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Research Article

Assessment of the Efficiency of Using Sand Filters for Four Different Types of Charcoal on Water Quality

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Abstract: A study was conducted on four types of charcoal filters: ground kinorcorps charcoal, ground olive tree charcoal, activated vegetable charcoal, and activated animal charcoal. The sand filter consisted of five layers: two charcoal layers, a cotton layer, a layer of fine gravel, and a layer of sand. One type of charcoal was used for each sand filter. The raw water was passed through the four filters and the concentrations of dissolved salts, electrical conductivity, pH, turbidity, dissolved oxygen, color, and phosphorus were measured. The results were compared between the raw water and the filtered water from each type of charcoal, and between the different types of charcoal. The efficiency of each type of charcoal for the study parameters was also estimated. The filtered water from the sand filter was also compared with the standard specifications for drinking water, irrigation, fish farming ponds, and recreation. The required treatments and the type of charcoal suitable for the uses approved in the study were also suggested. The results showed that there were significant differences between the olive charcoal samples in the pH parameter when comparing the raw water with the filtered water from the four types of charcoal. There were also significant differences between all the study samples in the total dissolved salts, electrical conductivity, phosphorus, and turbidity parameters. Only the olive charcoal and activated animal charcoal samples recorded significant differences in the dissolved oxygen parameter. The study showed that the treatment efficiency for the turbidity parameters was 77%, 74%, 46%, and 43% for activated animal charcoal, activated vegetable charcoal, olive charcoal, and kinorcorps charcoal, respectively. The treatment efficiency for the phosphorus parameter was 0%, 72%, 49%, and 45%, where this parameter recorded an increase in the concentrations of the filtered water for activated animal charcoal. The treatment efficiency for the dissolved salts and electrical conductivity parameters were 29%, 40%, 44%, and 43%, respectively. The removal efficiency for the dissolved oxygen parameter was 30%, 24%, 48%, and 5% for activated animal charcoal, activated vegetable charcoal, olive charcoal, and kinorcorps charcoal, respectively. The study also showed that the filtered water samples from the four types of charcoal were higher than the limits of the approved specifications for the use in recreation, drinking, and fish farming ponds, which requires simple treatments. whereas, the filtered water from most types of charcoal was within the specifications for the use in irrigation, except for olive charcoal. the results of the study showed that the filtered water samples from the types of activated vegetable charcoal, activated animal charcoal, and kinorcorps charcoal are suitable for direct use in irrigation, with the preference for kinorcorps charcoal, except for olive charcoal. The filtered water from kinorcorps charcoal, olive charcoal, and activated vegetable charcoal is suitable for use in drinking, fish farming ponds, and recreation, with simple treatments before use. The activated animal charcoal is completely excluded from these uses.

Keywords: Types of charcoal, treatment efficiency, water quality, standard specifications.

INTRODUCTION

Water is one of the most precious resources on Earth. Water quality is an essential part of human life, and improving it is essential for the well-being of society. With the increasing pollution of water, which has become a concern in all parts of the world, it is urgent to protect the remaining clean water and to treat polluted water. The methods of treating polluted water vary depending on the degree of technology used in the treatment process, the complexity of the process, and the distance from simplicity, in terms of technology, capabilities, energy consumption, maintenance difficulty, operating conditions, and the need for skilled labor in operation. All of this depends on the extent of water deterioration and pollution. Perhaps one of the best ways, due to its simplicity, ability to remove pollutants at a lower cost, maintenance, and energy consumption is the simple sand filter method, which is widely used because of its simplicity. It is used in times of war, crises, and emergencies, as its materials are available in most places and times, and it can be easily made by hand. However, it is required that the water be between slightly and moderately polluted. The advantages of simple sand filters lie in their ability to remove suspended materials, bacteria, microorganisms, and some heavy metals. (Wagh, *et al.* ,2016, Fitriani,2023). The efficiency of the sand filter in treating water depends on the size and shape of the sand and gravel grains, the depth of the grains, the flow rate of water, the quality of water, and the maintenance of the sand filter (Hammer, 2012, Morris, *et al.* ,2013, Sisson, 2008, Abdiyev,2023).

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A simple sand filter contains charcoal as one of its layers to take advantage of the charcoal's properties in treating pollutants. Charcoal has long been known as an effective adsorbent, especially for removing color and odor from water (Correa & Kruse, 2018). The use of charcoal adsorption began in the 20th century during World War I and II to remove taste and odor from water and control them (Goci *et al*., 2023; Ahmed *et al*., 2023). The porous structure of charcoal provides a large surface area for absorption, which allows it to trap and remove the organic compounds responsible for odor and color in an effective way (Jamilatun & Mufandi, 2020; Hermawan *et al*., 2023). Through these features, charcoal is used in water purification. In addition, charcoal is chemically inert and stable, making it safe for water treatment (Hermawan *et al*., 2023). There are many different types of charcoal, which vary depending on the source from which the charcoal is taken. Each type of charcoal may have a different processing efficiency than the other (Smith *et al*., 2018; Chen *et al*., 2019). Therefore, it is very useful to evaluate the processing efficiency of different types of charcoal to reach the best types for processing and improve the quality of water for different purposes. One type of charcoal may be suitable for a specific use and not suitable for another. This is because the type of charcoal used in sand filters can have a significant impact on the quality of the filtered water produced. There are different types of charcoal with varying levels of adsorption capacity, which affects their ability to remove impurities from water. Some types of charcoal may also contain different types of pollutants based on their source or components. It may be necessary to make adjustments to the filtered water to make it suitable for different uses. For all of these reasons, it is necessary to evaluate different types of charcoal and to know their impact on the quality of the filtered water in the sand filter.

Many studies have evaluated the efficiency of simple sand filters in removing pollutants (Smith *et al*., 2018; Chen *et al*., 2019). Therefore, this study will not focus on this issue. Thus, the objectives of the study will focus on the following aspects: 1-Evaluate the efficiency of four types of charcoal in sand filters on water quality. 2-Evaluate the suitability of using the filtered water in sand filters for the four types of charcoal under the approved specifications in the study for the purpose of use in irrigation, drinking, recreation, and fish farming ponds.

3-Determine the extent to which

The filtered water needs the appropriate treatments, and the type of charcoal suitable for the uses approved in the study.

MATERIALS AND METHODS:

Four types of charcoal were used in the study: ground Kinorcorps tree charcoal, ground olive tree charcoal, activated vegetable charcoal, and activated animal charcoal. Bottled water bottles with a capacity of 1.5 liters were used. The bottom part was cut off, then turned over and the layers of the simple sand filter were placed: The first layer is cotton from the neck of the bottle to the end of the neck. The second layer is charcoal. The third layer is gravel. The fourth layer is sand. The fifth and last layer is charcoal that receives the treated water as shown in

Figure 1. One type of charcoal was used for each of the four samples with three replicates for each sample. The thickness of each layer of sand, fine gravel, and charcoal was 5 cm. The filters were leveled and tamped well.

The raw water used in the study was from the tap. The raw water was passed through the four filters and measurements were taken with three replicates for each filter. The parameters of dissolved salts in water, electrical conductivity, pH, turbidity, dissolved oxygen, and color were measured by observation. Phosphorus was estimated according to APHA *et al*. (2005).

The total dissolved salts in water and electrical conductivity give an idea about the nature of the removal of dissolved salts in water as a whole. The pH gives an idea about the increase in alkalinity or acidity in water after passing through the filters. The dissolved oxygen gives an impression of the extent of absorption and withdrawal of gases through the types of charcoal used in the sand filters for the study. Turbidity gives an impression of the extent of removal of suspended and colloidal materials in water through the filters. Phosphorus and color give an estimate of the extent of adsorption of charcoal for impurities and organic matter.

A comparison was made between the concentrations of raw water and the water passing through the simple sand filter for each type of the four types of charcoal studied (Kinorcorps tree charcoal, olive charcoal, activated vegetable charcoal, and activated animal charcoal) that are

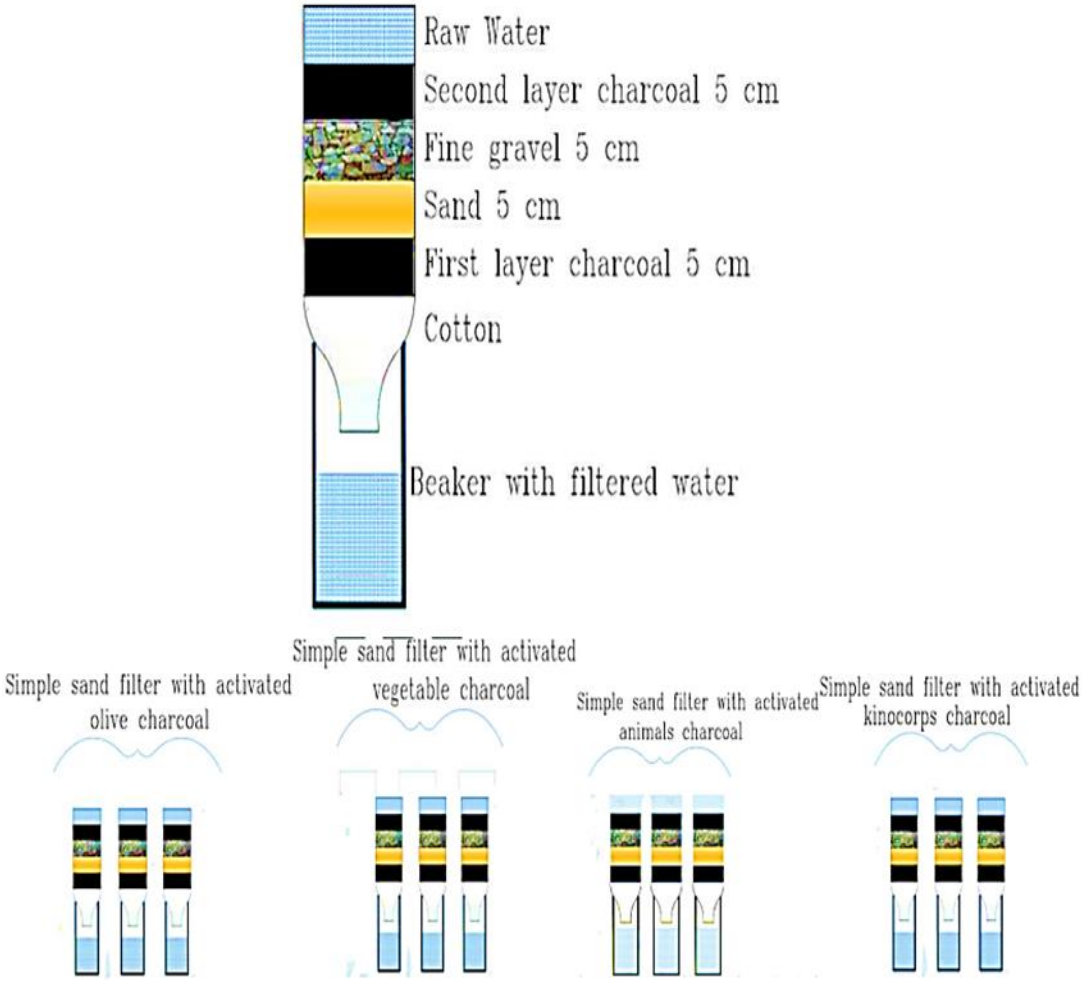

Figure 1. The parts of the simple sand filter used in the study, as well as the simple sand filter with the four types of charcoal

included in the composition of the sand filters, at the TDS, EC, DO, TUR, pH, P, and color parameters. A comparison was also made between the four types of charcoal. Table (1) shows the concentrations of the study parameters at the raw water and the water produced from the sand filters with the four types of charcoal. The efficiency of each type of the four types of charcoal for the study parameters was also estimated. A comparison of the filtered water from the simple sand filter with the standard specifications for drinking water, irrigation, fish farming, and recreation through the following organizations was also performed (World Health Organization, Iraqi Drinking Water Standards, Food and Agriculture Organization of the United Nations, US Environmental Protection Agency, and Saudi Recreation Standards). The required treatments for each standard in the case that the samples were outside the approved specifications for the purposes of the study were also proposed. The type of charcoal suitable for the uses approved in the study was also proposed. Table 3 shows the standard specifications for the study samples for the purpose of using water for irrigation, fish farming, recreation, and drinking. Care was taken to ensure that the type and source of sand and gravel were the same in the sand filters for the study. The thickness and diameter were also the same so that it does not enter as a variable in addition to the type of charcoal. Statistical analysis was performed using SPSS V.19 (Amin, 2008).

RESULTS AND DISCUSSION

1-Total Dissolved Solids (TDS):

The results showed that all filters for different types of charcoal had lower concentrations of the parameter than the raw water. Olive charcoal filter recorded the highest efficiency (recorded the lowest reading) in removing dissolved salts from water with an average of 1050 mg/L at a removal rate of 44%, while the least efficient filter in removing total dissolved solis from water was animal charcoal filter (recorded the highest reading) with an average of 1328 mg/L at a removal rate of 29%. The results at this standard showed significant differences between the concentrations of raw water with the four types of charcoal filters, specifically between Kinorcorps charcoal and animal charcoal, as well as between olive charcoal and animal charcoal. However, the water did not reach the drinking water suitability limits yet, which requires the use of simple sand filters only when the salts are within the drinking water suitability limits or slightly higher than the upper limits. The study also showed a significant difference between all filtered water samples related to the four types of charcoal with the raw water. Table (1) shows the concentrations of the study parameters at raw water, and at filtered water from the simple sand filter containing the four different types of charcoal. Table (2) shows the results of the statistical analysis of the study samples, and Table (3) shows the standard specifications approved in the study for the use of water for the purposes of irrigation, fish farming, recreation, and drinking. Based on this parameter, it was found that the filtered water from the Kinorcorps, olive, and activated vegetable charcoal samples were slightly higher than the specifications of the World Health Organization, the United States Environmental Protection Agency, and Iraqi specification, while the filtered water sample from the activated animal charcoal was higher than the approved drinking water specifications (COSQC, 2001, WHO,1984, EPA, 2014) . As a result, it is necessary to treat the filtered water to make the water quality suitable for drinking at this standard by passing the water more than once through the same sand filter. The quality of the water improves if it is passed more than once through the simple sand filter and the sand filter becomes more efficient in trapping impurities and the water efficiency increases (EPA, 2004, Donald, 2012, John, *et al*., 2013). The use of water for recreation is also subject to the same requirements as drinking water. As for the use of water for irrigation, the quality of the filtered water is suitable for this purpose of use under the raw water used according to the specifications of the Food and Agriculture Organization of the United Nations (Ayers RS, *et al*., 1985). With regard to the use of water for fish farming, under this type of water, all filtered samples for the four types of charcoal were compatible with fish farming that complies with these types of water, and if you want to raise fish that only live in freshwater environments, you should treat the water by passing the filtered water again through the same sand filter.

2- Electrical Conductivity (EC):

The results at this standard showed significant differences between the concentrations of raw water with the four types of charcoal filters, while the filters did not record significant differences except for the activated animal charcoal filter with the Kinorcorps charcoal filter, as well as the activated animal charcoal filter with the olive charcoal filter. The results showed that all filters for the study types of charcoal had lower concentrations of the standard than the raw water. Olive charcoal filter recorded the lowest reading at the electrical conductivity standard with an average of 2535 µS/cm at a removal rate of 44%, while the highest reading recorded was at the animal charcoal filter with an average of 3213.7 µS/cm at a removal rate of 29%. The electrical conductivity standard matches the total dissolved solids standard in terms of the suitability of using the filtered water samples of the four types of charcoal for the purpose of use in irrigation, recreation, drinking, and fish farming under the standard specifications approved in the study, as well as the same methods and techniques for treating the filtered water from the sand filter.

3-Dissolved Oxygen in Water (DO):

The measurements showed that the concentration of the standard decreased in all four charcoal filters from its initial concentration in the raw water, but to varying degrees. The greatest decrease was recorded in the olive charcoal filter, with an average of 4.54 mg/L and an absorption rate of 48%, while the least decrease was recorded in the Kinorcorps charcoal filter, with an average of 8.24 mg/L and an absorption rate of 5%. The statistical analysis showed significant differences between the concentration of the raw water and the concentrations of the filtered water for the two types of olive charcoal and activated animal charcoal. Significant differences were also recorded between the filters with each other, except for the activated vegetable charcoal filter and the activated animal charcoal filter. The filtered water samples of the study for the types of charcoal, Kinorcorps, activated vegetable charcoal, and activated animal charcoal were within the limits of the drinking water specifications according to the United States Environmental Protection Agency (EPA, 2014), but the filtered water samples of olive charcoal were less than the permitted specifications at this standard, which requires processing of these waters before using them for drinking. This processing includes aeration, adding compressed oxygen to the water, agitating the water to gain more oxygen, or adding pure oxygen (Chen, *et al*., 2018, Zhen, 2009, EPA, 2023), or placing the water in a clay jar, as it has been proven that this will increase the dissolved oxygen in the water according to Alradiny and *et al*. (2022). The same treatments are used for the filtered water sample from olive charcoal in case the water is used for fish farming (Sughosh, 2022, FAO, 2019), while there are no specific limits for this standard in case of using this water for irrigation, recreation, or recreation. Therefore, there is no need to apply any treatment to olive charcoal samples when used in recreation and irrigation for this standard.

4-Tubidity:

The statistical analysis showed significant differences at all four charcoal filters for the turbidity standard with the raw water. Significant differences were also recorded between the charcoal filters with each other, except for the olive charcoal filter and the Kinorcorps charcoal filter, as well as the filtered water sample of the activated vegetable charcoal filter and the activated animal charcoal filter. The results showed that all filters reduced the turbidity values compared to the raw water values, and the most efficient type in reducing turbidity values was the activated animal charcoal filter, with an average of 1.43 NTU and a removal rate of 77%, while the least efficient type in removing turbidity was Kinorcorps charcoal, with an average of 3.5 NTU and a removal rate of 43%. All study samples of the four types of charcoal were within the limits of FAO specifications for using water for fish farming (for most types of fish), as turbidity exceeding 10 NTU can negatively affect fish and can lead to problems such as decreased growth rate, increased mortality rate, decreased fertility, weakened immune system, or increased risk of disease (Magnuson, 1976, Bell, 2003, Farrell, 2012). FAO also did not require any specific limits for the purpose of using water for irrigation at this standard, and the study samples were suitable for drinking within the specifications of the World Health Organization (WHO, 1984), while all water samples were not suitable for drinking within the specifications of the United States Environmental Protection Agency (EPA, 2014) and not suitable for use in recreation according to the specifications of the World Health Organization (WHO, 2016). Therefore, it is necessary to treat the water before using it for drinking and recreation in order to remove and reduce turbidity from water, which includes the use of coagulation and flocculation, settling and Decanting, backwash filter, Reverse Osmosis Filtration (RO), Ultrafiltration (UF) systems. (CWS, 2023).

5-pH:

Most types of charcoal filters showed an increase in raw water value at this standard after passing it through the four types of charcoal filters, at varying rates. The results of the statistical analysis showed significant differences only at the olive charcoal filter with the other types. The results showed that the highest recorded value for the pH standard was at the olive charcoal filter with an average of 9.33, while the lowest increase was recorded at the Kinorcorps charcoal filter with an average of 7.77. No significant differences were recorded between the raw water and the charcoal filters, except for the raw water with the olive charcoal filter. All study samples for this standard were within the limits of the EPA specifications for using water for drinking, while the olive charcoal samples were the only ones higher than the FAO specifications for the purpose of using water for irrigation. For the purpose of using water for swimming only, the olive charcoal and activated animal charcoal samples were higher than the World Health Organization specifications, while when using water for fish farming ponds, all study samples were within the limits of the FAO specifications.

6- Phosphorous (P):

The results showed significant differences between the Kinorcorps, olive, and activated vegetable charcoal filters and the activated animal charcoal filter. All four types of charcoal samples also showed a significant difference between them and the raw water. The results showed that all filters reduced the concentrations of the phosphorus standard compared to the concentration of the raw water, except for the samples of water filtered from the activated animal charcoal. The most efficient type in removing the phosphorus standard was the activated vegetable charcoal with an average of 0.07 mg/L and a removal rate of 72%, while the least efficient type in removing this standard was the activated animal charcoal with an average of 0.85 mg/L at a removal rate of 0%, where an increase in concentration was observed, and thus a sample of phosphorus was contaminated. The contamination of the filtered water samples of the activated animal charcoal samples may be due to the contamination of this type of charcoal with phosphorus or that phosphorus is included in one of its components. All study samples of the four types of charcoal were higher than the limits of the specifications approved for the use of water for drinking, swimming, and fish farming ponds, which requires the process of passing the filtered water through the same filter more than once in order to reach the permitted limits according to the specifications for use in swimming, drinking, and fish farming (EPA, 2004, Donald A. Hammer, 2012, John C. Morris, *et al.*, 2013), except for the samples of activated animal charcoal, which increased the concentrations of phosphorus after passing the water through the sand filter, unlike the other types of charcoal, which reinforces the probability of contamination of this type of charcoal with phosphorus or that phosphorus is one of the components of this charcoal, and therefore it is not recommended to use this type of charcoal if you want to use the filtered water for drinking, swimming, and fish farming, except for use in irrigation, where the specifications in irrigation do not require certain limits for use, or experiments and other uses that are not affected by the increase in phosphorus concentrations. In agriculture, phosphorus is an essential nutrient for plant growth, as it is involved in photosynthesis, as it also helps to improve soil quality, and studies have shown that phosphorus also helps to increase crop yield and improve the taste and flavor of fruits and vegetables. The optimal level of phosphorus in irrigation water depends on the type of plant and the soil conditions, but it should remain at a concentration of less than 10 milligrams per liter ((Pilbeam, 2005, Smith, 2002, Sadowsky, 2009).

7-Color:

Blue dye was added to the raw water and passed through the sand filters of the four types of charcoal. The color disappeared completely in the samples of activated animal and vegetable charcoal with the same degree of purity, followed by olive charcoal, and then Kinorcorps charcoal, where the water was more inclined to colorless.

The study showed that the samples studied for the four types of charcoal for simple sand filters were not within the limits of the specifications approved for use for swimming, fish farming, and drinking purposes, as one or more of the parameters were outside the limits of the specifications, which requires simple treatments of the filtered water before using it for those purposes. However, most of the study samples were in compliance with the specifications approved for use in irrigation, except for olive filter samples in which the pH standard exceeded the specifications. Therefore, if it is required to use the water for irrigation within the quality of the raw water or slightly approaching it, then all types of charcoal are available, except for olive charcoal, which should be the last option because its pH is higher than the specifications, and the priority for use is for Kinorcorps charcoal because it recorded the highest percentage of treatment of total dissolved solids after olive charcoal. While if it is required to use the water for swimming, drinking, and fish farming, I should exclude activated animal charcoal because it pollutes the samples with phosphorus, and the priority for use is for activated vegetable charcoal.

In another way, if it is required to reduce the total solids to the lowest possible concentration and raise the pH to the highest possible degree, olive charcoal is used. If the goal is to achieve the highest possible removal ratio for color, turbidity, and phosphorus, activated vegetable charcoal is used. However, if the objective is to achieve the best removal of turbidity and color and the increase in phosphorus concentration in the filtered water does not affect the purpose of water use, activated animal charcoal is used.

The more the quality of the water deteriorates, the more likely it is to use additional treatments on the filtered water from the simple sand filter, until the quality of the deteriorated water reaches the point where it becomes necessary to dispense with this type of treatment and replace it with a higher-grade treatment that is more expensive, more complex, and more complex, in terms of techniques, capabilities, energy consumption, and difficulty in maintenance.

Table 1: Concentrations and values of parameters to samples studied for simple sand filter

parameter / Charcoal type	T C^0	TDS mg/L	pH	DO mg/L	EC µs/cm	Turbidity NTU	P mg/L
Raw water	32	1880	7.6	8.67	4550	6.11	0.25
Kinocorps1	30	1155	7.7	8.32	2795	3.7	0.16
Kinocorps2	29.4	930	7.8	8.15	2251	3.2	0.13
Kinocorps3	29.7	1115	7.8	8.24	2698	3.6	0.12
Average	29.7	1067	7.77	8.24	2581	3.5	0.137
Efficiency%	-	43	-	5	43	43	45
Olive1	29.4	1150	9.4	3.79	2772	3	0.14
Olive2	28.9	1135	10.2	4.15	2735	3.5	.11
Olive3	29.2	870	8.4	5.67	2097	3.3	.13
Average	29.17	1052	9.33	4.54	2535	3.27	.127
Efficiency%	-	44	-	48	44	46	49
Activated vegetable1	29.2	1020	7.80	6.93	2463	1.41	0.08
Activated vegetable2	29.2	1160	7.83	7.41	2801	1.42	0.07
Activated vegetable3	29.4	1185	7.78	5.34	2862	2	0.06
Average	29.27	1122	7.80	6.56	2709	1.61	0.07
Efficiency%	-	40	-	24	40	74	72
Activated animal1	30	1570	8	5.79	3799	1.48	0.87
Activated animal2	30	1245	8.12	5.92	2963	1.35	0.93
Activated animal3	30	1170	8.2	6.44	2879	1.47	0.74
Average	30	1328.3	8.11	6.05	3213.7	1.43	0.85
Efficiency%	-	29	-	30	29	77	0

Table 2. statistical analysis of samples studied

Parameter / Description			pH	TDS mg/L	Ec µS/cm	DO mg/L	Turbidity NTU	P mg/L
The least significant difference at 0.05	**Between charcoal types**	**Types with each other**	0.03 ±0.189	0.000 ±88.33	0.000 ±214.17	0.000 ±0.427	0.000 ±0.452	0.000 ±0.772
		Kinocorps - olive	.001 ±0.333	0.895 ±110.95	0.865 ±266.61	0.000 ±0.553	0.233 ±0.183	0.796 ±0.376
		Kinocorps – Activated vegetable	0.915 ±0.333	0.631 ±110.95	0.643 ±266.61	0.013 ±0.553	0.000 ±0.183	0.107 ±0.376
		Kinocorps- Activated animal	0.374 ±0.333	0.04 ±110.95	0.039 ±266.61	0.003 ±0.553	0.000 ±0.183	0.000 ±0.376

		Olive-Activated vegetable	0.001 ±0.333	0.542 ±110.95	0.529 ±266.61	0.004 ±0.553	0.000 ±0.183	0.163 ±0.376
		Olive-Activated animal	0.004 ±0.333	0.032 ±110.95	0.029 ±266.61	0.021 ±0.553	0.000 ±0.183	0.000 ±0.376
		Activated vegetable - Activated animal	0.431 ±0.333	0.092 ±110.95	0.087 ±266.61	0.378 ±0.553	0.359 ±0.553	0.000 ±0.376
	Between raw water and types	**Raw water-Kinocorps filtered**	0.916	0.007	0.007	0.645	0.004	0.016
		Raw water-olive filtered	0.041	0.012	0.012	0.02	0.002	0.022
		Raw water-Activated vegetable filtered	0.073	0.005	0.004	0076	0.002	0.003
		Raw water-Activated animal filtered	0.952	0.046	0.045	0.005	0.000	0.006

Table 3. Specifications of irrigation, drinking, Aquaculture and fish farming ponds and Recreation. (COSQC, 2001, WHO,1984, EPA, 2014, Ayers RS,et. al,1985)

Parameter / Purpose	Specification	TDS mg/L	Ec µS/cm	pH	Turbidity NTU	P mg/L	DO mg/L
Drinkingwater	WHO	1000	-	6.5-8.5	5	-	-
	Iraqi specification	1000	-	6.5-8.5	5	-	-
	EPA,2014	500[13]	2500	6.5-9.5	<1 or ,<0.2	(0.015-0.02)[1]	(5-8)[2]
Irrigation	FAO	450-2000	(0.7-3)[3]	6.5-8.4	-	-	-
Aquaculture and fish farming ponds	FAO	-	-	6.5-9[9]	<10[13]	0.05-0.1[6+7]	>5[10+11]
Recreation	WHO	1000[5]	-	7.8-7.2[4]	0.5[4]	0.015-0.02[1]	-

1:(Voudouris, *et al*.,2012); 2- (EPA,2000); 3- in (ds/m) unit.;4-(WHO,2016); 5-(PHA,2021);6-(FAO,2014);7-(FAO,2022);8: (FAO,2009); 9:(FAO,2011); 10: (Sughosh,2022);11: (FAO,2019); 12: (FAO,2018);13: (EPA,2021).

CONCLUSIONS

1. The results showed that there were significant differences between the raw water and the filtered water for the four types of charcoal, for the pH, total dissolved solids (TDS), electrical conductivity (EC), phosphorus, and turbidity. Only olive charcoal and activated animal charcoal showed significant differences for the dissolved oxygen.

2. Olive charcoal showed the highest treatment efficiency for the TDS and EC parameters, at 44% and 29%, respectively. Olive charcoal also showed the highest pH value, at 9.33, while Kinorcorps charcoal showed the lowest pH value, at 7.77. Kinorcorps charcoal showed the lowest dissolved oxygen absorption efficiency, at 5%, while olive charcoal showed the highest dissolved oxygen absorption efficiency, at 48%. Activated animal charcoal showed the highest turbidity treatment efficiency, at 77%, while Kinorcorps charcoal showed the lowest turbidity treatment efficiency. Activated vegetable charcoal showed the highest phosphorus treatment efficiency, at 72%, while activated animal charcoal showed the lowest phosphorus treatment efficiency, at 0%.

3. The study showed that the filtered water samples from the four types of charcoal were higher than the approved specifications for the purpose of use in recreation, drinking, and fish farming. This requires simple treatments to be

applied. The filtered water samples from most types of charcoal were within the specifications for use in irrigation, except for olive charcoal.

4. The results showed that the filtered water samples from the four types of charcoal were suitable for direct use in irrigation, with the preference for Kinorcorps charcoal. Olive charcoal is not suitable for direct use in irrigation unless it is treated. The filtered water samples from Kinorcorps, olive, and activated vegetable charcoal were suitable for use in drinking, fish farming, and recreation, with simple treatments applied before use. Activated animal charcoal is not suitable for any of these uses.

Recommendations

1. The efficiency of a simple sand filter decreases over time, so it is necessary to conduct regular water tests to perform filter maintenance or replacement in accordance with the test results.

2. It is recommended to introduce other parameters, as well as more types of charcoal, for the purpose of studying their effects on water quality and higher grades of water quality, and to record cases where the simple sand filters for different types of charcoal become unable to treat or where the treatment efficiency deteriorates significantly.

3. It is preferable to filter the water two or more times and take tests each time to find the extent of removal efficiency for each time at each standard, and the feasibility of repeating the filtration.

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