

## Original Article



# Efficiency of Tehran Hospital Wastewater Treatment Processes in Complying With Effluent Quality Standards

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Email: [h.r.tashauoei@gmail.com](mailto:h.r.tashauoei@gmail.com)**Abstract****Background:** Hospital wastewater is an important component of urban wastewater and exhibits distinct quality characteristics due to the variety of healthcare services provided. These properties have necessitated the installation of on-site treatment systems in most hospitals. This study aimed to evaluate the performance of such systems in Tehran hospitals with respect to Iranian national standards and to identify factors influencing their efficiency.**Methods:** Data on the quantity and quality of hospital wastewater were collected from six hospitals in western Tehran in 2024. Parameters including pH, dissolved oxygen (DO), temperature, chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS), nitrate, phosphate, and chloride were analyzed in both raw wastewater and treated effluent according to Standard Methods for the Examination of Water and Wastewater. Statistical analyses, including t-tests performed in Microsoft Excel, were used to interpret the results.**Results:** The average wastewater generation rate among the studied hospitals was 511 liters per bed per day. The highest and lowest pollutant removal efficiencies were recorded for TSS (94.6%) and chloride (26.1%), respectively. Half of the treatment plants achieved effluent quality compliant with national standards for BOD and COD, whereas nitrate concentrations exceeded permissible limits in 75% of facilities discharging effluent into wells.**Conclusion:** Although most effluent parameters met national standards, enhancing treatment capacity and optimizing operational conditions, through the installation of advanced treatment units and the employment of skilled operators, are essential steps toward improving hospital wastewater quality.**Keywords:** Hospital wastewater, Wastewater management, Urban pollution, Tehran**Please cite this article as follows:** Tashauoei H, Kashitarash Esfahani Z, Nourieh N, Emami N. Efficiency of Tehran hospital wastewater treatment processes in complying with effluent quality standards. J Adv Environ Health Res. 2025; 13(4):238-244. doi:10.34172/jaehr.1414**Introduction**

Healthcare facilities, including hospitals and clinics, are major sources of municipal wastewater.<sup>1</sup> Hospital wastewater poses severe health and environmental risks due to the presence of infectious agents, pharmaceuticals, and hazardous chemicals.<sup>2</sup> Discharging this wastewater into the environment can spread diseases, as it often contains high concentrations of bacteria, viruses, and other pathogens.<sup>3</sup> In addition, chemical pollutants in hospital wastewater from various sections such as laboratory, surgical, inpatient units, as well as food solutions, are also recognized as an environmental risk.<sup>4,5</sup> Consequently, hospital wastewater contains a diverse range of contaminants that can adversely affect both soil and water ecosystems.<sup>6,7</sup> Hospital wastewater is a major concern in urban management because it contains toxic compounds such as drugs, heavy metals, and organisms that can pose serious risks to human health and the

environment.<sup>8</sup> In recent decades, growing awareness of these risks has led to the establishment of discharge standards and the development of on-site hospital wastewater treatment systems. In Iran, national standards define permissible discharge limits for key parameters in effluents released into surface waters or absorption wells. The most common management strategy involves transferring hospital wastewater to municipal treatment plants; however, in some cases, decentralized treatment systems discharge effluents directly into the environment.<sup>9</sup>

Compliance with national discharge standards depends largely on the efficiency of the hospital's wastewater treatment system, which in turn is influenced by the design, operational conditions, and characteristics of the raw wastewater. Previous studies have shown that hospitals consume large quantities of,<sup>10</sup> which directly affects wastewater generation rates. Reported water consumption in hospitals ranges from 200 to 1200 liters



per bed per day, whereas hospitals in developed countries typically consume between 200 and 400 liters per bed per day.<sup>11,12</sup> As a result, wastewater production in hospitals is estimated to range from 250 to 570 m<sup>3</sup> per day, depending on hospital size and patient load.

Different models of hospital wastewater management have been used in different countries based on national laws and standards.<sup>13</sup> For example, in many developing countries, hospital wastewater is discharged into drainage systems, lakes, and rivers.<sup>14</sup> Some countries classify hospital wastewater as industrial waste due to its complex composition, requiring pretreatment prior to connection to the municipal network. In other cases, hospital effluent is discharged directly into municipal sewer systems.<sup>15</sup> Therefore, adopting sustainable treatment strategies is essential to ensure the safe handling and disposal of hospital wastewater and to minimize public health and environmental risks.<sup>13</sup> Most previous studies have focused on developing new treatment technologies or assessing the environmental impacts of hospital wastewater, leaving a research gap regarding the performance evaluation of existing treatment systems, particularly in large urban centers. Tehran, the largest city in Iran, faces specific challenges due to its high population density and the aging infrastructure of many hospital wastewater treatment systems. These conditions raise serious concerns about effluent quality and potential public health implications. Therefore, this study aimed to assess the efficiency of on-site hospital wastewater treatment systems in Tehran in meeting national discharge standards and to identify key factors influencing their performance.

## Materials and Methods

As illustrated in Figure 1, this study was conducted in

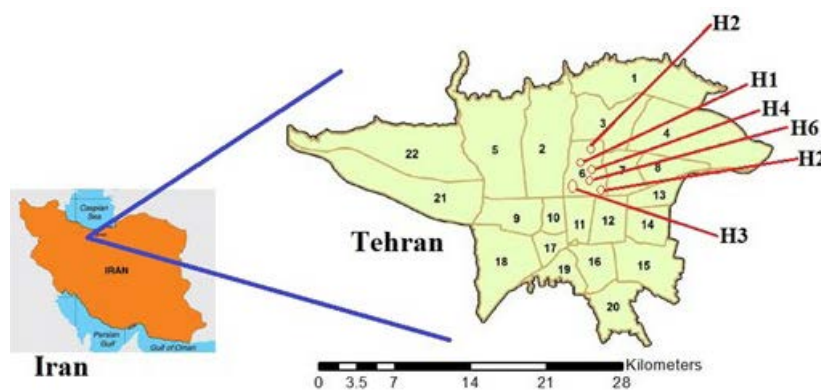


Figure 1. Location of the hospitals studied (H1-H6)

Table 1. Wastewater quantity in studied hospitals

	H1	H2	H3	H4	H5	H6
Number of beds	80	220	50	103	204	174
Wastewater flow (L/s)	0.35	0.4	0.27	0.84	1.9	1.73
Per capita (L/bed/day)	378	157	466	704	804	560
Treatment method	Filtration	Extended aeration	Extended aeration	SBR	CAS	Extended aeration
Effluent discharge	Absorption well	Absorption well	Absorption well	Absorption well	Sewage network	Sewage network

2024 across six hospitals located in the central part of Tehran, Iran. Tehran is divided into 22 districts, and the selected hospitals are situated in District 6 at geographical coordinates 35.7072°N and 51.3890°E. Hospital wastewater management in Tehran generally follows an on-site treatment model, where each hospital is equipped with its own wastewater treatment plant (WWTP). In this study, the status of wastewater management in six hospitals (H1, H2, H3, H4, H5 and H6) located in District 6 of Tehran was evaluated. Data on hospital wastewater characteristics—including quantity, treatment processes, effluent management methods, and operational conditions—were collected through structured interviews with hospital personnel and from official records. The parameters analyzed to evaluate the performance of hospital WWTPs included biochemical oxygen demand (BOD<sub>5</sub>), chemical oxygen demand (COD), dissolved oxygen (DO), pH, temperature, nitrate, phosphate, and chloride. Sampling and measurements were performed monthly throughout the one-year study period, following the procedures described in the Standard Methods for the Examination of Water and Wastewater.

The treatment efficiency for each parameter was determined using the difference between the concentrations in raw influent and treated effluent, as shown in Equation 1:

$$\eta = [(C_{out} - C_{in})/C_{in}] \times 100 \quad (1)$$

Where, where  $C_{in}$  and  $C_{out}$  represent the concentrations of the parameter in the influent and effluent, respectively.

## Results and Discussion

The results of the wastewater quantity estimation in the studied hospitals have been shown in Table 1. It was

found that the highest wastewater flow rate in H5 was 7.03 times higher than the lowest wastewater flow rate observed in H3. Also, the wastewater flow rate in the total of the hospitals studied was 173,132 m<sup>3</sup>/year. Considering the difference in the capacity of the studied hospitals, it can be useful to compare the wastewater quantity based on the per capita wastewater production. Accordingly, the wastewater flow rate in the hospitals has been indicated in Table 1. The highest per capita wastewater production in H5 was 4.12 times higher than the lowest per capita wastewater production observed in H2. On average, the per capita wastewater production in the hospitals was 511 L/bed/day.

Wastewater management in the hospitals studied involved on-site treatment, followed by effluent discharge into either an absorption well or the municipal sewage network, as presented in Table 1. In all the hospitals, wastewater treatment was based on the activated sludge process, with extended aeration being the most common method, accounting for 50% of the systems used. In four of the six hospitals, the treated effluent was discharged into an absorption well, whereas in hospitals H5 and H6 (representing 34% of the total), it was discharged into the municipal sewage collection network.

The results illustrated that the average values of temperature, pH, TSS, COD, BOD<sub>5</sub>, nitrate, phosphate, and chloride in the hospitals were 25.35 °C, 7.6, 393.64 mg/L, 475.56 mg/L, 210.55 mg/L, 24.53 mg/L, 25.35 mg/L, and 162.4 mg/L, respectively. In addition, the average microbial density of total coliforms, determined using the MPN method, was  $4.2 \times 10^5$  MPN/100 mL in summer and  $4.7 \times 10^5$  MPN/100 mL in autumn. The corresponding values for fecal coliforms were  $3.8 \times 10^5$  MPN/100 mL in summer and  $2 \times 10^5$  MPN/100 mL in autumn. Overall, the results indicated that most of the analyzed parameters did not vary significantly between seasons. However, DO showed a statistically noticeable difference between summer and autumn, as confirmed by the t-test analysis (Table 2).

The concentrations of BOD<sub>5</sub>, COD, TSS, and nitrate in the effluent of the hospitals have been shown in Figure 2.

In H5, most of the measured parameters exceeded the national standard limits. Moreover, the difference between the national nitrate standards for effluent discharge into absorption wells and those for discharge into surface waters resulted in only H5 and H6 showing nitrate concentrations below the respective standard limits. However, as illustrated in Figure 3, the removal efficiency of the examined parameters varied among the wastewater treatment plants of the studied hospitals.

In recent decades, population growth and urbanization have increased sources of environmental pollution, including wastewater.<sup>16,17</sup> As the findings of this study indicated, the hospitals are also among the significant contributors to urban wastewater generation. Thus, obtaining complete and accurate information on the quantity of hospital wastewater is crucial for effective planning, efficient management of this pollution source, and mitigation of its associated impacts.<sup>18,19</sup> Although the range of wastewater production among the studied hospitals was wide—approximately 0.27 to 1.9 L/s—the application of the per capita wastewater production index allowed for a meaningful comparison between hospitals. The per capita wastewater production in the studied hospitals ranged from 157 to 800 L/bed/day, which aligns with the observations of other studies. For instance, per capita water consumption in Iranian hospitals has been reported to range between 400 and 1200 L/bed/day.<sup>20</sup> Considering that the water-to-wastewater conversion rate typically falls between 85 and 95%, it can be inferred that the wastewater generation rate in hospitals across the country is approximately 350 to 1100 L/bed/day.

The wide range of per capita wastewater generation in the hospitals studied may have been influenced by the diversity of service and specialized units as well as the different water consumption patterns in each of the hospitals. For example, different hospital departments can play a significant role in wastewater generation, including laundry, kitchen, sanitary facilities, accommodation and lodging facilities for companions, and various specialized departments.<sup>21</sup> These units exist at different scales in each hospital, which contributes to variation in wastewater production. Furthermore, water consumption patterns and resource management practices are influenced by “green hospital” programs and other management strategies implemented at the institutional level. Such measures can directly affect per capita water consumption and, consequently, wastewater generation.<sup>22</sup> For instance, the use of automatic or sensor-operated valves and water-saving devices within hospital plumbing systems can substantially decrease water consumption. When these devices are adopted to varying extents among hospitals,<sup>23</sup> differences in wastewater production rates can result. A study conducted at a specialized obstetrics and gynecology hospital in Behshahr reported a per capita wastewater generation rate of 550 L/bed/day, which is comparable to that of hospital H6 in the current study. This value is higher than those recorded in hospitals H1 and H2, but lower

**Table 2.** t-Test analysis of DO in the hospitals studied in different seasons

	Summer	Autumn
Mean	2.025	2.316667
Variance	0.32275	0.146667
Observations	6	6
Pearson Correlation	0.94912	
Hypothesized Mean Difference	0	
df	5	
t Stat	-3.00787	
P (T<=t) one-tail	0.014914	
t Critical one-tail	2.015048	
P (T<=t) two-tail	0.029829	
t Critical two-tail	2.570582	

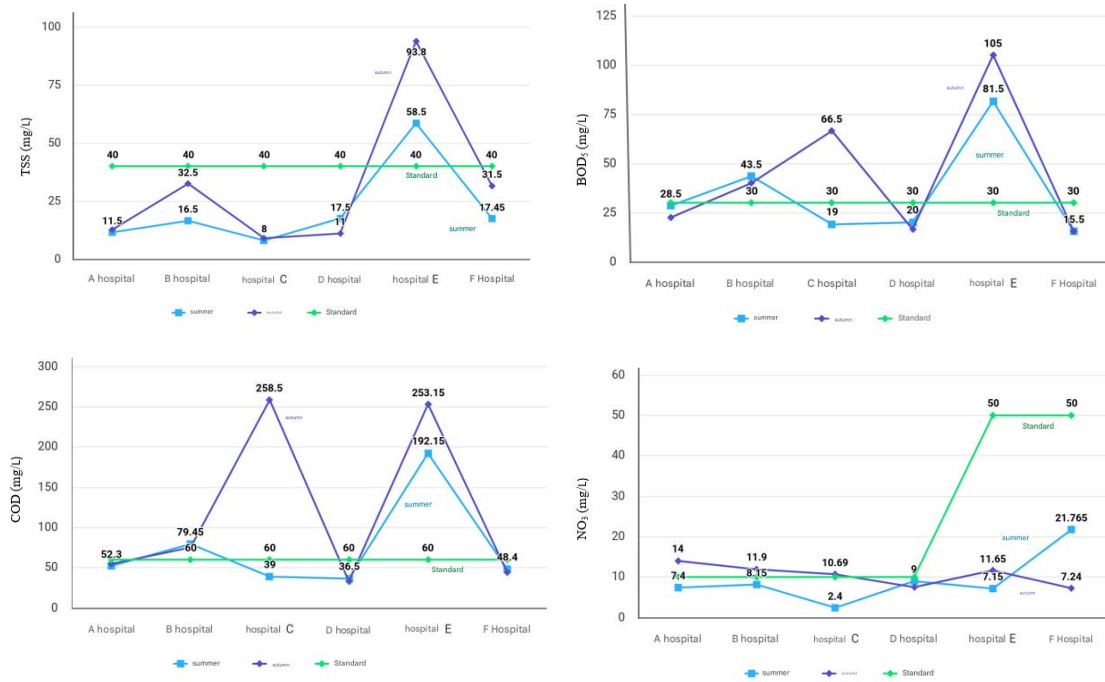


Figure 2. Concentration of the parameters studied in effluent

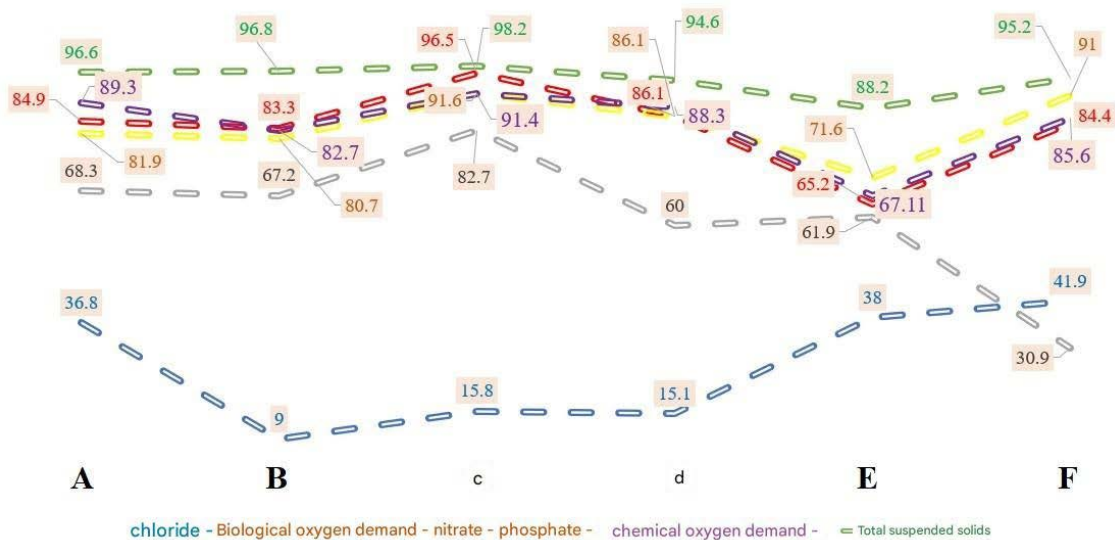


Figure 3. Reduction efficiency in the wastewater treatment plants of the hospitals (%)

than those in hospitals H4 and H5.<sup>24</sup> Most of the physical, chemical, and biological parameters measured in the raw wastewater of the studied hospitals were considerably higher than the national standards for discharge into the environment. Among the analyzed parameters, only pH was within the acceptable range for discharge to surface waters (6.5–8.5). Similar observations have been reported in other studies conducted in Iran, where hospital wastewater quality parameters frequently exceed national discharge standards. This situation has necessitated the construction of on-site wastewater treatment plants in many hospitals.<sup>20</sup> For example, a study of hospitals in Markazi Province reported COD concentrations ranging from 200 to 1200 mg/L, whereas the national standard

for discharge to the environment is 60 mg/L.<sup>25</sup> Likewise, wastewater quality analyses in a hospital in Dezful showed BOD<sub>5</sub> and COD concentrations ranging from 110–250 mg/L and 170–580 mg/L, respectively, while the corresponding standard limit for discharge is 30 mg/L.<sup>20</sup> The microbial density in the wastewater of the studied hospitals was also notably high. In all analyzed samples, total coliform counts exceeded 10<sup>5</sup> MPN/100 mL, whereas the standard permissible limit for discharge into the environment is 1000 MPN/100 mL. Elevated microbial loads are a typical characteristic of hospital wastewater and have been similarly reported in other studies of hospitals across Iran.<sup>26</sup> The appropriate efficiency of the wastewater treatment plants of the hospitals studied resulted in a

reduction of pollution to below the national standard in most parameters. The results showed that TSS in the effluent was reduced to less than 40 mg/L as a standard for discharge to surface water. However, in H5 it was higher than the standard in two consecutive seasons. Also, COD and BOD<sub>5</sub> in the effluent in H2 and H5 Hospitals in two consecutive seasons and also in the autumn in H3 were higher than 60 mg/L and 30 mg/L as a standard. Nitrate concentration in the effluent in H1, H2 and H3 Hospitals in the autumn was slightly higher than 10 mg/L as a standard for discharge to the absorption well, and due to the discharge of wastewater from these hospitals to the absorption well, environmental standards were not met. However, the effluent from the wastewater treatment plants of all the studied hospitals except H5 contained phosphate less than 6 mg/L as a standard for discharge to the environment. Also, in all the studied treatment plants, the microbial density in the effluent was observed to be less than 1000 MPN/100 mL total coliforms and less than 400 MPN/100 mL fecal coliforms, which was lower than the national standard.

The chloride concentration and pH in the effluents of the studied treatment plants were within the standard range. pH is a key indicator of wastewater quality; extreme acidic or alkaline conditions can increase the risk of pipe and equipment corrosion or lead to scale formation within pipelines.<sup>25,27</sup> Therefore, the effluent conditions observed in this study did not pose such risks, as pH values in all samples were within the range of 6.5–8.5.

The observed efficiency in TSS reduction in the treatment plants of the hospitals was consistent with the performance reported for the activated sludge process in previous studies.<sup>24</sup> The use of sedimentation tanks and laminar flow systems with appropriate hydraulic retention times contributes to effective solids removal from the effluent.<sup>28,29</sup> However, the observed variation in efficiency—particularly in hospital H5—could be attributed to operational factors, as the proper operation and maintenance of wastewater treatment units play a crucial role in determining treatment efficiency.<sup>30,31</sup> Moreover, the high wastewater volume in H5 may have contributed to the elevated concentration of suspended solids in its effluent, exceeding the standard limits. The ability of the activated sludge process to reduce organic matter through microbial activity and cell mass production was the primary reason for the observed reduction in COD and BOD<sub>5</sub> in the effluents.<sup>32</sup> The consumption of organic compounds by microorganisms and their subsequent growth form the basis of the activated sludge process, whereby organic matter is converted into settleable biomass. However, the relatively poor efficiency of hospitals H2 and H5 in reducing organic load may be attributed to differences in influent concentration and operational conditions. The results showed that the initial concentration of organic matter in H5 was considerably higher and more variable than in other hospitals, while no noticeable difference in initial concentration was observed

in H2. Therefore, possible deficiencies in operation and maintenance could explain the lower efficiency observed in H2. Maintaining suitable environmental and operational conditions for microbial growth and activity is essential for the performance of the activated sludge process. Given the presence of pharmaceutical, antibiotic, and chemical compounds in hospital wastewater,<sup>33</sup> these substances may have adversely affected microbial performance, contributing to the lower treatment efficiency in H5 and H2. Furthermore, treatment capacity plays a critical role in achieving optimal performance.<sup>34</sup> Analysis of wastewater quantity showed that in H5, per capita wastewater production was 60% higher than the average and five times greater than in H2. Under such conditions, a reduced hydraulic retention time and a mismatch between treatment capacity and influent flow rate may have contributed to the poor treatment efficiency in H5.

The removal of nitrogen and phosphorus is one of the major objectives of biological treatment processes such as activated sludge.<sup>35</sup> The results indicated that the average nitrate and phosphate removal efficiencies in the studied treatment plants exceeded 60 and 80%, respectively. This high performance can be attributed to the use of aerobic processes that support a complete nitrogen cycle and effective nitrification.<sup>36</sup> Also, the return sludge system in activated sludge processes—also observed in this study—helps maintain conditions conducive to microbial phosphorus uptake and promotes phosphate removal by extending the solids retention time.<sup>37</sup> Nevertheless, the effluent nitrate concentration in most of the studied hospitals remained higher than the discharge standard, particularly during autumn.

Although the activated sludge process is highly effective in reducing organic compounds and nutrients such as nitrogen and phosphorus,<sup>35</sup> its biological nature limits its efficiency in removing microorganisms. Consequently, disinfection processes—either chemical or photochemical—are applied as the final treatment step to lower the microbial density in the effluent.<sup>38</sup> In the studied treatment plants, two main disinfection methods, chlorination and ozonation, were employed before effluent discharge. The results showed that both achieved over 99% microbial removal efficiency, with final microbial densities below the permissible standard.

The effectiveness of chlorination and ozonation depends on factors such as wastewater pH and the presence of oxidizing agents.<sup>38</sup> Therefore, the neutral pH range of the hospital effluents, along with the prior removal of most oxidizable organic matter and suspended solids during the activated sludge process, contributed to the high disinfection efficiency observed in this study.

## Conclusion

It was found that high concentrations of organic matter, suspended solids, nitrate, phosphate, and microbial density exceeding environmental standards posed potential health

risks and environmental hazards. Consequently, all of the hospitals studied employed on-site wastewater treatment systems. Analysis of the effluents from these treatment units revealed that only one hospital met all standard parameters, while one hospital failed to meet the required standards for most parameters. The remaining four hospitals complied with the standards for most measured parameters. Regarding nitrate concentration, 75% of the hospitals that discharged effluent into absorption wells did not meet environmental standards, whereas both hospitals that discharged into the municipal sewage network complied with the nitrate standard. Overall, it can be concluded that the hospital wastewater treatment processes applied in Tehran are generally effective; however, capacity limitations resulting from increased wastewater production and operational deficiencies contributed to the observed cases of non-compliance. To improve hospital wastewater management and ensure compliance with environmental standards, the following measures are recommended:

- Upgrading treatment capacity in response to the increasing inflow rate of hospital wastewater.
- Implementing Green Hospital initiatives to reduce water consumption and wastewater generation.
- Conducting regular maintenance and upgrades of treatment equipment and processes to sustain performance and meet discharge standards.

Employing skilled operators and promoting research into alternative treatment technologies, including the effects of seasonal variations.

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#### Competing Interests

The author declares no conflict of interest.

#### Ethical Approval

There were no ethical considerations to be considered in this research.

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