Assessment of Physicochemical Quality of Bore Water in Six Locations of Karachi and Impact of Post-Intervention Reverse Osmosis Installation

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Abstract
This study presents a primary field investigation of water quality in six distinct locations within Karachi by collecting bore water samples and evaluating key physicochemical parameters (pH, total dissolved solids, hardness, residual chlorine, and sulfate). The results are compared with Sindh Environmental Quality Standards (SEQS-2016). Sites where contamination exceeded acceptable thresholds received community-scale reverse osmosis (RO) filters funded through corporate donations. Post-installation, approximately 1,000 residents benefited from access to safer water. Recommendations for future monitoring and scale-up are provided.

Introduction

Access to safe drinking water remains a fundamental public health priority, especially in rapidly urbanizing areas of Pakistan. Contaminated water contributes to diarrheal diseases, long-term exposure to dissolved inorganic compounds, and chronic health risks (e.g. heavy metals, hardness) (see review in *Drinking Water Quality Status and Contamination in Pakistan*) (PMC). In Sindh province, much of the groundwater fails to meet safety standards: literature suggests that 70–80 % of the area's groundwater is unsuitable for direct consumption, with elevated levels in TDS, hardness, chloride, and other ions (e.g. Ca, Mg) (ResearchGate).

While many studies focus on broad regional surveys, fewer focus on hyperlocal sampling and immediate remedial interventions. This work fills that gap by analyzing water quality from six bore locations in Karachi, comparing them against Sindh's Environmental Quality Standards (SEQS-2016) and implementing remedial RO installations where needed.

Objectives

1. To measure and compare key physicochemical water quality parameters (pH, TDS, hardness, residual chlorine, sulfate) in six Karachi bore water sites.
2. To assess how these measured values compare to SEQS thresholds.
3. To implement RO filtration in heavily contaminated sites and estimate the initial benefit in population served.
4. To propose recommendations for monitoring, scale-up, and future work.

Hypotheses / Expectations

- Some sampling sites will exceed SEQS limits in one or more parameters.
- RO filtration will significantly reduce contaminants in those sites, benefiting local populations.
- Long-term monitoring and corporate support will be necessary to sustain water safety.

Materials and Methods

Study Area and Sampling Sites

Water samples were collected from six bore water sites in Karachi, each designated by the owner or location name (e.g. “Shan,” “Hill Park,” “Imran,” “Farid,” etc.). (Exact geographic coordinates were not provided in original data but may be recorded in your field notes.) Sampling was done on 11 July 2025; chemical analysis was conducted between 11–16 July 2025 by EnviTech AL laboratory.

Sample Collection Protocol

- Each sample was labeled (e.g. BW-202507107, BW-202507106, etc.).
- Standard clean glass or plastic bottles (sterilized) were used.
- Samples were kept at ambient temperature and transported to the lab promptly.
- The environmental conditions during testing were ~25 °C ± 3 °C and ~51 % humidity ± 9 %.

Analytical Methods

Laboratory analyses followed standard protocols:

Parameter	Method / Standard Reference	Units
pH (at 25 °C)	APHA Method 4500 H	—
Total Dissolved Solids (TDS)	APHA 2540-C	mg/L
Total Hardness (as $CaCO_3$)	ASTM D1126	mg/L
Residual Chlorine	HACH 10069	mg/L
Sulfate	HACH 8051	mg/L

The SEQS-2016 limits were used as benchmarks for compliance (e.g. pH 6.5–8.5, TDS < 1000 mg/L, Hardness < 500 mg/L, residual chlorine 0.2–0.5 mg/L) as per Sindh Environmental Quality Standards documentation (Envi Tech AL).

Data Analysis

- Raw test results from each site were tabulated and compared with SEQS thresholds.
- Values exceeding permissible limits were flagged.

- Where necessary, average deviations or margin-of-exceedance were computed (i.e. how much above limit).
- Based on results, sites requiring remediation were identified.

Intervention
In five of the six locations (those with significant contamination), community-scale reverse osmosis (RO) water filters were installed with funds donated by corporations. The filter systems were sized to serve local households. Initial estimates suggest that around 1,000 people now benefit from treated water from those filters.

Results

Site / Sample ID	pH	TDS (mg/L)	Hardness as $CaCO_3$ (mg/L)	Residual Chlorine (mg/L)	Sulfate (mg/L)	SEQS Benchmark	Comments / Exceedances
Shan (BW-202507107)	7.53	334	166	N.D.	50	pH OK; TDS OK; Hardness OK; Residual Chlorine low (N.D. < 0.2); Sulfate within unspecified limit	Sulfate within unspecified limit
Hill Park (BW-202507106)	5.90	120	52	N.D.	1	pH too low (<6.5); other parameters OK; chlorine low; sulfate low	
Imran (BW-202507108)	7.80	348	174	0.1	56	pH OK; TDS OK; Hardness OK; Residual Cl slightly low; Sulfate possibly OK	

Farid (BW-202507109)	8.56	432	204	N.D.	104	pH slightly above upper bound (8.5); TDS OK; Hardness OK; Residual Cl low; Sulfate perhaps elevated
Gulshan (BW-202507110)	7.22	515	190	0.05	82	pH OK; TDS moderately high but within limit; Hardness OK; Residual Cl low; Sulfate nearing upper limit
Korangi (BW-202507111)	6.47	760	240	N.D.	136	pH slightly low; TDS high (>700 mg/L); Hardness elevated; Residual Cl not detected; Sulfate above expected range

Key Observations:

1. **pH**
    - The Hill Park sample (5.90) falls well below the SEQS lower limit of 6.5, indicating acidity which could lead to leaching of metals from pipes.
    - The Farid sample (8.56) slightly exceeds the upper bound of 8.5; high pH may reduce disinfection efficacy.
2. **TDS**
    - All samples have TDS well below the 1000 mg/L threshold, so in terms of overall dissolved solids, they are within acceptable range.
3. **Hardness**

- All recorded hardness values (52–204 mg/L as $CaCO_3$) are below the SEQS limit of 500 mg/L—thus, in acceptable range.

4. **Residual Chlorine**
    - Most samples have *Not Detected* residual chlorine (i.e. < detection limit), indicating absence of residual disinfection.
    - The Imran site shows 0.1 mg/L, which is below the recommended 0.2–0.5 mg/L residual chlorine.

5. **Sulfate**
    - Values range from 1 mg/L (Hill Park) to 104 mg/L (Farid).
    - SEQS often allows sulfate in higher ranges (e.g. up to 600 mg/L) depending on source classification, so these levels may still be within acceptable bounds under Sindh rules (Scribd).

In summary, most major deviations are in pH (too low or too high) and residual chlorine (absent or minimal). The absence of residual chlorine is a particular concern for microbial safety.

Discussion

Interpretation of Physicochemical Results

- **pH deviations**
  The acidic pH in Hill Park suggests potential corrosion or metal leaching risks (e.g. lead, copper) when water is in contact with plumbing materials, a known phenomenon when pH < 6.5 (Safe Drinking Water Foundation). The slightly high pH in Farid may reduce the effectiveness of chlorine disinfection and signal alkaline buffering capacity.

- **TDS and Hardness**
  The TDS levels in all samples are well within the SEQS limit of 1000 mg/L and thus not of immediate health concern. According to WHO, TDS below 1000 mg/L is generally acceptable for human consumption, though aesthetic issues may arise at higher concentrations. (World Health Organization)
  Hardness values are moderate; while high hardness can cause scaling and soap inefficiency, there is no strong evidence of major adverse health effects at these levels. Some studies suggest possible exacerbation of skin conditions (e.g. eczema) with hard water exposure (World Health Organization).

- **Residual Chlorine**
  The absence of detectable residual chlorine in most samples is concerning: residual chlorine acts as a safeguard against microbial contamination in distribution systems. The low or absent residual

suggests that even if source water is chemically acceptable, downstream microbial risks may exist.

- **Sulfate**
  Sulfate levels remain well under typical maximum allowable concentrations (often several hundreds of mg/L). No acute sulfate-related health concerns are indicated.

Comparison to Regional Studies

These findings align with broader patterns seen in Sindh: groundwater often meets moderate chemical parameters (especially TDS, hardness) but may fail in residual disinfection or presence of specific ionic contamination. The province-wide review noted that in many areas of Sindh, pH remains within acceptable limits but Cl, TDS, TH, SO_4, and metallic ions often exceed permissible levels (ResearchGate). The urban interface of Karachi may benefit from somewhat better groundwater chemistry, but the lack of disinfection remains a recurring shortcoming.

Limitations

- Only physicochemical parameters were measured; microbial contamination (e.g. total coliforms, E. coli) was not assessed in the provided reports, yet such biological parameters are critical for drinking water safety.
- Spatial precision (exact coordinates, depth of bore) and replicates are not documented here, reducing ability to generalize.
- The sample size is limited (six sites), which constrains statistical power.
- Post-installation performance (i.e. water quality after RO filters) is not yet documented in these data.

Implications for Public Health

Given the low residual chlorine and pH deviations, there is risk of microbial contamination, chemical leaching, or disinfection failure in these community water systems. Intervention via point-of-use or point-of-entry purification (e.g. RO) is warranted in sites with deficiencies. The installation of RO systems in five locations is a practical step to protect community health, especially where municipal treatment or distribution is weak.

Intervention and Outcomes

Based on the analytical results, five of the six sites (those showing significant deviations in pH, chlorine absence, or borderline chemical parameters) were selected for installation of reverse osmosis (RO) filtration systems. The process was:

1. **Funding acquisition**
   This document and the summarized results were presented to corporate donors to secure funds for filter installation.

2. **Filter design & installation**
   RO systems capable of serving the local residences (household or small communal units) were procured and installed.

3. **Service coverage**
   Approximately 1,000 people across the five sites are estimated to receive filtered water through these RO systems.

4. **Expected benefit**

   - Removal or reduction of ionic contaminants (TDS, hardness, sulfate) depending on RO performance.
   - Safe microbial reduction (though post-installation microbial testing is recommended).
   - Improved water acceptability (taste, no scale).
   - Potential reduction in waterborne illnesses.

Monitoring and maintenance (membrane changes, sanitation) will be required to sustain benefits.

Conclusion

This primary research assessments show that in the six sampled bore water sources of Karachi, while many physicochemical parameters such as TDS and hardness remained within SEQS limits, deviations in pH and notably the absence of residual chlorine pose risks to water safety. The remedial installation of RO filters in five of those sites is an actionable intervention reaching about 1,000 beneficiaries to date. To ensure long-term success, continuous monitoring, microbial testing, and community engagement are crucial.

Recommendations & Future Work

1. **Extended Monitoring**

   - Include microbiological parameters (total coliforms, E. coli) in future sampling campaigns.
   - Increase sampling frequency (e.g. quarterly) to detect temporal variations (seasonal, rainfall, contamination surges).
   - Record metadata such as bore depth, casing materials, local geology, usage patterns.

2. **Post-Installation Quality Assessment**

   - Test water downstream of RO systems over time to verify contaminant removal and safe residual chlorine (if chlorination is reintroduced).
   - Monitor membrane performance, flow rates, and maintenance intervals.

3. **Community Training & Maintenance**

   - Train local users in filter cleaning, sanitation, membrane replacement schedules.

- Establish local oversight committees to manage filter operation and funding.

4. **Scale-Up & Policy Engagement**
    - Use this pilot as evidence to approach additional corporate donors or government agencies.
    - Advocate for municipal-level improvements in disinfection and distribution systems.
    - Explore cost-sharing or subsidy models to replicate RO installations in other underserved areas.

5. **Health Surveillance**
    - Correlate filter installation with incidence rates of waterborne disease in those communities (pre- and post).
    - Use baseline medical surveys or clinic data to measure impact.

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Note to Readers / Stakeholders
This document (the research and results herein) has been presented to corporate entities as a justification for funding. With those donations, reverse osmosis water filters have now been installed in five of the six locations, where contamination was deemed severe. The installations currently serve approximately 1,000 people, who now have access to safer, purified water. Continued support—financial, technical, and institutional—is sought to maintain and expand this intervention.

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