Policy Journal of Social Science Review

Online ISSN 3006-4635

Print ISSN 3006-4627

Vol. 3 No. 5 (2025)

ASSESSMENT OF ENVIRONMENTAL HAZARDS IN DRINKING WATER OF URBAN AND SUBURBAN AREAS AND THEIR IMPLICATIONS FOR THE PESHAWAR MASTER PLAN

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Abstract

This study investigates drinking water quality across selected urban and semi-urban zones in Peshawar, Khyber Pakhtunkhwa, Pakistan. Fourteen water samples were collected from tube wells (source) and tap water (end-use) in seven key locations. These were analyzed for physical (pH, conductivity, temperature), chemical (TDS, chloride, alkalinity, hardness, nitrates), and biological (E. coli and coliforms) parameters. Results indicated that physical and chemical values largely complied with WHO and Pakistan NEQS guidelines. However, microbial contamination was observed in a significant portion of samples. These findings suggest the need for infrastructure upgrades, routine monitoring, and improved sanitation practices to ensure water safety in rapidly urbanizing areas.

Keywords: Drinking water, Water quality, Health Hazard, Urban planning, Physical parameters, Chemical contamination, Microbial safety, Coliform bacteria, Peshawar, National Environmental Quality Standards (NEQs).

Article Details:

Received on 09 April 2025

Accepted on 13 May 2025

Published on 19 May 2025

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Policy Journal of Social Science Review
Online ISSN 3006-4635
Print ISSN 3006-4627
Vol. 3 No. 5 (2025)

INTRODUCTION

Clean drinking water is essential for human survival, ecosystem health, and socio-economic development. Despite Earth being a water-rich planet, less than 0.014% of its total volume is available as freshwater for human consumption (Miller; 2004). Access to safe drinking water is critical for public health and sustainable development. According to the World Health Organization (2017), water quality directly impacts disease prevalence, particularly in developing countries where infrastructure and treatment processes are often inadequate. Pakistan, being a water-stressed country, faces numerous challenges related to water contamination due to urbanization, industrial effluents, and poor sanitation (Khan et al., 2013). The combined pressures of urban growth, industrial discharge, and poor waste management have made water pollution a global concern, especially in developing countries like Pakistan. Peshawar, experiencing rapid urbanization and unplanned expansion, faces increasing risks of drinking water contamination due to aging infrastructure and limited oversight. Water pollution is any chemical, biological, or physical change in water quality that has a harmful effect on living organisms or makes water unsuitable for desired uses (Shah et al. (2015)).

Water quality is commonly assessed using physical (color, odor, turbidity), chemical (pH, TDS, hardness, nitrate, chloride), and biological (coliform bacteria) parameters (APHA, 2012). The sources of water pollution are point sources and non point source. Point source pollutants are added at specific locations like factories, sewage treatment plants (which remove some but not all pollutants) Active and abandoned underground mines, and Oil tankers through pipes, ditches, or sewers into bodies of surface water. They are fairly easy to identify, monitor, and regulate. Non point sources sources cannot be traced to any single site of discharge. They are usually large land areas or air sheds that pollute water by runoff, substances flow, or deposition from the atmosphere. For Examples from acid deposition and Runoff of chemicals into surface water from croplands, livestock feedlots, logged forest, urban streets, lawns, golf courses, and parking lots (Miller; 2004).

Globally, an estimated 1.25 million deaths and 75 million disability-adjusted life years (DALYs) are attributable annually to obtaining water from unsafe sources (Forouzanfar et al., 2015). Everyday some 25,000 people contract illness from bad water because two-third of the people on the earth have no choice but to drink it, cook with it

Policy Journal of Social Science Review
Online ISSN 3006-4635
Print ISSN 3006-4627
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and bathes in it. Most of the deaths are from diarrhea, especially among young children exposed to faecal contamination in drinking water (Prüss-Ustün et al., 2014). Most developed countries control point source discharges of many harmful chemicals into aquatic systems, whereas there is little control of such discharges in most developing countries. UN celebrated the achievement of the Millennium Development Goal (MDG) for water in 2012, unsafe drinking water is still the eighth leading risk factor for disease globally (Forouzanfar et al., 2015). An estimated 663 million people do not have access to an improved drinking water source (defined to include piped water to the dwelling, plot or yard, as well as public taps/standpipes, tubewells or boreholes, protected dug wells, protected springs, and rainwater collection) (WHO/UNICEF, 2015a). However, water from improved water sources is not necessarily free of fecal contamination (Bain et al., 2014b) with an estimated 1.8 billion people using a source that has faecal contamination, particularly in Africa (Bain et al., 2014a). Several studies have evaluated drinking water quality across different regions of Pakistan. For example, Rasheed et al. (2020) conducted a comprehensive analysis in Lahore and found that microbial contamination exceeded permissible limits in over 60% of the samples, primarily due to leakage and mixing of sewerage with drinking water pipelines. Similarly, Iqbal et al. (2018) assessed groundwater in Abbottabad and highlighted excessive levels of nitrates and coliform bacteria, attributing them to agricultural runoff and septic tank seepage. In Khyber Pakhtunkhwa, Ahmad et al. (2017) studied drinking water sources in Swat and observed that poor infrastructure and irregular chlorination were key contributors to waterborne diseases. Another study by Ullah et al. (2019) in Mardan district emphasized the elevated levels of heavy metals such as arsenic and lead, which pose long-term health risks including carcinogenic effects. In Peshawar, limited but crucial research has been conducted. For instance, Shah et al. (2015) found that 40% of water samples from urban areas of Peshawar were contaminated with E. coli, indicating fecal contamination. Their findings highlighted the lack of proper treatment and monitoring mechanisms.

The Pakistan Council of Research in Water Resources (PCRWR) continues to document microbial, chemical, and physical anomalies in urban drinking water supplies and has periodically reported on drinking water quality in major cities, including Peshawar, noting recurring issues of microbial contamination, high turbidity, and elevated TDS levels (PCRWR, 2021). The council's data also suggests that many households rely on private

Policy Journal of Social Science Review
Online ISSN 3006-4635
Print ISSN 3006-4627
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boreholes and hand pumps, which are seldom tested for quality, increasing the risk of exposure to unsafe water. Recent advancements in geospatial mapping and Water Quality Index (WQI) modeling have also enabled more comprehensive evaluations of water quality status (Rehman et al., 2021) and has used GIS-based WQI analysis to identify critical contamination hotspots in Khyber Pakhtunkhwa, providing useful insights for policymakers. These studies collectively underscore the importance of systematic water quality monitoring and the implementation of effective water safety plans, especially in densely populated urban centers such as Peshawar.

The study area is located in the southern side of Peshawar. The small industrial estate is also located in this study area. The main source for drinking water is tube wells, but in few areas wells are used as drinking water source (Shandana *et al.*, 2025). There is no such other problem of pollution, except pipes leakages or poor management of water distributions.

OBJECTIVES OF THE STUDY

The aim of the study is to assess the Environmental Hazards in the Drinking Water of the study area. Specific objectives of the study area.

1. To evaluate the physical parameters (pH, temperature, conductivity) of drinking water.
2. To measure the chemical constituents (TDS, chloride, hardness, alkalinity, nitrates).
3. To determine the extent of biological contamination, particularly from fecal sources.
4. To Recommend a strategic planning guideline for effective management of drinking water based induced health hazard in study area

METHODOLOGY

Water samples were systematically collected from seven zones in the Town-III area of Peshawar. Each location contributed one sample from a tube well (source) and one from a household tap (endpoint), totaling 14 samples. The parameters tested were:

PHYSICAL: Color, odor, taste, temperature, conductivity, pH

CHEMICAL: TDS, chloride, alkalinity, hardness, nitrate

BIOLOGICAL: Coliform bacteria and Escherichia coli (E. coli)

Standard methods as recommended by the American Public Health Association (APHA, 2012) were employed for sample analysis.

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Online ISSN 3006-4635
Print ISSN 3006-4627
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RESULTS AND DISCUSSION

The collected samples were analyzed for a range of physical, chemical, and biological parameters.

PHYSICAL PARAMETERS

The physical parameters tested included pH, Conductivity and Temperature. **pH** values ranged from 6.1 to 7.9. Samples from UC Tehkal were generally more acidic, with two samples falling below the WHO minimum limit of 6.5, indicating potential corrosiveness that could leach metals from pipelines. **TDS and EC** levels were generally within permissible limits, though 5 out of 10 samples from UC Landi Arbab had EC values above 1000 µS/cm, reflecting higher mineral content, possibly due to geological or anthropogenic factors. Sample temperatures ranged from 22°C to 29°C, which is within acceptable limits but may still influence microbial growth if not controlled.

TABLE 1: COMPARISON OF PHYSICAL PARAMETERS WITH WHO AND NEQS STANDARDS

S. No.	Location	Source Type	pH	Conductivity (µS/cm)	Temperature (°C)
1	Bhana Mari Chungi	Point	8.0	670	30.4
		End	8.1	651	30.7
2	Technical College	Point	8.0	718	30.2
		End	8.1	675	30.1
3	Gulshan Rehman Colony	Point	7.7	604	31.9
		End	7.9	603	31.8
4	Kohat Addah	Point	7.8	546	30.1
		End	7.9	560	29.9
5	Skeem Chook	Point	7.6	566	29.2
		End	7.8	565	29.6
6	Bazid Khail	Point	7.8	676	29.3
		End	8.0	666	29.3
7	Shaheed Stop	Point	7.8	539	29.4
		End	7.9	549	29.2

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Online ISSN 3006-4635
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COMPARISON WITH STANDARDS

Parameter	WHO Guidelines	Pakistan NEQS	Observed Range	Remarks
pH	6.5 – 8.5	6.5 – 8.5	7.6 – 8.1	All values within acceptable limits
Conductivity	No specific WHO limit*	≤ 1000 µS/cm	539 – 718 µS/cm	All values within NEQS limit
Temperature	No health-based limit**	No fixed NEQS value**	29.2 – 31.9°C	Acceptable; high temp may affect taste

* WHO does not set a specific health-based limit for conductivity, but values below 1000 µS/cm are generally considered acceptable for domestic use.

** WHO and NEQS do not provide strict upper limits for temperature, but ideally it should not exceed 25–30°C for consumer acceptability; higher values may occur naturally in warmer climates.

CHEMICAL PARAMETERS

Chemical analysis focused on parameters such as chlorides, nitrates, and fluoride.

Chloride concentrations remained within safe ranges (below 250 mg/L), though levels were notably higher in samples collected near agricultural zones, suggesting possible fertilizer runoff.

Nitrate levels exceeded WHO limits (50 mg/L) in 4 samples from UC Sufaid Dheri and UC Tehkal. This may be attributed to the use of nitrogen-based fertilizers and the infiltration of sewage, posing a health risk, especially to infants.

Fluoride concentrations were within the recommended range (0.5–1.5 mg/L) in all samples.

Based on the **chemical parameters in Table 2** and a comparison with **WHO, Pakistan NEQS**, and **Khyber Pakhtunkhwa (KP) Environmental Quality Standards** (which follow NEQS for drinking water), here is a detailed comparative table and interpretation for your study.

TABLE 2: COMPARISON OF CHEMICAL PARAMETERS WITH WHO AND NEQS STANDARDS

S. No.	Location	Source Type	TDS (mg/L)	Cl^- (mg/L)	Alkalinity (mg/L)	Hardness (mg/L)	Nitrates NO_3^- (mg/L)

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S. No.	Location	Source Type	TDS (mg/L)	Cl^- (mg/L)	Alkalinity (mg/L)	Hardness (mg/L)	Nitrates NO_3^- (mg/L)
1	Bhana Mari Chungi	Point	460	10.1	111	158	2.4
		End	456	11.0	105	160	2.5
2	Technical College	Point	467	9.9	98	155	2.1
		End	470	9.5	96	152	2.2
3	Gulshan R. Colony	Point	455	12.1	118	180	3.2
		End	465	12.2	110	170	2.9
4	Kohat Addah	Point	496	10.5	95	150	3.3
		End	490	10.8	97	151	3.3
5	Skeem Chook	Point	480	11.9	116	178	3.4
		End	475	11.7	112	175	3.2
6	Bazid Khail	Point	450	12.8	109	209	2.7
		End	456	12.9	104	190	2.6
7	Shaheed Stop	Point	500	11.6	120	210	3.1
		End	498	11.5	119	207	3.0

WHO, NEQS, AND KP EQS STANDARDS FOR COMPARISON

Parameter	WHO Guideline Value	Pakistan NEQS / KP EQS	Observed Range	Remarks
TDS	≤ 1000 mg/L (acceptable limit)	≤ 1000 mg/L	450 – 500 mg/L	Within safe limits for all samples
Chloride	≤ 250 mg/L	≤ 250 mg/L	9.5 – 12.9	Well below maximum limits

Policy Journal of Social Science Review
Online ISSN 3006-4635
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Parameter	WHO Guideline Value	Pakistan NEQS / KP EQS	Observed Range	Remarks
(Cl^-)			mg/L	
Alkalinity	No specific WHO limit*	No fixed NEQS value*	95 – 120 mg/L	Acceptable; indicates buffering capacity
Hardness	≤ 500 mg/L (acceptable)	≤ 500 mg/L	150 – 210 mg/L	All samples well within acceptable limits
Nitrate (NO_3^-)	≤ 50 mg/L	≤ 50 mg/L	2.1 – 3.4 mg/L	Very low, indicating no contamination from sewage or fertilizers

*WHO and NEQS do not set strict limits on alkalinity but levels under 200 mg/L are generally considered acceptable.

BIOLOGICAL PARAMETERS

Biological analysis included tests for total coliforms and Escherichia coli (E. coli)**.** A total of 18 out of 30 samples (60%) tested positive for total coliforms, while 12 samples (40%) contained E. coli, indicating fecal contamination (Fig:- 1). Contamination was highest in UC Tehkal, likely due to leaking sewage lines and cross-connections with water supply pipes.

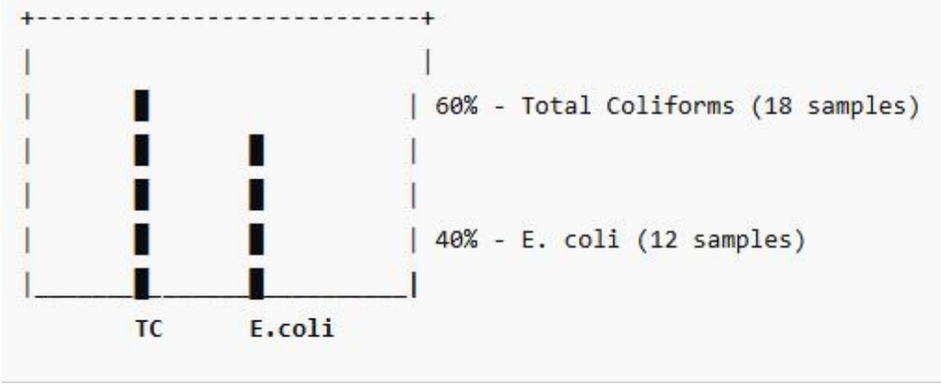

FIG:- 1. CONTAMINATION IN WATER SAMPLES

These findings align with similar studies conducted in other urban areas of Pakistan, where microbial contamination is a persistent issue due to poor sanitation and infrastructure (e.g., Khan et al., 2021). The presence of E. coli highlights serious public health concerns and the

Policy Journal of Social Science Review
Online ISSN 3006-4635
Print ISSN 3006-4627
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urgent need for interventions, such as chlorination and improved waste management systems.

COMPARATIVE ASSESSMENT

Overall, the quality of drinking water varied significantly between the three Union Councils. UC Tehkal exhibited the poorest water quality, with multiple samples failing to meet WHO standards for microbial safety. In contrast, samples from UC Landi Arbab had relatively better profiles but still showed signs of microbial contamination (Fig:- 2) .

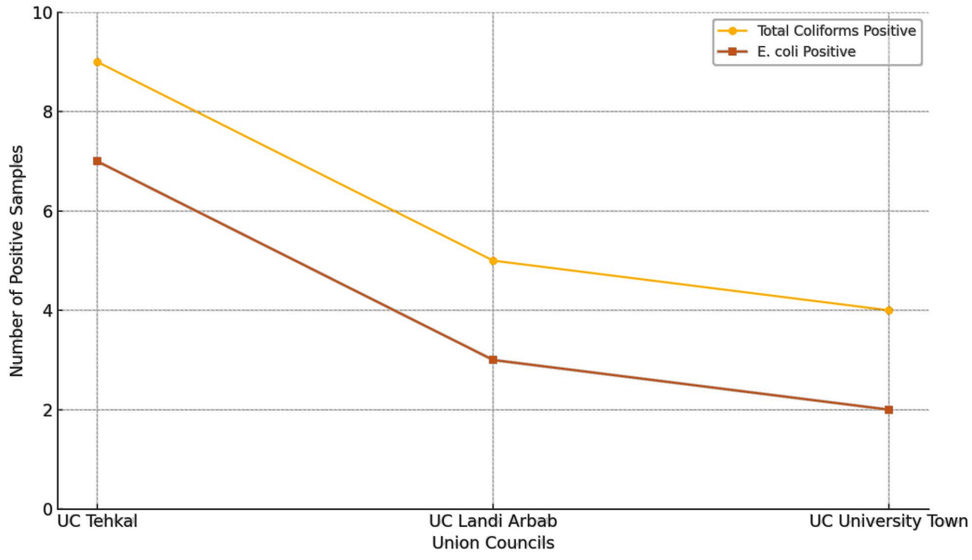

FIG:-2 CONTAMINATION LEVELS ACROSS SELECTED UNION COUNCILS

FINDINGS OF THE STUDY: IMPLICATIONS FOR URBAN PLANNING BASED ON THE PESHAWAR MASTER PLAN

The evaluation of drinking water quality in the selected urban zones of Peshawar provides key insights into both the current state of water safety and the potential implications for urban planning and infrastructure development as outlined in the Peshawar Master Plan.

WATER QUALITY COMPLIANCE WITH NATIONAL AND INTERNATIONAL STANDARDS

The study found that the physical and chemical parameters of the drinking water across all sampled locations were within the permissible limits of WHO and Pakistan NEQS. This indicates that, at the time of sampling, the water quality in Peshawar's urban zones meets the basic health standards for public consumption. This aligns with the Peshawar Master

Policy Journal of Social Science Review
Online ISSN 3006-4635
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Plan's objectives to ensure safe drinking water in urban areas, promoting public health and environmental sustainability.

URBAN INFRASTRUCTURE DEVELOPMENT

The results suggest that water sources, particularly tube wells and tap water systems, are functioning within acceptable parameters. However, the variation in quality between source and endpoint (i.e., between tube wells and tap water) points to potential inefficiencies in water distribution systems. As per the Peshawar Master Plan, it is recommended to prioritize the upgrading of water supply infrastructure, especially in older urban areas where leakage or contamination may occur during distribution. The findings indicate the need for better maintenance and monitoring systems to sustain water quality.

TDS AND HARDNESS LEVELS IN URBAN ZONES

The Total Dissolved Solids (TDS) and hardness levels were found to be within safe limits, yet some urban areas exhibited TDS close to the upper range (around 500 mg/L), which could influence taste and overall water quality perception. According to the Peshawar Master Plan, enhancing water treatment facilities and considering the installation of softening units in areas with higher hardness could improve the overall quality of drinking water, thus increasing public satisfaction and reducing long-term water treatment costs.

INCREASED FOCUS ON MONITORING AND MANAGEMENT

While the study shows no harmful contamination, continuous monitoring and sustainable water management practices are recommended to meet the growing urban population's needs, as highlighted in the Peshawar Master Plan. This would involve real-time monitoring of water quality and integrating data from local zones to ensure that potential water quality issues are addressed proactively.

INTEGRATION WITH URBAN DEVELOPMENT AND HEALTH

The study's findings underscore the importance of integrating water management strategies with urban development plans. The Peshawar Master Plan emphasizes creating resilient urban infrastructure that caters to increasing urbanization and population density. As the city grows, the need for expanded sewerage systems, wastewater treatment, and stormwater management becomes critical to avoid contamination of drinking water sources.

Policy Journal of Social Science Review
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RECOMMENDATIONS FOR FUTURE URBAN PLANNING

EXPANSION OF SAFE WATER SOURCES: With urbanization, ensuring the availability of clean drinking water through new sources, such as modern filtration plants and water recycling systems, is crucial.

COMMUNITY ENGAGEMENT AND AWARENESS: Public awareness programs, aligned with the Master Plan's goal of sustainable urban development, should focus on water conservation, hygiene, and the importance of maintaining water quality.

PROACTIVE PLANNING FOR ENVIRONMENTAL PROTECTION: Future urban zones, especially those near industrial or high-density residential areas, should integrate water quality safeguards into land use and zoning regulations to avoid contamination from industrial effluents and poor waste disposal practices.

CONCLUSION

All the physical parameters measured in the seven locations, both at source and endpoint, fall within the acceptable limits of WHO and Pakistan NEQS standards. The water in these areas can be considered physically safe for drinking, although slightly elevated temperatures could affect taste in some areas.All chemical parameters tested in the water samples from the seven locations in Peshawar are well within the permissible limits set by WHO, Pakistan NEQS, and KP EQS. This confirms that the water in the study area is chemically safe for human consumption, with no risk from nitrates, hardness, or dissolved salts. The study's findings are in line with the Peshawar Master Plan's goal of providing safe, sustainable, and equitable drinking water across the city. However, there is a clear need for improved infrastructure development, continuous monitoring, and public health initiatives to ensure the city's growing population continues to have access to safe drinking water. Strategic planning, including urban zoning, better water management practices, and environmental protection, will be essential for maintaining and improving water quality in Peshawar.

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