original article

Coliforms removal by an integrated activated sludge-maturation pond system

Mohammad Bagher Miranzadeh, Rohullah Dehghani, Mahmoud Bigdeli, Ashraf Mazaheri Tehrani, Mohsen Heidari[1]

Department of Environmental Health Engineering, Faculty of Health, Kashan University of Medical Sciences, Kashan, Iran, [2]Environment Research Center, Isfahan University of Medical Sciences (IUMS), Isfahan, Iran, and Department of Environmental Health Engineering, School of Public Health, IUMS, Isfahan, Iran

Address for correspondence:
Dr. Mohammad Bagher Miranzadeh,
Department of Environmental Health Engineering, Faculty of Health, Kashan University of Medical Sciences, Kashan, Iran.
E-mail: miranzadehm@ymail.com

ABSTRACT

Aims: This study assesses the removal of fecal indicators (i.e., total coliforms, fecal coliforms) in a full-scale activated sludge and maturation pond system with primary screening facility that is operating in center of Iran.
Materials and Methods: A total of 54 grab samples for microbiological test were collected from the inlet and outlet of activated sludge (AS) and maturation pond (MP) during the winter and summer 2010 (3 sample per month in 3 locations). Collected samples were sent to laboratory and were analyzed for total coliformbacteria (TCB) and fecal coliform bacteria (FCB) according to Standard Methods.
Results: The results of this study show that the maximum TCB removal in AS (92.2%) and MP (99.2%) were occurred in summer. Also, for FCB, the highest removal rate (99.7%) was recorded during the summer. The mean winter TCB numbers for AS and MP effluents were 2.7×10^7 and 2.3×10^6 (MPN per 100 ml), respectively. However, the effluent still contained a significant number of coliforms, which was greater than the permissible limit for unrestricted irrigation as prescribed by Iranian and WHO guidelines.
Conclusion: Removal efficiencies of fecal indicator bacteria were maximum during summer and minimum during winter. Statistical analysis indicated that TCB and FCB removal in MP is significantly affected by ambient temperature, whereas there was weak correlation between ambient temperature and coliform removal in AS system.

Key words: Activated sludge, coliform removal, maturation pond, wastewater treatment

INTRODUCTION

The most appropriate wastewater treatment is that which will produce an effluent, meeting the recommended microbiological quality guidelines both at low cost and with minimal operational and maintenance requirements. Different system are used worldwide for wastewater treatment such as activated sludge, trickling filter, and waste stabilization pond or a combination of them in series.[1,2] In Iran, because of water shortage, main usage of treated wastewater is for unrestricted irrigation.[3]

The potential presence of pathogens in treated effluent is assessed using indirect measures such as coliform bacteria, which is indicator of the safety of effluent. World health organization (WHO) has recognized total coliform

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bacteria (TCB) and fecal coliform bacteria (FCB) as the key fecal indicator. These indicators provide a total spectrum of waterborne disease. Total coliform indicate the presence of bacterial pathogens while FCB indicates the presence of bacterial pathogens as well as the presence of enteric viruses through vogue their relationship being with coliphages.[4,5] Coliform removal efficiencies in WTP are utilized as indicators of the ability of the process to affectively remove pathogenic viruses and bacteria. Thus, the effectiveness of wastewater treatment systems with respect to the elimination of microbial pollution is often measured by determining the numbers of TCB and FCB in effluent of WTP.[2,5]

The process responsible for the reduction of coliform and pathogen population in WTP systems are known to be controlled by a combination of physical, chemical, and biological factors.[2,6-8] Viruses may be adsorbed by soil, the treatment media and organic litter, or deactivated due to lack of an appropriate host. On the other hand, in natural wastewater treatment processes such as waste stabilization pond (WSP), the bacteria are mainly removed by sedimentation, high retention time, exposure to sunlight, alkaline condition, natural die-off, and predation by zooplankton. Efficiency analysis for WTP must take into account local climatological conditions, especially ambient temperature and sunlight.[2,5,9-11]

Worldwide studies on various wastewater treatment plants were revealed that activated sludge process can remove indicator microorganisms up to 99% and for WSP system in the case of proper design and operation, this values can reach up to 99.999%. Also, efficiency removal of fecal bacteria in natural wastewater treatment process were higher in warm seasons rather than in cold seasons.[8,12,13]

Kashan is a tropical city in center of Iran with an estimated population of over 200,000 residents and is located at 930 m above the sea level. In this city, the university of medical sciences has commissioned since 1986 and at now, has over 3000 students in the field of medicine and health. The water consumption in this university is supplied by a deep water well. A wastewater treatment plant (WTP) consisting of an activated sludge system (extended aeration) and a maturation pond is now in operation in series. The wastewater is mainly domestic, and mean daily flow rate is 300 cubic meter per day. Because of economical and technical problems, the chlorination system was the out of service, and instead a maturation pond with rock baffle was constructed in series to activated sludge system. Final effluent from this WTP is used for irrigation of lawn and a variety of trees in surrounding of university under on surface drip irrigation system. Hence, quality control of the treated effluent, particularly its microbiological quality, is of considerable concern because of public health and environment protection.[3]

The main objective of the current research was the evaluation of the TCB and FCB bacteria removal efficiency in a full-scale integrated activated sludge - maturation pond wastewater treatment system in Kashan university of medical sciences.

MATERIALS AND METHODS

The experimental work on the performance evaluation of Kashan university of medical sciences wastewater treatment plant (Kaums-WTP) for pathogen removal was based on the use of indicator organisms, specifically TCB and FCB bacteria.

Wastewater treatment plant

The Kashan university of medical sciences wastewater treatment plant comprises of lift station, bar screen, two aeration tank in parallel with surface aerator, secondary clarifier, chlorination system (out of service), and a maturation pond with rock baffle [Figure 1]. Details of each unit in the system are shown in Table 1. The system was designed to remove biochemical oxygen demand (BOD), total suspended solid (TSS), and pathogenic microorganisms. Disinfection is not applied on AS effluent. The effluent of Kaums-WTP systemis used for lawn and plants watering in areas surrounding the university. Table 2 presents the minimum, maximum, and average of ambient temperature for the region during the studied period. As it is reported in Table 2, the daily average of ambient temperature was about 19.8°C in the studied region.

Wastewater sampling

Raw and treated wastewater samples were simultaneously collected three times per month during the winter and summer 2010 at three different locations including influent (raw sewage), outlet of AS, and MP system. Grab sampling procedure was adopted for microbiological analysis as per the methods prescribed in standard methods.[14] Wastewater samples for microbiological test were collected from inlet and outlet units of treatment plants in non–reactive sterilized borosilicate glass bottle of 250 ml capacity. Sample collection dates were randomly

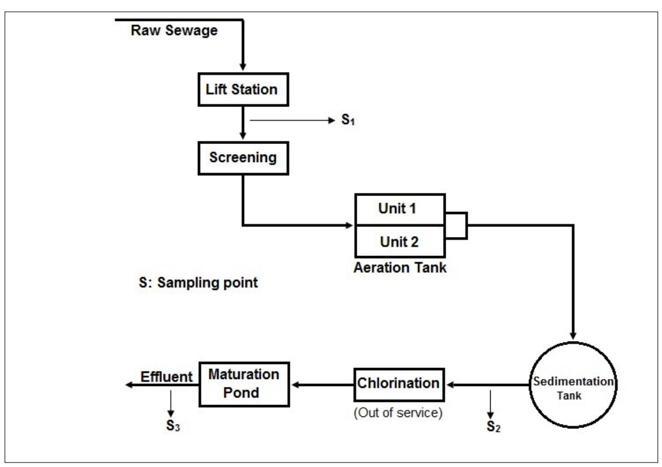

Figure 1: Schematic of kashan university of medical sciences wastewater treatment plant

Table 1: Minimum, maximum, and average of ambient temperature in Kashan city for the monitoring period

Session	Winter 2010				Summer 2010			
Month	January	February	March	Average session	July	August	September	Average session
Obs.min. ambient temperature°C	-2°C	4°C	4°C	3.33°C	22°C	21°C	15°C	19.33°C
Obs.max. ambient temperature °C	22°C	27°C	35°C	28°C	45°C	42°C	41°C	42.66°C
Average monthly	9.3°C	9.47°C	16.1°C	15.6°C	33.1°C	-30.8°C	28.6°C	30.9°C

Table 2: Dimensions and hydraulic retention time of each unit in kashans- WTP

Unit	HRT	Area (m^2)	Depth (m)
Aeration tank	24 (hr)	124	3
Sedimentation tank	4 (hr)	28	3
Maturation tank	10 (day)	765	1.2

chosen, and all collections were done between 08:00-10:00 am. The collected samples were brought in an insulated container during transport. The samples were analyzed in water and wastewater laboratory, faculty of health, Kashan university of medical sciences on the same day of sample collection.

Sample analysis

The number of total and fecal coliforms was determined using the most probable number (MPN) method. Total coliform and fecal coliform were enumerated by multiple tube fermentation technique as described in standard methods for the examination of water and wastewater, by using laurel tryptose broth incubated at 35°C (24-48 h) for TCB and medium incubated at 44°C (24-48 h) for FCB.[14] Statistical tables were used to interpret the results, which were expressed as number of organism in 100 ml of the sample.

RESULTS

The monthly variation in TCB and FCB bacteria for Kaums-WTP in the winter and summer of 2010 are shown in Tables 3 and 4. The number of TCB and FCB in raw sewage ranged between 8.3×10^7 to 2.1×10^8 and 9.1×10^6 to 9.1×10^7 during winter, while TCB and FCB varied from 8.6×10^7 to 1.9×10^8 and 1.8×10^7 to 4.1×10^7 (MPN per 100 ml) in summer, respectively. From Table 3, the mean winter TCB numbers for AS and MP effluents were 2.7×10^7 and 2.3×10^6, respectively, and from Table 4, the corresponding summer values were 1.03×10^7 and 6.67×10^4 MPN/100 ml, respectively. The mean FCB numbers for AS and MP effluent in winter were 4.5×10^6 and 3.04×10^5, and in summer were 2.17×10^6 and 5.6×10^3 MPN/100 ml, respectively.

Total and fecal coliforms monthly average removal efficiencies for Kaums-WTP are shown in Figures 2 and 3. As shown in Figure 2 for winter, TCB and FCB removal rates were 78.4% (February) to 81.2 (July) and 74.5% (February) to 83% (March) in AS system and for MP were 82.95% (March) to 94.7% (February) and 86.2% (March) to 97.4% (February) as respectively. Also, seasonally average removal of TCB and

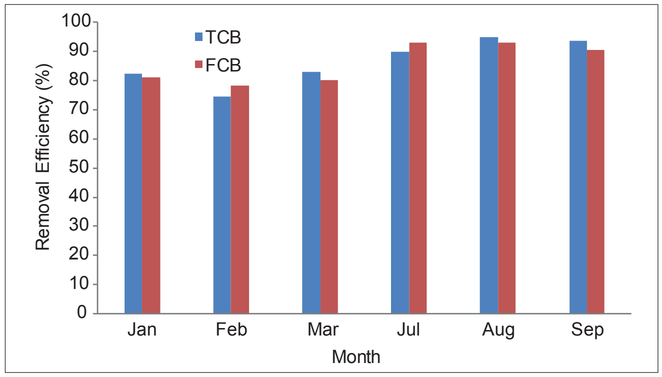

Figure 2: Monthly average removal of TCB and FCB in AS system

FCB in Kaums–WTP were shown in Figure 4. The overall average removal of TCB and FCB by AS system were found to be 86% and 94.2%, respectively. The corresponding values for MP system were 95.5% and 96.5%, respectively. The TCB and FCB removal in total system (AS-MP) were 99.16% and 99.86% during studied period.

DISCUSSION

The number of the two pathogen indicators in the raw sewage is quite different for the two season with an increase during the winter. Because of low water consumption in winter, the numbers of TCB and FCB in raw sewage were greater in winter respect to in summer.[12,13] Based on obtained results, we concluded that in AS system, a considerable number of microbes were left in the effluent and could not be removed by AS process; therefore, an additional treatment step is required to remove microbes more effectively. The results show that, the minimum number of the indicator bacteria were recorded in the warmer month, which might be attributed the rapid die-off with increasing of solar radiation and higher temperature. Exposure to sunlight (UV radiation) is the main mechanism of bacterial die-off. Also, high pH values produced during algal photosynthesis is an important parameter for bacterial death in stabilization pond.[9,12,15]

The maximum TCB removal in AS system (92.2%) and MP (99.2%) were occurred during summer 2010. For FCB, the highest removal rates were recorded during summer 2010 (92.9% in AS system and 99.7% in MP). The results are in coherence with the findings of earlier studies that stated 90-98% reduction of bacteria in AS process.[6,12,16,17]

Table 3: Total and fecal coliform number for Kaums- WTP during winter 2010

Sampling location	Bacteria group	Winter 2010									Winter 2010 $n=9$	
		January			February			March			Mean	S.D
		1	2	3	1	2	3	1	2	3	1.43E8	4.37E7
Influent	T CB	1.5E8	1.1E8	2.1E8	1.2E8	1.7E8	9.5E7	1.6E8	1.9E8	8.3E7		
	F CB	9.1E8	9.1E6	4.3E7	3.9E7	5.2E7	2E7	4.5E7	1.7E7	1.9E7	1.28E8	2.76E7
AS Effluent	T CB	3.4E7	2.2E7	2.9E7	3.8E7	3.9E7	9.7E6	3.9E7	1.1E7	2.4E7	2.73E7	1.14E7
	F CB	3.2E6	3.6E6	3.8E6	5.6E6	7.5E6	4.8E6	5.7E6	2.5E6	4.5E6	4.57E6	1.44E6
MP Effluent	T CB	4.2E6	7.9E5	9.9E5	9.4E5	2.3E6	7.3E5	2.6E6	1.5E6	7.4E6	2.33E6	2.07E6
	F CB	3.1E5	1.3E5	1.3E5	1.8E5	8.1E4	1.7E5	8.3E5	3.7E5	5.4E5	3.04E5	2.31E5

Table 4: Total and fecal coliform number for Kaums- WTP during summer 2010

Sampling location	Bacteria group	Summer 2010									Summer 2010 $n=9$	
		July			August			September				
		1	2	3	1	2	3	1	2	3	Mean	S.D
Influent	T CB	8.6E7	1.1E8	1.6E8	1.3E8	9.6E7	1.2E8	1.9E8	1.5E8	8.8E7	1.25E8	3.34E7
	F CB	3.1E7	3.8E7	1.8E7	3.4E7	2.2E7	2.5E7	4E7	4.1E7	2.6E7	3.05E7	7.8E6
AS Effluent	T CB	5.1E6	9.9E6	9.6E6	3.9E6	1.3E7	1.3E7	1.9E7	9E6	1.1E7	1.03E7	4.22E6
	F CB	3.2E6	3.8E6	1.8E6	1.7E6	6.6E5	1.7E6	2.8E6	2.1E6	1.8E6	2.17E6	3.89E5
MP Effluent	T CB	5.2E3	4.9E4	1.4E5	7.8E4	1.3E4	1.3E3	1.9E5	9E4	3.3E4	6.67E4	6.1E4
	F CB	3.6E3	3.8E2	1.8E3	6.8E3	3.3E3	3.4E3	2.8E3	1.8E4	1.1E4	5.6E3	5.2E3

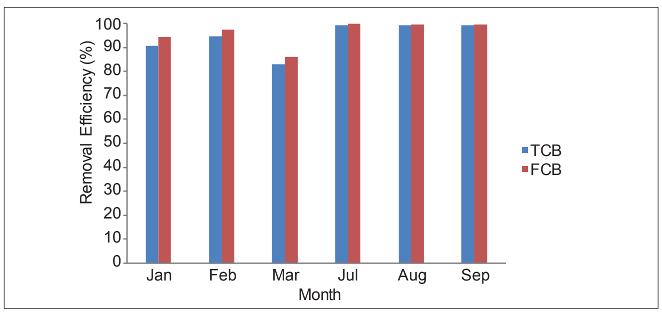

Figure 3: Monthly average removal of TCB and FCB in MP system

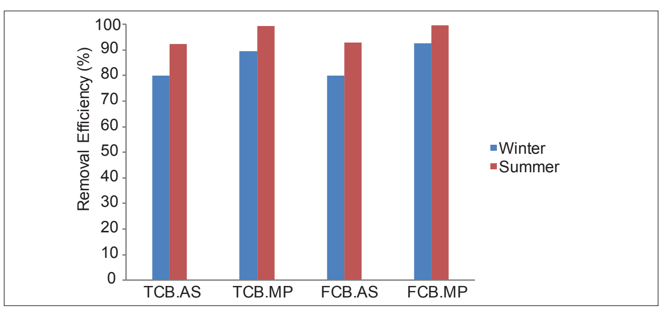

Figure 4: Seasonally average removal of TCB and FCB in Kaums -WTP

Study by Barjenbrach and Erler showed that removal rate of TCB and FCB reaching to 99.99% in maturation pond is not in agreement with our study finding. This difference is due to lower retention time and higher depth (1.5 m) in MP in Kaums-WTP. Other research finding shows that shallow maturation ponds (0.4 m) were more efficient as microbiological disinfection than deeper ones. Coliform die-off in pond decreases with an increase in pond depth.[17,18-21]

Coliform removal efficiencies in wastewater treatment plants are utilized as indicators of the ability of the process to effectively remove pathogenic viruses and bacteria.[7,11,22] Based on the data reported in Tables 3 and 4, it was observed that the treated effluent in Kaums-WTP still contained significant numbers of TCB ($6.1 \times 10^4 - 2.07 \times 10^6$ MPN/100 ml) and FCB (5.2×10^3-2.3×10^5 MPN/100 ml) during the period studied. These numbers are greater than the permissible limit specified by Iranian (TCB $\leq$ 1000 and FCB $\leq$ 400 MPN/100 ml) and WHO (FCB $\leq$ 1000 MPN/100 ml) guidelines for unrestricted irrigation. This is probably due to insufficient hydraulic retention time in maturation pond because of an improper selection of design criteria.[4,15,20,21,23]

Based on another study, the overall removal of coliforms has been reported to be 90-95% and 90-98% in complete mix and extended aeration activated sludge system, respectively. Also, reported coliform removal in conventional activated sludge system was 98%. Earlier studies by kuivunen *et al.* on activated sludge plants have shown 90-99% enteric bacterial reductions, which is compatible nearly with our study findings.[5,12,22,24]

Statistical analysis for Kaums-WTP shows no significant variation in coliform removal in AS system during all the months of studied period ($P = 0.08$) because AS process performance is not strongly affected by ambient temperature.[12,13] In contrast, in MP, a significant variation for coliform removal is found during winter and summer ($P = 0.02$) because stabilization pond performance is directly affected by ambient temperature. This means that sunlight exposure is considered to be the most important causes of natural disinfection in the waste stabilization pond (WSP) and hence, indicator microorganisms die off is highly affected by ambient temperature.[10,16,19,25]

Thus, we investigated the effect of ambient temperature on inactivation of indicator bacteria as an exposure to sunlight, which is the main factor for disinfection in WSP system.[6,16,17,20,24] Among the climatological parameters, temperature and light intensity plays an important role in removal or inactivation of pathogens in WSP system. Based on findings of other study, it is observed that the fecal coliform mortality rate constantly increases with increasing pH and temperature. High level of dissolved oxygen (DO) due to algal photosynthesis (which is affected by ambient temperature) and high visible light are rapidly fatal to coliforms bacteria.[16,17,21] Pond depthis a critical limiting factor. In addition, the algae population and degree ofmixing are factors affecting penetration of solar radiation into the pond water.[8,13,21,23,25]

CONCLUSIONS

Although overall reduction of TCB and FCB in Kaums-WTP has been found to be significant, still final treated effluent exceeds Iranian and WHO guidelines for unrestricted irrigation. Thus, hydraulic retention time in maturation pond must be increased to more than 10 days or another MP must be constructed in series with existing pond. Removal efficiency of TCB and FCB was maximum during summer (99.7%) and minimum during winter (79.95%); this emphasizes the role of climatological condition on wastewater treatment process. The effect of ambient temperature on removal efficiency of TCB and FCB on activated sludge system was not significant, but a significance correlation between coliform removal and ambient temperature was found in maturation pond. Coliforms removal by an integrated activated sludge- maturation pond system.

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