Iranian J Publ Health, Vol. 41, No.4, Apr 2012, pp.87-93

Original Article

Performance Evaluation of Different Filter Media in Turbidity Removal from Water by Application of Modified Qualitative Indices

*G Badalians Gholikandi[1], E Dehghanifard[2], *M Noori Sepehr[2], A Torabian[3], S Moalej[1], A Dehnavi[4], AR Yari[5], AR Asgari[6]*

1. Power and Water University of Technology (PWUT)/Water Research Institute (WRI), Tehran, Iran
2. Dept. of Environmental Health Engineering, School of Public Health, Alborz University of Medical Sciences, Tehran, Iran
3. Faculty of Environment, University of Tehran, Tehran, Iran
4. Dept. of Environment Civil Engineering, Civil Engineering School, Tarbiat Modares University, Tehran, Iran
5. Dept. of Environmental Health Engineering, School of Public Health, Qom University of Medical Sciences, Qom, Iran
6. Dept. of Environmental Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran

(Received 18 Oct 2011; accepted 15 Jan 2012)

Abstract

Background: Water filtration units have been faced problems in water turbidity removal related to their media, which is determined by qualitative indices. Moreover, Current qualitative indices such as turbidity and escaping particle number could not precisely determine the efficiency of the media in water filtration, so defining new indices is essential. In this study, the efficiency of Anthracite-Silica and LECA-Silica media in turbidity removal were compared in different operating condition by using modified qualitative indices.

Methods: The pilot consisted of a filter column (one meter depth) which consisted of a layer of LECA (450 mm depth) and a layer of Silica sand (350 mm depth. Turbidities of 10, 20, and 30 NTU, coagulant concentrations of 4, 8, and 12 ppm and filtration rates of 10, 15, and 20 m/h were considered as variables.

Results: The LECA-Silica media is suitable media for water filtration. Averages of turbidity removal efficiencies in different condition for the LECA-Silica media were 85.8±5.37 percent in stable phase and 69.75±3.37 percent in whole operation phase, while the efficiency of total system were 98.31±0.63 and 94.49±2.97 percent, respectively.

Conclusion: The LECA layer efficiency in turbidity removal was independent from filtration rates and due to its low head loss; LECA can be used as a proper medium for treatment plants. Results also showed that the particle index (PI) was a suitable index as a substitute for turbidity and EPN indices.

Keywords: Dual media filter, Water turbidity, Filtration, LECA, Silica

Introduction

Filtration is a separation process that consists in passing a solid-liquid mixture through a porous material (filter) which retains the solids and allows the liquid (filtrate) to pass through (1). Removing suspended solids by high-rate granular media filtration is a complex process involving a number of phenomena. Attempts to develop theories that quantitatively predict solids removal performance

***Corresponding Author:** Email : golnara2006@yahoo.com

with sufficient precision and versatility to be of use in practical filter design have met with relatively little success. Consequently, filter media selection is often an empirical process. Pilot investigations are common tools for assessing the performance of a particular filter design (2-4).

The common types of media used in granular bed filters are Silica sand, Anthracite coal, and Garnet or Ilmenite. These may be used alone or in dual- or triple-media combinations a number of properties of a filter medium are important in affecting filtration performance and also in defining the medium. These properties include size, shape, density, and hardness. The porosity of the granular bed formed by the grains is also important (2).

Although the selection of filter media type and characteristics is the heart of any filtration system, selection is usually based on arbitrary decisions, tradition, or a standard approach. Pilot plant studies using alternative filter media and filtration rates can determine the most effective and efficient media for a particular water (5).

Turbidity is considered as a common index for filtration efficiency determination; however, this index is weak for particles with diameter of 1-10 µm including pathogen microorganisms. Along with the EPN (escaped particle number), turbidity is used to control filtration efficiency too, but these indices are not satisfactory (5).

Some studies have been conducted to evaluate the performance of filter media on removal of different pollutants from water and wastewater (6-10). In these studies, however, no efficient indices have been applied to evaluate the performance of filter media and to compare the efficiencies of different media.

LECA (Light Expanded Clay Aggregates) has been considered as a media for water filtration due to its characteristics such as high adsorption capacity, abundant resources, inexpensive in compare to other media and etc, however most of studies were applied LECA as an adsorbent(11, 12).

In this research, the LECA application as a filter medium has been considered besides the adsorption characteristics that have been researched in previous studies. Therefore, this study was aimed on investigation of dual media LECA-Silica efficiency for better turbidity removal in different operation condition.

Materials and Methods

Filter

The pilot used in this study had several units which were an artificial turbidity injector, a chemical coagulant injector and a flash mixer, a flow meter, dual layer LECA-Silica filter and a filter backwash system that have been shown in Fig. 1.

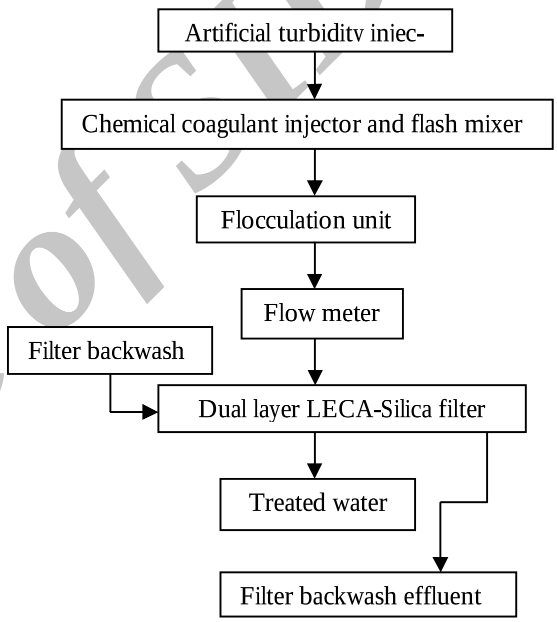

Fig. 1: Pilot diagram of dual media LECA-Silica Filter

The artificial turbidity injector was consisted of a turbidity stock solution tank (total and net capacity of 80 and 50 liters, respectively) and stable height tank (500 liter) which were equipped with a 1450-rpm electromechanical mixer, a dosing pump that injects turbidity solution to the stable tank and a globe valve.

The flash mixer unit was consisted of a flash mixing tank (quadrangle section with 15.6 liter capacity), a variable rate mixer (mixing rate of 250 rpm, two blades shovel flat wing with ratio of 4:1). The flocculation unit was consisted of three parts of

the flocculation tank (300 liters), the variable rate mixer (50-70 rpm) and mixing wing.
The flow meter used in this study was consisted of a Plexiglas tank with parts of inlet, regulator, flow conductor to filter, and backwash water effluent. A 30º triangle channel section was used for water quantity regulation that has entered to the filter. The considered water quantities of this study were 5.24, 7.86 and 10.48 L/min that yield filtration rates of 10, 15 and 20 m/h (m^3/m^2.h).

Dual media LECA-Silica filter

The filter used in this study had several parts of filter column, filtration rate regulator, head loss monitoring system, and filter media. In order to explain the filter that was used in this study, the detailed specifications were noticed in the next section.

Filter column

The filter column (200 mm internal diameter and 2 m height) was consisted of two 1 m columns. The required instruments such as head loss measurer, sampling valves and backwash accessories were installed properly.

Head loss monitoring system

For measuring the head loss in the filter column, seven manometers, and a manual gauge (1 mm accuracy) was used. Table 1 shows manometers depth that was installed on filter column.

Table 1: Manometers depth of filter column

Manometer No.	1	2	3	4	5	6	7
Depth from bed surface (cm)	10	20	30	40	55	70	80

Filter media

The filter media was consisted of one layer of LECA (450mm depth) and one layer of Silica sand (350mm depth). In addition, a support layer of Silica gravel (200mm depth) was used. The detailed specification of media filter has been shown in Table 2.

Table 2: Filter media specifications

No.	Media type	Layer depth (mm)	Uniformity coefficient	Effective size (mm)
1	LECA	450	≈ 1	2.14
2	Silica	350	1.4	0.9

Backwash accessories

The backwash method of this study was up flow water wash with air scour with water quantity for 35 L/min based on suggestion of AWWA (2). The backwash phase was continuing until the system head loss reached to 200 mm, and backwash effluent was gathered at the end of the phase.

Samples characteristic

Inlet turbidity (10, 20, and 30 NTU), coagulant concentration (4, 8, and 12 ppm) and filtration rates (10, 15, and 20 m/h) are the most variables of this study. The inlet turbidity was created by water conduction through clay of 200 meshes. In addition, Ferric chloride was used as the coagulant agent. The filtration rates of 10 and 15 m/h were chosen as filtration rates of water treatment plants and the 20 m/h for critical conditions. Coagulant concentrations were selected by jar test and based on different inlet turbidity.

Sampling methods and analysis

Samplings were done from 30 cm depth of LECA layer for efficiency determination of this media, and at the water outlet for efficiency determination of total system. Samples were gathered from 1mm diameter valves to prevent turbulence condition in filter media. Head loss measurements were done in sampling valves.
All sampling methods and analysis were in accordance with Standard methods for the examination of water and wastewater (13). Samples turbidities were measured by portable turbidity meter HACH-2100 and the escaped particles were analyzed by diameter measurer LATS-1(14). This study was conducted in about one year based on several variables. All samples were gathered after backwash phase and during 0-17 hours of filter operation. The maximum head loss for backwash

phase was 160 cm that 20 cm of that was for system head loss and others for operation head loss. Indices, which were considered for evaluation of filter efficiency, were the EPN and the PI (Particle Index). The PI was calculated by multiplying the EPN to particle diameter (PD) (Equation 1).

$$PI\ (N.mm) = PD\ (mm) \times EPN\ (N) \qquad \text{(Eq. 1)}$$

Statistical analysis

To compare the efficiency of the media on turbidity removal (in different condition), statistical analyses of ANOVA (analysis of variance) and t-test were used (P_{value}<0.05) (15).

Results

Results of filter head losses in different conditions of turbidities and filtration rates have been shown in Figure 2.

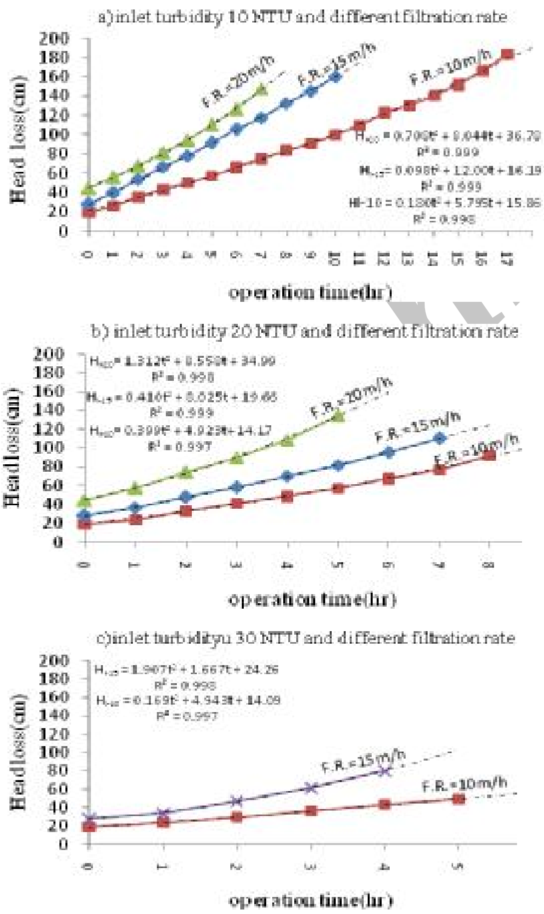

Fig. 2: Filter head losses in different conditions of turbidities and filtration rates

Turbidities of 10, 20, and 30 NTU and different filtration rates were separated in A, B and C graphs. These graphs were only for entire filter column and demonstrated that increasing the operation phase and filtration rate in stable inlet turbidity caused the not linear trend of head loss increasing and this increasing was getting more by longer operation phase and filtration rate. Results of head losses showed that the average head loss for LECA layer with 40 cm depth was 16.59±1.1 percent and others for Silica layer. This parameter had changed between 14.75±1.26 to 17.68±2.2 percent.

Fig. 3 and 4 show outlet water turbidities in 30 cm and final depth of the filter, respectively.

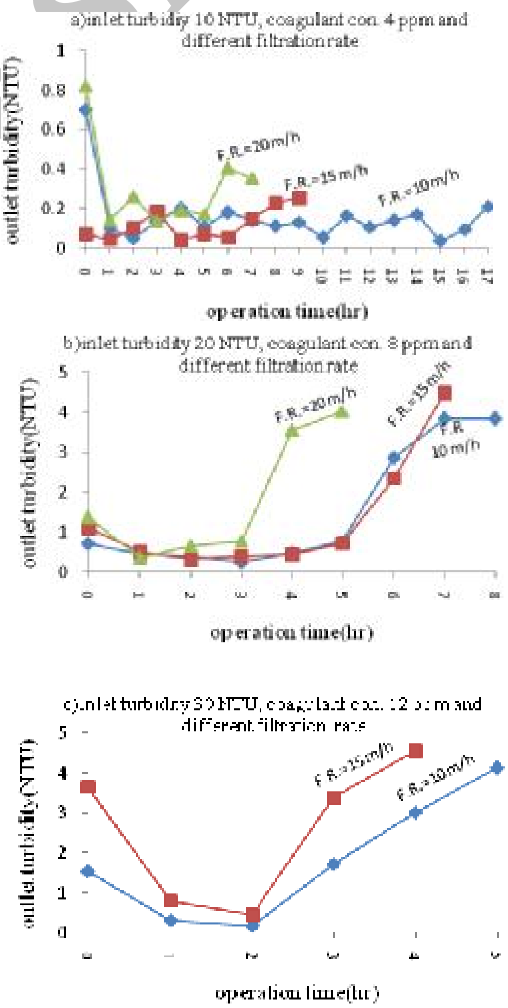

Fig. 3: Outlet turbidities of the filter in whole depths of filter column in different conditions

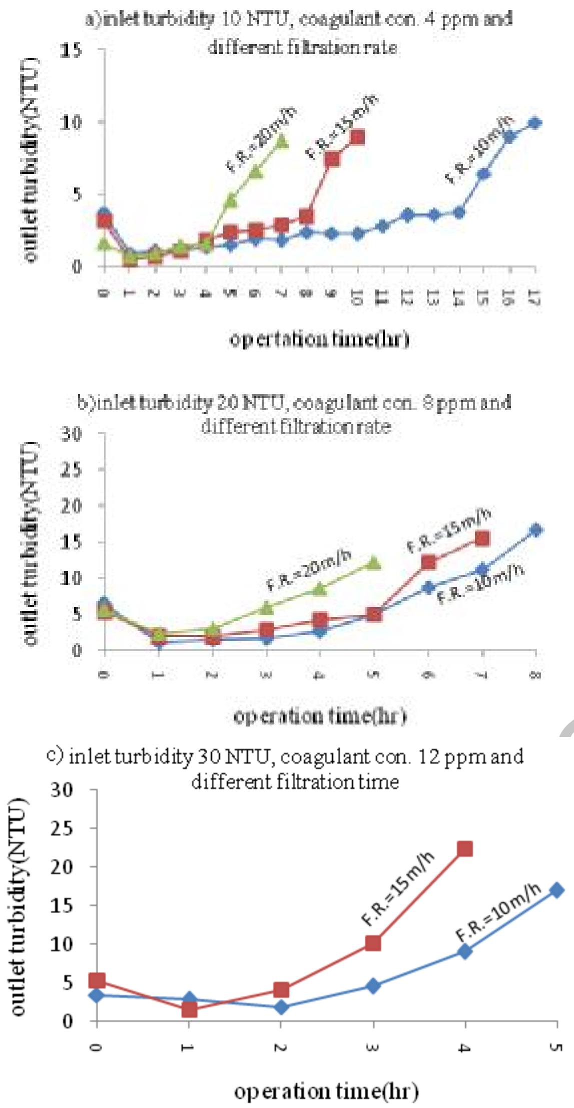

Fig. 4: Outlet turbidities of the filter in 30 cm depths of filter column in different conditions

Results show that the LECA layer and specially the first 30 cm depth has considerable effect on turbidity removal which could reach to more than 85.8±5.37 percent in stable phase and 69.75±3.37 percent in whole operation phase, while the efficiency of total system were 98.31±0.63 and 94.49±2.97 percent, respectively.

Discussion

The dual media LECA-Silica filter could be a suitable choice for turbidity removal especially for waters with low turbidities; which most turbidity removals of stable and whole phases in LECA layer.

Figure 3 and 4 demonstrate outlet turbidities of the filter in 30 cm and whole depths of filter column in different conditions. These figures show that the period of stable phase of the filter decreased by increasing the filtration rate. Moreover, by inlet turbidity increasing, the stable phase of the filter operation decreased, the outlet turbidity and lines slopes increased.

As shown, standard deviations of turbidities averages were high in lag and breakpoint operation phases, however was more proper in stable phase due to stability of filter operation and efficiency. It seems that coagulant concentration increasing has not considering effect on stable phase and outlet turbidity in relation to inlet turbidity, due to being coordination between inlet turbidity and coagulant concentration. This condition was also true for LECA layer and entire depth; however, the removal efficiencies were different. It could be concluded that increasing the turbidity and coagulant concentration and also operation time decreasing, has no effects on LECA layer efficiency, however the total filter efficiency decreased slightly. Therefore, it is obvious that the LECA layer plays an important role in filtration process for more turbidity removal and less head loss in relation to Silica layer. It is valuable to say that the more filtration rate and inlet turbidity, the more outlet turbidity was reached. However, the total efficiency of the system changed slightly. As well, the LECA layer in comparison with the Silica layer caused less head loss and more turbidity removal efficiency in the filter column. Hegazy reported that the LECA layer could be a proper media for filtration process, which its performance has been independent from the filtration rate (16).

Indices, which were considered for evaluation of filter efficiency, were the EPN and the PI. These indices were used because escaped particles from filter may be related to outlet water quality, while the inlet turbidity was stable. In the other words, the less number and diameter of the escaped particle, the more turbidity removal was achieved. Outlet turbidities, the EPN and the PI in whole depths of filter columns in different conditions have been shown in Fig. 5 and 6.

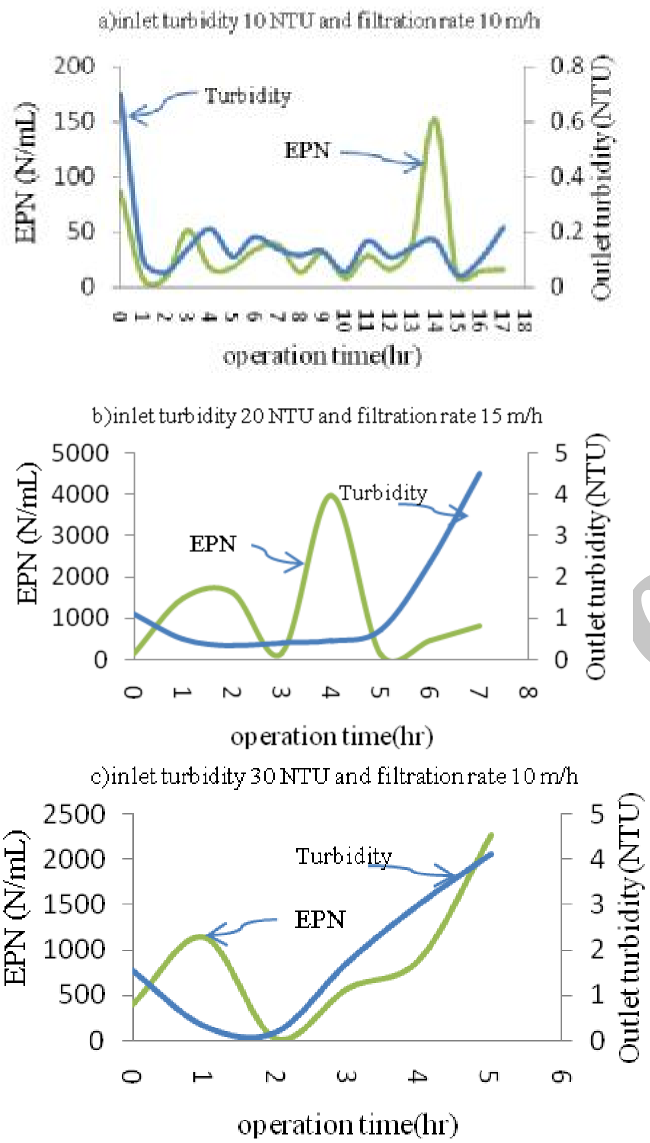

Fig. 5: Outlet turbidities and EPN in whole depths of filter column in some of different conditions

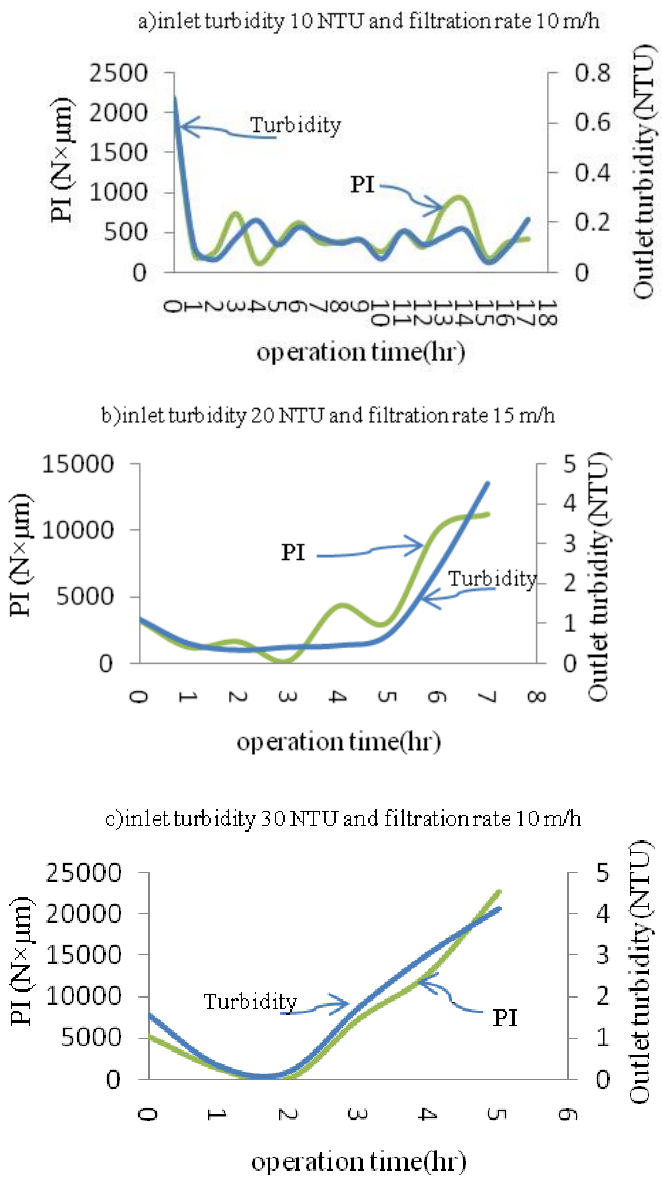

Fig. 6: Outlet turbidities and PI in whole depths of filter column in some of different conditions

In some cases, the outlet turbidity was in standard range while the EPN was more than standards. Therefore, the turbidity index was not enough for filter efficiency determination due to its weak ability for determining filtration efficiency. In other hands, while the outlet turbidity was in standard range, the EPN was out of range and diameter distribution of particles was inconsistent; so using the EPN without consideration to their diameter effect is useless.

The PI can be used as a suitable index. By analyzing the graphs, it can be concluded that by increasing or decreasing the EPN and the PI, filters got to the stable and breakpoint phases, respectively. According to American drinking water standards, the allowable particles in drinking water are 50 per milliliter with diameter limit of 2-10 µm (2). Thus, the PI is between 100-500 N.µm/mL. The average of the EPN is more than 300 per milliliter corresponding to 99.99% Giardia and Cryptosporidium removal. While the outlet turbidity was in standard ranges, the PI may not less than 300 per milliliter and this condition shows again that the turbidity and the EPN were not solely enough for determination of filter efficiency.

Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely observed by the authors.

Acknowledgments

Authors highly appreciate Power and Water University of Technology (PWUT) for their financial supports for this study. The authors declare that there is no conflict of interests.

References

1. Degremont O (2002). *Water treatment handbook*. 6th ed. Lavoisier Wiley. New Jersey.
2. AWWA (2004). *Water quality and treatment*. 4th ed. American Water Works Association: McGraw-Hill. New York.
3. Baruth EE (2005). *Water treatment plant design*. 4th ed. McGraw-Hill. New York.
4. Montgomery JM (1985). *Water treatment principles and design*. John Wiley&Sons. New Jersey.
5. Kawamura S (2000). *Integrated Design of Water Treatment Facilities*. John Wiley&Sons. New Jersey.
6. Devi R, Alemayehu E, Singh V, Kumar A, Mengistie E (2008). Removal of fluoride, arsenic and coliform bacteria by modified homemade filter media from drinking water. *Bioresource Technol*, 99 (7): 2269-74.
7. Fuerhacker M, Haile TM, Monai B, Mentler A (2011). Performance of a filtration system equipped with filter media for parking lot runoff treatment. *Desalination*, 275 (1-3): 118-25.
8. Ho L, Grasset C, Hoefel D, Dixon MB, Leusch FDL, Newcombe G, et al. (2011). Assessing granular media filtration for the removal of chemical contaminants from wastewater. *Water Res*, 45 (11): 3461-72.
9. Remize PJ, Laroche JF, Leparc J, Schrotter JC (2009). A pilot-scale comparison of granular media filtration and low-pressure membrane filtration for seawater pretreatment. *Desalination Water Treat*, 5: 6-11.
10. Templeton MR, Andrews RC, Hofmann R (2007). Removal of particle-associated bacteriophages by dual-media filtration at different filter cycle stages and impacts on subsequent UV disinfection. *Water Res*, 41 (11): 2393-406.
11. Malakootian M (2009). Removal of heavy metals from paint industry's wastewater using Leca as an available adsorbent. *Int J Environ Sci Technol*, 6 (2): 183-90.
12. Roque-Malherbe RM (2007). Lead, copper, cobalt and nickel removal from water solutions by dynamic ionic exchange in LECA zeolite beds. *Int J Environ Pollut*, 31 (3-4): 292-303.
13. APHA (2005). *Standard methods for the examination of waters and wastewaters*. 21st ed. American Public Health Association (APHA). Washington DC.
14. ASTM (2007). *Standard test method for turbidity of water*. American Society for Testing and Materials (ASTM). Philadelphia.
15. Berthouex PM, Brown LC (2002). *Statistics for environmental engineers*, Lewis Publishers. New Jersey.
16. Hegazy BE (2008). A simple technology for industrial wastewater treatment. *J Appl Sci Res*, 4: 397-402.