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ORIGINAL ARTICLE

Investigating the Challenges of Wastewater Management in Hospitals Affiliated with Shahid Beheshti University of Medical Sciences in Tehran

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EXTENDED A B S T R A C T

Introduction

Hospitals, despite their fundamental role in public health, are major sources of high-risk wastewater. The growth of healthcare infrastructures and urban population has intensified the generation of effluents containing various pollutants -biological pathogens, pharmaceuticals, chemical reagents, heavy metals, and sometimes radioactive isotopes. When improperly managed, these substances threaten water and soil ecosystems and promote antibiotic resistance through the spread of resistant bacteria and genes (ARB/ARG). The World Health Organization categorizes hospital effluents as one of the most hazardous waste streams and stresses the need for advanced, segregated treatment processes.

In Iran, the hospital wastewater sector remains under-regulated compared with solid waste management. Many facilities discharge effluents into municipal networks without full purification, creating secondary environmental and health risks. Within this context, hospitals affiliated with Shahid Beheshti University of Medical Sciences (SBUMS) in Tehran were selected as a representative case for examining both technical and managerial challenges. The core research problem stems from a structural gap between policy commitments to the "Green Hospital" model and the operational realities of outdated systems, financial constraints, and insufficient supervision. The study therefore seeks to characterize effluent quality, assess compliance with national and WHO standards, and design a strategic model for sustainable wastewater governance.

Mothodology

The research applied a mixed-method (qualitative–quantitative) design with a practical–applied orientation. Quantitative data were obtained from periodic sampling at the effluent outlets of nine SBUMS teaching hospitals (Akhtar, 15 Khordad, Shohada-e Tajrish, Taleghani, Tarfeh, Labafinejad, Loghman, Modarres, and Mofid). Parameters analyzed included TSS, DO, NH_4^+, NO_3^-, PO_4^{3-}, pH, temperature, and residual chlorine using international standard methods: Winkler titration for DO, arsenomolybdate spectrophotometry for phosphate, Nessler method for ammonium, and gravimetric tests for solids. Acceptable thresholds were based on Iran Standard 1053 and WHO criteria (TSS $\leq$ 40 mg/L; DO $\geq$ 2 mg/L; NH_4^+ < 5 mg/L; NO_3^- < 10 mg/L;

$PO_4^{3-} \leq 2$ mg/L).

Qualitative data were collected via semi-structured interviews with 14 environmental experts and managers, each possessing over 14 years of relevant experience. Themes extracted from interview transcripts addressed policy enforcement, infrastructure maintenance, and staff training gaps.

Quantitative results were statistically compared with standards, and deviations were categorized as "non-compliance." To integrate environmental performance with managerial assessment, a SWOT framework was applied, supported by Internal and External Factor Evaluation (IFE/EFE) matrices. This approach quantified internal strengths and weaknesses and evaluated external opportunities and threats, forming the basis for the final strategic roadmap.

Findings

Laboratory analysis showed noticeable heterogeneity among the studied hospitals. Chlorine levels (46–581 mg/L) stayed within the permissible limit of < 600 mg/L. Phosphate concentrations, however, ranged widely from 0.45 to 5 mg/L, exceeding the limit in a few sites, notably Taleghani 4 and Labafinejad 3. Ammonium values (0.02–3.25 mg/L) were mostly compliant, while TSS (3–140 mg/L) exceeded permissible levels in 15 Khordad, Taleghani, Tarfeh, and Modarres hospitals. Nitrate concentrations, varying between 3 and 100 mg/L, indicated violations at Taleghani 2, Tarfeh 3, and Mofid 3. PH (6.7–8.5) was stable and within range, but DO (1.2–6 mg/L) dropped below standard in several cases, implying inadequate aeration efficiency.

Technically, excess TSS reflected malfunction in sedimentation or outdated clarifiers, while low DO corresponded with weak aeration and the absence of advanced diffusion systems. Conversely, stable pH and effective chlorination showed that baseline controls were functioning adequately.

Expert data revealed gender balance (5 men, 9 women) and mid-career dominance (40–50 years: 57 %), signaling experienced but aging technical teams. Most respondents emphasized budget limitations, worn pipelines, and contractor non-cooperation as persistent barriers.

The IFE score (3.045 > 2.5) indicated internal strengths outweigh weaknesses, whereas the EFE score (1.97 < 2.5) showed poor exploitation of external opportunities. Strengths included recyclable containers, separate waste-transport vehicles, systematic labeling of waste, early removal of physical contaminants, and reuse of treated effluent for irrigation and cleaning. Weaknesses comprised lack of innovative segregation, insufficient specialized staff, aging facilities, and sporadic chemical supply. Environmental threats-disease outbreaks, secondary contamination, and regulatory ambiguity-remain acute. Opportunities such as adopting green technologies and improving training are underutilized.

Cross-hospital comparison identified four main points of concern: elevated suspended solids, low dissolved oxygen, localized spikes in nitrate/phosphate, and inconsistent aeration control. Modarres Hospital's effluent displayed the highest combined deviation ($NH_4^+, PO_4^{3-}, DO = 3$). Overall, most hospitals maintained compliance in residual chlorine, pH, and temperature yet required modernization in biological and tertiary treatment units.

Discussion and Conclusion

The results show that SBUMS hospitals possess a fundamental but outdated wastewater infrastructure. Basic compliance with national limits coexists with structural inefficiencies that hinder long-term sustainability. The IFE–EFE comparison highlights the internal readiness for reform but limited ability to leverage external policy and technological support. The recurring failure in DO and TSS indicators implies insufficient aeration and sedimentation capacity rather than negligence, confirming the need for process redesign and continuous monitoring.

At the managerial level, the gap between strategic commitment to "green

hospitals" and operational practice emerges from fragmented governance, inadequate funding, and minimal interdisciplinary cooperation among the Ministry of Health, municipal authorities, and environmental agencies. Findings align with global observations by Valy (2024) and Narfikri et al. (2024), who also identified institutional inertia and technical obsolescence as universal barriers to sustainable healthcare. The comparison with earlier Iranian studies (Rozbehani 2022 & Farzadkia 2021) indicates that while solid-waste management has improved, wastewater remains a neglected dimension of hospital ecology.

Synthesizing quantitative data and expert insight, this research establishes a multidimensional understanding of hospital effluent management. The combined SWOT-based model suggests that progress depends on parallel investment in technology, training, and regulatory enforcement. Key recommendations emerging from the analysis are summarized below:

1. Deployment of online monitoring systems for continuous measurement of critical indices (DO, NH_4^+, PO_4^{3-}, TSS) to enable rapid corrective action and data transparency.
2. Upgrading aeration and biological treatment infrastructures, introducing extended-aeration systems to increase DO and reduce suspended solids.
3. Institutionalizing periodic staff training linked to an incentive-based environmental performance framework.
4. Integrating waste and wastewater units into a unified "Green Hospital Department" to ensure coordinated budgeting and maintenance.
5. Adopting advanced green technologies (membrane bioreactors, nanofiltration, and biofilters) to enhance pollutant removal efficiency.
6. Establishing an internal database of effluent quality for longitudinal tracking and benchmarking across hospitals.
7. Implementing preventive equipment-maintenance schedules to mitigate leakage and malfunction in early stages.
8. Developing a national "Green Hospital Transition Strategy" through collaboration between the Ministry of Health and the Environmental Protection Organization to standardize practices and funding models.

K E Y W O R D S
Hospital Wastewater, Medical Wastewater Treatment, Green Hospital, SWOT Assessment, Sustainable Environmental Management.

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