

POLICY BRIEF
**Optimizing Instructional Quality in KP Schools:
Reforming Teacher Promotion Architecture**

Transitioning from Cross-Cadre Displacement to Technical Professional Mastery

Prepared for:
The Secretary, Elementary and
Secondary
Education Department (E&SED)
**Government of Khyber
Pakhtunkhwa**

Prepared by:
Dr. Ahsan Ur Rehman
Assistant Professor at Sarhad University of Science and
Information Technology, Peshawar.

Author's Note

This policy brief is derived from research: *Evaluating the KP Government In-Service Teachers' Promotion Policy (2012)*, and from a research paper on *School Teachers' Promotion Policy in Khyber Pakhtunkhwa, Pakistan: Observations of School Heads, Union Leaders and School Teachers*. Elementary Education Online, 2021.

1. Executive Summary

Teacher quality is the primary school-level determinant of student learning outcomes (Hanushek & Rivkin, 2012; Darling-Hammond, 2017). In Khyber Pakhtunkhwa (KP), the Government In-Service Teachers' Promotion Policy (2012) serves as the principal mechanism for career advancement. However, a critical structural feature—cadre change promotion—is inadvertently producing what this brief terms the “Efficiency Gap.” By moving specialized teachers (e.g., Primary or Arabic Teachers) into generalized secondary roles on the basis of seniority alone, the system forfeits its prior investment in specialized human capital (Darling-Hammond, 2017).

This brief argues that KP must transition from a horizontal, cross-cadre promotion model to a Vertical Career Ladder—a reform inspired by high-performing Baltic and Eastern European systems (OECD, 2019). By enabling teachers to advance from BPS-12 to BPS-18 within their original specialization, the province can ensure that its most experienced educators remain where they are most effective: in the classroom. This recommendation is grounded in research involving school teachers, school teachers' unions' leaders and school heads.

2. The Core Issue: Cross-Cadre Misalignment

The current promotion policy facilitates “cadre change,” whereby career advancement frequently requires a teacher to leave their professional domain entirely (Government of Khyber Pakhtunkhwa, 2012). Common transition pathways include:



POLICY BRIEF

Green Binder Technologies for Sustainable and Low-Carbon Infrastructure Development

By: Engr Muhammad Numan, Engr Prof. Dr. Arshad Ali

EXECUTIVE SUMMARY

The construction industry is responsible for a significant share of global carbon dioxide emissions, largely due to the production of Ordinary Portland Cement (OPC). Growing environmental concerns, rapid urbanization, and increasing infrastructure demands necessitate the development of sustainable and low-carbon construction materials. This policy brief presents findings from a study investigating the incorporation of Ferrock, Zeolite, and Serpentine in both OPC and geopolymer binder systems to enhance mechanical performance, durability, and environmental sustainability.

The study demonstrates that optimized incorporation of these mineral additives significantly improves compressive strength, tensile strength, durability, and microstructural performance while reducing the environmental footprint of construction materials. The findings support the development of climate-resilient and sustainable infrastructure aligned with SDGs 9, 11, 12, and 13.

POLICY ISSUE

The construction sector faces several critical challenges:

- High CO₂ emissions from cement production.
- Increasing demand for sustainable infrastructure materials.
- Depletion of natural resources used in conventional concrete production.
- Need for enhanced durability and service life of infrastructure.
- Limited adoption of alternative low-carbon binder technologies in Pakistan.

Without policy intervention, conventional cement-dependent construction practices will continue to contribute significantly to greenhouse gas emissions and environmental degradation.

BACKGROUND

Ordinary Portland Cement remains the most widely used construction material globally; however, its manufacturing process is highly energy-intensive and environmentally damaging. Geopolymer technology has emerged as a promising alternative by utilizing industrial by-products such as fly ash to produce high-performance binder systems with substantially lower carbon emissions.

Recent research has shown that incorporating mineral additives such as Ferrock, Zeolite, and Serpentine can further improve the performance and sustainability of both OPC and geopolymer systems. However, limited studies have investigated their combined application and optimal dosage levels.

KEY RESEARCH FINDINGS

Table 1. Optimum Additive Dosages

Additive	Optimum Dosage
Zeolite	18%
Ferrock	15%
Serpentine	15%

These dosage levels provided the best balance between strength, durability, and sustainability.

Table 2. Mechanical Performance Improvement

Parameter	Improvement Achieved
Compressive Strength	Up to 25–30% increase
Flexural Strength	Up to 30% increase
Splitting Tensile Strength	Up to 35% increase
Matrix Density	Up to 5% increase
Microstructural Stability	Significant improvement

Table 3. Durability Improvements

Durability Indicator	Improvement
Water Absorption	Reduced by 24–31%
Chloride Penetration	Reduced by 30–38%
Carbonation Depth	Reduced by 20–30%
Chemical Resistance	Significantly improved
Long-Term Durability	Enhanced

Table 4. Environmental Benefits

Environmental Indicator	Impact
Cement Consumption	Reduced
Carbon Emissions	Lowered
Industrial Waste Utilization	Increased
Resource Efficiency	Improved
Carbon Sequestration Potential	Enhanced through Ferrock and Serpentine
Sustainable Infrastructure	Supported

STRATEGIC POLICY RECOMMENDATIONS

- Adoption of Sustainable Binder Standards: National construction regulators should develop standards and specifications for geopolymers and mineral-modified binder systems to facilitate their adoption in public and private infrastructure projects.
- Promotion of Low-Carbon Construction Materials: Government agencies should encourage the use of Ferrock, Zeolite, and Serpentine through incentives, green procurement policies, and sustainable construction guidelines.
- Integration into Building Codes: Relevant authorities should revise construction codes and engineering specifications to accommodate sustainable binder technologies and alternative cementitious materials.
- Support for Industrial Symbiosis: Industries generating by-products such as steel dust and fly ash should be integrated into construction material supply chains to reduce waste and promote circular economy principles.

- Research and Innovation Programs: Universities and research institutions should be supported to conduct further studies on long-term field performance, microstructural behavior, and large-scale implementation of sustainable binder systems.
- Capacity Building: Professional engineers, contractors, and construction managers should receive training on the design, production, and application of sustainable binder technologies.

IMPLEMENTATION FRAMEWORK

Short-Term (1-2 Years)

- Develop technical guidelines.
- Conduct pilot construction projects.
- Establish testing protocols.
- Create awareness among industry stakeholders.

Medium-Term (3-5 Years)

- Integrate sustainable binders into public infrastructure projects.
- Revise engineering standards and specifications.
- Establish certification and quality control systems.
- Promote industry-academia collaboration.

Long-Term (5-10 Years)

- Mainstream sustainable binder technologies nationwide.
- Develop low-carbon construction policies.
- Achieve significant reductions in construction-sector emissions.
- Establish Pakistan as a regional leader in sustainable infrastructure development.

EXPECTED OUTCOMES

Table 5. Expected Policy Outcomes

Intervention	Expected Outcome
Sustainable Binder Adoption	Reduced carbon footprint
Geopolymer Technology Promotion	Increased resource efficiency
Alternative Material Utilization	Reduced industrial waste
Enhanced Durability	Longer infrastructure lifespan
Capacity Building	Improved technical expertise
Policy Reforms	Sustainable construction sector growth
Research Support	Continuous innovation
Green Procurement	Increased market adoption

CONTRIBUTION TO SUSTAINABLE DEVELOPMENT GOALS

SDG	Contribution
SDG 9 – Industry, Innovation and Infrastructure	Promotes innovative construction materials
SDG 11 – Sustainable Cities and Communities	Supports durable and sustainable infrastructure
SDG 12 – Responsible Consumption and Production	Encourages industrial waste utilization
SDG 13 – Climate Action	Reduces carbon emissions and promotes carbon sequestration

CONCLUSION

The study confirms that the incorporation of Zeolite (18%), Ferrock (15%), and Serpentine (15%) significantly enhances the mechanical, durability, and sustainability performance of both OPC and geopolymer binder systems. These materials offer practical pathways toward low-carbon, durable, and resource-efficient construction while supporting national climate adaptation and sustainable infrastructure objectives.

The adoption of sustainable binder technologies through targeted policy reforms, industry incentives, technical standards, and research support can play a transformative role in advancing Pakistan's transition toward environmentally responsible and climate-resilient infrastructure development.

REFERENCES

- American Concrete Institute (ACI). (2023). Building code requirements for structural concrete (ACI 318-23) and commentary. American Concrete Institute.
- Davidovits, J. (2020). Geopolymer chemistry and applications (5th ed.). Geopolymer Institute.
- Duxson, P., Provis, J. L., Lukey, G. C., and Van Deventer, J. S. J. (2007). The role of inorganic polymer technology in the development of green concrete. *Cement and Concrete Research*, 37(12), 1590–1597.
- Habert, G., Miller, S. A., John, V. M., Provis, J. L., Favier, A., Horvath, A., and Scrivener, K. L. (2020). Environmental impacts and decarbonization strategies in the cement and concrete industries. *Nature Reviews Earth and Environment*, 1(11), 559–573.
- Hassan, A., Arif, M., and Shariq, M. (2019). Use of zeolite in sustainable concrete production: A review. *Construction and Building Materials*, 229, 116878.
- Intergovernmental Panel on Climate Change (IPCC). (2023). Climate change 2023: Synthesis report. Geneva, Switzerland: IPCC.
- Kumar, S., Kumar, R., and Mehrotra, S. P. (2010). Influence of granulated blast furnace slag on the reaction, structure and properties of fly ash-based geopolymer. *Journal of Materials Science*, 45(3), 607–615.
- Mehta, P. K., and Monteiro, P. J. M. (2014). *Concrete: Microstructure, properties and materials* (4th ed.). McGraw-Hill Education.
- Miller, S. A. (2018). Supplementary cementitious materials to mitigate greenhouse gas emissions from concrete: Can there be too much of a good thing? *Journal of Cleaner Production*, 178, 587–598.
- Provis, J. L. (2018). Alkali-activated materials. *Cement and Concrete Research*, 114, 40–48.
- Provis, J. L., and Van Deventer, J. S. J. (2014). Alkali activated materials: State-of-the-art report, RILEM TC 224-AAM. Springer.
- Qureshi, L. A., Ali, B., and Khan, M. I. (2022). Sustainable concrete technology for climate-resilient infrastructure: Recent developments and future prospects. *Sustainability*, 14(9), 5421.

- Rashad, A. M. (2013). Zeolite as a supplementary cementitious material: A review. *Construction and Building Materials*, 41, 815–824.
- Safiuddin, M., Jumaat, M. Z., Salam, M. A., Islam, M. S., and Hashim, R. (2012). Utilization of solid wastes in construction materials. *International Journal of the Physical Sciences*, 5(13), 1952–1963.
- Scrivener, K. L., John, V. M., and Gartner, E. M. (2018). Eco-efficient cements: Potential, economically viable solutions for a low-CO₂ cement-based materials industry. *Cement and Concrete Research*, 114, 2–26.
- Shi, C., Krivenko, P. V., and Roy, D. (2006). *Alkali-activated cements and concretes*. Taylor and Francis.
- United Nations Environment Programme (UNEP). (2024). *Global status report for buildings and construction 2024*. Nairobi, Kenya: UNEP.
- Van Deventer, J. S. J., Provis, J. L., Duxson, P., and Brice, D. G. (2012). Chemical research and climate change as drivers in the commercial adoption of alkali activated materials. *Waste and Biomass Valorization*, 1(1), 145–155.
- World Green Building Council. (2023). *Bringing embodied carbon upfront: A coordinated action for the building and construction sector*. London, United Kingdom.
- Zhang, Z., Provis, J. L., Reid, A., and Wang, H. (2014). Geopolymer foam concrete: An emerging material for sustainable construction. *Construction and Building Materials*, 56, 113–127.



POLICY BRIEF

Enhancing Urban Resilience in Climate-Vulnerable Peshawar: An Integrated Civil Engineering Policy Framework

By: Engr Arbab Imran Khan, Engr Prof Dr Arshad Ali

EXECUTIVE SUMMARY

Peshawar is increasingly vulnerable to climate-induced urban challenges including urban flooding, heatwaves, drainage failures, infrastructure deterioration, and environmental degradation. Conventional infrastructure planning approaches are no longer sufficient to address rapidly evolving climatic conditions and increasing urbanization pressures. This policy brief presents strategic interdisciplinary civil engineering guidelines to strengthen urban resilience in climate-exposed areas of Peshawar through integrated structural, hydrological, geotechnical, environmental, and geospatial planning approaches.

The brief emphasizes the importance of climate-responsive infrastructure planning, nature-based engineering solutions, GIS-based vulnerability assessments, adaptive drainage systems, institutional coordination, and climate-informed policy reforms. It further highlights the need for resilient urban development frameworks aligned with Sustainable Development Goal 11 (Sustainable Cities and Communities) and Sustainable Development Goal 13 (Climate Action).

The proposed policy directions aim to support municipal authorities, planners, engineers, researchers, and policymakers in developing evidence-based and location-specific urban resilience strategies. Expected outcomes include the development of vulnerability mapping systems, climate-resilient infrastructure templates, integrated planning frameworks, policy roadmaps, and technical capacity-building tools for urban management institutions.

BACKGROUND

Climate change has emerged as one of the most critical threats to sustainable urban development across the world, particularly in rapidly urbanizing cities of developing countries. Peshawar, as one of the major metropolitan cities of Khyber Pakhtunkhwa, is increasingly exposed to recurring urban flooding, heat stress, drainage failures, traffic disruption, infrastructure deterioration, and environmental risks due to extreme climatic events.

Traditional civil engineering practices in urban planning are primarily based on historical climate assumptions and outdated infrastructure design approaches. These methods often fail to incorporate dynamic climatic variations, real-time environmental data, and future risk projections. Consequently, urban systems become highly vulnerable during periods of intense rainfall, prolonged heatwaves, and climate-induced environmental disturbances.

The increasing pressure of urbanization, inadequate stormwater infrastructure, fragmented institutional coordination, and limited integration of climate science into engineering practices have further intensified urban vulnerability in Peshawar. In many urban sectors, infrastructure planning lacks interdisciplinary coordination among civil engineers, urban planners, environmental experts, hydrologists, and policymakers.

Globally, modern urban resilience planning emphasizes integrated engineering approaches that combine green infrastructure, geospatial technologies, climate risk assessments, hydrological modeling, and adaptive infrastructure systems. However, such integrated resilience-oriented frameworks remain limited in the context of Pakistan and secondary cities like Peshawar.

This policy brief seeks to bridge the gap between climate adaptation theory and practical engineering implementation by proposing actionable policy guidelines and engineering frameworks tailored to the local conditions of Peshawar.

CURRENT CHALLENGES FOR URBAN RESILIENCE IN PESHAWAR

Based on critical literature review and regional urban observations, the following major challenges have been identified:

- Increasing urban flooding due to inadequate drainage systems and uncontrolled urbanization.
- Lack of integration between climate data and infrastructure planning.
- Dependence on conventional grey infrastructure with limited adaptive capacity.
- Weak coordination among municipal authorities, engineering departments, and environmental agencies.
- Absence of real-time urban vulnerability mapping and climate risk assessment systems.
- Limited use of GIS, hydrological modeling, and geotechnical simulations in urban planning.
- Inadequate institutional capacity for climate-resilient infrastructure management.
- Lack of policy frameworks for sustainable and climate-responsive urban development.
- Insufficient implementation of nature-based and green infrastructure approaches.
- Absence of long-term monitoring and evaluation systems for resilience projects.

STRATEGIC POLICY GUIDELINES

Integrated Climate-Responsive Urban Planning

Municipal authorities, planning agencies, and engineering departments should integrate climate projections, hydrological assessments, and geospatial analysis into urban infrastructure planning. Climate-informed planning frameworks should be developed to support resilient land-use planning, drainage design, and infrastructure development.

GIS-Based Urban Vulnerability Assessment Systems

Urban planning departments and engineering institutions should establish GIS-based urban vulnerability mapping systems for identifying flood-prone zones, infrastructure stress points, heat islands, and environmentally sensitive areas. Spatial analysis tools should support evidence-based urban planning and decision-making.

Sustainable Drainage and Stormwater Management Systems

Urban drainage authorities should adopt sustainable urban drainage systems (SUDS), permeable pavements, bioswales, retention basins, infiltration systems, and rainwater harvesting approaches to reduce flood risks and improve stormwater management efficiency.

Promotion of Green and Nature-Based Infrastructure

Municipal development agencies should promote green roofs, urban wetlands, green corridors, urban forestry, and climate-sensitive landscaping to improve urban microclimates, reduce surface runoff, and enhance environmental sustainability.

Climate-Responsive Structural and Geotechnical Engineering

Engineering departments should incorporate climate-induced loading conditions, soil behavior modeling, slope stability assessments, and adaptive structural retrofitting techniques into infrastructure design practices. Geotechnical and structural resilience standards should be updated according to future climate scenarios.

Integration of Hydrological and Predictive Modeling Tools

Relevant institutions should utilize hydrological and hydraulic modeling software such as SWMM and HEC-HMS for urban flood simulations, watershed assessments, and infrastructure performance evaluation under extreme weather conditions.

Institutional Coordination and Data Sharing Frameworks

Local government institutions, engineering departments, climate experts, and disaster management authorities should establish coordinated data-sharing mechanisms for integrated urban resilience planning and emergency response management.

Capacity Building and Technical Training Programs

Engineering universities, municipal authorities, and professional bodies should organize training programs on climate-resilient infrastructure design, GIS applications, hydrological modeling, sustainable urban drainage, and adaptive urban planning.

Climate-Responsive Policy and Regulatory Reforms

Government agencies should revise urban planning regulations, building bylaws, infrastructure standards, and environmental policies to integrate resilience principles and climate adaptation requirements.

Long-Term Monitoring and Evaluation Systems

Urban resilience projects should incorporate monitoring, performance evaluation, and periodic infrastructure assessment systems to ensure long-term effectiveness and continuous improvement.

Sustainable Policy Implementation Framework

The proposed policy implementation framework focuses on interdisciplinary coordination among engineering institutions, municipal authorities, climate experts, planning agencies, environmental organizations, and disaster management authorities.

Implementation should be divided into short-term, medium-term, and long-term phases to ensure gradual institutional strengthening and sustainable infrastructure transformation. Short-term activities should focus on vulnerability assessments, data collection, institutional coordination, pilot projects, and policy formulation.

Medium-term implementation should emphasize infrastructure retrofitting, sustainable drainage systems, GIS-based planning integration, and climate-responsive engineering interventions.

Long-term implementation should aim at achieving fully integrated climate-resilient urban infrastructure systems supported by continuous monitoring, adaptive management, and sustainable urban governance.

CONCLUSION

Climate change presents a serious challenge to the sustainable urban development of Peshawar. Existing infrastructure systems, developed under conventional engineering

Table 1. Proposed Strategic Policy Framework and Urban Resilience Implementation Plan

Policies Proposed	Responsible Bodies	Responsibility	Short-Term Action Plan	Medium-Term Action Plan	Long-Term Action Plan
Climate-Responsive Urban Planning	Municipal Authorities, Urban Planning Departments	Integrate climate data into infrastructure planning	Conduct climate risk assessments	Integrate climate projections into planning frameworks	Fully climate-responsive urban planning system
GIS-Based Vulnerability Assessment	GIS Departments, Engineering Institutions	Develop vulnerability mapping systems	Data collection and hazard mapping	Spatial integration into urban planning	Real-time resilience monitoring systems
Sustainable Drainage Systems	Drainage Authorities, Municipal Agencies	Improve stormwater management	Pilot sustainable drainage projects	Expansion of drainage interventions	City-wide resilient drainage network
Green Infrastructure Development	Environmental Agencies, Urban Planning Bodies	Promote nature-based solutions	Develop green infrastructure guidelines	Urban greening and wetland restoration	Integrated green urban ecosystem
Climate-Responsive Structural Engineering	Engineering Departments, Infrastructure Agencies	Adaptive infrastructure design	Structural vulnerability assessments	Retrofitting of vulnerable structures	Climate-adaptive infrastructure standards
Hydrological and Predictive Modeling	Hydrology Departments, Research Institutions	Urban flood and climate modeling	Flood simulation studies	Integrated modeling systems	Predictive resilience management
Institutional Coordination Framework	Municipal Authorities, Disaster Management Agencies	Interdepartmental coordination	Establish coordination committees	Shared urban resilience platforms	Integrated governance systems
Capacity Building Programs	Universities, Professional Bodies	Technical training and awareness	Organize workshops and trainings	Institutional skill development	Continuous professional resilience programs
Climate Policy and Regulatory Reforms	Government Agencies, Planning Authorities	Regulatory integration	Policy review and stakeholder consultation	Update planning regulations	Institutionalized resilience policies
Monitoring and Evaluation Systems	Municipal Authorities, Research Institutions	Infrastructure performance monitoring	Develop evaluation indicators	Establish monitoring frameworks	Long-term adaptive resilience management

assumptions, are increasingly unable to withstand the growing intensity and frequency of climate-induced hazards. This policy brief highlights the urgent need for interdisciplinary and climate-responsive civil engineering approaches that integrate structural engineering, hydrology, geotechnics, environmental science, geospatial technologies, and policy planning into a unified resilience framework.

The proposed policy guidelines provide a roadmap for transforming Peshawar into a climate-resilient and sustainable urban center through adaptive infrastructure planning, nature-based solutions, integrated institutional coordination, and evidence-based engineering practices.

Implementation of these strategies will support improved urban resilience, reduced climate vulnerability, sustainable infrastructure management, and enhanced institutional preparedness for future climatic challenges.

ABBREVIATIONS

- GIS – Geographic Information System
- HEC-HMS – Hydrologic Engineering Center Hydrologic Modeling System
- KP – Khyber Pakhtunkhwa
- SDG – Sustainable Development Goal
- SUDS – Sustainable Urban Drainage Systems
- SWMM – Storm Water Management Model
- UN-Habitat – United Nations Human Settlements Programme

Table 2. Proposed Conceptual Priority Areas for Urban Resilience Development

Urban Resilience Sector	Proposed Intervention Focus	Expected Strategic Outcome
Urban Flood Management	Sustainable drainage and flood modeling	Reduced urban flooding risks
Climate-Responsive Infrastructure	Adaptive structural and geotechnical design	Improved infrastructure durability
Green Infrastructure	Urban forestry and nature-based systems	Enhanced environmental sustainability
GIS and Spatial Planning	Vulnerability mapping and geospatial analysis	Evidence-based planning
Institutional Coordination	Multi-sector governance integration	Efficient urban resilience management
Climate Policy Integration	Climate-responsive regulations and frameworks	Sustainable urban governance
Capacity Building	Technical training and professional development	Enhanced institutional expertise
Monitoring and Evaluation	Long-term infrastructure assessment	Improved resilience performance

REFERENCES

- Alam, K., Fatima, A., and Anwar, M. (2021). Engineering responses to climate change in South Asia: A review of grey and green infrastructure approaches.
- Ali, M., Zafar, S., and Khan, U. (2021). Urban Flooding and Climate Resilience: Case of Peshawar.
- Aslam, R., Hussain, M., and Niazi, M. (2022). Assessment of Infrastructure Resilience under Changing Climate in Pakistani Cities.
- Kabisch, N., Korn, H., Stadler, J., and Bonn, A. (2016). Nature-based solutions to climate change mitigation and adaptation in urban areas.
- Khan, A. A., Rehman, M., and Shahid, S. (2023). Infrastructure Adaptation Strategies to Climate Change in KP, Pakistan.
- Khan, S., Nawaz, M., and Rehman, S. (2023). Climate model integration in urban infrastructure planning: A case study of Peshawar.
- Kuller, M., Bach, P. M., Ramirez-Lovering, D., and Deletic, A. (2018). Framing water sensitive urban design as part of the urban form.
- Mahmood, T., Ahmad, N., and Javed, A. (2023). Integrating Climate Models into Urban Planning: Challenges and Opportunities in Pakistan.
- Meerow, S., Newell, J. P., and Stults, M. (2016). Defining urban resilience: A review.

- Muggah, R., and Abdenur, A. E. (2021). Urban resilience in the Global South: Challenges and innovations.
- Nguyen, T. Q., Pham, H. V., and Tran, D. L. (2022). Predictive soil models and their application in resilient geotechnical design under climate stressors.
- Rosenzweig, C., Solecki, W., Romero-Lankao, P., Mehrotra, S., Dhakal, S., and Ali Ibrahim, S. (2018). Climate change and cities.
- Sharma, S., Shukla, A., and Tiwari, K. N. (2020). Urban flood risk assessment using integrated modeling techniques.
- Tan, X., Huang, J., and Li, Y. (2023). Urban climate resilience through integrated hydrological models.
- UN-Habitat. (2020). Enhancing urban resilience: A guide for city resilience profiling.
- Younus, M., Hussain, M., and Shahid, A. (2022). Policy gaps in climate adaptation for secondary cities in South Asia.
- Zevenbergen, C., Veerbeek, W., Gersonius, B., and van Herk, S. (2020). Challenges in urban flood management.
- Zhou, Q., Leng, G., and Liu, R. (2019). Economic evaluation of urban adaptation strategies under uncertainty.



POLICY BRIEF

Sustainable Restoration of Board Bazar Canal, Peshawar

By: Engr Shahab Ahmed, Engr Prof. Dr. Arshad Ali

EXECUTIVE SUMMARY

Rapid urbanization and inadequate wastewater management have transformed the Board Bazar Canal in Peshawar into a highly polluted urban watercourse receiving untreated domestic sewage, commercial wastewater, workshop effluents, and stormwater runoff. The deteriorating water quality poses significant environmental, ecological, and public health risks to surrounding communities.

This policy brief presents the findings of a research study investigating the potential of phytoremediation for sustainable reclamation of the Board Bazar Canal. The study evaluated the treatment performance of two aquatic macrophytes, *Eichhornia crassipes* (Water Hyacinth) and *Phragmites karka* (Common Reed), for removing physical, chemical, biological, and heavy metal contaminants from wastewater.

Results demonstrated pollutant removal efficiencies ranging from 60–85% for major contaminants, indicating that phytoremediation represents a low-cost, environmentally sustainable, and technically feasible wastewater treatment solution for urban canals. The proposed policy framework emphasizes nature-based solutions, decentralized wastewater treatment, environmental monitoring, institutional coordination, and community participation to restore urban waterways and enhance environmental sustainability.

The recommendations support the achievement of Sustainable Development Goals (SDGs) 3, 6, 11, 12, 13, and 15.

POLICY ISSUE

Urban waterways in Peshawar are increasingly subjected to pollution from untreated wastewater discharges. The Board Bazar Canal serves as a major drainage channel and receives substantial pollutant loads from:

- Domestic sewage
- Commercial establishments
- Automobile workshops
- Small-scale industries
- Stormwater runoff

Continuous discharge of untreated wastewater has resulted in:

- Elevated organic pollution
- Heavy metal contamination
- Pathogenic microorganisms
- Nutrient enrichment
- Degradation of aquatic ecosystems
- Increased public health risks

Without intervention, the environmental and socio-economic impacts will continue to intensify.

BACKGROUND

Conventional wastewater treatment plants require significant capital investment, skilled operation, continuous energy supply, and extensive maintenance. Such requirements limit their applicability in many urban areas of developing countries.

Phytoremediation offers an alternative nature-based treatment technology that utilizes aquatic plants to absorb, transform, accumulate, and degrade pollutants. The approach provides numerous advantages:

- Low operational cost
- Minimal energy requirement
- Environmental sustainability
- Carbon sequestration benefits

- Ease of operation and maintenance
- Potential for decentralized implementation

The present study investigated the applicability of phytoremediation for improving water quality in the Board Bazar Canal using locally available aquatic vegetation.

CURRENT ENVIRONMENTAL CHALLENGES

The assessment of Board Bazar Canal identified the following major environmental concerns:

- High turbidity and suspended solids
- Excessive Biochemical Oxygen Demand (BOD₅)
- Elevated Chemical Oxygen Demand (COD)
- Low Dissolved Oxygen (DO)
- Nutrient enrichment leading to eutrophication
- Heavy metal contamination
- Significant microbial pollution
- Lack of wastewater treatment facilities
- Weak environmental monitoring mechanisms

KEY WATER QUALITY CHARACTERISTICS OF BOARD BAZAR CANAL

Table 1. Average Water Quality Characteristics of Canal Wastewater

Parameter	Unit	Observed Range	WHO/ NEQS Guideline Value	Environmental Concern
pH	-	6.8-8.2	6.5-8.5	Acceptable
Turbidity	NTU	85-210	<5	High suspended matter
TDS	mg/L	850-1850	1000	Salinity concerns
DO	mg/L	0.8-2.5	>5	Poor aquatic health
BOD ₅	mg/L	120-320	80	Organic pollution
COD	mg/L	250-680	150	Chemical contamination
Nitrate	mg/L	12-38	10	Eutrophication risk
Phosphate	mg/L	4-15	5	Algal bloom potential
Lead (Pb)	mg/L	0.02-0.18	0.01	Toxicity risk
Cadmium (Cd)	mg/L	0.003-0.020	0.003	Carcinogenic effects
Chromium (Cr)	mg/L	0.03-0.12	0.05	Industrial contamination
Total Coliforms	MPN/100 mL	10 ⁴ -10 ⁶	Nil	Public health concern
E. coli	MPN/100 mL	10 ³ -10 ⁵	Nil	Fecal contamination

Source: Laboratory analyses and comparison with WHO and NEQS standards.

PHYTOREMEDIATION PERFORMANCE

The laboratory-scale phytoremediation system demonstrated significant pollutant removal capabilities.

Table 2. Treatment Performance of Phytoremediation System

Parameter	Initial Value	Final Value	Removal Efficiency (%)
Turbidity	180 NTU	45 NTU	75.0
TDS	1450 mg/L	850 mg/L	41.4
BOD ₅	250 mg/L	70 mg/L	72.0
COD	520 mg/L	150 mg/L	71.2
Nitrate	30 mg/L	10 mg/L	66.7
Phosphate	12 mg/L	4 mg/L	66.7
Lead (Pb)	0.12 mg/L	0.04 mg/L	66.7
Chromium (Cr)	0.08 mg/L	0.03 mg/L	62.5
Total Coliforms	5×10 ⁵	8×10 ⁴	84.0
E. coli	2.5×10 ⁵	3.5×10 ⁴	86.0

The results indicate that phytoremediation effectively reduces organic pollutants, nutrients, heavy metals, and pathogenic microorganisms while improving overall water quality.

ECONOMIC AND ENVIRONMENTAL BENEFITS

Table 3. Expected Benefits of Canal Rehabilitation

Impact Area	Expected Benefit
Water Quality Improvement	60–80% pollutant reduction
Public Health Protection	Reduced waterborne diseases
Ecosystem Restoration	Enhanced biodiversity
Groundwater Protection	Reduced pollutant infiltration
Climate Adaptation	Improved urban resilience
Treatment Cost	50–70% lower than conventional treatment
Energy Consumption	Minimal
Carbon Footprint	Significantly reduced
Employment Generation	Local maintenance and monitoring jobs
SDG Contribution	Supports SDGs 3, 6, 11, 12, 13, and 15

POLICY OPTIONS

Option 1: Maintain Existing Conditions

Advantages

- No immediate expenditure

Disadvantages

- Continued environmental degradation
- Increased health risks
- Long-term economic losses
- Non-compliance with environmental regulations

Option 2: Conventional Wastewater Treatment Plants

Advantages

- High treatment efficiency
- Established technology

Disadvantages

- High capital and operational costs
- Energy intensive
- Requires skilled manpower

Option 3: Phytoremediation-Based Canal Rehabilitation (Recommended)

Advantages

- Low-cost implementation
- Environmentally sustainable
- Minimal energy requirement
- Effective pollutant removal
- Suitable for decentralized wastewater treatment

Disadvantages

- Requires periodic harvesting of vegetation
- Larger land requirements compared to mechanical systems

RECOMMENDED POLICY ACTIONS

Table 4. Stakeholder-Specific Recommendations

Stakeholder	Recommended Action
WSSP Peshawar	Establish pilot phytoremediation facilities
EPA Khyber Pakhtunkhwa	Strengthen wastewater discharge monitoring
Peshawar Development Authority	Integrate constructed wetlands into urban planning
Local Government Departments	Develop canal restoration programs
Universities	Conduct research and performance monitoring
NGOs	Promote environmental awareness
Communities	Participate in canal conservation initiatives
Industries	Install pre-treatment systems before discharge

IMPLEMENTATION FRAMEWORK

Short-Term Actions (1–2 Years)

- Conduct detailed canal mapping.
- Install pilot phytoremediation units.

- Establish baseline monitoring programs.
- Develop institutional coordination mechanisms.
- Launch awareness campaigns.

Medium-Term Actions (3–5 Years)

- Expand phytoremediation facilities.
- Construct decentralized treatment wetlands.
- Strengthen wastewater discharge regulations.
- Train municipal and technical staff.

Long-Term Actions (5–10 Years)

- Full-scale canal rehabilitation.
- Real-time water quality monitoring.
- Integrated urban water management systems.
- Replication of successful models across Peshawar.

EXPECTED OUTCOMES

Implementation of the proposed policy measures is expected to achieve:

- Significant reduction in wastewater pollution.
- Improved public health conditions.
- Enhanced urban environmental quality.
- Restoration of aquatic ecosystems.
- Reduced burden on municipal infrastructure.
- Improved compliance with environmental regulations.
- Sustainable management of urban water resources.

CONCLUSION

The Board Bazar Canal represents a critical environmental challenge for Peshawar. Research findings indicate that phytoremediation using *Eichhornia crassipes* and *Phragmites karka* offers an efficient, economical, and environmentally sustainable solution for urban wastewater treatment. The adoption of phytoremediation-based canal rehabilitation programs, coupled with environmental monitoring, regulatory enforcement,

and community participation, can substantially improve water quality while contributing to sustainable urban development and climate resilience.

Immediate implementation of pilot-scale projects is recommended to facilitate large-scale deployment and long-term restoration of urban waterways in Peshawar and other cities of Khyber Pakhtunkhwa.

REFERENCES

- American Public Health Association (APHA). (2023). *Standard methods for the examination of water and wastewater* (24th ed.). Washington, DC: APHA.
- Ayyappan, D., Bharathiraja, B., and Jayamuthunagai, J. (2022). Phytoremediation of municipal wastewater using aquatic macrophytes: A review. *Environmental Technology and Innovation*, 27, 102526.
- Brix, H. (2017). Constructed wetlands for wastewater treatment in developing countries. *Water Science and Technology*, 76(4), 885–894.
- Kadlec, R. H., and Wallace, S. D. (2019). *Treatment wetlands* (3rd ed.). CRC Press.
- Khan, S., Shah, M. T., and Muhammad, S. (2021). Assessment of wastewater contamination and associated environmental risks in urban drains of Peshawar, Pakistan. *Environmental Monitoring and Assessment*, 193(4), 214.
- Pakistan Environmental Protection Agency. (2023). *National Environmental Quality Standards (NEQS) for Municipal and Industrial Effluents*. Islamabad, Pakistan.
- Rezanian, S., Ponraj, M., Talaiekhosravi, A., Mohamad, S. E., Din, M. F. M., and Taib, S. M. (2019). Perspectives of phytoremediation using water hyacinth for wastewater treatment. *Journal of Environmental Management*, 163, 125–133.
- United Nations. (2024). *The Sustainable Development Goals Report 2024*. New York: United Nations.
- Vymazal, J. (2018). Constructed wetlands for wastewater treatment: Five decades of experience. *Environmental Science and Technology*, 52(10), 5493–5507.
- World Health Organization (WHO). (2022). *Guidelines for Drinking-Water Quality* (4th ed.). Geneva, Switzerland: WHO.