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Comparison of technical and economic efficiency of extended aeration and sequencing batch reactors processes in hospital wastewater treatment

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Original Article

Abstract

Wastewater of hospitals can cause many risks to public health due to having a variety of pathogenic microorganisms, pharmaceutical substances, and other hazardous toxic substances. The aim of this study was to evaluate the chemical quality of effluents from wastewater treatment plant of Falsafi Hospital and Hakim Jorjani Hospital in Gorgan, Iran, and to compare them technically and economically. This descriptive-analytical study was performed on 64 samples of raw wastewater entrance and output effluent obtained from treatment plants using extended aeration process and sequencing batch reactors (SBR) in two hospitals in Gorgan. All experiments for determination of pH, free residual chlorine, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS) were performed using standard methods. Finally, the obtained data were analyzed using t-test and Mann-Whitney test in SPSS software. Based on the results, the removal efficiency of BOD, COD, and TSS of the extended aeration system was 91, 90.8, and 95.7 percent, respectively, while these values for the SBR system were found to be 91.7, 91.9, and 95.3 Percent, respectively. Moreover, in the output of the two hospitals, pH values were recorded as 6.69 ± 0.26 and 7.33 ± 0.2 and the average amount of free residual chlorine was 0.12 and 0.13 mg/l, respectively. This study demonstrates good performances of the extended aeration activated sludge system and the SBR system in terms of reduction of pollution load to its standard limits for agriculture and irrigation purposes. However, due to slightly better efficiency, lower cost of investment, and operation compared to other methods, the SBR system is recommended.

KEYWORDS: Hospital Wastewater, Extended Aeration, Sequencing Batch Reactor, Iran

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Introduction

Generally, hospital wastewater in terms of quality is categorized as domestic or sanitation sewage.[1] However, due to the presence of hazardous, toxic, and pathogenic factors, this type of wastewater is considered as a health and environmental issue.[2-3] Many drugs are not completely metabolized after consumption by the patient and are disposed into the wastewater. Some of the non-biodegradable materials may pass through

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the sewage of wastewater treatment plants into surface water or reach underground water after use of sludge as fertilizer.[4] In recent years, the use of groundwater to supply drinking water has been increased. Based on the studies in this field, lack of pollution control and discharge of hospital wastewater into the ground and surface water, as well as wasting large amounts of money, can pose a major risk to the health of society.[2,5-6]

Strict observance of existing laws on the entry of certain elements and materials into the receiving waters, achieving the standards of effluent disposal, recognition of hospital wastewater properties, and reduction of harmful agents are considered necessary.[7]

In order to treat hospital wastewater, various methods, including extended aeration,[1] activated sludge using materials such as ozone, activated carbon powder, and Fenton,[3,8-9] membrane bio-reactor (MBR),[10] and sequencing batch reactor (SBR),[11] are used. Depending on the type of treatment used, the resulting effluent quality will be somewhat different. In order to assess the quality of treated wastewater for future use, determination of parameters, such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), and pH, is essential.[12-13]

Many studies have been performed in different countries to assess the quality of effluent from hospital wastewater treatment plants using different processes.[3,14-15] For example, Golbabaei Kootenaei and Amini Rad in a study in 2013 on hospital wastewater treatment by MBR, achieved 99% removal of COD and 88% of nitrogen nitrate (NH_3-N).[16] In another study carried out in 2012 by Amouei et al. on the quality of hospital wastewater using the extended aeration method, 74.3, 79.6, and 76.5 percent of BOD, COD, and TSS was removed, respectively.[1] Each method of wastewater treatment has certain advantages and disadvantages.[13] Among the available methods of treatment, activated sludge process with extended aeration and SBR has been the most commonly used in Iran due to its benefits, including the high ability to remove organic matter from wastewater, and has been used in many hospitals for wastewater treatment.[17-18]

In Gorgan, Northern Iran, due to the presence of particular ecosystems and critical natural resources such as rivers, sea, meadows, and forests in this city, assessment of sewage disposal methods in hospitals as well as continuous monitoring of the effluent quality of these centers is of great importance. Therefore, this study aimed to evaluate the technical and economic efficiency of wastewater treatment in Falsafi Hospital and Hakim Jorjani Hospital of Gorgan using the extended aeration method and SBR and to compare the quality of effluents from these two applied methods.

Materials and Methods

Samples were obtained from Hakim Jorjani Hospital (using extended aeration method) and Falsafi Hospital (using SBR Method), Gorgan, and then, obtained samples were immediately sent to the Water and Wastewater Laboratory, School of Health, in Gorgan for testing.

Samples were collected from the raw sewage influent and output effluent of the hospitals' treatment plants. In total, 16 samples were obtained from the entrance and 16 samples from the output of each treatment plant. Thus, 32 samples were collected from each plant and a total of 64 samples were tested in this study.

Sampling was carried out once every 2 weeks for 4 months from May to August 2014. For generalization of results to the entire wastewater, sampling was done intermittently during hours of the lowest and highest wastewater production on different days of the week. Instant sampling method was chosen in this study and wide span sterile containers with sanding lids were used for sampling.[19]

The parameters of pH, BOD, COD, TSS,

and free residual chlorine were determined in the input and output sewage of wastewater treatment plants. PH value and residual free chlorine were measured and recorded on-site using chlorine measurement kits (Merck, Germany).

For TSS assessment, the D2540 standard measuring method was used. For this purpose, the wastewater was passed through 2.1 µ thick fiberglass filter paper and after being dried in the oven at a temperature of 103 ºC to 105 °C for 1 hour, TSS values were determined through calculating the difference in weight of the filter.[19] BOD and COD parameters were measured using D5210 (manometric method) and D5220 (distillation back enclosed) standard methods, respectively.[19]

The obtained data were analyzed using Excel and SPSS software (SPSS Inc., Chicago, IL, USA). Normality of the data was approved with the Shapiro-Wilk test. For descriptive data, central indices and mean standard deviation were used. T-test was used for analytical data and nonparametric Mann-Whitney test was applied for parameters that were not normally distributed.

Results and Discussion

In this section, the findings related to the two hospitals and the current standards are presented in tables.

Table 1 shows the mean of studied parameters of raw sewage and output effluent of the extended aeration system and SBR system.

The quality of raw sewage and effluent of the extended aeration system are illustrated in figures 1 and 2, respectively.

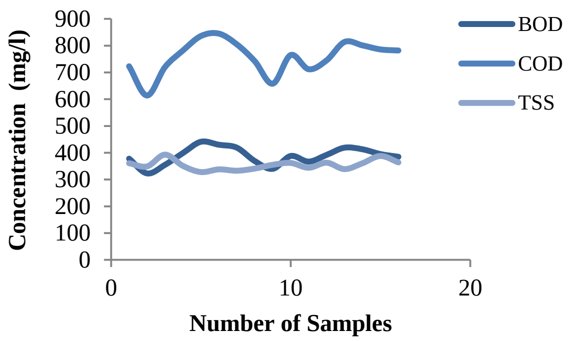

Figure 1. Quality of influent wastewater in the extended aeration system

BOD: Biochemical oxygen demand; COD: Chemical oxygen demand; TSS: Total suspended solids

Figures 3 and 4, respectively, show the quality of raw sewage and effluent of the SBR system. The comparison of input raw wastewater quality of the two systems shows that both hospitals have high intensity and strong sewage. The average input COD in the SBR system is higher than the extended aeration system, since the SBR system is managed privately, and thus, is provided with better service with more sewage intensity.

Table 1. The mean of studied parameters of raw sewage and effluent of the extended aeration and sequencing batch reactors (SBR) systems

Type of treatment system	Parameters	Influent (Mean ± SD)	Effluent (Mean ± SD)
Extended aeration system	BOD (mg/l)	388.31 ± 32.48	34.68 ± 11.15
	COD (mg/l)	614.00 ± 62.59	56.00 ± 22.10
	TSS (mg/l)	354.37 ± 18.10	14.93 ± 5.06
	pH	7.04 ± 0.18	6.96 ± 0.26
	Residual chlorine (mg/l)	-	0.12 ± 0.12
Sequencing batch reactor	BOD (mg/l)	387.37 ± 25.73	31.87 ± 9.24
	COD (mg/l)	757.93 ± 46.68	61.5 ± 17.59
	TSS (mg/l)	348.68 ± 13.50	16.43 ± 5.50
	pH	7.36 ± 0.18	7.33 ± 0.20
	Residual chlorine (mg/l)	-	0.30 ± 0.27

BOD: Biochemical oxygen demand; COD: Chemical oxygen demand; TSS: Total suspended solids; SD: Standard deviation

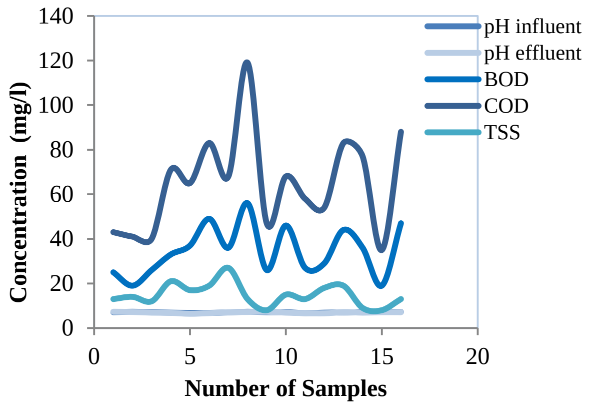

Figure 2. Quality of effluent of extended aeration system

BOD: Biochemical oxygen demand; COD: Chemical oxygen demand; TSS: Total suspended solids

Table 2 shows the efficiency of the two systems. According to the results, the efficiency of the two systems was close, with higher efficiency of the SBR system in some cases.

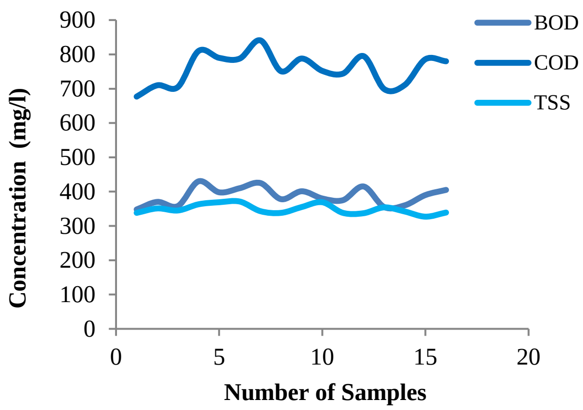

Figure 3. Quality of influent wastewater in the sequencing batch reactors (SBR) system

BOD: Biochemical oxygen demand; COD: Chemical oxygen demand; TSS: Total suspended solids

The assessed parameters for the comparison of input and output wastewater quality of the treatment plants included flow rate, pH, BOD, COD, TSS, and free residual chlorine which are discussed in the following sections.

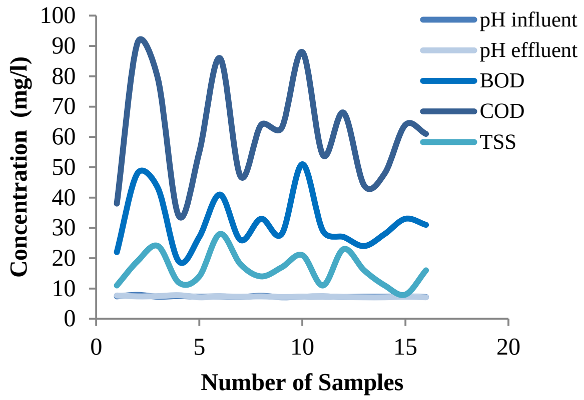

Figure 4. Quality of effluent of sequencing batch reactors (SBR) system

BOD: Biochemical oxygen demand; COD: Chemical oxygen demand; TSS: Total suspended solids

Flow rate

In this study, the input flow rate in the extended aeration system was about 52 m^3/day and in the SBR system around 60 m^3/day. The amount of flow rate in Falsafi Hospital was more than Hakim Jorjani Hospital.

The rate of pH

The concentration of hydrogen ions is considered as an important parameter in the quality of water and wastewater procedures. Increase or decrease in this parameter can cause corrosion, fouling, and damage to different sewage ducts and treatment plants, and also cause interference in the biological processes of wastewater treatment.[9] As shown in table 1, pH of input effluent of extended aeration wastewater treatment plant and SBR were 7.04 and 7.36, respectively. Moreover, based on the results, the average pH in the output effluent of the extended aeration system and SBR were 6.69 and 7.33, respectively. The pH level in the hospital with extended aeration system was almost neutral and slightly close to acidic, while in the hospital with the SBR system, the pH value was slightly alkaline. In the study by Amouei

Table 2. Comparison of the efficiency of BOD, COD, and TSS removal in the extended aeration and sequencing batch reactors (SBR) systems

Treatment system	BOD (mg/l)			COD (mg/l)			TSS (mg/l)		
	Influent	Effluent	Efficiency	Influent	Effluent	Efficiency	Influent	Effluent	Efficiency
Extended aeration system	388.3	34.7	91.0	614.0	56.0	90.8	354.4	14.9	95.7
SBR	887.4	31.9	91.7	757.9	61.5	91.9	348.7	16.4	95.3

BOD: Biochemical oxygen demand; COD: Chemical oxygen demand; TSS: Total suspended solids; SBR: Sequencing batch reactors et al. in 2012, pH of raw wastewater and output effluent of the hospital was found to be 7.5 and 7.4, respectively.[1] The reason for these differences may be the different qualities of waste produced in each region.

In another study by Sarafraz et al. in 2007 on a number of hospitals in Iran, the average pH of raw and output wastewater was 7.4 and 7.39, respectively.[17]

According to the standards, the pH of output effluent from both hospitals was within the acceptable limits for discharge into surface water and drainage wells, and agriculture and irrigation. Based on the statistical analysis (Mann-Whitney test), the pH value of output wastewater of the two hospitals were significantly different ($P < 0.05$).

The rate of biochemical oxygen demand

BOD indicates the amount of biodegradable organic matters, in other words, it indicates the amount of oxygen required by the bacteria for oxidation of organic matters. This parameter is considered as one of the main indicators for determining the quality of wastewater and pollution of natural waters.[17] High BOD levels can cause damage to aquatic life and indirectly affect the health of humans.[20] According to the results represented in table 1, the average BOD level of influent wastewater of the extended aeration system was 388.31 mg/l, while this level was found to be 387.37 in the SBR system. The BOD level of the two hospitals was close, and the high value of BOD indicates a strong sewage.[13] These values are much greater than the average BOD of studied hospitals in the study by Sarafraz et al. in Hormozgan, Iran (BOD: 291 mg/l).[17] The difference in BOD rate in various studies is related to the type and different quality of produced wastewater. After purification of the effluent, BOD values of hospital effluents with the extended aeration system and SBR were decreased to 34.68 and 31.87 mg/l, respectively. This indicates the efficient operation of the wastewater treatment systems of both hospitals in terms of removal of organic matter from wastewater.

BOD removal efficiency in treatment plants with extended aeration system and SBR was 91% and 91.7%, respectively. Rezaee et al. reported a BOD removal efficiency of 82.2% in a study on a hospital treatment plant using an anaerobic-aerobic reactor with a fixed environment.[4] Moreover, in the study by Majlesi Nasr and Yazdanbakhsh in 2008, the average BOD removal efficiency of 70 hospitals in Iran was found to be 67.5%.[21] Based on the statistical results of this study, there was no significant difference between the BOD removal efficiency of the two tested hospital treatment plants ($P > 0.05$). According to the Environmental Protection Agency standards, the maximum permissible BOD level for discharge into the environment for agricultural and irrigation applications are 100 and 50 mg/l, respectively.[22] Therefore, the wastewater of both hospitals (except in two instances) was at an optimal level and suitable for all irrigation and agricultural purposes during the experimental period.

The rate of chemical oxygen demand

The oxygen required for chemical analysis is generally used to determine the organic concentration of wastewater and the type of natural water contaminants.[13] As is shown in table 1, the average COD amount of the hospitals' treatment plant influent were 614 and 757.9 mg/l for extended aeration and SBR systems, respectively. COD levels, like BOD levels, represent the presence of strong effluents.[13] Comparison of BOD/COD ratio in the influent of the treatment plants with extended aeration system and SBR were 0.63 and 0.51, respectively. This indicates that the majority of organic material in the wastewater of these hospitals are biodegradable organic material.[20] In the study by Amouei et al., the average COD of raw wastewater was reported as 616 mg/l.[1] After wastewater treatment, the COD level of effluents of the extended aeration system and SBR was decreased to 56 and 61.5 mg/l, respectively. This finding shows the efficiency of the hospital wastewater treatment system in the removal of COD.

The COD removal efficiency in the extended aeration system and SBR were 90.8 and 91.9 percent, respectively. Golbabaei

Kootenaei and Amini Rad, in a study in 2013 on hospital wastewater treatment by MBR, reported 92% efficiency in COD removal.[16] Amouei et al. also achieved 76.5% efficiency in COD removal.[1] No significant difference was observed in terms of COD removal between the extended aeration system and SBR treatment plants (P > 0.05).

According to the Environmental Protection Agency standards, the maximum permissible amount of COD discharge into the environment for agricultural and irrigation purposes is 200 and 100 mg/l, respectively. Based on the obtained average COD levels and standard levels, the investigated hospitals were within the standard limits (except in one instance).

The rate of total suspended solids

Another common parameter for the evaluation of the efficiency of wastewater treatment systems is the amount of TSS in the treated wastewater.[1]

Based on our study findings, the average TSS amount in raw sewage entering the extended aeration and SBR systems were 354.37 and 348.68 mg/l, respectively. These values were higher than the levels reported by Amouei et al. (296 mg/l).[1] This can be due to different regional conditions and different activities in the studied hospitals. Nevertheless, the mentioned values decreased to 14.93 and 16.43 mg/l respectively. Thus, the TSS removal efficiency in the activated sludge system with extended aeration and SBR were 95.7 and 95.3%, respectively.

Fernandes et al. demonstrated 70% efficiency in the removal of TSS.[18] In addition, Sarafraz et al. showed an approximate 92% efficiency in the removal of TSS.[17]

Based on the obtained values in this study, the raw wastewater produced by both hospitals, in terms of TSS, were strong wastewater.[13] However, the treated wastewaters of both hospitals reached the standard environmental protection levels for agricultural purposes (100 mg/l), which indicates the efficiency of both treatment plants in the removal of TSS from wastewater. There was no significant difference between the performances of the two studied treatment plants in terms of TSS removal (P > 0.05).

Free residual chlorine

A variety of methods are used in order to disinfect wastewater and the most common is the use of chlorine and its compounds. The purpose of adding sufficient chlorine is to obtain free residual chlorine to ensure the chlorination operation.[13]

As is shown in tables 1 and 2, the average concentration of free residual chlorine in the effluent of treatment plants with extended aeration system and SBR was 0.12 and 0.3 mg/l, respectively.

The Environmental Protection Agency has set a standard limit of 1 and 0.2 mg/l free residual chlorine for the discharge of effluents into surface water and for agricultural purposes, respectively. Therefore, with respect to the obtained values, in 50% of experiments in the SBR system and 62% of experiments in the extended aeration system, the residual chlorine concentration was less than the standard limit or zero. Due to the infectious potential of hospital wastewater, these amounts can be dangerous.

Economic comparison of the two treatment systems

Table 3 shows the economic comparison of the two systems in regards to investment and the cost of the operation. Assessments and

Table 3. The economic comparison of the extended aeration and sequencing batch reactors (SBR) systems

Treatment system	Operation cost (dollar/m^3 of treated wastewater)	Electric cost (dollar/m^3 of treated wastewater)	Construction cost (dollar/m^3 of treated wastewater/day)
Extended aeration system	0.25	0.040	667
SBR	0.17	0.013	600

SBR: Sequencing batch reactors

calculations showed that in the extended aeration system, because of use of crystals with higher ability, more number of diffusers, separate sedimentation, and sludge return systems and more aeration time, investment and operation costs were higher compared to the SBR system. No study has been performed on the economic analysis of hospital wastewater treatment systems in Iran.

Conclusion

This study was performed on two hospitals in the city of Gorgan and the values of pH, BOD, COD, TSS, and free residual chlorine in the influent and effluent of the treatment plants were determined. The study results demonstrated the high levels of BOD, COD, and TSS in the influent of both hospitals. The pH values in the influent and effluent were in the neutral range, and thus, could not be considered as an environmental problem. Quality assessment of the effluent showed the good performance of the extended aeration activated sludge wastewater treatment system and SBR system in terms of the reduction of pollution to its standard limits. There was no significant difference in the reduction of pollution load between the two systems and both showed good performances. However, the removal efficiency of organic matter was slightly higher in the SBR system. The lower than standard limit and, in many cases, the zero range values of free residual chlorine could lead to the existence of different organisms and pathogenic agents in the wastewater of these hospitals.

Due to the efficiency of both wastewater treatment systems of the investigated hospitals and cost-effectiveness, low space, lack of smell, and etc. of the SBR system, SBR is recommended as a better option for hospital wastewater treatment.

Conflict of Interests

Authors have no conflict of interests.

Acknowledgements

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References

1. Amouei A, Asgharnia HA, Mohammadi AA, Fallahm H, Dehghani R, Miranzadeh MB. Investigation of hospital wastewater treatment plant efficiency in north of Iran during 2010-2011. International Journal of Physical Sciences 2012; 7(31): 5213-7.
2. Lin AY, Wang XH, Lin CF. Impact of wastewaters and hospital effluents on the occurrence of controlled substances in surface waters. Chemosphere 2010; 81(5): 562-70.
3. Kovalova L, Siegrist H, von Gunten U, Eugster J, Hagenbuch M, Wittmer A, et al. Elimination of micropollutants during post-treatment of hospital wastewater with powdered activated carbon, ozone, and UV. Environ Sci Technol 2013; 47(14): 7899-908.
4. Rezaee A, Ansari M, Khavanin A, Sabzali A, Aryan M. Hospital Wastewater Treatment Using an Integrated Anaerobic Aerobic Fixed Film Bioreactor. Am J Environ Sci 2005; 1(4): 259-63.
5. Fijan S, Poljsak-Prijatelj M, Steyer A, Koren S, Cencic A, Sostar-Turk S. Rotaviral RNA found in wastewaters from hospital laundry. Int J Hyg Environ Health 2006; 209(1): 97-102.
6. Luo Y, Guo W, Ngo HH, Nghiem LD, Hai FI, Zhang J, et al. A review on the occurrence of micropollutants in the aquatic environment and their fate and removal during wastewater treatment. Sci Total Environ 2014; 473-474: 619-41.
7. Prado T, Silva DM, Guilayn WC, Rose TL, Gaspar AM, Miagostovich MP. Quantification and molecular characterization of enteric viruses detected in effluents from two hospital wastewater treatment plants. Water Res 2011; 45(3): 1287-97.
8. Kajitvichyanukul P, Suntronvipart N. Evaluation of biodegradability and oxidation degree of hospital wastewater using photo-Fenton process as the pretreatment method. J Hazard Mater 2006; 138(2): 384-91.
9. De Witte B, Van Langenhove H, Demeestere K, Saerens K, De Wispelaere P, Dewulf J. Ciprofloxacin ozonation in hospital wastewater treatment plant effluent: effect of pH and H_2O_2. Chemosphere 2010; 78(9): 1142-7.
10. Liu Q, Zhou Y, Chen L, Zheng X. Application of MBR for hospital wastewater treatment in China. Desalination 2010; 250(2): 605-8.
11. Yang Z, Zeng G, Gao F, Chen J. Study on Piggery

Wastewater Treatment by Screening-UASB-SBR Processes. Journal of Hunan University (Naturnal Science) 2002; (29): 95-9.
12. World Health Organization. Guidelines for the safe use of wastewater, excreta and greywater - Volume 1: Policy and regulatory aspects [Online]. [cited 2006]; Available from: URL: http://www.who.int/water_sanitation_health/wastewater/gsuweg1/en/. 2016.
13. Tchobanoglous G, Burton FL, Stensel D. Wastewater engineering: treatment and reuse. New York, NY: McGraw-Hill Education; 2003.
14. Yuan S, Jiang X, Xia X, Zhang H, Zheng S. Detection, occurrence and fate of 22 psychiatric pharmaceuticals in psychiatric hospital and municipal wastewater treatment plants in Beijing, China. Chemosphere 2013; 90(10): 2520-5.
15. Gros M, Rodriguez-Mozaz S, Barcelo D. Rapid analysis of multiclass antibiotic residues and some of their metabolites in hospital, urban wastewater and river water by ultra-high-performance liquid chromatography coupled to quadrupole-linear ion trap tandem mass spectrometry. J Chromatogr A 2013; 1292: 173-88.
16. Golbabaei Kootenaei F, Amini Rad H. Bioreactor Membrane Filtration-Nano Novel by Wastewater Hospital of Treatment. Iranica J Energy & Environ 2013; 4(1): 60-7.
17. Sarafraz S, Khani MR, Yaghmaeian K. Quality and quantity survey of hospital wastewaters in Hormozgan province. Iran Environ Health Sci Eng 2007; 4(1): 43-50.
18. Fernandes H, Jungles MK, Hoffmann H, Antonio RV, Costa RH. Full-scale sequencing batch reactor (SBR) for domestic wastewater: performance and diversity of microbial communities. Bioresour Technol 2013; 132: 262-8.
19. Eaton AD, Franson MA. Standard Methods for the Examination of Water & Wastewater. Washington, DC: American Public Health Association; 2005.
20. Meo MI, Haydar S, Nadeem O, Hussain G, Rashid H. Characterization of hospital wastewater,risk waste generation and management practices in lahore. Proceedings of the Pakistan Academy of Sciences 2014; 51(4): 317-9.
21. Majlesi Nasr M, Yazdanbakhsh AR. Study on wastewater treatment systems in hospitals of Iran. J Environ Health Sci Eng 2008; 5(3): 211-5.
22. Iranian Environmental Protection Agency (IEPA). Environmental regulations and standards of Iran. Tehran, Iran: Iran Global Environmental Law; 2008. p. 234-39. [In Persian].