Effect of aeration then granular activated carbon on removal efficiency of TOC, COD and Coliform, Fecal coliform for “Sorkheh Hesar Canal" water

Amerah A. Radhi and Mahdi Borghei

***Abstract*—This study describes an experiment in which aeration and granular activated carbon (GAC) have been used for removal of dissolved organic matter, bacteria from river water. River water samples were collected from "Sorkheh Hesar Canal" east Tehran, Iran and subjected to aeration process then to granular carbon activated. The aeration process has been continuously effective during 24 hours followed by granular carbon activated filter during the treatment process. The sample treated water was taken to determine of chemical oxygen demand (COD), total organic carbon and coliform, fecal coliform tests. the spectrophotometer has been used in the laboratory experience for measure COD, total organic carbon analyzer for measure TOC and method total coliform bacteria (TC) for measure coliform, fecal coliform. The efficiency of this experiment has been investigated in the removal COD, TOC and coliform, fecal coliform significantly decreased as it reached to 77.5, 76.6, 56.7, 56.7% respectively.**

***Index Terms*— Sorkheh Hesar Canal, aeration, granular activated carbon, organic matter.**

I. Introduction

Water is the lifeblood of the first life, so there are no human, plant or animal without it [1]. Although water occupies more than 80 percent of the earth area, drinking water is only 1 percent of it [2]. The distillation and filtering of water from dirt, impurities, microbes, and algae is very important to make it fit for human use [3]. Water distillation and distillation processes take high energy consumption, and therefore consume fossil fuels for this purpose [4]. The consumption of fossil fuels causes major environmental problems. The consumption of this volatile fuel is also a threat to national economic security [5]. The shift to the use of renewable and alternative energies for fossil fuels to produce potable water is very important [6, 7]. Solar energy can be considered an excellent alternative to water production and distillation and has been used for thousands of years to obtain potable water [8, 9, and 10].

Water quality observation is a main tool in the administration of freshwater resources, allowing the identification of sources of pollution, which can help maintain pollution resources - free from microorganisms and chemicals [11]. As indicators which representing the level of organic matter, biochemical oxygen demand (BOD) and chemical oxygen demand (COD) have been used mainly. Total organic carbon (TOC) is the most important parameter for measuring organic pollution in water [12-13]. The method of chemical oxygen demand (COD) you need (a few hours) to complete compared with BOD test [14-18]. In comparison, TOC measurement can be treated more quickly, without the need for large quantities of reagents. This is possible because the TOC analysis is done by measuring carbon dioxide resulting from the direct oxidation of the organics [19]. Total organic carbon (TOC) is generally derived from decaying vegetation, bacterial growth, and metabolic activities of living organisms [20]. The chemical oxygen demand (COD) test is usually used to measure the amount of organic compounds in water [21]. COD, TOC reduction is the most important parameter when evaluating filter performance in water treatment. COD, TOC is the most significant contaminant in surface water. Therefore, its effective reduction is particular importance [22, 23]. Aeration is a process that collects water and air in closed contact, these processes, which use dissolved oxygen, help to make the waste harmless, break organic waste into simple substances to make it a food for bacteria [24]. Operations by aeration lead to effective removal of the unwanted gas and remove many organic pollutants such as hydrocarbons, some pesticides and halogenated organic compounds [25]. Activated carbon is a solid substance Non-porous, it consists of wide layers of graphite and has a high surface area; It has been treated in special ways to make it porous. It has a high ability to adsorb gases and toxins, especially micro-organic pollutants from water in addition to the removal of other background organic compounds measured as total organic carbon [26-28]. It is also used to purify contaminated water and wastewater, also used to kill bacteria and improves taste, odor and color associated with organic matter found in water. Carbon consists of a positive charge and is designed to attract negatively

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charged water pollutants [27, 29, 30]. Activated carbon has two types powdered or granular. Granular activated carbon (GAC) is used in dedicated columns in the form of a filter [31]. In Europe and North America, the use of granular activated carbon is common seeking to remove micro-pollutants from drinking water [32]. Activated carbon adsorption is one of the recommended processes for removal of byproducts precursor decontamination, organic micro-pollutants, and compounds that transmit taste and odor to drinking water [33]. It has been activated in special ways to obtain a large surface area (500-1500 g/m^2) and almost one gram of activated carbon has a surface area in excess of 3,000 m2. Activated carbon particle consists of particles of the size of each of them about one millimeter - ie, greater than 10 to 100 times of the powder granules and typical particle sizes that can be removed by carbon filters range from 0.5 to 50 µm [28]. Activated coal is used as an absorbent material for organic and non-polar materials, as well as in the treatment of gases and water. It is the most used substance as a sorbent for gases. Furthermore, it seems very effective for the removal a wide groups of artificial volatile organic [34-37]. The Objective of this research was to assess the effect of aeration and granular activated carbon filter for reducing of water contaminants content to find the effective treatment process of “Sorkheh Hesar Canal” water. Physical & chemical properties of water were measured before and after treatment and these water parameter tested were: Chemical Oxygen Demand (COD), Total Organic Carbon (TOC) and Coliform and fecal coliform.

II. MATERIALS AND METHODS

A. Study Area

This study was conducted in Sorkheh Hesar canal during August 2015, which is situated in east of Tehran. This canal runs from Alborz Mountains, through districts of 7, 14 and 20 of Tehran municipality within the city limits which also named as "Abazar Canal" (as Figure 1). Water from Alborz Mountain, flow through this canal which collects rain water and surface waters. During the course of water flow, sewage and polluted water run into the canal causing wide spread contamination.

B. Sampling

Water samples were collected from Sorkheh Hesar Canal water in east Tehran at varying times. Where they were collected in plastic bottles and transferred to the laboratory. The parameters have been measured such as chemical oxygen demand (COD), total organic carbon (TOC) and coliform, fecal coliform. These parameters have been selected for their spread in sewage and industrial water. Samples were analyzed subsequently for determination physical and chemical variables.

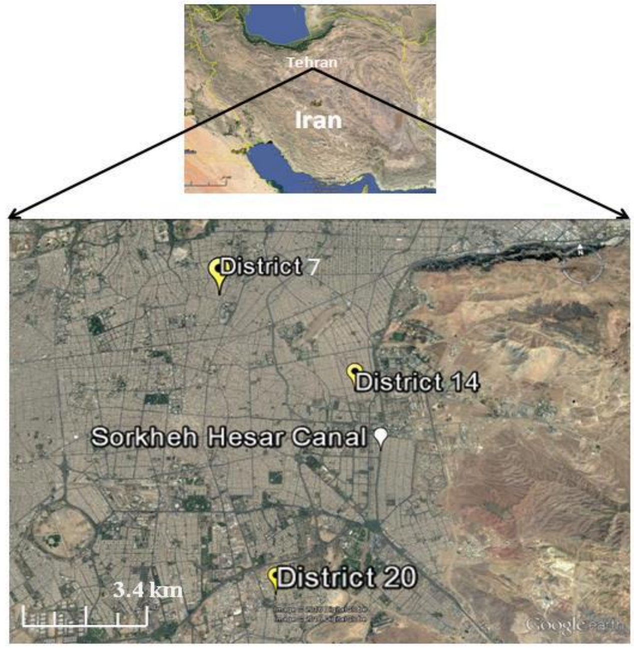
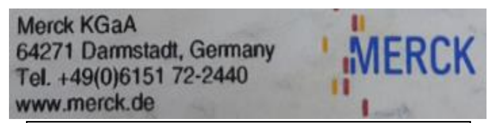


Figure (1): Map of Tehran City illustrates the study sites on Sorkheh Hesar Canal

C. Specification of GAC used in the laboratory



Specifications	
Identity	conforms
Substances soluble in nitric acid	≤ 5 %
Chloride (Cl)	≤ 200 ppm
Cyano compounds (CN)	passes test
Pb (Lead)	≤ 20 ppm
Zn (Zinc)	≤ 100 ppm
Polycyclic aromates	passes test
Tar products	passes test
n-Hexane adsorption	≥ 30 %
Residue on ignition (600 °C)	≤ 8 %
Loss on drying	≤ 10 %

D. Experimental work

The raw water was treated through aeration then granular activated carbon filter as soon as it arrived at the lab. The laboratory system consists of the aeration reactor, it consists of a rectangular tank 70 cm length and 40 cm wide, at the bottom of tank there is a slot Through which comes out the water treated by aeration to the granular activated carbon filter. In this process, activated carbon is used to remove dissolved organic matter and bacteria. The water is passed through a filter containing the carbon medium. When water is allowed to flow through a filter at a slow rate, contaminants are exposed to filtration medium for a longer period of time. Activated carbon absorbs dissolved organic matter and bacteria found in contaminated water. The filter consists of a length of 60 cm, diameter of 5 cm, activated carbon granules occupy 50 cm of the original length of the column and at the bottom of filter there is a slot, where treated water is collected as shown in Figure 2. Physical and chemical tests are performed on treated water. Basic parameters such as total organic carbon (TOC), chemical oxygen demand (COD), coliform and fecal coliform contents were measured according to methods used of test water and wastewater [38].

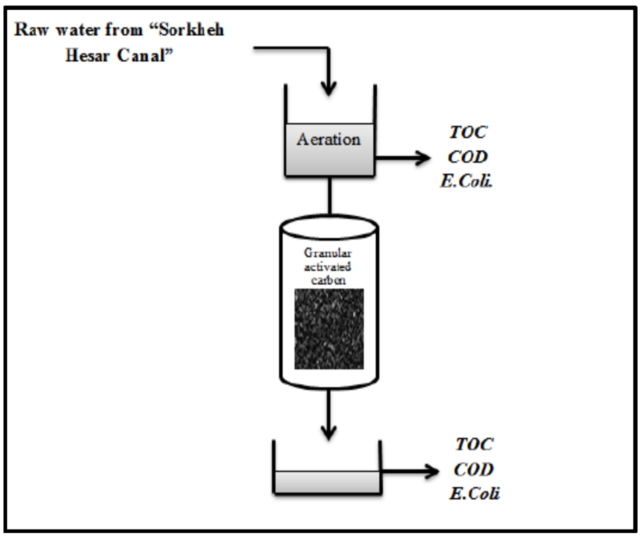


Figure (2): Planned Methodology & Experimental set-up

E. Analysis

- Chemical oxygen demand: - is an inexpensive and quick way, used widely to determine the amount of organic pollutants present in surface water or wastewater which are subject to oxidation by strong chemical oxidation, making COD a useful measure of water quality. This is expressed in milligrams per liter (mg / L).

COD removal was measured by using spectrophotometer wavelength (420nm) is manufactured by UNICO America, model UV-2100. Moreover, hot COD meter HACH model DRB 200 used in Sharif University of Technology/ Iran.

- Total organic carbon: - In order to determine TOC, total organic carbon analyzer by manufactured Australia (S.G.E) model ANA TOC used in Sharif University of Technology/ Iran.
- Total coliform bacteria (TC):-This examination is performed for the purpose of detecting coliform bacteria group in water. Multi-pipe method is used because analysis depends on small sample they are taken from a large sample, all methods depend on the rules of statistical (Most probable number (M.P.N)) and it is considered one of the oldest methods used. The bacteria were tested in the biological laboratory at Sharif University of Technology / Iran. The removal efficiency (% Removal) was calculated from the following equation:

$$R\% = \frac{(C_i - Cf)}{C_i} * 100 \quad (1)$$

Where, Ci = initial concentration, Cf = final concentration, for each COD, TOC and coliform, fecal coliform before and after treatment. The parameters measured for "Sorkheh Hesar Canal" before treatment shown in Table I.

TABLE I
SUMMARIZES THE MEASURED PARAMETERS FOR "SORKHEH HESAR CANAL" WATER BEFORE TREATMENT

Parameters	Average value
COD	43 mg/L
TOC	20 mg/L
Total coliform	M.P.N/100ml > 1600
Total fecal coliform	M.P.N/100ml > 1600

III. Results and Discussion

A. Total organic carbon (TOC)

The results showed that aeration and granular activated carbon filter was more effective for removal of TOC from the Sorkheh Hesar Canal water. The reduction in content TOC was from 20 mg/l in raw water to 2.27 mg/l in treated water with a mean removal efficiency of 76.6 %. The principle of absorption requires water to come in contact with the granular activated carbon and increased contact time also increases the TOC removal. The higher removal efficiency of TOC is observed at 110 Days in this study. Water is pumped from aeration into a column which contains granular activated carbon; the water comes out through the column constantly, which gives an accumulation of substances on the filter. Processes involve the transfer of the pollutant from the water to the carbon. During certain periods of 10, 30, 50, 70, 90 and 110 Days, the removal efficiency of TOC was 24, 18.7, 34.7, 31.5, 60.3, 76.6 % respectively. Increasing time after 90 Day resulted in significant improvement in TOC removal efficiency. Also, this work has shown that the removal of TOC by aeration then granular activated carbon filter appears to reach up to removal efficiency of 76.6 % at time 110 Day as shown in the Figure 3. Therefore the removal here does not indicate a complete degradation of organic matter. The study results agree with those of previous studies [39-41] that examined the performance of granular activated carbon in removal of organic matter.

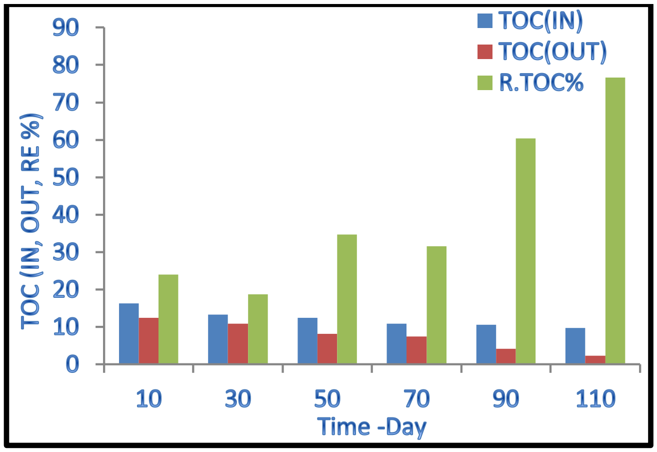


Figure (3): Effect of aeration then granular activated carbon filter on (IN, OUT, Removal) Total organic carbon

B. Chemical oxygen demand (COD)

The results showed that aeration and granular activated carbon filter was more effective for removal of COD from the Sorkheh Hesar Canal water. The reduction in COD content was from 43 mg/l in raw water to 4 mg/l in treated water with a mean removal efficiency of 77.5 %. The principle of absorption requires water to come in contact with the granular activated carbon. And increased contact time also increases the COD removal. The higher removal efficiency of COD is observed at 110 Days in this study. Water is pumped from aeration into a column which contains granular activated carbon; the water comes out through the column constantly, which gives an accumulation for materials in the filter. Processes involve the transfer of the pollutant from the water to the carbon. During certain periods of 10, 30, 50, 70, 90 and 110 Days, the removal efficiency of COD was 36, 37.8, 46, 58, 72.7, 77.5% respectively. Increasing the aeration then granular activated carbon filter time after 70 Day resulted in significant improvement in COD removal efficiency.

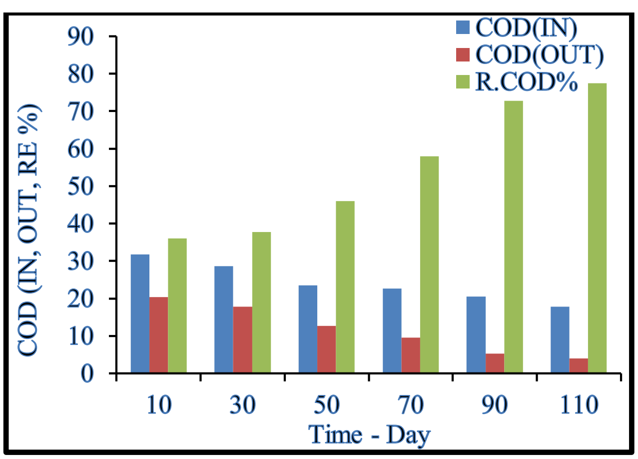


Figure (4): Effect of aeration then granular activated carbon filter on (IN, OUT, Removal) Chemical oxygen demand

C. Total Coliform and Fecal coliform

Also, this work has shown that the removal of COD by aeration and granular activated carbon filter appears to reach up to removal efficiency of 77.5 % at time 110 Day as shown in the Figure 4. Therefore the removal here does not indicate a complete degradation of organic matter. The study results agree with those of previous studies [29-31] that examined the performance of granular activated carbon in removal of organic matter.

The results showed that aeration then granular activated carbon filter was effective for removal of both bacteria from the Sorkheh Hesar Canal water. Where it has gave both bacteria the mean removal efficiency of 56.7 % at 110 Day. Increased contact time also increases the bacteria removal. Note, increasing adsorption time after 90 Day resulted in significant improvement in both bacteria removal efficiency up to 44%. The higher removal efficiency of both bacteria is observed at 110 Days as shown the Figure 5. Also, this work has shown that the removal of both bacteria via aeration follow granular activated carbon filter appears to have good removal efficiency. It seems very clear that both bacteria removal efficiency was also similar. The study results agree with those of previous studies [29-31] that examined the performance of granular activated carbon in removal of coliform, fecal coliform.

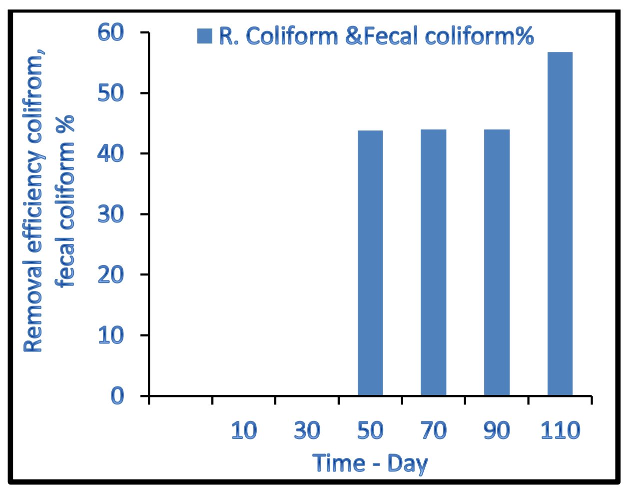


Figure (5): Effect of aeration then granular activated carbon filter on removal efficiency coliform, fecal coliform

The study results show the performance of aeration then granular activated carbon filter on as follows: The highest removal efficiency was for COD, TOC, and Coliform, Fecal coliform 77.5, 76.6, 56.7, 56.7% respectively, As Figure 6 manifests.

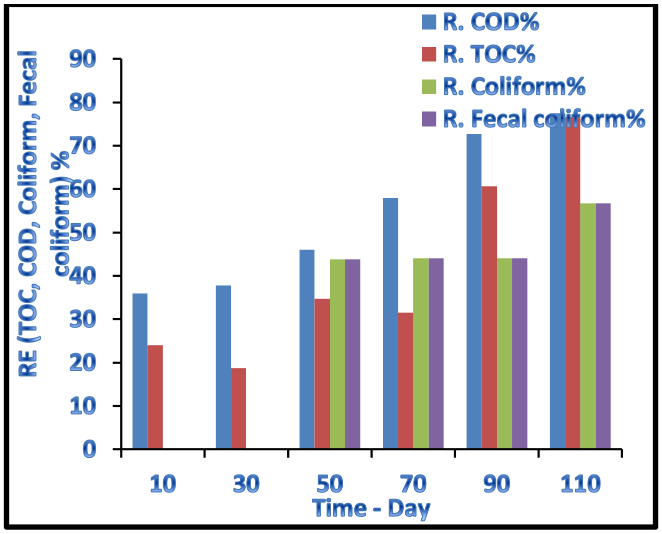


Figure (6): Effect of granular activated carbon filter after aeration on removal efficiency TOC, COD and coliform, fecal coliform

IV. Conclusions

Finally, it can be concluded that the aeration then the granular activated carbon process can be considered as a reliable method, flexible, efficient and economical to river water treatment. The source of contamination by various chemicals are generated such as industrial waste as well as domestic wastewater, which are released to Sorkheh Hesar Canal that has raised a wide pollution and this in turn sources great concern because affects human health and the environment. Based upon the experiment results in this study, the following observations and conclusions could be drawn:

1-The aeration and granular activated carbon have an important impression on water and sewages treatment, special for organic matter and bacteria.

2- The efficiency of the deletion with increasing the contact time has a direct relationship.

3-where chemical oxygen demand was correlated with total organic carbon value. However, the decrease of total organic carbon level leads to lower chemical oxygen demand of treated water.

4- It also removes coliform and fecal coliform in an acceptable manner.

References

[1] M. T. Chaichan, H. A. Kazem, K. I. Abaas, A. A. Al- Waeli, "Homemade solar desalination system for Omani families," International Journal of Scientific & Engineering Research, vol. 7, No. 5, pp. 1499-1504, 2016.

[2] M. T. Chaichan & H. A. Kazem, "Using aluminum powder with PCM (paraffin wax) to enhance single slope solar water distillator productivity in Baghdad-Iraq winter weathers," International Journal of Renewable Energy Research, vol. 1, No. 5, pp. 151-159, 2015.

[3] M. T. Chaichan, K. I. Abaas, H. A. Kazem, "Design and assessment of solar concentrator distillating system using phase change materials (PCM) suitable for desertec weathers," Desalination and water treatment, vol. 57, No. 32, pp. 14897-14907, 2016. DOI: 10.1080/19443994.2015.1069221

[4] M. T. Chaichan, "Enhancing productivity of concentrating solar distillating system accompanied with PCM at hot climate," Wulevina, vol. 23, No. 5, pp. 1-18, 2016. http://dx.doi.org/10.1016/j.rser.2017.03.048

[5] H. M. S. Al-Maamary, H. A. Kazem, M. T. Chaichan, "Climate change: the game changer in the GCC region," Renewable and Sustainable Energy Reviews, vol. 76, pp. 555-576, 2017.

[6] M. T. Chaichan, K. I. Abaas, "Productivity amelioration of solar water distillator linked with salt gradient pond," Tikrit Journal of Engineering Sciences, vol. 19, No. 4, pp: 24-34, 2012.

[7] H. M. S. Al-Maamary, H. A. Kazem, M. T. Chaichan, "Changing the energy profile of the GCC States: A review," International Journal of Applied Engineering Research (IJAER), vol. 11, No. 3, pp. 1980-1988, 2016.

[8] H. M. S. Al-Maamary, H. A. Kazem, M. T. Chaichan, "The impact of the oil price fluctuations on common renewable energies in GCC countries," Renewable and Sustainable Energy Reviews, vol. 75, pp. 989-1007, 2017.

[9] H. M. S. Al-Maamary, H. A. Kazem, M. T. Chaichan, "Renewable energy and GCC States energy challenges in the 21st century: A review," International Journal of Computation and Applied Sciences IJOCAAS, vol.2, No. 1, pp. 11-18, 2017.

[10] M. T. Chaichan, H. A. Kazem, "Energy conservation and management for houses and building in Oman-case study," Saudi Journal of Engineering and Technology, vol. 1, No. 3, pp. 69-76, 2016.

[11] L. Gustavsson and M. Engwall, "Treatment of sludge containing nitro-aromatic compounds in reed-bed mesocosms–Water, BOD, carbon and nutrient removal," Waste management, vol. 32, pp. 104-109, 2012.

[12] S. Vaillant, M. Pouet, and O. Thomas, "Basic handling of UV spectra for urban water quality monitoring," Urban Water, vol. 4, pp. 273-281, 2002.

[13] M. Wang, X. Liu, B. Pan, and S. Zhang, "Photodegradation of Acid Orange 7 in a UV/acetylacetone process," Chemosphere, vol. 93, pp. 2877-2882, 2013.

[14] P. Chevakidagarn, "BOD 5 Estimation by using UV absorption and COD for rapid industrial effluent monitoring," Environmental monitoring and assessment, vol. 131, pp. 445-450, 2007.

[15] L. R. Chevalier, C. Irwin, and J. Craddock, "Evaluation of InSpectra UV Analyzer for measuring conventional water and wastewater parameters," Advances in Environmental Research, vol. 6, pp. 369-375, 2002.

[16] J. L. Weishaar, G. R. Aiken, B. A. Bergamaschi, M. S. Fram, R. Fujii, and K. Mopper, "Evaluation of specific ultraviolet absorbance as an indicator of the chemical composition and reactivity of dissolved organic carbon," Environmental science & technology, vol. 37, pp. 4702-4708, 2003.

[17] E. Tipping, H. T. Corbishley, J.-F. Koprivnjak, D. J. Lapworth, M. P. Miller, C. D. Vincent, et al., "Quantification of natural DOM from UV absorption at two wavelengths," Environmental Chemistry, vol. 6, pp. 472-476, 2009.

[18] H. Zhuang, H. Han, S. Jia, B. Hou, and Q. Zhao, "Advanced treatment of biologically pretreated coal gasification wastewater by a novel integration of heterogeneous catalytic ozonation and biological process," Bioresource technology, vol. 166, pp. 592-595, 2014.

[19] C.-W. Li, M. M. Benjamin, and G. V. Korshin, "Use of UV spectroscopy to characterize the reaction between NOM and free chlorine," Environmental science & technology, vol. 34, pp. 2570-2575, 2000.

[20] T. R. S. Oil, "Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States," Washington: Independent Statistics & Analysis and US Department of Energy, 2013.

[21] C. N. Sawyer, P. L. McCarty, and G. F. Parkin, Chemistry for environmental engineering and science, 2016.

[22] A. A. Radhi and M. Borghei, "Evaluation of TOC, COD, Coliform, Fecal coliform removal efficiency use by sand filter for “Sorkheh Hesar Canal" water." International Journal of Computation and Applied Sciences IJOCAAS, Volume3, Issue 1, August 2017, ISSN: 2399-4509.

[23] A. A. Radhi and M. Borghei, "Comparison of Different Coagulants after aeration in Investigation for TOC & COD removal efficiency for “Sorkheh Hesar Canal" water." International Journal of Computation and Applied Sciences IJOCAAS, Volume3, Issue 1, August 2017, ISSN: 2399-4509.

[24] J. Nadayil, D. Mohan, K. Dileep, M. Rose, and R. R. P. Parambi, "A Study on Effect of Aeration on Domestic Wastewater," International

Journal of Interdisciplinary Research and Innovations, vol. 3, pp. 10-15, 2015.
[25] M. Mcgee and G. Pearson, "Wastewater Technology Fact Sheet, Fine Bubble Aeration," Epa. org. US Environmental Protection Agency, 1999.
[26] J. M. M. C. Engineers, "Water treatment principles and design," in Water treatment principles and design, ed, 1985, pp. 708-708.
[27] B. Bolto, D. Dixon, and R. Eldridge, "Ion exchange for the removal of natural organic matter," Reactive and Functional Polymers, vol. 60, pp. 171-182, 2004.
[28] E. C. Dillon, J. H. Wilton, J. C. Barlow, and W. A. Watson, "Large surface area activated charcoal and the inhibition of aspirin absorption," Annals of emergency medicine, vol. 18, pp. 547-552, 1989.
[29] T. A. Bellar, J. J. Lichtenberg, and R. C. Kroner, "The occurrence of organohalides in chlorinated drinking waters," Journal (American Water Works Association), pp. 703-706, 1974.
[30] J. J. Rook, "Formation of haloforms during chlorination of natural waters," Water Treat. Exam., vol. 23, pp. 234-243, 1974.
[31] C. E. Coimbra, R. V. Santos, J. R. Welch, A. M. Cardoso, M. C. de Souza, L. Garnelo, et al., "The First National Survey of Indigenous People's Health and Nutrition in Brazil: rationale, methodology, and overview of results," BMC Public Health, vol. 13, p. 52, 2013.
[32] P. J. Moel, J. Q. Verberk, and J. Van Dijk, Drinking water: principles and practices: World Scientific Publ., 2007.
[33] J. C. Crittenden, R. R. Trussell, D. W. Hand, K. J. Howe, and G. Tchobanoglous, MWH's water treatment: principles and design: John Wiley & Sons, 2012.
[34] M. M. Johns, W. E. Marshall, and C. A. Toles, "Agricultural by-products as granular activated carbons for adsorbing dissolved metals and organics," Journal of Chemical Technology and Biotechnology, vol. 71, pp. 131-140, 1998.
[35] S. A. Dastgheib and D. A. Rockstraw, "Pecan shell activated carbon: synthesis, characterization, and application for the removal of copper from aqueous solution," Carbon, vol. 39, pp. 1849-1855, 2001.
[36] L. H. Wartelle and W. E. Marshall, "Nutshells as granular activated carbons: physical, chemical and adsorptive properties," Journal of chemical technology and biotechnology, vol. 76, pp. 451-455, 2001.
[37] M. Stenzel and S. Gupta, "Air pollution control with granular activated carbon and air stripping," J. Hazard. Waste Manage, vol. 35, pp. 1304-1309, 1995.
[38] J. C. Young, L. S. Clesceri, and S. M. Kamhawy, "Changes in the biochemical oxygen demand procedure in the 21st edition of Standard Methods for the Examination of Water and Wastewater," Water environment research, vol. 77, pp. 404-410, 2005.
[39] E. Manual, "Guidelines for water reuse," EPA/625/R-92/0041992.
[40] S. S. Dalahmeh, M. Pell, B. Vinnerås, L. D. Hylander, I. Öborn, and H. Jönsson, "Efficiency of bark, activated charcoal, foam and sand filters in reducing pollutants from greywater," Water, Air, & Soil Pollution, vol. 223, pp. 3657-3671, 2012.
[41] S. Sirianuntapiboon, S. Vinitnantharat, and W. Chamlongras, "Removal of Organic Matters and Phenol Compounds from the Waste Water by Using Granular *Activated Carbon–Sequence Batch Reactor System," Thammasat International Journal of Science and Technology, vol. 4, pp. 38-48, 1999.*