Evaluation study on efficiency of using sandy filters as primary processing of sewage water in Ramadi city

Kamal H. Al-Dulaimi
University of Anbar

Emad Telfah Abdel Ghani
University of Anbar

Evaluation study on efficiency of using sandy filters as primary processing of sewage water in Ramadi city

Cite as: AIP Conference Proceedings **2404**, 070003 (2021); https://doi.org/10.1063/5.0069540
Published Online: 11 October 2021

Kamal Hameed Ohmaid, Emad Telfah Abdel Ghani and Mustafa Subhi Abdul Jabbar

Evaluation Study on Efficiency of Using Sandy Filters as Primary Processing of Sewage Water in Ramadi City

Kamal Hameed Ohmaid[1, a)], Emad Telfah Abdel Ghani[2, b)], and Mustafa Subhi Abdul Jabbar[1,c)]

[1]*University of Anbar, College of Agriculture, Soil Science and Water Resources Dept., 31001, Anbar, Iraq.*
[2]*University of Anbar, Upper Euphrates Basin Development Center, Planning & Databases Dept., 31001, Anbar, Iraq*

[a)] Corresponding author: kmhm81@uoanbar.edu.iq
[b)] emadabdulghani@uoanbar.edu.iq
[c)] Mustafa.subhi@uoanbar.edu.iq

Abstract. Sewage water characterization is of high importance to reduce its harmful effects. Hence this study was carried out to evaluate primary processing of sewage water of Ramadi city using sandy filters. The experiments were conducted in the College of Agriculture, University of Anbar during the spring season of 2019. Three separation funnels of 250 ml volume, with the diameter and length of 4 cm and 20 cm, respectively, were designed. Each funnel had a conical end and was provided with a valve to control the water movement. To perform the experiments, the funnels were filled with different sizes of sand particles, namely fine sand (FS) (with 0.85-1.70 mm diameter), coarse sand (CS) (with 2.36-3.36 mm diameter), and sand mixture (SM) (50:50 ratio). Then the sewage water was passed through the three funnels and all extracted water was collected from each funnel separately. The chemical properties of water samples were also measured both before and after processing to evaluate the efficiency of processing. The chemical analyses consisted of pH, EC, Ca, Mg, Na, K, Cl, and SO4 as well as heavy and micronutrients (Cu, Cd, and Pb). The biological oxygen demand (BOD) and chemical oxygen demand (COD) were also measured. The efficiency of processing by sand showed contrasting results, where the FS was more efficient in decreasing Pb and Cd as well as COD and BOD, while there was an increase in Na, Cl, and SO_4, in addition to pH and EC. The CS was the most efficient filter in decreasing Mg, Ca, and Cl contents, whereas MS was more efficient in reducing Ca and K concentrations.

Keywords: wastewater, processing efficiency, Ramadi, sandy filters, fine sand, coarse sand.

INTRODUCTION

Sewage is defined as the liquid waste resulting from human activities whether domestic, commercial, institutional or industrial, and is collected through a network of pipes and canals to reach a specific point (Assembly Station) [1]. The indiscriminate use of this water in fields and farms adjacent to cities and its addition to water bodies, such as rivers, will lead to serious environmental pollutions as well as adverse health effects on humans. As sewage water is mostly collected near the root zone of agricultural crops, it is highly possible that the edible parts of crops will be contaminated [2].

Due to water scarcity, increased population, industrial progress, and increased well-being in most parts of the world, sewage volumes have increased considerably; as a result, means of processing for agricultural irrigation must be sought[3]. Sewage is a sustainable source of irrigation water for agriculture, and its importance comes not only in

2nd International Conference on Engineering & Science
AIP Conf. Proc. 2404, 070003-1–070003-8; https://doi.org/10.1063/5.0069540
Published by AIP Publishing. 978-0-7354-4136-1/$30.00

meeting crop needs, [4] but also in promoting micro-organisms in the soil with organic materials [5], especially those nutrients which are essential in crop production and other growth traits[6].

There are many strategies adopted in wastewater treatment to reduce the harmful effects resulting from the presence of pollutants in this water, including the use of sand filters in water purification as the surface of the material obtained by adsorption is of great importance depending on the type of charge, the porosity and the size of the pores as well as their distribution on the surface [7].

[8] Studied adsorption of methyl green (MG) dye from artificial wastewater by adsorption method and showed that the adsorption kinetics of MG onto adsorbent was strongly represented by a pseudo-second order kinetic model.

[9] Showed that the hybrid systems have been proven to be the most efficient technology for quickly lowering the concentration of dissolved pollutants in an effluent wastewater.

Filtration is the passage of contaminated water through layers of sand of different particle sizes as water penetrates through it to remove the pollutants [10]. [11] confirmed that the sand filter has the ability to prevent fats and oils from gathering and clogging the pipes, which causes less decomposition of organic matters. The results obtained by [12] showed that the sand filter has the ability to remove iron, manganese, zinc, as well as ammonium. He explained the reason for this to the adhesion of these elements to sand layers. As for the role of sand filter in removing heavy elements, [13] showed that sand filter is capable of removing 20% of the elements of cadmium and copper, with a removal rate of about 35-40% of the elements of lead and zinc. [14] obtained a removal efficiency of 99% for BOD when using a sandy filter, and that the removal efficiency of BOD and COD depends on the quality and sizes of sand particles forming the sandy filter layers.

MATERIALS AND METHODS

The study is conducted at the College of Agriculture at the University of Anbar during the spring season of 2019 to assess the efficiency of sandy filters in wastewater treatment as primary processing.

Water Used in the Study

Unprocessed sewage collected from one of the assembly centres of the Ramadi City Sewerage Directorate was used in this study. Chloroform was also added to the samples to stop microbial activity. The samples were stored in plastic containers in the fridge which was set at 4^{o} C to perform the required chemical analysis according to[15]) (Table 1).

The Chemical and Physical Properties of Water

Different instruments and methods were applied to measure the chemical and physical properties of water. The pH-meter (Jenway-3510) was used to measure hydrogen potential (pH) [16] [17] . As for the electrical conductivity (EC), the EC-meter (WTW class Cand. 315 | SET) was used to measure EC after calibration with KCl (0.02 N) solution at temperature of 25^{o}C[18] [19]. Moreover, the soluble calcium and magnesium were measured by titration with Ethylene Diamine Tetra Acetic Acid (EDTA) of (0.01N) using Eriochrom Black T indicator, according to [20], whereas the soluble sodium and potassium were measured using flame photometer device, according to [21] [22]. Chloride was also estimated using Mohr method by calibration, using silver nitrate solution (0.005N) with k_2CrO_4 potassium chromium indicator, according to [23]. The A.P.H. Association method [15] was used to estimate the sulphate in turbidity method using a spectrophotometer.
Likewise, The A.P.H. Association method [15] was used to calculate the BOD and COD, while the micro and heavy elements were measured using atomic absorption spectrophotometer.

Preparing Sandy Filter

In this study, three conical end funnels of 250 ml volume with a diameter and length of 4 cm and 20 cm, respectively, and with a valve to control the descent of water were designed. The filters were filled with different sizes of sand (fine sand, ranging from 0.85 to 1.70 mm in diameters, coarse sand, ranging from 2.36 to 3.36 mm in diameter, and mixed sand of 50:50 ratio). The sands were all sifted accordingly through different sieves to get the required sand gradients. Having prepared the filters, the sewage water samples were passed through all the three funnels and then the extracted water was collected from each funnel separately to measure the chemical and physical properties. The properties measured consisted of pH, EC, cations (Ca, Mg, Na, K), anions (SO_4, Cl) and organic indicators (BOD, COD), as well as micro and heavy elements (Cu, Cd, Pb). The sandy filter configuration used in this study was adapted from Liu et al. [11] (figure 1).

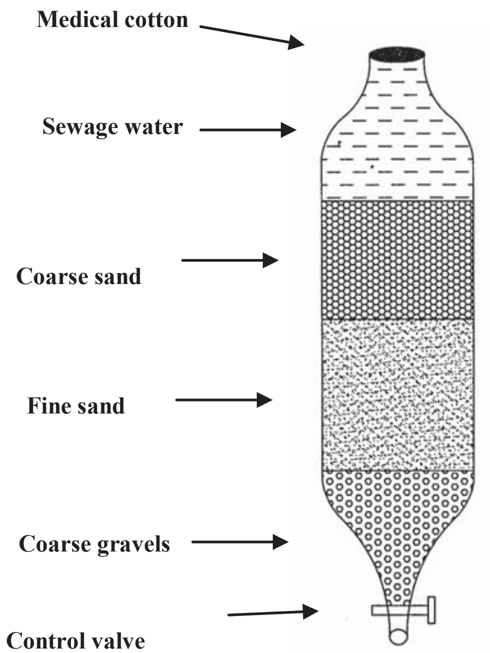

FIGURE 1. A Separation Funnel with Sand Distribution after the Sandy Filter Column Was Formed, the Sewage Water Was Added Directly to It by 150 ml, and Then a Layer of Medical Cotton Was Placed at a Height of 0.5 Cm.

Processing Efficiency (PE) Estimation (%)

PE of ions and contaminants treatment in processed sewage water is calculated as follows[24] . Table 2 shows the PE values (%).

$$PE\% = \frac{\text{ions concentration at primary processing (before extraction)} - \text{ions concentration at final processing (after extraction)}}{\text{ions concentration at primary processing (before extraction)}} \times 100$$

Properties of Water before Processing

Table 1 presents the chemical properties of sewage used before treatment. As seen in the Table, the acidity number pH was in the basic direction of 7.20 and is within the permissible limits for sewage (which is 6.9, according to [25], depicted in Table3 It can also be noticed that the value of the EC electrical receipt was as high as 4.6 $dS.m^{-1}$ which is classified as saline water [25], presented in Table 3). This is due mainly to the biodegradation of organic compounds in sewage [26]).

The composition of water was characterized by the supremacy of calcium, magnesium, sodium, and potassium ions over other ions, reaching 4.26, 3.70, 7.21, and 1.13 mmol. $Liter,^{-1}$ respectively. This is because of the water content of organic waste as well as the nature of the sources of pollution [24] . The most important negative ions affecting water salinity are sulphates and chlorides. It can be seen from Table 1 that their concentration in sewage before treatment was 8.24 and 14.77 mmol.liter,$^{-1}$ respectively. According to the Iraqi standard specifications No. 417 for the year 2000 Standardization, Control, and Quality Institution (Table 3), which is limited to 200 mg. Liters^{-1} for each, these values are higher than the permissible limits for liquid wastes to be dumped into rivers. The results presented in Table 1 also show that BOD and COD values for sewage water before processing were as high as 360 and 846 mg.Liter,$^{-1}$ respectively. According to the [27] depicted in Table 3, these values are higher than the critical limit which will make the water unsuitable for agricultural irrigation, owing to the increased concentration of biodegradable organic compounds in sewage [28]) .

The most significant micro-and heavy elements diagnosed in sewage were copper, cadmium, and lead. As seen in Table 1, the concentration of copper in sewage before processing exceeded the limits set by the Iraqi standard specifications No. 417 for 2000 Standardization, Control, and Quality (Table 3) of 1.0 mg.Liter^{-1}. The concentrations of cadmium and lead were also as high as 3.4 mg and 1.52 mg.1iter^{-1}, respectively. Based on the Iraqi standard No. 417, these values also exceeded the limits allowed to be dumped into rivers which could be maximum as high as 0.01and 0.05 mg.L^{-1}, respectively. The reason for this lies in the fact that the residential waste contains detergents and other materials, which are the main sources leading to the increase of concentration of these elements [28]).

TABLE 1. Chemical Properties of Sewage before Processing

Properties	Concentration	Unit
pH	7.2	-----
EC	4,6	ds.m^{-1}
Ca^{+2}	4.26	Mmol.l^{-1}
Mg^{+2}	3.7	Mmol.l^{-1}
Na^{+}	7.21	Mmol.l^{-1}
K^{+}	1.13	Mmol.l^{-1}
Cl^{-}	14.77	Mmol.l^{-1}
$SO_4^{=}$	8.24	Mmol.l^{-1}
BOD	360	mg.l^{-1}
COD	846	mg.l^{-1}
Cu	1.96	mg.l^{-1}
Pb	0.9	mg.l^{-1}
Cd	1.52	mg.l^{-1}

Efficiency of Sandy Filters in Processing Water

Table 2 illustrates the efficiency of different sandy filters in processing sewage water. As seen, the results presented in Table 2a show that when using CS and MS the degree of water interaction pH increased by 111% for both filters, while the increase of pH was lower when using FS (104%). It can also be seen that FS had the highest efficiency in increasing EC of water delivery which is 122%, followed by CS and MS (104% each). It is also clear from the results that sand filters react to the shortage of nutrients in sewage by increasing the concentration of Ca, Mg, and Na in water, with FS having the efficiency of 242%, 367%, and 201%, respectively, followed by MS with the efficiency ratio of 156%, 192%, and 172%, respectively. When using the CS filters, on the other hand, the concentration ratio decreased dramatically to 75%, 95%, and 112%, respectively. Regarding potassium (K), the results showed that FS had the highest PE (87%), while CS and MS had the efficiency of 81% and 68%, respectively.

Sulphates and chlorides are the most important anions affecting sewage water salinity. As is illustrated by table 2, sand filters increased SO_4 ions significantly, with FS having the efficiency of 147%, followed by MS (111%) and CS

(108%). On the other hand, FS increased Cl concentration by 104%, while MS and CS decreased the concentration of Cl by 101% and 82%, respectively. As far as the organic indicators (BOD and COD) are concerned, their concentrations in water decreased (Table 2). The removing ratio of BOD and COD, using FS values, were 38 and 21, followed by MS with removing ratios of 24 and 16, while CS had a lower removing ratio of 16 and 3, respectively. These results are consistent with the findings of [14].

The sandy filters also showed the ability to reduce the concentration of micro and heavy elements (Cu, Cd, Pb) in sewage water. As is presented by table 2, the MS reduced the concentration of Cu with a removing ratio of 5, followed by CS with a removing ratio of 1. By contrast, the FS had no effect in reducing the concentration of copper (Cu) in the water. These findings lie in the fact that soil generally uptakes heavy and micro elements, while other elements are released and this is consistent with the findings of [29] and [30].

As for the effects of sandy filters on the removal of Cd and Pb in sewage water, the results showed that FS had the highest removing ratio of 13 and 23, followed by MS with removing ratio of 9 and 13, respectively, whereas CS had a removing ratio of 0 and 1, respectively. The reason for this lies in the fact that fine sand releases the largest amount of elements as a result of leaching them with water compared to other separations. The results are well consistent with the findings of[30].

TABLE 2. Efficiency of Different Sand Separates in Processed Wastewater (%)

	Sand Separates								
	Fine Sand			**Coarse Sand**			**Mixed Sand**		
Properties	**After processing**	**Efficiency%**	**Conc.**	**After processing**	**Efficiency%**	**Conc.**	**After processing**	**Efficiency%**	**Conc.**
pH	7.52	104	+4	7.96	111	+11	8	111	+11
EC $ds.m^{-1}$	5.6	122	+22	4.8	104	+4	4.8	104	+4
Ca $Mmol.l^{-1}$	10.3	242	+142	3.21	75	-25	6.65	156	+56
Mg $Mmol.l^{-1}$	13.6	367	+267	3.5	95	-5	7.1	192	+92
Na $Mmol.l^{-1}$	14.5	201	+101	8.1	112	+12	12.4	172	+72
K $Mmol.l^{-1}$	0.98	87	- 13	0.92	81	- 19	0.77	68	-32
Cl^{-} $Mmol.l^{-1}$	15.33	104	+4	12.17	82	-18	14.92	101	+1
SO_4^{-2} $Mmol.l^{-1}$	12.11	147	+47	8.86	108	+8	9.12	111	+11
BOD $mg.l^{-1}$	223.5	62	-38	241.7	84	-16	273.6	76	-24
COD $mg.l^{-1}$	671.2	79	-21	823.8	97	-3	712.4	84	-16
Cu $mg.l^{-1}$	1.96	100	0	1.94	99	-1	1.87	95	-5
Cd $mg.l^{-1}$	0.78	87	-13	0.90	100	0	0.82	91	-9
Pb $mg.l^{-1}$	2.75	78	-22	3	99	-1	2.84	87	-13

(+) The percentage of increased concentration in wastewater, (-) The percentage of decreased concentration in wastewater

TABLE 3. Index of Irrigation Water Quality and Permitted Ranges by Different Organizations

(FAO, 1985) index				
Severe	Degree of Restriction on Use Slight to Moderate	None	Unit	Potential Irrigation problem
	Normal Range 6.5 – 8.4		–	pH
>3.0	0.7 – 3.0	< 0.7	dS.m-1	ECw
(FAO, 1977) index				
Properties			**Unit**	**Ranges**
Biological oxygen demand (BOD)			$mg.l^{-1}$	280 –160
chemical oxygen demand (COD)			$mg.l^{-1}$	700 – 550
Chloride (Cl)			$mg.l^{-1}$	60 – 50
(ISC*, 2000) index				
SO_4			$mg.l^{-1}$	200
Cl			$mg.l^{-1}$	200
Fe			$mg.l^{-1}$	0.3
Cu			$mg.l^{-1}$	1
Cd			$mg.l^{-1}$	0.01
Pb			$mg.l^{-1}$	0.05

*ISC = Iraqi Standard Characteristics No. (417)

CONCLUSION

It is important to characterize sewage water to reduce its harmful effects on both environment and human. Thus, in this study the primary processing of sewage water of Ramadi city was assessed using sandy filters. Different chemical and physical properties of water were measured. The study found that fine sands (FS) recorded the highest efficiency in removing heavy elements and reducing the two organic indicators (BOD and COD) as well as Pb and Cd, Whereas the coarse sands (CS) were the most efficient filter in decreasing Mg, Ca, and Cl contents. The mixed sands (MS) were more efficient in reducing Ca and K concentrations. Therefore, the study recommends the use of sand in general in sewage water processing as a primary treatment and will be more effective when determining different components of sewage water, such as heavy metals.

ACKNOWLEDGEMENTS

This research was funded by the University of Anbar Grant Vote No. 9442500. The authors would like to thank all who provided the insight and expertise that greatly assisted in the research. The authors also appreciate the efforts of academic and support staffs of the Department of Soil and Water Resources - College of Agriculture, in providing all the required assistance and materials in conducting this research

REFERENCES

1. M. L. Davis, *Water and wastewater engineering: design principles and practice*. McGraw-Hill Education, 2010.
2. D. J. Ashworth and B. J. Alloway, “Soil mobility of sewage sludge-derived dissolved organic matter, copper, nickel and zinc,” *Environ. Pollut.*, vol. 127, no. 1, pp. 137–144, 2004.
3. M. Abdel-Sabour, “Techniques of Wastewater and its Reuse for Agricultural Purposes,” *J. Environ. Stud.*, vol. 19, p. 33, 2000.
4. C. Becerra-Castro, A. R. Lopes, I. Vaz-Moreira, E. F. Silva, C. M. Manaia, and O. C. Nunes, “Wastewater reuse in irrigation: A microbiological perspective on implications in soil fertility and human and environmental health,” *Environ. Int.*, vol. 75, pp. 117–135, 2015.
5. F. Garc\'\ia-Orenes, F. Caravaca, A. Morugán-Coronado, and A. Roldán, “Prolonged irrigation with municipal wastewater promotes a persistent and active soil microbial community in a semiarid agroecosystem,” *Agric. Water Manag.*, vol. 149, pp. 115–122, 2015.
6. B. A. Abdoulkader, B. Mohamed, M. Nabil, B. Alaoui-Sossé, C. Eric, and L. Aleya, “Wastewater use in agriculture in Djibouti: Effectiveness of sand filtration treatments and impact of wastewater irrigation on growth and yield of Panicum maximum,” *Ecol. Eng.*, vol. 84, pp. 607–614, 2015.
7. A. M. C. Dulaimi, “Effect of sewage water of Fallujah city on the chemical pollution of Euphrates water, Soil and plant,” Master thesis. Faculty of Agriculture, University Of Anbar., 2011.
8. S. M. Alardhi, J. M. Alrubaye, and T. M. Albayati, “Adsorption of Methyl Green dye onto MCM-41: equilibrium, kinetics and thermodynamic studies,” *Desalin. Water Treat.*, vol. 179, pp. 323–331, 2020.
9. T. M. Albayati, “Application of nanoporous material MCM-41 in a membrane adsorption reactor (MAR) as a hybrid process for removal of methyl orange,” *Desalin. Water Treat.*, vol. 151, pp. 138–144, 2019.
10. ICE, “Water purification, Distribution and sewage disposal. peace corps by Volunteers for international technical assistance,” pp. 251 – 709, 1998.
11. Q. Liu, K. Mancl, and O. H. Tuovinen, “High fat wastewater remediation using layered sand filter biofilm systems,” in *Proceedings of the international symposium on animal, agricultural and food processing wastes, ASAE, St. Joseph, Michigan*, 2000, pp. 242–248.
12. Y. W. Kang, K. M. Mancl, and O. H. Tuovinen, “Biological treatment of turkey processing wastewater with coarse/fine sand filtration,” in *Animal, Agricultural and Food Processing Wastes-IX*, 2003, p. 1.
13. D. B. Aulenbach and Y.-Y. Chan, “Heavy metals removal in a rapid infiltration sand column,” *Part. Sci. Technol.*, vol. 6, no. 4, pp. 467–481, 1988.
14. X. J. . K. M. M. and O. H. Tuovinen, “Tragus for motions and assume mutation of carbon in gravel/sand filters treating cheese,” in *Proceeding of the ninth International symposium. on animal, Agricultural and food processing wastes*, 2003, p. 341–349.
15. A. P. H. Association, A. W. W. Association, W. P. C. Federation, and W. E. Federation, *Standard methods for the examination of water and wastewater*, vol. 2. American Public Health Association., 1912.
16. M. Pansu and J. Gautheyrou, *Handbook of soil analysis: mineralogical, organic and inorganic methods*. Springer Science & Business Media, 2007.
17. C. A. Black, D. D. Evans, J. L. White, L. E. Ensminger, and F. E. Clark, “Methods of soil analysis. American Society of Agronomy, Madison,” *Wisconsin, Monogr.*, no. 9, pp. 1162–1164, 1965.
18. D. L. Corwin and S. M. Lesch, “Application of soil electrical conductivity to precision agriculture: theory, principles, and guidelines,” *Agron. J.*, vol. 95, no. 3, pp. 455–471, 2003.
19. P. R. Hesse, “A textbook of soil chemical analysis,” 1971.
20. H. G. Graham, T. C. Mcright Jr, and E. D. Frederick, “Determination of calcium in phosphate materials by titration with EDTA in the presence of calcium indicator. Agric,” *Food Chem*, vol. 10,

p. 447, 1962.
21. M. L. Jackson, *Soil chemical analysis: Advanced course*. UW-Madison Libraries Parallel Press, 2005.
22. M. L. Jackson, "Soil Chemical Analysis--Prentice Hall Inc," *Englewood cliffs, NJ, USA*, 1967.
23. J. Ryan, G. Estefan, and A. Rashid, *Soil and plant analysis laboratory manual*. ICARDA, 2001.
24. K. H. O. Dulaimi, "Effect of organic matter and irrigation on treated sewage in the growth and yield of barley and its content of some nutrients in calcareous soil," Faculty of Agriculture, University Of Anbar., 2016.
25. R. S. Ayers and D. W. Westcot, "Water quality for agriculture. FAO Irrigation and drainage paper 29 Rev. 1," *Food Agric. Organ. Rome*, vol. 1, p. 74, 1985.
26. O. K. K. Al Salmani, "A study of the use of treated Fallujah sewage water in the environmental pollution of the soil and the growth of sorghum plant," faculty of Agriculture . Anbar University., 2013.
27. R. E. Leffel and others, "Process Design Manual: Wastewater Treatment Facilities for Sewered Small Communities.," 1977.
28. and M. J. R. Sundara, K. K., P. K. Sundara., "Performance evaluation of wastewater treatment plant," *Int. J.Sci. Tech*, vol. 2, no. 12, pp. 7785–7796, 2010.
29. Y. L. Qian and B. Mecham, "Long-term effects of recycled wastewater irrigation on soil chemical properties on golf course fairways," *Agron. J.*, vol. 97, no. 3, pp. 717–721, 2005.
30. I. A. B. A.-J. A.-S. Milad, Ramadan Ali. Mustafa Ali bin Zokta. Mahmoud Ayyash, "An evaluation study on the efficiency of using sand filters in purification Wastewater," *Int. Ref. J. Eng. Sci. Inf. Technol.*, vol. 6, no. 1, pp. 16–21, 2019.