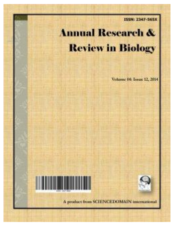

Annual Research & Review in Biology

23(1): 1-8, 2018; Article no.ARRB.38905
ISSN: 2347-565X, NLM ID: 101632869

New Approach to Understand the Removal Efficiency of Some Anions in Well Water by Slow Sand Filtration

Barkouch Yassir[1*], Zahar Chaimae[1], Ait Melloul Abdelaziz[2], El Khadiri Mohy Eddine[3] and Pineau Alain[4]

[1]Laboratoire de Recherche des Sciences Appliquées à l'Environnement et au Développement Durable, Ecole Supérieure de Technologie d'Essaouira, Université Cadi Ayyad, Km 9, Route d'Agadir, Essaouira Aljadida BP.383, Essaouira, Morocco.
[2]Laboratoire Régional du Diagnostic Epidémiologique et d'Hygiène du Milieu, Marrakech, Morocco.
[3]Physical Chemistry of Materials and Environment Laboratory, Department of Chemistry, Faculty of Sciences of Semlalia, Université Cadi Ayyad, Marrakech, Morocco.
[4]UFR de Sciences Pharmaceutiques et Biologiques, Centre de Dosage des Eléments Minéraux (CDEM), 9 rue Bias, BP 53508, 44035 Nantes, France.

Authors' contributions

This work was carried out in collaboration between all authors. Authors BY and ZC designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors AMA, BY and EKME managed the analyses of the study. Author PA managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARRB/2018/38905
Editor(s):
(1) Olatunde Samuel Dahunsi, Environmental Biotechnologist, Landmark University, Nigeria.
(2) George Perry, Dean and Professor of Biology, University of Texas at San Antonio, USA.
Reviewers:
(1) Esraa Ashraf Ahmed ElHawary, Ain Shams University, Egypt.
(2) Narcis Barsan, Vasile Alecsandri University of Bacau, Romania.
(3) Buba Apagu Ankidawa, Modibbo Adama University of Technology, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/22926

Original Research Article

Received 20th November 2017
Accepted 23rd January 2018
Published 30th January 2018

ABSTRACT

Aims: Slow sand filtration (SSF) is a simple technique widely used for the treatment of drinking water. However, little attention has been accorded to the improvement of the understanding of this process model. The main objective of this work is to develop a numerical tool allowing the prediction

**Corresponding author: E-mail: Yassirbark@yahoo.fr;*

and the evaluation of the efficiency of slow sand filtration to decontaminate contaminated well water.
Materials and Methods: This evaluation was done by comparing data from contaminated well water filtered through the laboratory columns with the same diameter (5 cm) but filled with sand to various heights (5 cm, 10 cm and 15 cm).
Results: Decontamination efficiency of slow sand filtration was determined in terms of selected physicochemical parameters such as sulphates, chlorides and total hardness. Results indicated significant difference in levels of sulphates and chlorides in filtered water through the three sand bed heights whereby decontamination efficiency of these parameters was found to be better at the highest sand bed (15 cm).

Keywords: Slow sand filtration; well water; decontamination; sand bed depth pollutants; modeling.

1. INTRODUCTION

Water has always been inseparable from human activity and it plays a decisive role in the lives of humans, animals and plants, it is unarguably the most essential and precious natural resource for life on earth. It is a universal solvent and as a solvent it provides the ionic balance and nutrients, which support all forms of life [1,2].

Water is generally obtained from two principal natural sources ; surface water such as fresh water lakes, rivers, streams, and groundwater such as borehole water and well water [3].

Unfortunately, industrialization and human activities have partially or totally turned our environment into dumping sites for waste materials [4]. As a result, many water resources have been rendered polluted and hazardous to human and other living systems [5].

Water is typically qualified as polluted when it is impaired by anthropogenic contaminants and it does not either support a human utilisation and/or undergoes a marked shift in its ability to support its constituent biotic communities [6]. Deposition of anthropogenic contaminants in groundwater from many human activities has been implicated for an increase in those contaminants concentration above recommended levels [7,8].

In many parts around the world, the major source of water used to meet the domestic, agricultural and industrial needs is the groundwater. The groundwater is defined as water that is found underground in cracks and spaces in soil, sand and rocks [2] and various physicochemical parameters have a significant role in determining the potability of this water [9].

In Morocco, groundwater is a main source of water supply in most rural communities. It has good microbiological and biological properties in general and requires a specific treatment to improve its chemical quality.

Such treatment can be provided by slow sand filtration. This process has been recognized as an appropriate technology for drinking water treatment in rural areas, and is recognized as a suitable filtration technology for removing water borne pathogens, organics and reducing turbidity [10].

Slow sand filters can be constructed from local materials, mainly from properly graded sand/gravel and standard piping and can operate without the use of specialized equipment. Also, slow sand filters operate under gravity flow conditions and energy and its on-going energy demand is minimal [10].

This study was carried out to evaluate the efficiency of slow sand filtration in removing the charge of anthropogenic chemical contaminants from well water in the Marrakech region in Morocco and try to facilitate the understanding of the mechanism of this filtration process.

2. MATERIALS AND METHODS

The Draa Lasfar region is located in northwest of the Mrabtine zone at approximately 10 Km in the west of Marrakech city (Fig. 1). It is located a few hundred meters from the Tensift River, close to a rural community of about 5790 ha, which 65% are occupied by farmland.

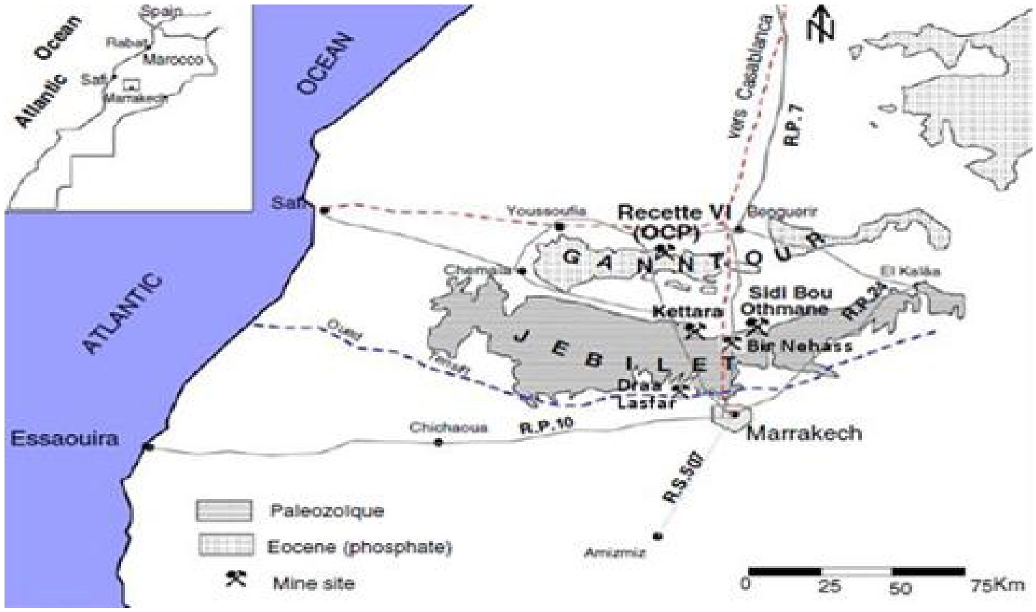

Fig. 1. Drâa Lasfar mine geographic situation in Marrakech region

Well water samples were collected once a month for three months between March and May 2017.

Well water samples were taken directly from wells in sterile glass bottles of 250 milliliters capacity [10,11,12], after rinsing the bottles three times with sample water. In order to collect the samples directly from well, a bottle with a string attached to neck was used. Another long clean string was tied to the end of sterile string and the bottle was lowered into the water allowed to be filled up. Then the bottle was raised and stopped. The collected samples were transported to the laboratory in ice within an insulated container and analyzed within 24 hours of collection. Temperature and pH of each sample was measured using mercury filled glass thermometer and digital pH meter respectively. Total hardness of the samples was estimated using Total hardness test kit.

Concentration of sulfates and chlorides in water samples was measured and expressed in mg/l.

In this study, sand is conceptualized as a porous medium which is considered as a continuous environment, cohesive or not, presenting internally a volume fraction accessible to a fluid. This "vacuum" volume fraction, composed specially of pores constitutes the porosity of the filtration bed. It is through these vacuums that the water flow processes take place in sand bed filtration [13].

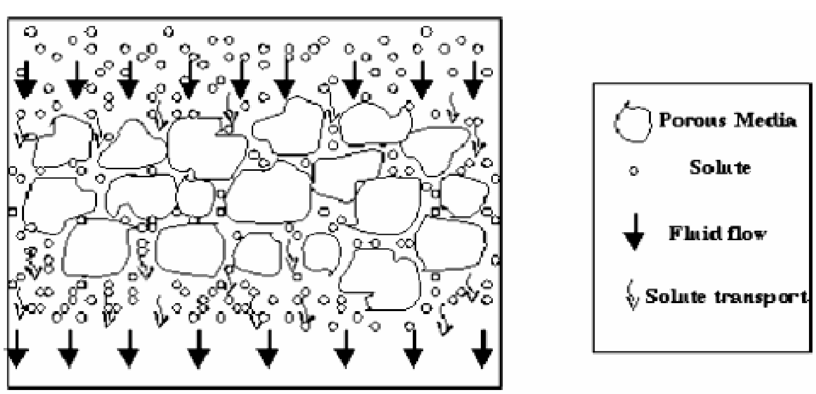

Fig. 2. Migration of contaminants through the sand bed filtration

The sand used was collected from Tensift river bed. The sand is first washed three times with demineralised water and oven dried at 105°C before use.

Sieve analysis of the sand is done using a series of sieves of size 300 µm, 150 µm, 90 µm, and 75 µm. D10 (effective size) and D60 sizes were 0.136 and 0.252 respectively giving uniformity coefficient as 1.9173. The Table 1 shows sieve analysis of the sand (2 kg).

The decontamination efficiency of slow sand filtration process was determined by percolation of contaminated well water through laboratory columns with the same diameter filled to various heights with sand.

To understand the effect of sand bed depth on dynamics of water pollutants (in this study, sulfates and chlorides, calcium and magnesium), this study was carried out on 3 columns of the same diameter (D = 5 cm) [14] filled to different heights with sand; 5 cm, 10 cm [14] and 15 cm [14,15].

All columns were closed at both ends with perforated caps. The upper cap hole was large enough to receive a tube from a peristaltic pump and allow air circulation. A test tube was connected to the hole in the lower cap to collect filtrated water. The collected filtered water samples were stored in ice in an isolated container and analyzed within 24 hours of collection.

Statistical analyses were performed using Statistical Package for Social Sciences. Removal efficiencies of sand filters for the studied pollutant were assessed by ANOVA. This treatment was done to determine if there were significant differences between pollutant concentrations in influent and effluent.

All statistical analyses were done at 95% level of confidence ($p = .05$).

3. RESULTS AND DISCUSSION

Total hardness, sulphates and chlorides concentrations in recovered solutions (effluent) are shown in Table 2 and Figs. 3, 4 and 5, respectively.

These results show that anions changed continuously in effluents according the filtration process time, whereas total hardness seems to be unchangeable in both water before (influent) and after filtration (effluent).

These results show also that the removal efficiency of filtration (to decontaminate) water depends greatly on the sand bed depth. Thus, the long filter eliminates more anions than the smaller ones.

The speed of this removal efficiency of filtration becomes increasingly weak and tends to stabilize and reach a maximum equilibrium value (MEV). This value remains almost equal to the initial water concentration (influent). This finding can be justified by saturation of fixation sites of pollutants anions on the sand bed filter, which is translated at the end of filtration process (100 min) by recovering a water solution which is roughly similar to the initial water solution (influent).

Table 1. Sieve analysis of the sand

Sieve size(mm)	Retained weight (g)	% of retained weight	% of cumulative weight
0.3	342	17.1	17.1
0.15	1366.11	68.3	85.4
0.09	224.72	11.2	96.6
0.075	29.05	1.5	98.1
0.001	38.1	1.9	100

Table 2. Results of physicochemical analyses of wells water before filtration

	Sulphates	Chlorides	Oxidisability	Total hardness	Nitrites	Nitrates
Wells water	84,98	1349	3,2	112	0,019	57,82
Moroccan standard	400	750	5	30	0,5	50

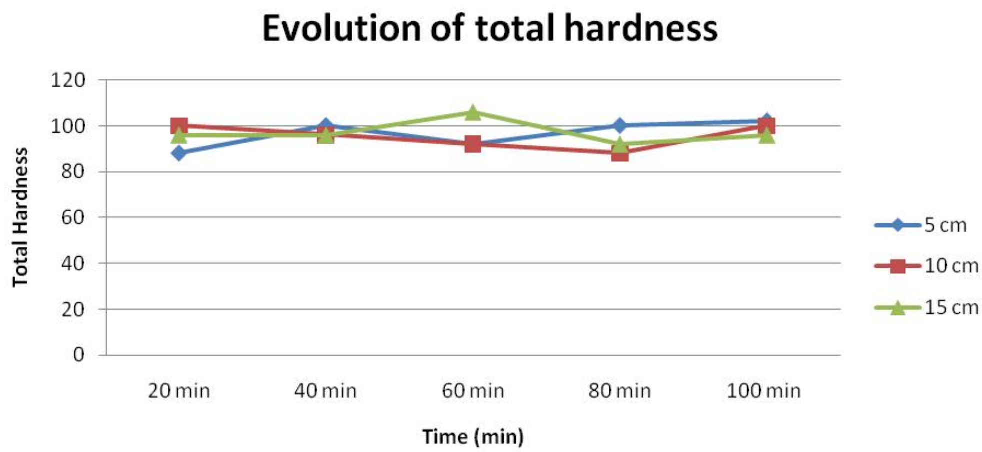

Fig. 3. Evolution of total hardness of filtrate water (effluent)

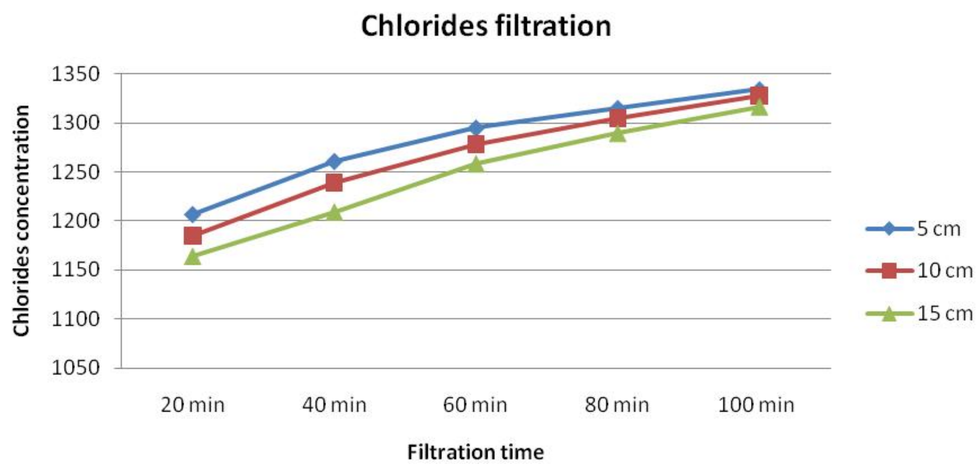

Fig. 4. Evolution of chlorides concentration in filtrate water (effluent) according to the time of filtration

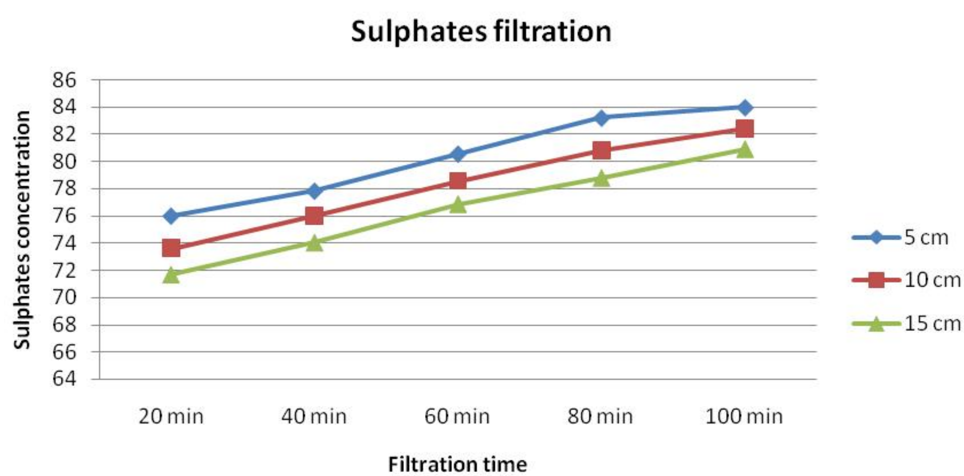

Fig. 5. Evolution of sulphates concentration in filtrate water (effluent) according to the time of filtration

Table 3. Evolution of Cl^-, SO_4^{2-} and total hardness according to the time of filtration

	Sand bed depth	Filtration time (min)					
		0	20	40	60	80	100
Cl^-	5 cm	1349	1207	1261	1295	1315	1334
	10 cm	1349	1185	1239	1278	1305	1327
	15 cm	1349	1164	1209	1258	1289	1316
SO_4^{2-}	5 cm	85.02	76.00	77.83	80.56	83.21	83.98
	10 cm	85.02	73.58	75.99	78.56	80.82	82.41
	15 cm	85.02	71.66	74.02	76.86	78.80	80.92
TH	5 cm	112	88	92	92	98	102
	10 cm	112	100	96	92	96	100
	15 cm	112	96	98	102	94	96

Statistical analyses of this results show that sand bed depth had no significant effect on removal efficiency of Ca and Mg. Although total hardness of the effluents was almost unchanged with increasing sand bed depth; there was no significant difference in effluent total hardness at depths 5cm, 10cm and 15cm and influent before filtration.

Chlorides in effluents decreased significantly ($p = .05$) in filtered effluents as compared with the unfiltered effluents although there were significant differences in chlorides increment at the three levels of depth (5, 10 and 15 cm). Decrease in chlorides was found to be at its highest level (1164 mg/l) at of depth of 15 cm (t=20 min) and at its lowest level (1207 mg/l) at the depth of 5 cm (t=20 min) (Fig. 4).

Sulphates decreased significantly ($p = .05$) with an increase in sand bed depth. Sulphates were found to be high in unfiltered effluents, but lower at all the three levels of experimental depths. Significant differences in sulphates were also observed among the three experimental depths (5 cm, 10cm and 15 cm) with the highest reduction being observed at 15 cm depth and the lowest reduction at 5cm depth (Fig. 5).

In this study, the removal rates of anion pollutants are similar to those mentioned in other studies using sand filters for the treatment of wastewater [16]. These studies mentioned also that longer depths of sand filters can be applied effectively as tertiary treatment for secondary effluents to decontaminate wastewater [17]. in our study, results showed that anions (Cl- and SO42-) were significantly higher ($p < 0.05$) in unfiltered effluents but decreased significantly with increasing depth and the values of these parameters were found to be lower at the highest depths of filter (15 cm). This manifested that sand bed depth affected the reduction of the anion pollutants in contaminate well water.

3.1 Modelling

Classical filtration theory, elaborated by Iwasaki [18] takes into account a solute transport and mass balance equations [19,20,21,22], is the most commonly used approach for evaluating migration, retention (sink term for solids deposition) and detachment (source term for solids deposition) [23].

The removal efficiency of anions by sand filtration is directly related to sand bed depth and residence time of anions in sand bed. This process can be described as time-dependent [24,25]. This finding is justified by the effect of time on the reactions between anions and their fixation sites on sand filter; these reactions include mainly complexation, adsorption and precipitation of anions on the sand surface, and their diffusion in the pores of sand [24].

Under these conditions, the Ci-Cf/Ci (Ci = initial concentration, cf = final concentration) ratio known as the extraction-ratio or elimination-ratio measures in general the rate of extraction (Ke) of a pollutant. The process of elimination of pollutants by sand filtration is exponential [13].

We consider Ct = Ci-Cf the concentration of pollutant fixed by the sand filter or the resident concentration of pollutant in the sand filter:

$$dCt/dt = - K\ L\ Ci$$

with K is filtration coefficient

$$dCt / Ci = - K\ L\ dt$$

$$dCt / Ci = - \int K\ L\ dt$$

$$LnCt/Ci = - K\ L\ t$$

$$Ct/Ci = \exp(-K\ L\ t)$$

$$Ct = Ci.\exp(-K\ L\ t) \quad (1)$$

In addition, expression of pollutant concentration at the exit of the column is:

$$Cf = Ci - Ct$$

becomes : $$Cf = Ci\,(1 - \exp(-K\,L\,t))$$.

The coefficient K is an expression which accounts for all different parameters which intervene in the transfer of pollutant from contaminated water into sand filter.

4. CONCLUSION

This study demonstrated that decontamination of well water using river sand as a medium in slow sand filter is feasible. The efficiency of this filtration to remove anion pollutants was generally higher at higher filter depths. This can be attributed to the exposition of new fixation sites of anion pollutants on the sand surface that facilitates the adsorption process. Nevertheless, efficiency of slow sand filter to reduce total hardness at different filter depths is not significant.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Biswajit R. Water quality and corrosivity of ground water of northwestern part of Bankura District, West Bengal. J. Environ. Poll. 2001;8(4):329-332.
2. Mohammed AI, Gupta SG. Studies on Heavy Metal Ion Pollution of Ground Water Sources as an Effect of Municipal Solid Waste Dumping. Afr J Basic Appl Sci. 2009;1(5-6):117-122.
3. Caroline M, Wilfred SR. Studies on leaching of heavy metals from e-waste. Orient J Chem. 2013;29(3):1149. DOI:http://dx.doi.org/10.13005/ojc/290343.
4. Barkoucch Y, El khadiri ME, Pineau A. A new approach to understanding well water contamination by heavy metals at a mining extract region in Marrakech. Morocco. Pol. J. Environ. Stud. 2016;25(3): 1347-1351.
5. Bakare AA, Lateef A, Amuda OS, Afolabi RO. The aquatic toxicity and characterization of chemical and microbiological constituents of water samples from Oba River, Odo-oba, Nigeria. Asian J. Microbiol. Biotechnol. Environ. Sci. 2003;5:11-17.
6. Gupta VK, Ali I. Environmental water: Advances in treatment. Remediation and Recycling, First Edition; 2013.
7. Maine MA, Sune NL, Lagger SC. Chromium bioaccumulation: Comparison of the capacity of two floating aquatic macrophytes. Water Res. 2004;38:1494.
8. Bako SP, Bhwankot ES, Ezealor AU, Chia AM, Funtua II. Human health implications of trace metal contents in parts of Maize (*Zea mays* L.) plants cultivated along highways in Nigeria's Guinea Savanna. Soil Remediation Series: Pollution Science, Technology and Abatement. Lukas Aachen and Paul Eichmann (Eds). Nova Science Publishers, Inc. Hauppauge, New York, United States of America. 2009;345-356.
9. Divya RT, Sunil B, Latha C. Physico-chemical analysis of well water at eloor industrial area-seasonal study. Current World Environment. 2011;6(2):259-264.
10. Ephrem G. Review on slow sand filtration in removing microbial contamination and particles from drinking water. Am J Food Nutr. 2015;3(2):47-55.
11. Nassar A, Hajjaj K. Purification of stormwater using sand filter. J Water Resou Prot. 2013;5:1007-1012.
12. Bagundol BT, Awa AL, Rosellynn M, Enguito C. Efficiency of slow sand filter in purifying well water. J Multidisc Stud. 2013;2(1):86-102.
13. Barkoucch Y, Sedki A, Pineau A. A new approach for understanding lead transfer in agricultural soil. Water Air Soil Pollut. 2007;186:3–13.
14. Tony SS, Pant K. Experimental and modelling studies on fixed bed adsorption of As(III) ions from aqueous solution. Sep Purif Methods. 2006;48(3):288–296.
15. De Matos AT, Fontes MPF, Da Costa LM, Martinez MA. Mobility of heavy metals as related to soil chemical and mineralogical characteristics of Brazilian soils. Environ Pollut. 2001;111(3):429–435.
16. Stevik TK, Aa K, Ausland G, Hanssen JF. Retention and removal of pathogenic bacteria in wastewater percolating through porous media: A review. Water Res. 2004;38(6):1355-1367.
17. Elliott MA, Stauber CE, Koksal F, DiGiano FA, Sobsey MD. Reductions of E-coli, echovirus type 12 and bacteriophages in intermittently operated household-scale slow sand filter. Water Res. 2008;42(10-11):2662-2670.

18. Iwasaki T, Slade JJ, Stanley WE. Some notes on sand filtration. J. Am. Water Works Ass. 1937;29(10):1591–1602.
19. Logan DJ. Transport modeling in hydrogeochemical systems. Publisher: Springer, New York, USA, 30–34.
20. Bradford SA, Simunek J, Bettahar, Van Genuchten MT, Yates SR. Modeling colloid attachment, straining, and exclusion in saturated porous media. J Environ Sci Techn. 2003;37:2242–2250.
21. Foppen JWA, Schijven JF. Evaluation of data from the literature on the transport and survival of *Escherichia coli* in aquifers under saturated conditions. Water Res. 2006;40(3):401–426.
22. Tufenkji N. Colloid and microbe migration in granular experiments: A discussion of modeling methods. In: Frimmel F.H., Von der Kammer F., Flemming H.-C. (Eds.) Colloidal Transport in Porous Media, 1st ed., Springer-Verlag: Berlin, Germany. 2007;119–142.
23. Jakub N, Marcin S, Paweł Z. New approach to modeling of sand filter clogging by septic tank effluent. J Ecol Eng. 2016;17(2):97–107.
24. Plassard F, Winiarski T, Petit-Ramel M. Retention and distribution of three heavy metals in a carbonated soil: Comparison between batch and unsaturated column studies. J Contam Hydrol. 2000;42(2–4): 99–111.
25. Marcos L. Etude expérimentale et modélisation du transfert du Zinc et du Plomb dans des milieux sableux modèles, thèse à l'école des mines de Nantes. N° ED 0376-001; 2001.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/22926