

1 *Type of the Paper is Review*

2 **Cost Effective Nature Based Solutions for Urban Water Quality** 3 **Improvement in Lahore, A Comparative Review**

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9 **Abstract**

10 Rapid urbanization and inadequate wastewater management have intensified water qual-
11 ity degradation in major cities of developing countries, particularly in Lahore, Pakistan.
12 Conventional centralized treatment systems often fail to deliver sustainable performance
13 due to high capital costs, energy dependence and institutional constraints. This study pre-
14 sents a systematic narrative review of cost-effective and sustainable urban water quality
15 improvement methods, with a primary focus on Lahore while maintaining broader ap-
16 plicability across Pakistan. The review evaluates nature-based solutions, low-cost techno-
17 logical interventions, decentralized treatment systems and policy-oriented approaches us-
18 ing a multi-criteria framework encompassing treatment efficiency, cost-effectiveness, en-
19 vironmental sustainability, scalability and contextual suitability. Comparative analysis in-
20 dicates that constructed wetlands, biochar-based adsorption systems, solar and photo-
21 catalytic disinfection technologies and community-based decentralized systems consist-
22 ently outperform conventional centralized treatment plants under local socio-economic
23 and environmental conditions. Constructed wetlands show high reclamation rates for or-
24 ganic pollutants, biochar systems demonstrate strong heavy-metal removal efficiency and
25 solar-based disinfection offers effective pathogen control under favorable climatic condi-
26 tions. The findings highlight that no single technology is universally optimal; instead, in-
27 tegrated hybrid treatment configurations aligned with Integrated Urban Water Manage-
28 ment principles provide the most viable pathway for sustainable urban water quality im-
29 provement. This review offers practical insights for urban planners, policymakers, and
30 water managers seeking resilient, low-cost solutions for rapidly growing cities such as
31 Lahore.

32 **Keywords:** Urban water quality management; Nature based solutions; Sustainable water
33 management.

35 **1. Introduction**

36 Safe drinking water is a basic human right and need to survive and live. Consump-
37 tion of water should not be in the presence of constituents that can have adverse effects
38 on the health of human beings such as toxic minerals, organic compounds and pathogenic
39 microorganisms. Nevertheless, a big percentage of the population in the third world coun-
40 tries still experiences water health issues because of poor access to clean drinking water

41 and microbiological pollution of the water sources [1]. It has been estimated that five mil-
42 lion children die each year in developing countries as a result of poor water quality, which
43 is further compounded by the rapid population growth, poor management of water-qual-
44 ity and the overloaded water-supply systems [2]. Poor quality of water is known to cause
45 about 30 percent of all diseases and 40 percent of all deaths in Pakistan [3]. Diarrhea is the
46 most common way of killing the infants and children and approximately 1 out of 5 people
47 experience diseases brought about by the contaminated water [4]. Although these are
48 alarming statistics, there is a little literature on drinking-water quality problem because
49 the policies governing water management in Pakistan still focus on quantity rather than
50 quality. The lack of a national water quality monitoring and surveillance system, ineffi-
51 cient institutional coverage, inadequate laboratories, lack of enforcement of the law and
52 insufficient awareness of the society about water-associated health hazards have also con-
53 tributed to the crisis [5].

54 Even though one of the most plentiful renewable resources on Earth is water, the
55 quality and availability of water are slowly getting jeopardized by the processes of popu-
56 lation growth, urbanization, industrialization and climate change [6]. This release of un-
57 treated industrial effluents and domestic wastewater into surface and underground water
58 systems has had deplorable effects on the aquatic life, drinking-water sources and posed
59 serious health risks to the populace due to the accretion of heavy metals and toxic wastes
60 [7], [8]. Inadequate and unreliable water supply in developing nations like Pakistan forces
61 populations to use unsafe water sources such as shallow dug wells and boreholes which
62 exposes them to water borne diseases [9]. There is also emerging research pointing to the
63 fact that the modern water-supplies technologies such as chemical composition of pipe-
64 lines may contribute to a physical, chemical and biological contamination of drinking wa-
65 ter unintentionally [10]. The lack of sufficient supply of safe drinking water, therefore, still
66 remains a significant challenge to the health of people and environmental sustainability.

67 Water degradation is also especially apparent in large Pakistani cities such as Lahore,
68 where access to sanitation and clean water is very limited and its health effects are very
69 dire. The consumption of polluted water and poor sanitation is leading to one of the most
70 common problems in low-income countries which claims lives of roughly 2.2 million
71 every year. The Sustainable Development Goals (SDGs) have identified that in the global
72 population, some 1.2 billion individuals continue to have no access to basic water services,
73 with most of them being rural inhabitants of Least Developed Countries (LDCs) [11]. Wa-
74 ter-borne diseases have caused over 60 per cent of the infant mortality in Pakistan and
75 almost 90 per cent of the rural population in Pakistan has no access to clean drinking water
76 [12]. According to UNICEF, water-related diseases, such as diarrhea, cholera, malaria,
77 hepatitis, typhoid, dysentery and giardiasis are the cause of 12.6 percent neonatal mortal-
78 ity and 7 percent fertility complication-related deaths with an estimated 0.2 to 0.25 million
79 children dying each year due to diarrhea alone [13].

80 The city of Lahore is the second most populated and 26th largest city in Pakistan and
81 is experiencing a severe and complicated water quality crisis. The climatic variability of
82 the city, which is expressed in the presence of five seasons and an active monsoon phase,
83 also makes a strong impact on the patterns of contamination. Research has reported high
84 levels of physio-chemical measurements, such as total dissolved solids (TDS), pH, calcium
85 (Ca^{2+}), magnesium (Mg^{2+}), turbidity and electrical conductivity (EC) in large residential
86 and urban spaces and in many instances go beyond the World Health Organization
87 (WHO) standards [14]. Aging distribution infrastructure, urban sprawl, inadequate waste
88 management systems, leakage of toxic chemicals and decreasing ground water levels are
89 the causes of these conditions. The Water Quality Index (WQI) evaluation of several La-
90 hore locations indicates that the water quality in the regions is rated as poor (59.66) and
91 very poor (77.30), which highlights the necessity to intervene immediately [14].

Poor treatment of wastewater and poor solid waste management activities are some of the major factors that lead to degradation of water in the city of Lahore [15]. The improper collection of garbage and solid waste encourages infiltration of leachates in the groundwater systems [16]. Reportedly, the concentration of pollutants in landfill sites, such as arsenic has been reported to be in excess of the acceptable levels [15], and discrepancies between the official and informal waste management systems have also been reported to negatively affect the efficiency of waste treatment [17]. Moreover, the further release of the untreated municipal and industrial wastewater into water surfaces increases the environmental pollution and the risk of infections among the population [18], [19]. Unless policy implementation, governance structures, and community involvement improve immediately, the extent of the water quality crisis at Lahore is likely to worsen.

Traditional urban water treatment systems are increasingly becoming pressured by the increasing complexity of pollutants, the accelerated urbanization and climate-related demands. The conventional means of treatment usually do not eliminate new pollutants like pharmaceuticals and microplastics are expensive in operation and consumption and have detrimental byproducts [20], [21]. As a reaction, integrated and sustainable approaches have become prominent. Frameworks such as Integrated Urban Water Management (IUWM) further encourage the management of the whole water cycle as a whole and foster water reuse to make the systems resilient and sustainable [22], [23].

Natural treatment systems specially made wetlands have come out as cheap and energy saving alternative in the treatment of wastewater and in tackling the emerging pollutants [22], [23]. Constructed wetlands (CWs) employ biological, chemical and physical treatment processes to treat wastewater effectively through the use of natural processes. Hybrid CW systems have shown to have high removal efficiency with removal of 92% biochemical oxygen demand (BOD₅), 89% chemical oxygen demand (COD) and 97% total suspended solids (TSS) in long-term systems [24]. Equally, the subsurface flow systems in horizontal systems under Mediterranean climates had exhibited mean declines in BOD₅ and COD of 55 and 60% respectively [25]. In addition to the treatment, CWs facilitate irrigation through water reuse, improve the aesthetics of urban landscapes, improve microclimates and foster biodiversity, which is in line with the principles of the circular economy [25], [26], [27]. However, there are issues like risks of ground water contamination and their maintenance which should be handled carefully to maximize their performance [26], [28].

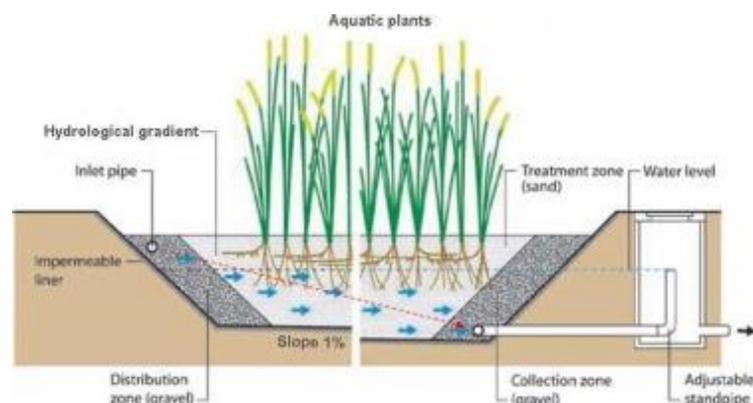


Figure 1: Typical CW Design [29]

Simultaneously, biochar and other inexpensive adsorbents have received some interest due to their usefulness in the removal of heavy metals in polluted water. The biochar will be a cheap and eco-friendly substitute to the normal activated carbon, which is made out of organic waste. The removal of heavy metals happens by the ion exchange, precipitation, complexation and electrostatic interactions with the functional surface groups [30].

132 Several modified biochars have been reported to have high adsorption capacities with a
133 reported value of 248.33 mg/1 lead and 228.05 mg/1 copper [31], whilst biomass sources
134 such as peanut shells have been reported to have removal efficiencies of upto 90% [32]
135 with reported values of 248.33 mg/1 lead and 228.05 mg/1 copper. Although this has its
136 benefits, more studies are needed on how to maximize the production procedure and im-
137 prove the adsorption performance to serve large scale use.

138 Photocatalytic and solar-based disinfection methods also hold a potential remedy to
139 the problem of microbial contamination of wastewater. Solar disinfection is a process that
140 depends on the ultraviolet radiation to inactivate pathogens, which depends on the pH
141 and the presence of oxidizing agents such as hydrogen peroxide[33]. Photocatalytic reac-
142 tions, especially titanium dioxide-based reactions and doped catalyst-based reactions,
143 yield reactive species in the presence of solar light breaking down organic contaminants
144 and inactivating microorganisms with disinfection yields of up to 100% [34], [35]. Solar
145 concentrators also increase the efficiency of the treatment and minimizes the costs of op-
146 eration [36]. Nevertheless, issues concerning the changing sunlight supply and compli-
147 cated wastewater compositions require further optimization.

148 Community-based and decentralized water treatment systems provide further ave-
149 nues to the idea of sustainable water management, especially in regions where centralized
150 water treatment infrastructure is either scarce or not economical. These systems save cap-
151 ital, lessen the amount of energy necessary in the transportation of wastewater and foster
152 localized consumption of resources [37]. Enhancing the elimination of the pollutants at
153 the subsystem level, decentralized systems will lead to environmental sustainability and
154 provide water reuse and nutrient recovery in a circular economy model [38], [39]. Com-
155 munity participation also increases the ownership, accountability and long-term perfor-
156 mance of the system yet regulatory, technical and social obstacles are still a big hurdle
157 [38], [40].

158 Last but not least, ineffective water quality management is still limited by persistence
159 of policy and governance gaps. Sustainable water governance suffers as a result of incon-
160 sistent legal frameworks, lack of coordination between institutions, financial transparency
161 and lack of public involvement [41], [42], [43]. There is a need to create an integrated policy
162 that closes urban-rural and sectoral gaps that can help mitigate these failures and promote
163 collaborative and holistic management strategies [44]. The solution of the governance is-
164 sues, as well as the technological and nature-based solutions, is important to attain long-
165 term enhancements in the quality of urban water.

166 2. Methodology

167 2.1. Study Area

168 Lahore, the capital city of Punjab province (Figure 2), is a fast-urbanizing city where
169 water quality issues are an important concern because of the large population density,
170 industrialization, and poor wastewater systems [14], [15]. Having a population more than
171 11 million people and an area of 1137.43Km², the city undergoes significant municipal
172 wastewater production, stormwater runoff and surface and groundwater resources pol-
173 lution [14], [15]. These circumstances precipitate the urgent requirement of cost-efficient
174 and sustainable water treatment systems to be employed within financial, institutional as
175 well as land-use limitations that are inherent in Lahore.

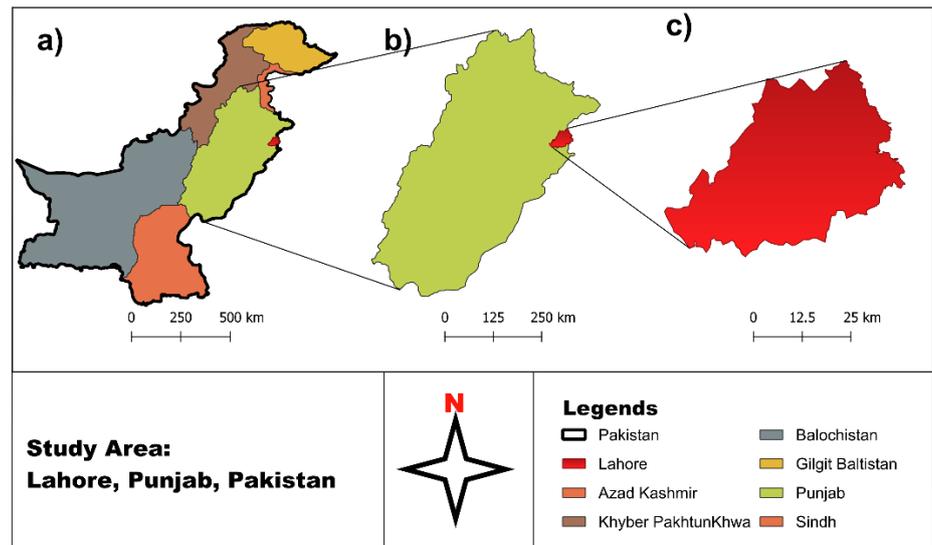


Figure 2: Map of study area showing a) Boundaries of Pakistan with its provinces, b) Boundaries of Punjab & c) Study area, Lahore.

2.2 Design and Analytical Framework

This review paper has assumed a systematic narrative review approach of assessing cost-effective and sustainable strategies of enhancing the water quality in cities, with a specific focus to developing countries like Lahore, Pakistan. Instead of producing new experimental data, the approach is concerned with the synthesis of empirical, applied and policy-oriented studies to find treatment options that are technically efficient, economically viable and environmentally friendly under urban conditions that are constrained by resources [21], [23]. The analysis is informed by the principles of the Integrated Urban Water Management (IUWM) and sustainable management of water resources, including decentralized pollution control, optimal use of resources and adjustment to climate changes, as well as adaptive governance in rapidly urbanizing conditions. Through a combination of the principles, the review allows making a well-balanced comparison between nature-based solutions and low-cost technological interventions in various performance aspects that are frequently found in Pakistan and other developing economies.

2.3 Evaluation criterion and comparative assessment.

In order to have uniformity in the heterogeneous treatment technologies, a multi-criteria assessment model was elaborated that includes the technical, economic, environment, and contextual dimensions. The efficiency of the treatment commonly called the reclamation rate was considered in studies that reported the system performance in the long-term or full-scale system, as these give more indicators of operational effectiveness than short-term laboratory studies. The indicators used to measure economic performance did not consider monetary values, but relative cost, since there is a large variation in construction, labor and energy costs across the region. Technologies were thus evaluated according to capital concentration, operational and maintenance needs, energy reliance and use of locally manufactured and imported materials. This type of comparative cost classification is widely used in sustainability-oriented water treatment reviews and allows us to make cross-context comparisons without the bias related to currencies. Environmental sustainability was considered via such indicators as energy use, implications of greenhouse gas emissions, water reuse potential and the correspondence to the principles of the circular economy. Environmentally friendly technologies included those that depend on passive methods of treatment, renewable sources of energy, or waste products. Social and

211 ecological co-benefits like improvement in biodiversity, landscape incorporation and
212 acceptance by the community were also included in the evaluation where reported. Context-
213 tual suitability was determined through the association of each method of treatment in
214 relation to the particular urban water quality issues such as: municipal wastewater pollu-
215 tion, stormwater run off, contaminated ground water with heavy metals and microbio-
216 logically unsafe drinking water. The evaluation, which is problem-oriented, would be in
217 line with IUWM principles and adaptive urban water governance frameworks [22], [23].

218 2.4 *Tabular Comparative Analysis of Treatment Methods.*

219 Table 1 gives a plotted comparison of the urban water quality improvement methods
220 in Lahore, Pakistan under the parameters of efficiency of treatment, cost-effectiveness, en-
221 vironmental sustainability, feasibility and scalability, social acceptance, policy alignment
222 and general suitability. The tabular evaluation will allow making a direct comparison be-
223 tween nature-based, technological, decentralized and governance-related interventions
224 and will offer a systematized foundation of interpretation of the relative merits and the
225 constraints of the Pakistani situation. As noted in the table, the constructed wetlands are
226 highly effective in organic pollution and suspended solids removal, the biochar-based ad-
227 sorbents are highly effective in removing heavy-metal, solar and photocatalytic systems
228 are highly effective in inactivating pathogens and decentralized systems are flexible and
229 scalable in infrastructure-constrained environments. The indirect impact of policy and
230 governance interventions on water quality is enabled by facilitating better performance of
231 the system, compliance and long-term sustainability.

232 2.5 *Comparative Findings Interpretation in Lahore, Pakistan.*

233 The comparative analysis Table 1 suggests that solutions based on nature and low
234 cost that are decentralized, persistently perform better as compared to conventional cen-
235 tralized systems in comparison with Pakistan-specific economic, infrastructural, and ad-
236 ministrative constraints. Wetlands on construction exhibit a high reclamation of organic
237 and suspended solids and have very low operational expenses and energy needs, which
238 makes them very appropriate in the treatment of urban water waste in cities like Lahore
239 [24], [26]. Their effects on the environment are mostly positive because of the improve-
240 ment of the ecosystem and the minimization of greenhouse gas emissions in comparison
241 with mechanical treatment systems [25], [28]. Adsorption systems that use biochar become
242 one of the most successful alternatives in the treatment of heavy-metal-contaminated
243 groundwater, which is becoming a more and more serious problem in Pakistan in the
244 context of the industrial discharge and landfill leachate intrusion [15], [31]. Their low pric-
245 ing, use of agricultural residues and high adsorption results are in line with the circular
246 economy targets and national sustainability targets [30], [32]. Solar and photocatalytic dis-
247 infection systems exhibit almost 100 percent pathogen elimination when the standard so-
248 lar conditions are favorable and are thus quite useful in dealing with microbiological con-
249 tamination of drinking water in Pakistani high-solar environment. Decentralized treat-
250 ment systems of wastewater also provide resilience and flexibility particularly in regions
251 that do not have a centralized infrastructure, although their effectiveness depends on the
252 proper design and maintenance of the system [37], [40].

253 Conversely, traditional centralized treatment facilities have remained limited to high
254 capital, energy reliance and operational inefficiencies, despite their high theoretical per-
255 formance, which lowers their effectiveness in the long run in urban settings in Pakistan
256 [18], [19].

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Table 1: Comparative Findings in context of Lahore

Method	Treatment Efficiency	Cost-Effectiveness	Environmental Sustainability	Feasibility / Scalability	Social / Community Acceptance	Policy / Regulatory Alignment	Overall Suitability in Pakistan
Constructed Wetlands (CW)	High for BOD, COD, and TSS; Moderate for pathogen removal (up to 90%)	Moderate; low operational costs but high land requirement	High; natural processes, minimal energy use, low carbon footprint	Moderate; land-intensive, limiting dense urban deployment	High; strong potential for community involvement	Moderate; Requires supportive land-use and wastewater policies	Suitable for Peri-urban and low-density areas
Biochar / Low-Cost Adsorbents	High; effective for heavy metals and organics (up to 90%)	High; low-cost, reusable, locally sourced materials	High; promotes circular economy and waste valorization	High; modular, scalable, and adaptable	Moderate; basic technical training required	Moderate; regulatory support needed for reuse and disposal	Highly suitable for urban and peri-urban treatment
Solar / Photocatalytic Disinfection	High for pathogens; Moderate for organics (up to 100% inactivation)	Moderate; higher initial cost but low operational expenses	High; solar-powered and environmentally clean	Moderate; dependent on sunlight and catalyst maintenance	Moderate; requires training and monitoring	Moderate; compliance with drinking water standards required	Suitable for point-of-use potable water treatment
Community-Based / Decentralized Systems	Moderate to High; technology-dependent performance	High; avoids centralized infrastructure costs	High; localized treatment reduces energy and discharge	High; flexible across settlement types	High; strong community ownership and participation	Moderate to High; supports decentralized governance	Highly suitable for informal and resource-limited communities
Policy / Governance Interventions	Indirect Impact; strengthens all technical solutions	Not Directly Applicable; focused on regulation and enforcement	High; enables sustainable practices and incentives	High; provides a framework for scaling interventions	High; promotes accountability and public engagement	High; essential for coordination and legal compliance	Critical across urban and rural settings

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2.6 *Methodological Implications.*

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The comparative evaluation has shown that there is no one optimum treatment technology that offers universal solution. Rather, hybrid treatment designs which take into account the combined use of constructed wetlands, biochar filtration and solar-based disinfection, represent the most balanced treatment based on cost, performance, sustainability and environmental impact indicators. These combined strategies comply with concepts of IUWM and constitute a viable way of sustainable urban enhancement of water quality in Pakistan

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3. Results

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The findings of the comparative analysis indicate that urban water quality improvement methods portray some specific performance trends when evaluated regarding the treatment effectiveness, cost, sustainability and contextual suitability. On the whole, the

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274 nature-based and decentralized systems prove to be more effective compared to the cen-
275 tralized ones given the financial, institutional, and infrastructural limitations that Paki-
276 stani cities like Lahore have to operate.

277 *3.1 Treatment Efficiency and Reclamation Performance*

278 In general, constructed wetlands had high reclamation rates of organic and sus-
279 pended solids, and BOD₅, COD, and TSS removal efficiencies were reported to be usually
280 over 85 and, in other longer-term systems, higher than 90 percent [24], [25], [26]. Their
281 results are affirmative that they are applicable in the municipal wastewater treatment in
282 Pakistan where organic pollution is still a major issue of concern [14], [15].

283 The adsorption systems that were constructed with biochar demonstrated good and
284 consistent capabilities of the removal of heavy-metals, with efficiencies generally in the
285 range of 70 to 90 percent of removed contaminants including lead, cadmium, copper and
286 zinc [30], [31], [32]. The solar and photocatalytic disinfection technologies had the best
287 reclamation of microbial contaminants with a pathogen inactivation efficacy of up to 100
288 percent when the solar conditions were favorable [33], [35]. Centralized treatment plants
289 on the contrary showed uneven real-life performance in terms of operational failures, en-
290 ergy shortage, and failure to maintain the system, especially in big urban areas [18], [19].

291 *3.2 Cost Performance and Economic Feasibility.*

292 The cost proved to be a critical factor that affected technology feasibility. Biochar-
293 based and constructed wetlands were always categorized as low-cost alternatives because
294 they were built with the use of the locally available resources and used passive treatment
295 mechanisms and consumed low energy [26], [30]. Solar disinfection systems were divided
296 into low-to-moderate cost categories, where the initial investment in infrastructure is com-
297 pensated by insignificant operating costs over a period [33], [36].

298 At the community scale, decentralized wastewater systems have shown desirable
299 performance in terms of costs since they minimize the cost related to conveyance infra-
300 structure and allow them to operate at a local scale [37], [40]. On the other hand, central-
301 ized treatment plants were characterized by high costs of capital and operation induced
302 by the energy-consuming processes and multicomponent maintenance needs, which
303 greatly reduces their scalability in Pakistan.

304 *3.3 Sustainability and Impact to the environment.*

305 Nature based solutions were much better in performance. Wetlands built helped to
306 increase biodiversity, enhance microclimates and use of non-drinkable water and had low
307 carbon footprint. The biosystems have facilitated the goals of waste valorization and cir-
308 cular economy through the utilization of agricultural residues to generate operational
309 treatment media.

310 There were insignificant systems on solar disinfection technology which revealed in-
311 significant environmental impact through the removal of chemical disinfectants and the
312 use of fossil fuel-based energy. Decentralized systems were also more sustainable with
313 the incentive to local ownership encouraging low infrastructure load and resilience to cli-
314 mate induced water stress. Centralized systems in turn were also linked with increased
315 environmental impact such as greenhouse gases and sludge management issues.

316 *3.4 Contextual Suitability*

317 A comparison of the results with the various water quality issues facing Pakistan
318 reveals that integrated treatment structures are the most suitable performance systems
319 compared to single technologies. The most flexible system to the Pakistani fractured urban
320 infrastructure and mixed profiles of contamination is the hybrid system with nature-based
321 and cheap technological interventions, as described in Table 1.

4. Discussion

The findings underscore the importance of aligning urban water treatment technologies with local economic, institutional and environmental conditions rather than relying solely on conventional centralized systems. While centralized treatment plants offer theoretical advantages in terms of capacity and standardized control, their effectiveness in Lahore, Pakistan is constrained by unreliable energy supply, high operational costs and limited technical expertise. These limitations reduce long-term system reliability and sustainability.

Nature-based solutions, particularly constructed wetlands, provide multiple co-benefits beyond wastewater treatment, including ecosystem enhancement, climate adaptation and water reuse opportunities. However, their primary limitation lies in land requirements, which may restrict large-scale deployment in densely populated urban cores. Biochar-based adsorption systems offer flexibility and effectiveness for heavy-metal removal but require periodic regeneration or replacement of media, necessitating proper waste handling strategies.

Solar and photocatalytic disinfection technologies are highly effective for pathogen removal and are especially suitable for regions with high solar irradiance. Their performance, however, may fluctuate under unfavorable weather conditions, indicating the need for hybrid integration with complementary treatment methods. Decentralized systems address infrastructure and governance challenges by enabling community-level management, though their success depends on institutional support, public awareness and capacity building.

The methodological framework applied in this study is transferable to other developing urban contexts facing similar constraints, such as cities in South Asia, Africa and Southeast Asia. Integrating performance indicators related to efficiency, cost and sustainability enables decision-makers to identify context-specific solutions rather than adopting uniform treatment strategies.

From a policy perspective, the results suggest that urban water management strategies should prioritize hybrid and decentralized treatment models, supported by regulatory incentives, land-use planning integration and capacity-building initiatives. Policymakers should encourage public-private partnerships, promote the reuse of treated wastewater, and incorporate nature-based solutions into urban development plans to enhance long-term water security.

5. Conclusions

This study demonstrates that nature-based and decentralized wastewater treatment systems offer more effective, economically viable and environmentally sustainable solutions for improving urban water quality in Lahore and similar cities. Constructed wetlands, biochar-based adsorption systems and solar disinfection technologies outperform centralized treatment plants under prevailing financial and institutional constraints.

The adoption of integrated hybrid systems that combine natural and low-cost technological approaches provides a practical pathway for addressing diverse pollution profiles and fragmented urban infrastructure. Future urban water policies in Pakistan should emphasize decentralized governance, sustainable financing mechanisms and the integration of nature-based solutions to achieve resilient and inclusive water quality management.

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