Journal of Environmental Health and Sustainable Development

The Main Challenges and Suggested Solutions for Optimization of Water Management in an Educational hospital

Fariba Abbasi [1], *Mohammad Reza Samaei* [1]*, *Akbar Mehdizadeh* [1]

[1] *Environmental Health Engineering, Shiraz University of Medical Science, Shiraz, Iran.*

ARTICLE INFO

ORIGINAL ARTICLE

Article History:
Received:28 April 2018
Accepted: 10 July 2018

***Corresponding Author:**
Mohammad Reza Samaei

Email:
mrsamaei@sums.ac.ir

Tel:
+983531492273

Keywords:
Hospitals,
Shiraz City,
Water,
Management.

ABSTRACT

Introduction: Hospitals are one of the main water consumers in urbane area. Due to lack of enough information, the challenges and some of the solutions were investigated for optimization of water management.

Materials and Methods: This study was a cross-sectional study in a Shiraz educational hospital. Data were collected by questionnaires with 146 items. The items was classified in several steps; (1) determination of present situation; (2) identification of challenges in water management; (3) identification of opportunities for reducing water consumption; (4) writing several practical scenarios; (5) cost-benefits analysis for each scenarios; (6) providing the results to the hospital for decision-making. Scenarios were including: installation of a bottle 1.5 litters in toilet flushing, substitution of water cooling with mixture ventilation system (natural and artificial air conditioning system), reuse of regeneration water from cation exchanger, substitution of flooding irrigation with dropping system, using the native or adaptable plants with dry climate.

Results: According to the results, 48488 m^3/month water was required; however, it was 431125 and 12491500 m^3/month in winter and summer (present situation). The cost-benefit of scenario 1,2,3,4 and 5 were 960,170,2370000,13500 and 7500 USD, respectively. Moreover, the investment repayment were 4 years, 1 month, 3.06 years, lower than 1 month, and 3.8 years, respectively.

Conclusion: Water consumption was 8-200 times higher than really water demand. It could be result of traditional distribution system and improper management. The scenario 4 was the best alternative for this hospital. Since the cost-benefit ratio to investment repayment period was higher than others.

Citation: Abbasi F, Samaei MR, Mehdizadeh A. **Investigation of the Main Challenges and Suggested Solutions for Optimization of Water Management in an Educational hospital**. J Environ Health Sustain Dev. 2018; 3(3): 585-92.

Introduction

Water is a key element for human life; however, freshwater scarce especially in southern and central areas of Iran [1]. Hospitals are one of the buildings with high water consumption [2]. Water conservation technologies and strategies are often the most overlooked aspects of a whole-building design strategy such as large hospitals [3]; however, many hospitals do not have an effective management for water consumption and planning replacements, such as pipes and valves [4]. As natural resources such as water become increasingly scarce, managers often seek policies to reduce water demand [5]. The first step in water management is identification of main water consumers and using policies for water consumption reduction while maintaining wellbeing [4, 6]. This step is very important in hospitals. Although the range of water consumers is vast (patients, staff, visitors and vendors), patients are incapable to participate in these programs. Therefore, other

[Downloaded from jehsd.ssu.ac.ir on 2026-11-22]

[DOR: 20.1001.1.24766267.2018.3.3.6.1]

strategies should be focused such as selected water conservation strategies according to the organizational management, including:

- Water-efficient plumbing fixtures such as ultra-low-flow toilets
- Irrigation and landscaping measures (water-efficient irrigation systems, irrigation control systems, water-efficient scheduling practices)
- Water recycling or reuse measures (Gray water and process recycling systems)
- Methods to reduce water consumption in Heating, Ventilation and Air Conditioning (HVAC) systems [7]. They are the main problems of water management in hospitals.

Accordingly, the implementation of policy measures is essential for development of a water-saving culture as it is occurred in European countries [6]. In water efficiency planning, the consumption level of water and costs, specification of water-saving solutions, installation of water-saving measures are analyzed. Then the best of them (the cost-effective alternative) selected [7]. Since hospitals consume the vast amounts of water and energy, saving program is essential. These programs are including monitoring water cosumption, installing water-efficient fixtures and technologies, growing drought-resistant plants, and repairing the leakage [8], since they can generate the maximum energy-conserving and the lowest cost [9].

According to the economic and dynamic theory, water management is related to various factors such as architectural agents [2], cost of water [10], weather and climate, land cover, infrastructure and social, economic and demographic factors [11]. However, other studies showed declining vegetation area, installation of water-saving appliances or removing thirsty landscaping, informational campaigns, watering restrictions and increasing water waste enforcement actions are the largest measureable factors in water management [12]. These models and results can help decision makers to identify water reuse and water reduction programs [2]. Moreover, it was expressed that changing in household habits can reduce water consumption [13]. Furthermore, controlling pump operation, optimization of valve and operation and water distribution systems can be effective.

The main goal of this study was to reduce water consumption without affecting routine tasks in hospitals and keeping safety situation for patients. Although water management problems in hospitals are one of the most important issues in developing countries such as Iran, little study has been conducted to solve them. In the present study attempts are made to determine challenges of water consumption and identification strategies for water consumption optimization in one of Shiraz educational hospitals. Moreover, economic analysis is a good idea for identification of burden cost and strategies for policymakers to optimize water consumption.

Materials and Methods

Location Study

Shiraz is one of the large cities, located in southern Iran (Figure 1) with 29° 36’37" N and 52°31’52" E [14]. There are about 16 educational hospitals in Shiraz. The studied hospital was established in 1952 with area of 90000 m^2. The total building area was 19387 m^2, 1.5 ha of which was covered by landscaping space. The capacity of hospital had been 300 beds; however, 220-245 beds were active.

[Downloaded from jehsd.ssu.ac.ir on 2026-11-22]

[DOR: 20.1001.1.24766267.2018.3.3.6.1]

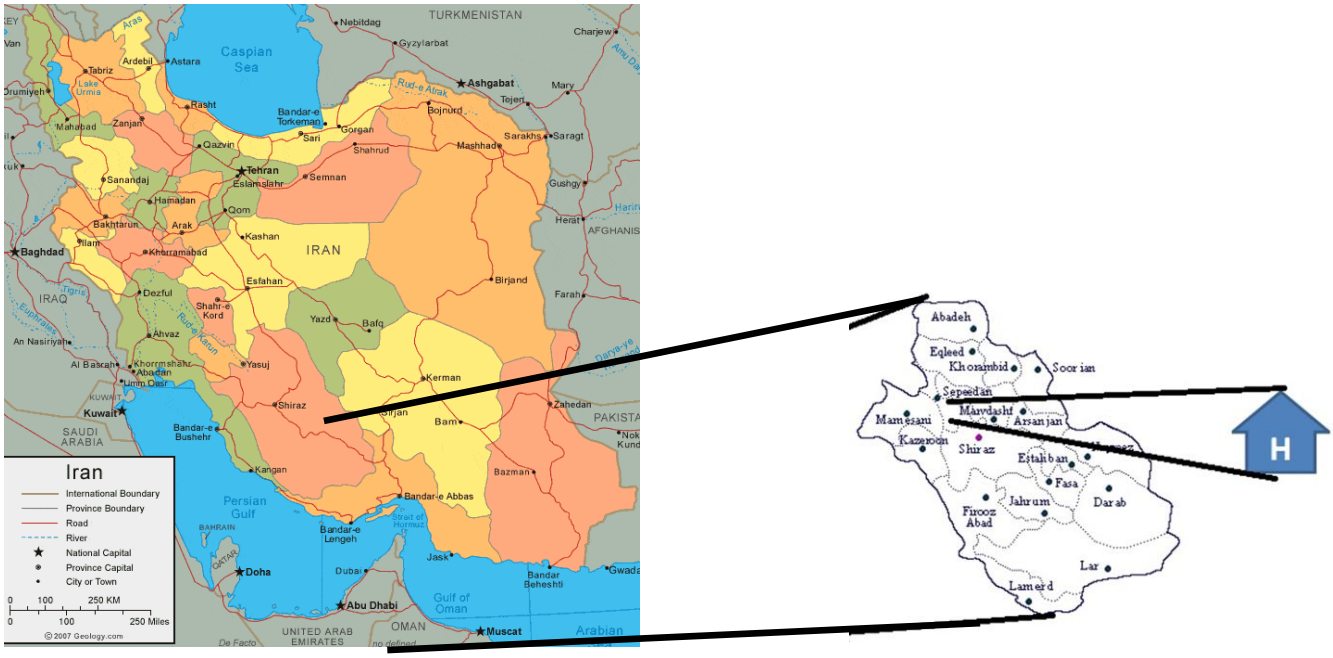


Figure 1: Location study

Data Gathering

Data were collected by questionnaires from the hospital in 2017. The questionnaire included 146 items. Its items were written based on the recommendation of previous water management literature. The items was classified in several steps including; (1) determination of present situation; (2) identification of challenges in water management; (3) identification of opportunities for water consumption reduction; (4) writing several practical scenarios; (5) cost-benefits analysis of each scenarios; (6) expression of the results for decision-making.

Initially, the current condition of water consumption was studied in the hospital. Then, the actual demand water was calculated based on the active beds mean. Sections, including landscaping, the ventilation system and toilet flushing were investigated. Then several scenarios were introduced with details. Moreover, the solutions and opportunities were presented for water consumption reduction. Furthermore, the evaluation method was the comparison of the scenarios cost-effectiveness with the present situation.

The scenarios are including:

Scenario 1: installation of a 1.5-liter bottle in toilet flushing

Scenario 2: water cooling substitution with the mixture ventilation system (natural and fan quell)

Scenario 3: reuse of rejected water from cation exchanger for toilet flushing or car washing

Scenario 4: substitution of flooding irrigation with dropping system

Scenario 5: using native or appropriate climate plants

These scenarios were written based on the hospital condition. The cost-benefit and investment repayment period for any one were calculated.

Assessment Method

both cost-benefit and the investment repayment period were used as indicators for scenarios comparison.

Results

In this study, the water consumption was estimated in the hospital. The total demand water was calculated from the following equation:

$$Q_T = Q_{d\ patient} + Q_{d\ personnel} + Q_{air\ cooling} + Q_f \quad (1)$$

That:

$Q_{d\ patient}$ = number of patient × 600-800 lit/d

$Q_{d\ personnel}$ = number of personnel × 100 lit/d

$Q_{air\ cooling}$ = number of water cooling system × 6-12 lit/d

[Downloaded from jehsd.ssu.ac.ir on 2026-11-22]

[DOR: 20.1001.1.24766267.2018.3.3.6.1]

$Q_f = 320\ C\sqrt{A}$ (Q_f = fire water, C = coefficient, A = surface area of hospital)

Q_{Tmax}= (240 + 500 L/d × 30 d) + (110 + 100 L/d × 30 d) + (22 × 12 L/hr × 12hr/24 × 30 d) + (320 × 1 × 19387 m^2) = 48488 m^3/month

Based on this equation $Q_{T\ max}$ was 48488 m^3/month.

Then, proper alternatives were considered and the best one was suggested. In this hospital, there were 108 toilets flushing with 6-8 liters capacity of reservoirs. One-third of the total water consumption was related to this equipment approximately. Therefore, the installation of a chamber such as a 1.5-liter bottle in toilet flushing could reduce the water consumption. Moreover, there was no central air conditioning system except water cooling system. Each of them consumes 8-16 lit/hr and the average operating period is about 12 hours per day. Accordingly, the total water consumption was estimated 63.36-126 m^3 per month. Therefore, substitution of water cooling system with the mixture ventilation system (natural and fan quell system) can minimize the required water for air conditioning system. Another challenge in this hospital was the use of ionic exchanger for water treatment. This plant consists of 2 columns with the capacity of 750 K grains. The produced water in this unit was estimated 56000 lit/day. Therefore, the use of regeneration water from exchanger can be a logical alternative. Moreover, the optimization of irrigation system and landscape of this hospital was another important issue for water consumption reduction, since; the landscape covered 1.5 ha of hospital space approximately. Water consumption was calculated about 6750 m^3 per month for the landscape (grass). In this condition, grass was the dominant landscape cover. However, other plants such as Pine tree needs less water and they grow in precipitation lower than 300 mm/year. Therefore, substitution of dropping with flooding irrigation or use of native or appropriate climate plants can be useful.

Discussion

According to equation 1, the maximum water demand was 48488 m^3/month. Because the mean of demand water in Iran's hospitals is 600-800 Lit/day.capital [15]. But in the current situation, the water consumption was 431125 and 12491500 m^3/month in winter and summer (average in 5 years). In other studies, it was estimated 614 [16] and 90-130 Lit/day.bed [17]. Although the calculation unit wasn't similar, this implies that water consumption was very high. While consumption pattern was appropriate and water was not used for washing of floor, walls, and other surfaces. This result can be associated to traditional distribution system or cost of water, because its water distribution network was operated 65 years ago and it was not replaced yet. This hospital classified as educational-medical that cost water was the lowest among other buildings. With regard this; the cost of water was an important factor on water consumption [10]. Moreover, the installation of flow-control devices could be one of the water-saving measures; whereas, in this hospital the regulator was used in first point of the system only. Therefore, the water consumption management was very difficult. However, programs of saving water can reduce operating costs and energy [2]. So that saved energy was 60 billion Btu due to processing and water using annually [3].

Although water reuse has been increasingly considered as a promising, efficient, cost-effective, and reliable alternative for dense urban population [14], in this hospital, water reuse was only conducted for Central Sterilization (CS). The reused water will be converted to steam and used in laundry ward.

Reduction of energy and potable water consumption is essential for water conservation strategies. Therefore, several scenarios were introduced, such as installation of a 1.5-liter bottle in the reservoir of toilet flushing, substitution of water cooling system with air-conditioning system, reuse of regenerated water from cation exchanger for toilet flushing or car washing, the use of dropping irrigation instead of the flood irrigation and the use of native or resistance plants to climate condition. In other studies, some strategies were conducted including water consumption reduction by implementing techniques and fixtures,

[Downloaded from jehsd.ssu.ac.ir on 2026-11-22]

[DOR: 20.1001.1.24766267.2018.3.3.6.1]

identifying unnecessary uses and fixing leakage, use of minimum amounts of water, installing meters on processes and equipment for monitoring and identifying suitable alternatives such as compress flush toilets [2].

Scenario 1: Installation of a 1.5-liter bottle in toilet flushing

This alternative is one of the simplest and lowest cost solutions. With installation a water bottle 1.5 in reservoirs of flush tank, the tank volume could be reduced (this condition was seen in half of the toilet flashings). Regarding this scenario, water consumption decrease to 320 m^3/month that is approximately equal to water demand for one person during one year in Iran. According to the federal law in USA, water consumption must be lower than 1.6 gallons per flush (GPF). Therefore, using ultra-low flush (ULF) toilets is suitable without clogging or double flushing [3]. Plumbing and pipes must be routinely checked to prevent of leakage [8]. Cost-benefit of this scenario was 960 USD annually. The cost in this method was negligible and its benefit was 320 m^3/month due to reduction of water consumption. The investment repayment in this condition was 4 years.

Scenario 2: Substitution of water cooling system with mixture ventilation system (natural and fan quell ventilation)

Water consumption in ventilation systems was very high. According to the previous studies in Iran, water consumption in water coolers is related to air temperature.

Water consumption in water coolers is:

Water consumption (L/hr) = 4.225 + [0.381 × air temperature (T = 17-43)] [18].

Therefore, the amount of used water was 123.55-153.64 m^3/month in temperature of 30-40^oC. This temperature is regular in summer in Shiraz. Although all of them were equipped to regulator, 50% of them were located under direct solar radiation. In this condition, water consumption was 11% higher than other water coolers.

Although water supply for the fan quell is closed loop and the water reservoirs fill one time annually, it is incapable to use this air conditioning system. Because the structure of building and was improper for this alternative. Therefore, the use of mixture fan quell and present condition (water cooling system) can be a logical alternative. On the other hand, better ventilation reduces energy and water consumption 30% approximately. Moreover, installation of an automatic shut-off valve is suitable [3]. The cost of this valve is 27.5 USD; however, water conservation is 300 USD annually. Therefore, cost-benefit of this scenario was 170 USD approximately. Furthermore, the investment repayment was one month.

Scenario 3: Reuse of regenerated water from cationic exchanger for toilet flushing or car washing

The operating duration of this plant was estimated 7 years and it regenerate by NaCl each 24 hr in summer and 48 hr in winter approximately. It was estimated that the total regenerated water was 39000 m^3/month. This flow of water could be used for car washing. The flow rate of this flow was 39 m^3/day and it could be used for washing of 58500 cars annually. The cost of construction and operation of car washing is 1150000 USD annually, whereas the benefit of this method is 3520000 USD annually. Therefore, cost-benefit of this scenario was 2370000 USD and the investment repayment was 3.06 years.

Scenario 4: Substitution of dropping system with flood irrigation

The dominant landscaping is grass and the non-potable water is used as the irrigation source. Flood irrigation system is used as the irrigation method and the irrigation flow for landscaping was not determined exactly. The irrigation program is every day from morning to noon. The consumed water is about 6750 m^3/month for landscaping. Fertilization is carried out annually twice for green coverage. In this hospital, the daily water demand was 150 m^3/ha for grass. Accordingly, the total consumed water was estimated 225 m^3/day for green spaces.

Water management in landscaping is including:

[Downloaded from jehsd.ssu.ac.ir on 2026-11-22]

[DOR: 20.1001.1.24766267.2018.3.3.6.1]

1) reduction of the amount of grass and other irrigated areas 2) ensuring about irrigation systems design, and 3) cultivation of native or adaptable plants with climate condition (Xeriscape) [3]. Alternative 2 is discussed in the following and alternative 3 is investigated in scenario 5.

The landscape area was 1.5 ha; therefore, the total demand water for irrigation was 6750 m^3/month. Although this water was taken from non-potable water and the use of non-potable water resources is often more cost-effective [3], it was a remarkable source of energy in future. Because water scarcity was a major water-related challenge particularly in the lower-middle income countries (e.g. Asia and Africa). Furthermore, urbanization is increasing fast and the local governments have limited capacity to deal with the rising of water supply and sanitation challenges [16]. Moreover, Shiraz water resources were decreasing over time, due to the fact that precipitation is one-third of global level and 70% of them were wasted in flooding irrigation. The productivity was 500-700 and 1500-2000 gr of cultivated crops per m^3 water in flood irrigation and dropping irrigation respectively. Therefore, water consumption was 3 times higher than dropping irrigation.

Another irrigation system for plants was groasis. In this method water was provided by water box and it was limited to the first year. It was estimated that the cost of dropping irrigation was $6000-7500 per ha. The total cost mean was $6750 and $1625 for dropping irrigation and groasis annually. However, in present condition, the annual cost for flooding irrigation is estimated 20250 USD. Therefore, the cost-benefit of this scenario was 13500 USD and 18625 USD for dropping irrigation and Groasis irrigation, respectively. Therefore, investment repayment was lower than one month.

Scenario 5: Use of native or adaptable plants with climate

The predominant landscaping is grass. It needs high level of water. Therefore, substation of grass with other plants such as drought-resistant plants can minimize water use and save cost [8]. Using native or adaptable plants with dry climate (local climate in Shiraz) require less water and are more likely to survive in drought conditions. Moreover, they are more resistant to pest and disease. A complete Xeriscaping strategy also has specific growth patterns, maintenance requirements and their interaction is consistent to the local climate and soil conditions. Cultivation of other plants such as Pine tree is favorable for Shiraz landscape, because this species has good resistance to dry and heat climate and it grows in precipitation lower than 300 mm/year. Moreover, cultivation cost of grass is very higher than other plants (based on the research centers in Iran). For this hospital, both costs were compared. For grass: operation cost was $107.5, cultivation cost was $35000 whereas for other covering plants this cost was $25 and $28500. Moreover, irrigation cost for covering plants was 35% of urbane water cost; however, it was 70% for grass.

The other solution is optimization of irrigation schedules. Irrigation system for this hospital was flood irrigation system that the high level water was wasted. Chang of the irrigation technology was identified as an effective factor on water conservation [12]. Therefore, this system could be replaced to dropping irrigation. However, the primary cost of this system was estimated higher than traditional systems. The cost-benefit of both systems was shown in following: cost-benefit of this scenario was 7500 USD annually, since the total cost of grass was estimated $36000 annually and for covering plant was $28500 in the same time. The investment repayment was 3.8 years.

Irrigation is the major user of total water resources in most of areas such as tropical countries located in Southeast Asia. Therefore, changes in irrigation are very important for long-term planning and management of water resources in these regions. Moreover, the irrigation demand will be much more variable in future. Therefore, the major challenges in water resources management will be handling the uncertainty that the further study is essential [19].

[Downloaded from jehsd.ssu.ac.ir on 2026-11-22]

[DOR: 20.1001.1.24766267.2018.3.3.6.1]

Conclusion

Hospitals are one of the main water consumption in urban area. In this study, the challenges and some of the solutions were considered for optimization of water management in one of the hospitals in Shiraz. Despite these challenges, there was not clear information about all of them. In this hospital, the monthly required water was 48488 m^3; however, the water consumption was 431125 m^3 and 12491500 m^3 in winter and summer, respectively. According to the results, the water consumption mean was 8-200 times higher than the requested water. It can be result of traditional distribution system and improper management. This study suggested five scenarios for reduction of water consumption in the hospital including: installation of a 1.5-liter bottle in toilet flushing, substitution of water cooling with the mixture ventilation system (natural and fan quell), reuse of the rejected water from resin for toilet flushing or car washing, substitution of dropping irrigation with flooding, use of native or adaptable plants with dry climate. The cost benefit and repayment period was estimated for comparison and selection of the best scenario. Based on these results, the cost-benefit of scenario 1, 2, 3, 4 and 5 were 960, 170, 2370000, 13500 and 7500 USD, respectively. Moreover, the investment repayments were 4 years, 1 month, 3.06 years, lower than 1 month and 3.8 years, respectively. Moreover, the ratio of cost-benefits of investment repayment were 240, 2040, 7×10^5, 10^4, 1973 USD/year, respectively. The results indicated that the scenario 4 was the best alternative for this hospital. Since the cost-benefit of the investment repayment period was higher than others.

Acknowledgment

The authors would like to express their appreciation to the hospital staff for their collaboration in the research process.

Funding

This project was financially supported by the Research Center of Health Sciences, Shiraz University of Medical Sciences (No: 95-01-04-13293).

Conflicts of Interest

No conflict of interest has been stated by the authors.

This is an Open Access article distributed in accordance with the terms of the Creative Commons Attribution (CC BY 4.0) license, which permits others to distribute, remix, adapt and build upon this work, for commercial use.

References

1. Pec JA, Coelhoa M, Gouveia VV, et al. Emotions toward water consumption: Conservation and wastage. Revista Latino American a de Psicología. 2016; 48: 117-126.
2. Faezipour M, Ferreira S. Assessing water sustainability related to hospitals using system dynamics modeling. Procedia Comput Sci. 2014; 36: 27-32.
3. Bourg J. Water conservation. WBDG (Whole Building Design Guide), a program of the National Institute of Building Science. 2016.
4. Naranjo-Gil D. Accomplishing water strategy policies in hospitals: The role of management information systems and managerial styles. Water. 2017; 9(2): 107.
5. Maas A, Dozier A, Manning DT, et al. Water storage in a changing environment: The impact of allocation institutions on value. Water Resources Research. 2017; 53(1): 672-87.
6. Chenoweth J, Lopez-Aviles A, Morse S, et al. Water consumption and subjective wellbeing: An analysis of British households. Ecological Economics. 2016; 130: 186-194.
7. U.S. DOE's Federal Energy Management Program's. Guidance to establish water efficiency improvement goal for federal agencies, Best Management Practices. 2013.
8. WHO. Healthy hospital, Healthy plant, Healthy people. Addressing climate change in health care settings. A discussion draft paper published by the World Health Organization and Health Care without Harm. 2009; 28: 1-25.
9. Jiang S, Wang J, Zhao Y, et al. Residential water and energy nexus for conservation and management: A case study of Tianjin. Int J

[Downloaded from jehsd.ssu.ac.ir on 2026-11-22]

[DOR: 20.1001.1.24766267.2018.3.3.6.1]

Hydrogen Energy. 2016; 41(35): 15919-29.
10. Dalhuisen JM, Florax RJG, Groot HLF, et al. Price and Income Elasticities of Residential Water Demand: A Meta-Analysis. Land Economics. 2003; 79 (2): 292- 308.
11. Mini C, Hogue TS, Pincetl S. The effectiveness of water conservation measures on summer residential water use in Los Angeles, California. Resour Conserv Recycl. 2015; 94: 136–45.
12. Brelsford C, Abbott J. Growing into Water Conservation? Decomposing the Drivers of Reduced Water Consumption in Las Vegas, NV. Ecological Economics. 2017; 133: 99–110.
13. Kang J, Grable K, Hustvedt G, et al. Sustainable water consumption: The perspective of Hispanic consumers. J Environ Psychol. 2017; 50.
14. Abbasi F, Samaei MR. The effect of temperature on airborne filamentous fungi in the indoor and outdoor space of a hospital. Environmental Science and Pollution Research. 2018. [In press]
15. Asefzadeh S, Golamalipoor S, Atighechian G. Comparison of energy consumption before and after implementation of subsidies targeting plan in hospitals of Qazvin University of Medical Sciences. Healthy Information Management. 2012; 1: 99-108.
16. Fahiminia M, Taherian E, Mohammadbeigi A. Surveying water and wastewater management in Hospitals of Qom Province. Hospital. 2014; 1(5).
17. Kavosi Z, Derakhshan F, Siavashi E. The relationship between energy consumption and hospital functional indicators in teaching hospitals of Shiraz University of Medical Sciences: 2009-2011. Manage Strat Health Syst. 2017; 1: 83-92.
18. Velayatti S, Sameei Dalooei MJ, Rasolli MB. Determining the difference between the loss of water coolers in the sun and in the shade. Second National Conference on Water and Wastewater operational approach. Tehran. 2013.
19. Tukimat NA, Harun S, Shahid S. Modeling irrigation water demand in a tropical paddy cultivated area in the context of climate change. Journal of Water Resources Planning and Management. 2017; 143(7). doi.org/10.1061/(ASCE)WR.1943-5452.0000753.

[Downloaded from jehsd.ssu.ac.ir on 2026-11-22]

[DOR: 20.1001.1.24766267.2018.3.3.6.1]