500-SO42--B, APHA, 24th Edition
Nitrate (N)	Standard Method 4500-NO_3-B, APHA, 24th Edition
TDS	Apha, 24th Edition
TSS	EPA Method 160.2
Dissolved Oxygen	Standard Method 2540-D, APHA, 24th Edition

3.3-Water Quality Index Calculation

The Water Quality Index (WQI) method of Weighted Arithmetic was used to calculate the overall water quality status for each station. WQI is a scale to determine overall quality of water based on the values of the water quality parameters. The WQI is widely used for water pollution detection and evaluation and can be described as a composite effect of various water quality parameters on the overall water quality (Horton, 1965). Like many other indices systems, a water quality index relates a set of water quality parameters to a common scale and aggregates them into a single index using a selected method of calculation [22]. The procedure involves three computational steps:

Step 1 — Quality rating:

For most parameters:

$$Qi = \frac{Vi}{Si} \times 100$$

For pH and DO:

$$Qi = \frac{Vi - Vo}{Si - Vo} \times 100$$

where:

- Vi = observed value of the parameter
- Vo = ideal value (pH = 7, DO = 14.6 mg/L, others = 0)
- Si = standard permissible value

Step 2 — Unit weight:

$$Wi = \frac{K}{Si}, \quad K = \frac{1}{\sum\left(\frac{1}{Si}\right)}$$

Step 3 — Final WQI:

$$WQI = \sum Qi \cdot Wi$$

(since Σ Wi = 1, WQI = Σ (Qi × Wi))

3.4-WQI Classification

The classification of water quality based on WQI values follows [22].

Table 3: ***Water Quality Index (WQI) classification categories, status levels, and corresponding possible usages.***

WQI Range	Water Quality Status	Possible Usages
0 – 25	Excellent	Drinking, irrigation, industrial
26 – 50	Good	Domestic, irrigation, industrial
51 – 75	Fair	Irrigation, industrial
76 – 100	Poor	Irrigation
101 – 150	Very Poor	Restricted use for irrigation
> 150	Unfit for all purposes	Proper treatment required before use

3.5-Reference Standard

The National Standards for Drinking Water Quality prescribed by the Government of Pakistan were used as the benchmark for parameter-wise compliance evaluation.

3.6-GIS-Based Spatial Analysis

ArcGIS was employed to collect, analyze, and visualize spatial data for the study area. The GIS component enabled spatial mapping of water quality parameters and sampling stations, helping to identify spatial variations and pollution hotspots in both dry and wet seasons.

4- RESULTS AND DISCUSSION

4.1-Dry Season Results

Table 4 presents the physico-chemical parameter values obtained during the dry season at the three sampling stations.

Table 4: ***Physico-chemical parameter values obtained during the dry season at sampling stations S1, S2, and S3.***

Parameter	S1	S2	S3	Units	NSDWQ Standard
Color	Colorless	Colorless	Colorless	–	–
Electrical Conductivity	624	577	825	µS/cm	750
pH	7.90	7.97	7.54	–	6.5–8.5
Turbidity	0.76	10.90	14.30	NTU	5
Alkalinity (as $CaCO_3$)	162	162	262	mg/L	NGVS
Bicarbonates	162	162	262	mg/L	NGVS
Calcium	65	61	81	mg/L	NGVS
Carbonates	BDL	BDL	BDL	mg/L	NGVS
Chlorides	40	36	60	mg/L	NGVS
Total Hardness	272	222	312	mg/L	500
Magnesium	27	17	27	mg/L	NGVS
Potassium	1.6	2.4	5.9	mg/L	NGVS
Sodium	15	28	46	mg/L	NGVS
Sulphate	80	65	68	mg/L	250
Nitrate (N)	1.16	0.79	1.02	mg/L	10
TDS	374	317	495	mg/L	1000
TSS	40	50	40	mg/L	NGVS
Dissolved Oxygen	9.00	2.34	0.98	mg/L	–

BDL = Below Detection Limit; NGVS = No Guideline Value Set under NSDWQ

4.2-Wet Season Results

Table 5 presents the physico-chemical parameter values obtained during the wet season at the three sampling stations.

Table 5: ***Physico-chemical parameter values obtained during the Wet season at sampling stations S1, S2, and S3.***

Parameter	S1	S2	S3	Units	NSDWQ Standard
Color	Colorless	Colorless	Colorless	–	–
Electrical Conductivity	626	675	886	µS/cm	750
pH	8.01	8.01	7.83	–	6.5–8.5
Turbidity	BDL	5.93	7.73	NTU	5
Alkalinity (as $CaCO_3$)	242	272	352	mg/L	NGVS
Bicarbonates	242	272	352	mg/L	NGVS
Calcium	85	68	84	mg/L	NGVS
Carbonates	BDL	BDL	BDL	mg/L	NGVS

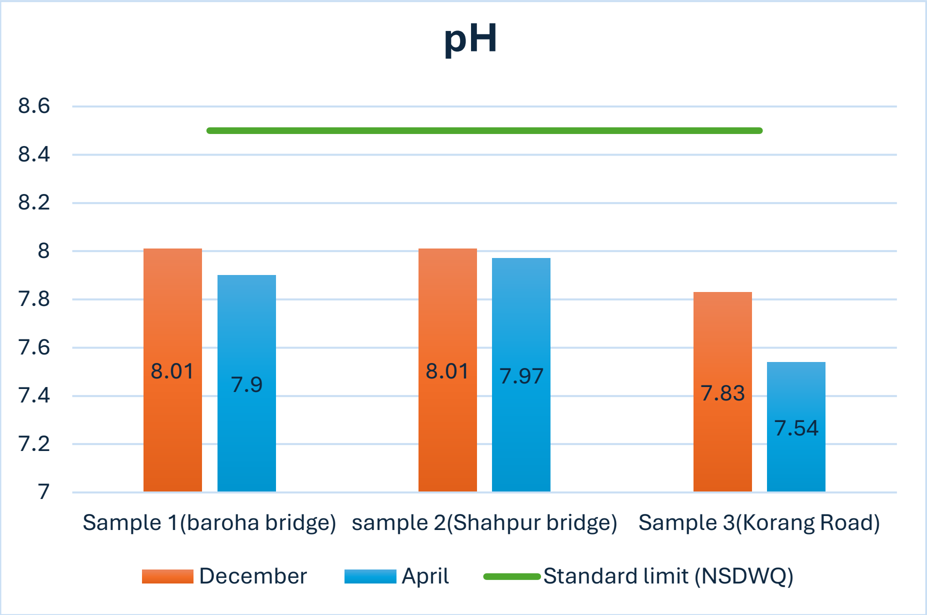
Chlorides	7	19	33	mg/L	NGVS
Total Hardness	252	242	302	mg/L	500
Magnesium	10	17	22	mg/L	NGVS
Potassium	5.8	8.3	12.9	mg/L	NGVS
Sodium	27	43	62	mg/L	NGVS
Sulphate	64	40	53	mg/L	250
Nitrate (N)	1.01	1.87	1.17	mg/L	10
TDS	376	405	532	mg/L	1000
TSS	40	50	40	mg/L	NGVS
Dissolved Oxygen	7.03	7.65	6.48	mg/L	–

BDL = Below Detection Limit; NGVS = No Guideline Value Set under NSDWQ

4.3- Discussion of Key Parameters

4.3.1-PH

In both seasons, pH values at all three stations remained within the NSDWQ permissible range of 6.5–8.5. During the dry season, pH values were 7.90 (S1), 7.97 (S2), and 7.54 (S3), while during the wet season they were 8.01 (S1), 8.01 (S2), and 7.83 (S3). The slightly higher pH in the wet season can be attributed to reduced dissolved CO_2 levels due to dilution and reduced photosynthetic activity. The trends indicate that the river maintained circum-neutral to mildly alkaline conditions throughout the study period.

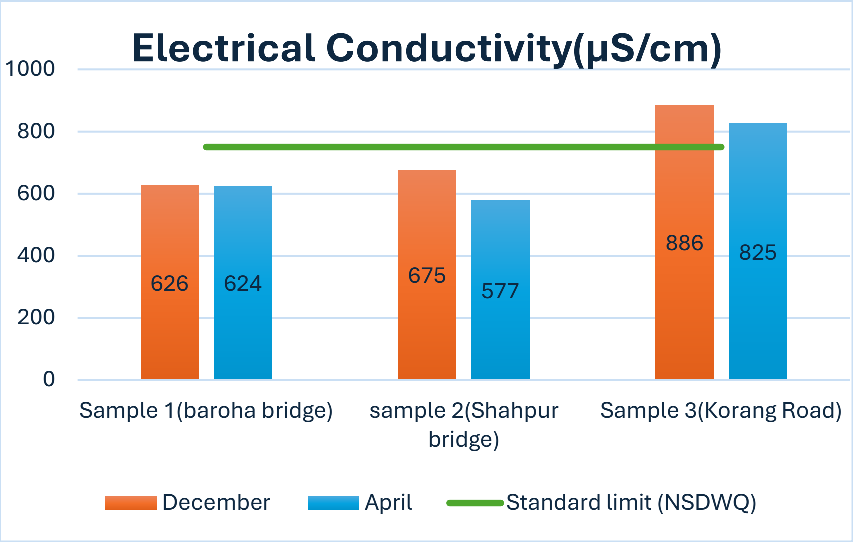


Graph 1 Spatial and seasonal variation of pH levels at sampling stations S1, S2, and S3 compared to the NSDWQ permissible limit.

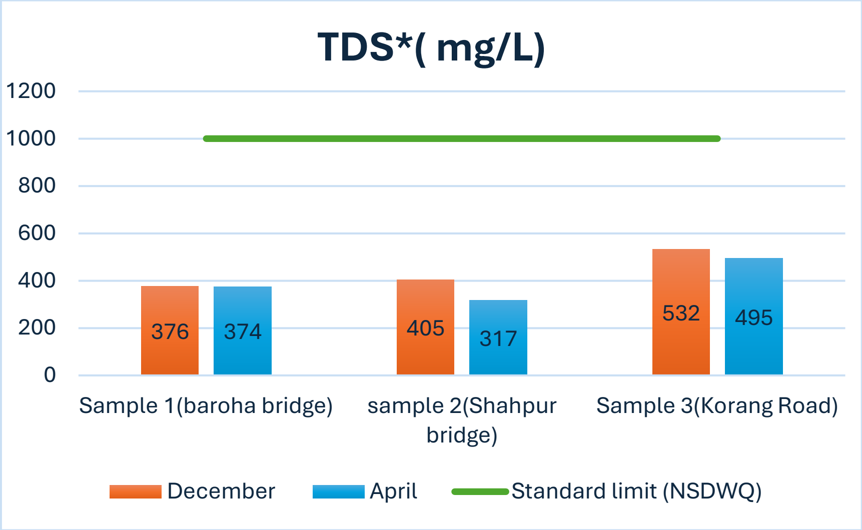
4.3.2-Electrical Conductivity and Total Dissolved Solids

The Electrical Conductivity values indicated a definite increase in conductivity from upstream to downstream, with the dry season values of 624 µS/cm (S1), 577 µS/cm (S2), and 825 µS/cm (S3), and the wet season values of 626 µS/cm (S1), 675 µS/cm (S2), and 886 µS/cm (S3). The downstream station (S3, Korang Road) was consistently above the NSDWQ standard of 750 µS/cm in both seasons, reflecting high levels of pollutant build-up in the downstream reach, mainly from domestic sewage, agricultural runoff and discharges of poultry waste into the river between the midstream and downstream stations.

The spatial pattern was similar for TDS, with dry season concentrations of 374, 317, and 495 mg/L at S1, S2, and S3 respectively, and wet season concentrations of 376, 405, and 532 mg/L at S1, S2, and S3 respectively. The progressive increase in TDS values downstream suggested ionic loading, but all TDS values were below the NSDWQ limit of 1000 mg/L.



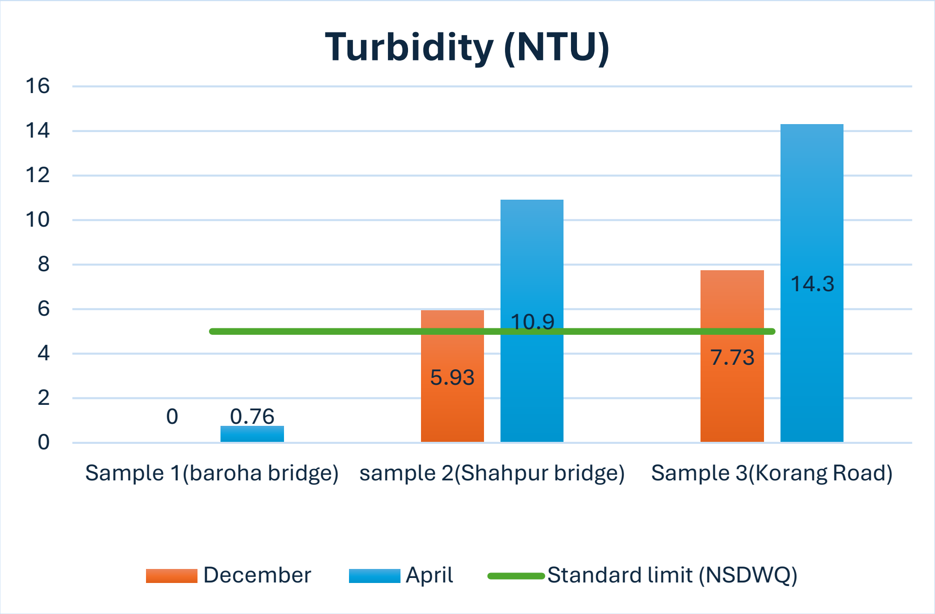
Graph 2 Spatial and seasonal variation of Electrical Conductivity levels at sampling stations S1, S2, and S3 in comparison to the NSDWQ standard limit.



Graph 3 Spatial and seasonal variation of Total Dissolved Solids (TDS) concentrations at sampling stations S1, S2, and S3 in comparison to the NSDWQ standard limit.

4.3.3-Turbidity

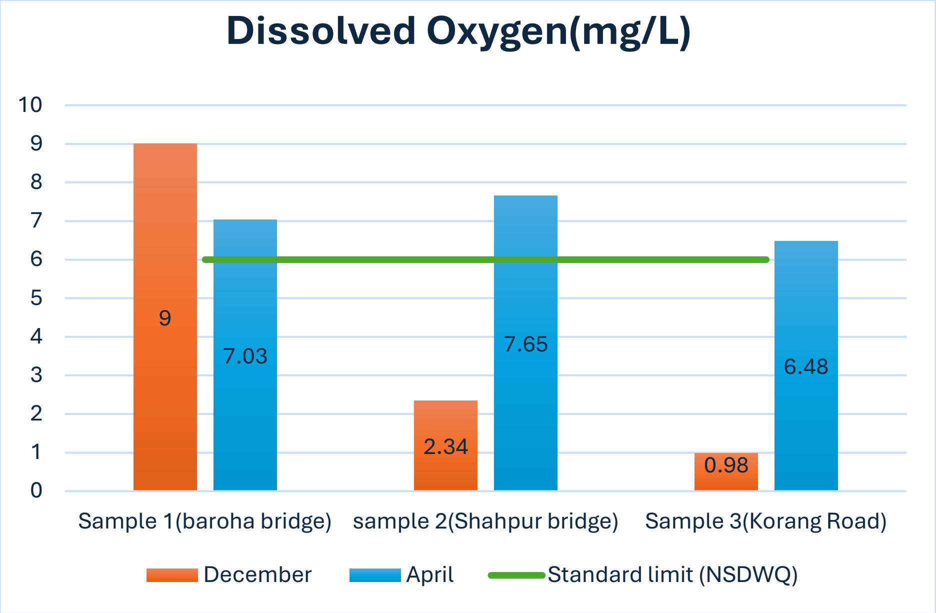
Turbidity exhibited dramatic spatial and seasonal variation. In the dry season, values were 0.76 NTU (S1), 10.9 NTU (S2), and 14.3 NTU (S3), with S2 and S3 exceeding the NSDWQ standard of 5 NTU. In the wet season, turbidity at S1 was below the detection limit, while S2 and S3 recorded 5.93 NTU and 7.73 NTU respectively. The persistently elevated turbidity at the downstream stations is indicative of suspended solids loading from surface runoff, soil erosion, and disturbance of bed sediments associated with urban and agricultural activity.



Graph 4 Spatial and seasonal variation of Turbidity (NTU) at sampling stations S1, S2, and S3 in comparison to the NSDWQ standard limit.

4.3.4-Dissolved Oxygen

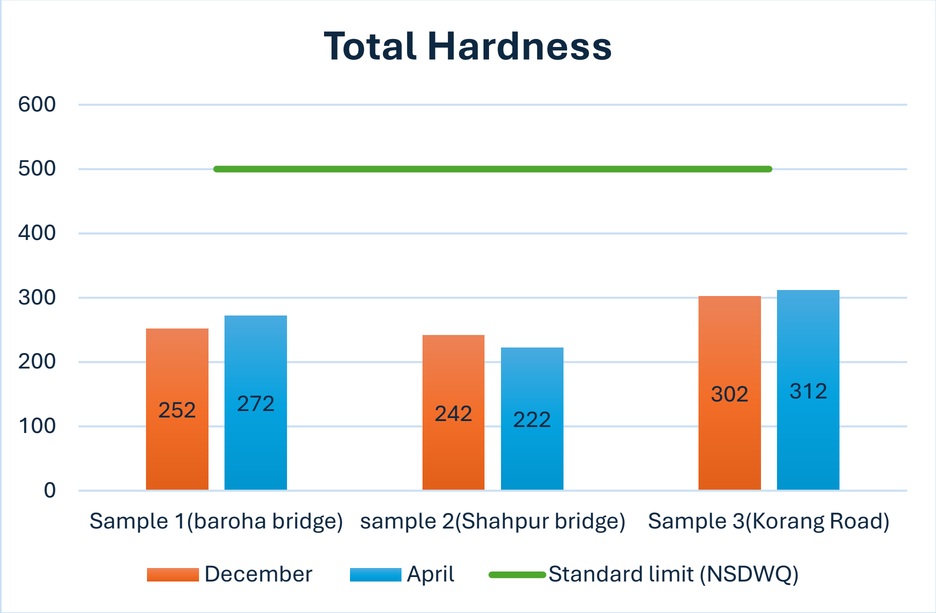
Dissolved Oxygen is one of the most informative indicators of organic pollution. In the dry season, DO was 9.00 mg/L at the upstream station (S1), but dropped dramatically to 2.34 mg/L at Shahpur (S2) and 0.98 mg/L at Korang Road (S3) — both indicating hypoxic conditions consistent with severe organic pollution from domestic wastewater, poultry waste, and solid-waste dumping. During the wet season, DO levels improved across all stations (7.03, 7.65, and 6.48 mg/L), attributable to the re-aeration effect of flowing stormwater and reduced stagnation. Although DO improve during the wet season, the downstream station remained near the lower end of acceptable thresholds, confirming persistent pollution stress at Korang Road.



Graph 5 Spatial and seasonal variation of Dissolved Oxygen (mg/L) concentrations at sampling stations S1, S2, and S3 in comparison to the NSDWQ standard limit.

4.3.5-Total Hardness, Calcium, and Magnesium

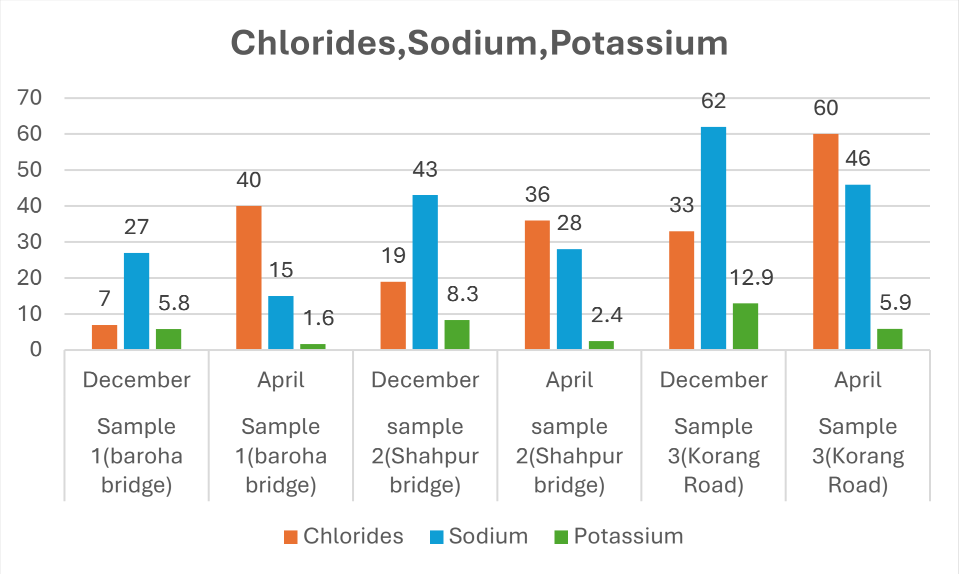
Total hardness values were within the NSDWQ limit of 500 mg/L at all stations in both seasons. Calcium and magnesium concentrations remained moderate, consistent with carbonate-type water typical of the Margalla Hills catchment. Carbonates were below the detection limit at all stations, while bicarbonates dominated — a hallmark of water draining limestone terrain.



Graph 6 Spatial and seasonal variation of Total Hardness (mg/L) at sampling stations S1, S2, and S3 in comparison to the NSDWQ standard limit.

4.3.6-Chlorides, Sodium, and Potassium

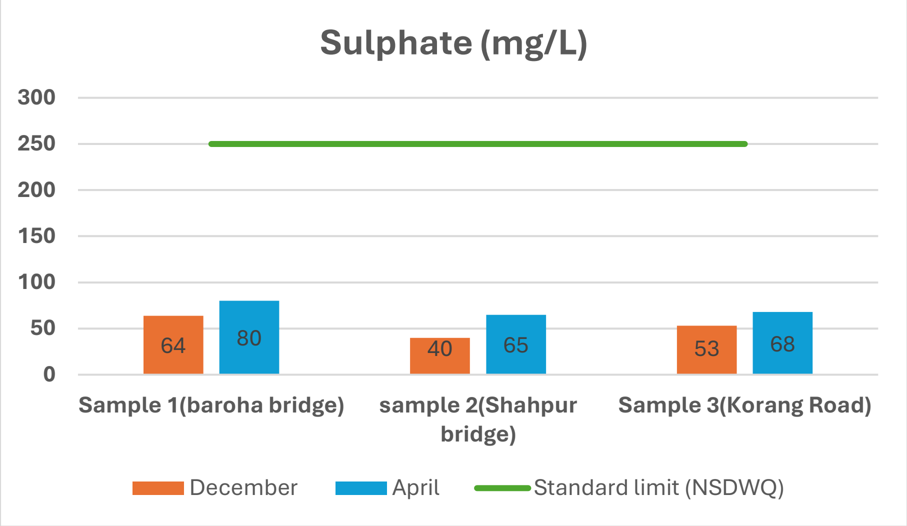
Chlorides and sodium showed clear downstream enrichment, particularly during the wet season: chlorides rose from 7 mg/L (S1) to 33 mg/L (S3), while sodium increased from 27 to 62 mg/L across the same stretch. Potassium also increased from 5.8 mg/L (S1) to 12.9 mg/L (S3) in the wet season. Such patterns are characteristic signatures of domestic sewage and agricultural fertilizer inputs entering the river at the downstream stations.



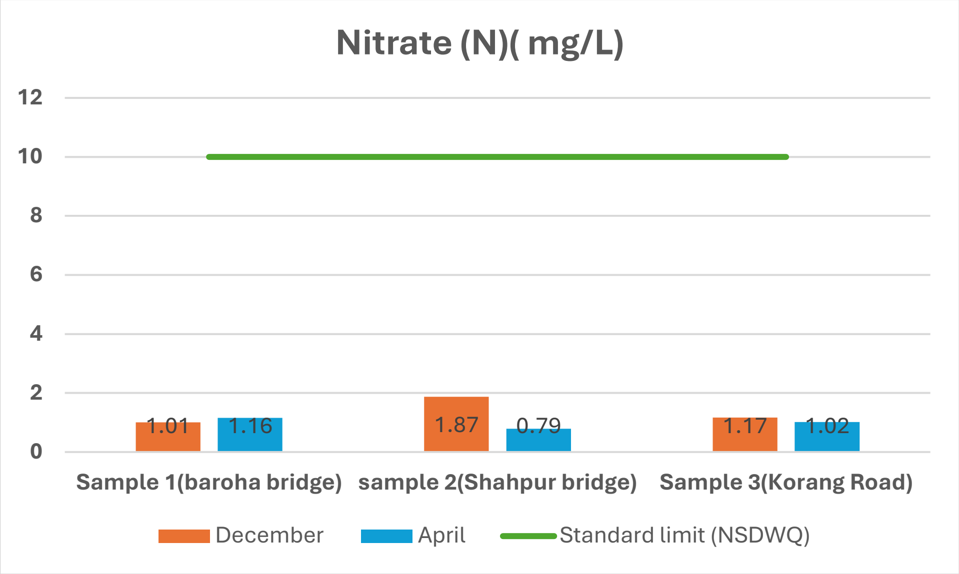
Graph 7 Spatial and seasonal variation of Chlorides, Sodium, and Potassium concentrations (mg/L) at sampling stations S1, S2, and S3.

4.3.7-Sulphate and Nitrate

Sulphate values remained well within the NSDWQ range of 250 mg/L at all stations across both seasons, ranging between 40 and 80 mg/L. Nitrate-N concentrations remained low (0.79–1.87 mg/L), well below the NSDWQ limit of 10 mg/L, suggesting that fertilizer-driven nitrate contamination was not severe at the time of sampling. However, the slightly elevated nitrate value at Shahpur during the wet season (1.87 mg/L) indicates localized agricultural or domestic discharge entering the river at this location.



Graph 8 Spatial and seasonal variation of Sulphate concentrations (mg/L) at samplings stations S1, S2, and S3 in comparison to the NSDWQ standard limit.



Graph 9 Spatial and seasonal variation of Nitrate (N) concentrations (mg/L) at sampling stations S1, S2, and S3 in comparison to the NSDWQ standard limit.

4.3.8-Alkalinity

Alkalinity increased downstream — particularly during the wet season (242 → 352 mg/L) — reflecting increased bicarbonate loading from urban drainage, soil leaching, and possible wastewater inputs. Although NSDWQ does not specify a numerical guideline for alkalinity, the rising trend serves as a useful supplementary indicator of progressive downstream contamination.

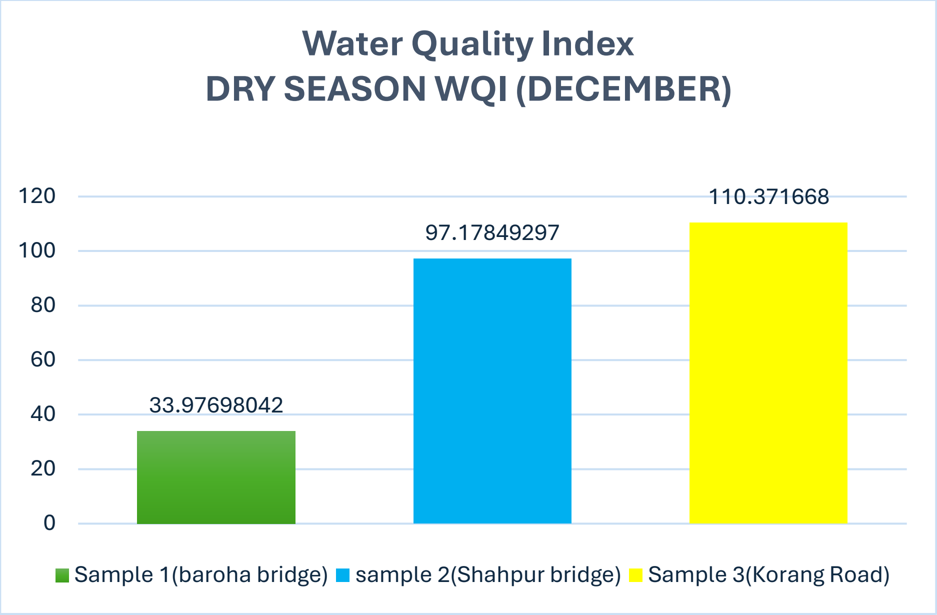
5-Water Quality Index Results

The calculated WQI values for both seasons, with the corresponding water quality classifications, are summarized in Table 6.

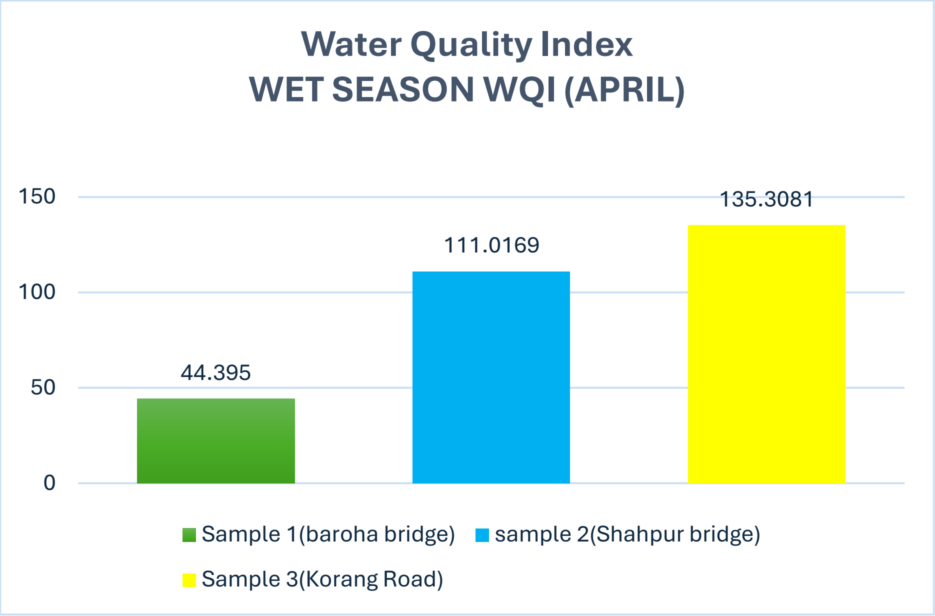
Table 6: *Summary of calculated Water Quality Index (WQI) values and corresponding water quality classifications for both dry and wet seasons across the sampling stations.*

Sampling Station	WQI — Dry Season	Classification	WQI — Wet Season	Classification
S1 — Baroha Bridge	33.97	Good	44.40	Good
S2 — Shahpur	97.18	Poor	111.02	Very Poor
S3 — Korang Road	110.37	Very Poor	135.31	Very Poor

The WQI results clearly indicate that water quality degrades progressively from upstream to downstream along the Korang River corridor. Baroha Bridge (S1) consistently fell within the *good* category during both seasons, with WQI values of 33.97 (dry) and 44.40 (wet). Shahpur (S2) shifted from *Poor* in the dry season (97.18) to *Very Poor* in the wet season (111.02), while Korang Road (S3) was consistently classified as *Very Poor*, with the WQI increasing from 110.37 (dry) to 135.31 (wet).



Graph 10 Water Quality Index (WQI) results for the dry season (December) across the three sampling stations.



Graph 11 Water Quality Index (WQI) results for the Wet season (April) across the three sampling stations.

The generally higher WQI values during the wet season can be attributed to elevated turbidity, EC, sodium, and potassium levels caused by stormwater conveyance of surface pollutants into the river channel. These results confirm that the combined effect of urban runoff, domestic waste discharge, and agricultural activity significantly deteriorates water quality in the downstream corridor of the Korang River.

6-GIS-Based Spatial Analysis

ArcGIS was employed to map the spatial distribution of water quality parameters and WQI values along the Korang River stretch for both seasons. The GIS-based maps clearly delineated pollution hotspots and spatial variation across the three sampling stations.

Dry Season GIS Map: Pollution was found to be concentrated along the Shahpur–Korang Road reach, with very limited pollution observed at Baroha Bridge. The spatial pattern reflects the upstream to downstream pollution gradient as seen by the WQI values.

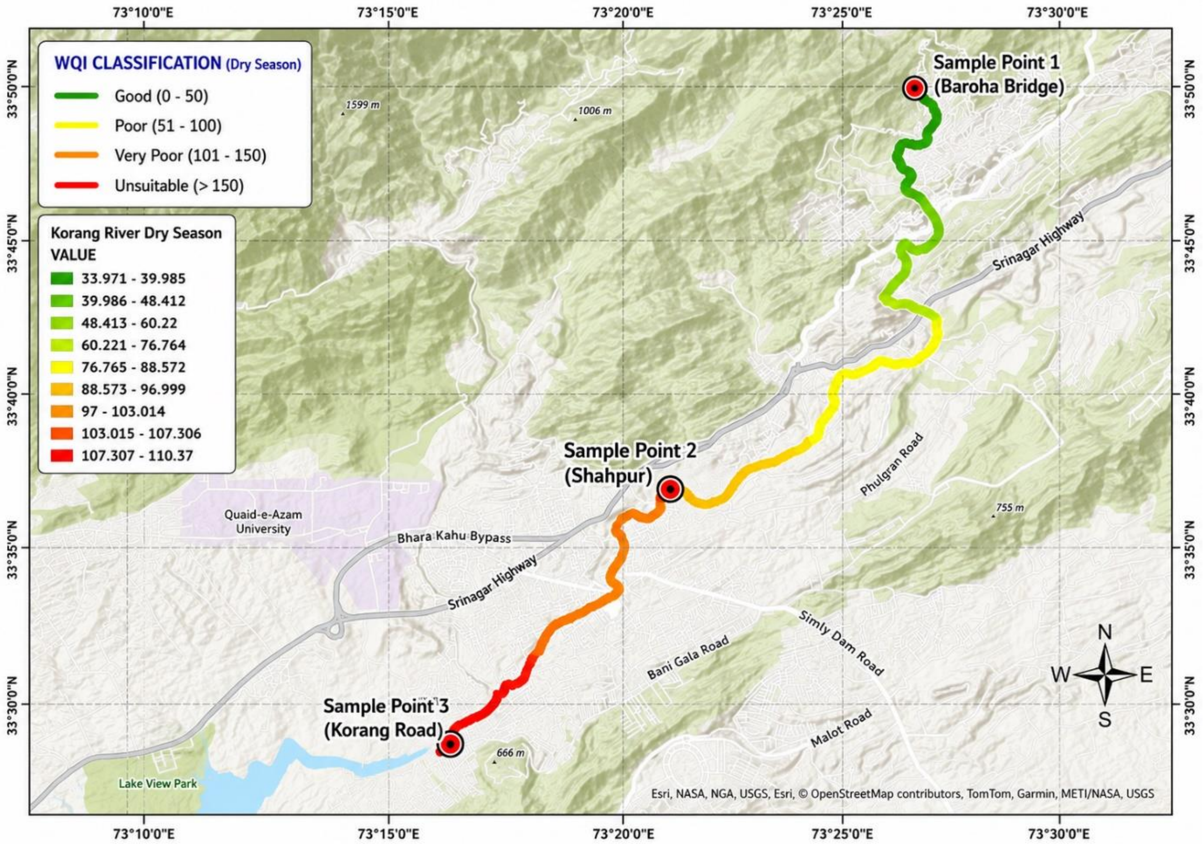


Figure 4 GIS-based spatial distribution of Water Quality Index (WQI) along the Korang River during the dry season, showing the gradient from Baroha Bridge to Korang Road.

Wet Season GIS Map: Pollution increased even more along the same corridor, in accord with surface runoff sweeping accumulated pollutants into the river channel. Korang Road was the most polluted road during the wet season as it had the highest elevated WQI and the highest concentration of various physico-chemical parameters.

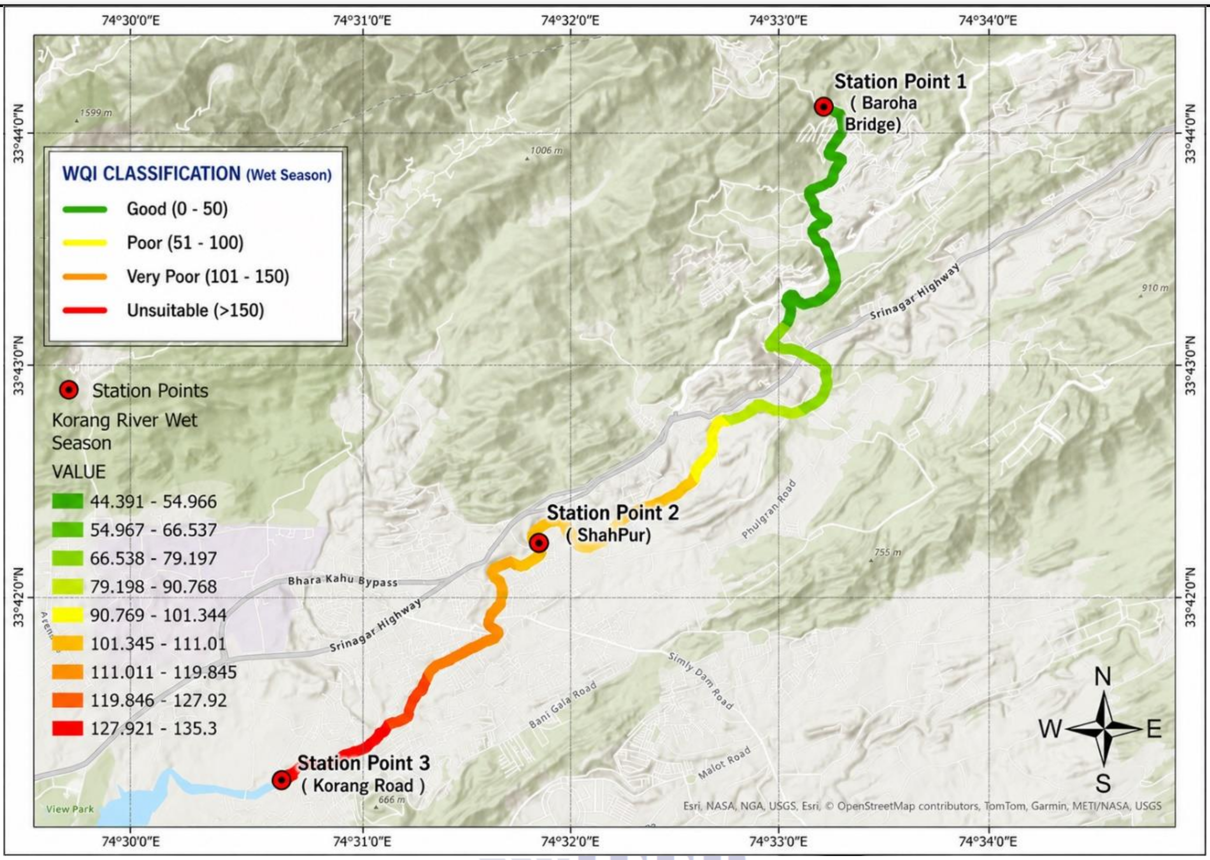


Figure 5 GIS-based spatial distribution of Water Quality Index (WQI) along the Korang River during the wet season, showing increased degradation at Korang Road.

The GIS component effectively converted the complex tabular dataset into easily interpretable spatial maps, making the information accessible to non-technical stakeholders such as municipal planners, regulatory authorities, and environmental managers. The mapped pollution hotspots can serve as a basis for prioritizing pollution-control interventions along the river corridor.

7-CONCLUSION

The following conclusions can be drawn from the seasonal assessment of the surface water quality of Korang River based on Water Quality Index and GIS based spatial analysis. The water quality was found to deteriorate in a downstream direction from Baroha Bridge to Korang Road which points to the accumulative effects of anthropogenic pressures along the river corridor. The majority of the physico-chemical parameters were found to be within NSDWQ standards, while the parameters like Turbidity, Electrical Conductivity and Chlorides were found to be above the standards in the localized areas of Shahpur and Korang Road. Dissolved Oxygen was very low at Shahpur (2.34 mg/L) and Korang Road (0.98 mg/L) during dry season suggesting hypoxic condition typical of organic pollution due to domestic and poultry waste discharge. The computed WQI values revealed that Baroha Bridge was Good in both seasons, Shahpur was Poor to Very Poor in both seasons and Korang Road was Very Poor in both seasons, getting worse in the wet season. The spatial mapping using GIS was successful in identifying pollution hotspots, especially at Korang Road, and visualizing the spatial variation of water quality along the river corridor. The need of the hour is to have regular monitoring and more stringent pollution control measures to ensure protection of the Korang River and to maintain the water quality of Rawal Lake that is a major source of drinking water for the twin cities of Islamabad and Rawalpindi.

8-RECOMMENDATIONS

The results from this study can be the basis for several recommendations for the sustainable management of the Korang River. Ongoing surveillance of surface water quality should be implemented at smaller spatial scales along the river to identify changes in water quality at an early stage. Pollution-control measures, such as treatment of domestic sewage, control of discharges at poultry farms and better management of solid wastes, should be implemented first at the two most polluted stretches which are identified as Shahpur and Korang Road. The provision of riparian buffers and best agricultural management practices should be promoted across the catchment to minimize non-point sources contributing to pollution of the river. In addition, public awareness programs and community monitoring initiatives must be encouraged to involve community members in the protection of the Korang River and Rawal Lake in the long term.

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