

REMOVAL OF MANGANESE (II) AND IRON (II) FROM POLLUTED WATER BY ADSORPTION ON ACTIVATED CHARCOAL CARBON FROM SALIX AEGYPTIACA

Saad M Elsaid⁽¹⁾ and Nabil M. Anwar⁽²⁾

1) Onaizah Private colleges, Kingdom of Saudi Arabia 2) Environment and Climate Research Institute (ECRI)

ABSTRACT

Pollution of groundwater wells with the heavy metals of Manganese (II) and Iron (II) is a serious problem that occurs at numerous locations in Egypt. Many clay deposits naturally contain these two heavy metals inherited from their parent rocks. In many cases in Egypt, Manganese and Iron may be released from these clay deposits to pollute groundwater wells. Removal of Mn(II) and Fe(II) from such waters is essential before use, especially as drinking water.

This work examines the activated charcoal that is obtained from the trunk wood of *Salix aegyptiaca* ("Al-Sefsaaf" tree) as adsorbent material. It is newly introduced as a cheap, environmentally friendly adsorbent material to remove heavy metals from polluted water using fixed bed column technique. The objective of this work is to experimentally investigate the parameter values for preparation and use of this adsorbent material for efficient removal of Mn(II) and Fe(II) from polluted water.

Activated carbons were prepared from *Salix aegyptiaca*, by chemical activation using hydrochloric acid and zinc chloride solution. Experimental results showed that (20% hydrochloric acid and 6.0 N zinc chloride) are the best combination for preparation treatment of the activated charcoal. In a fixed column bed, with 5.0 liters solution volume, and 1.24 and 4.18 mg/l concentrations of Mn(II) and Fe(II); respectively. The obtained values for best adsorption removal efficiency are: contact time of 40 minutes, pH at 7.0 to 8.0, and charcoal dose of 60 g.

Results show that adsorption capacity of the activated charcoal is thought to be higher than the obtained values, and it is recommended for further investigation. It is concluded that the newly introduced activated charcoal from *Salix aegyptiaca* is appropriate for use in adsorption removal of iron (II) and manganese (II) from polluted waters at normal pollution levels, and even higher pollutant concentrations up to 10 mg/l. At higher pollutant concentrations, the polluted water should go through more than one run to reach the permissible limits for use.

Keywords: polluted water – manganese (II) and iron (II) - adsorption - activated charcoal - *salix aegyptiaca*

INTRODUCTION

Surface and groundwater pollution with heavy metals is a serious problem that occurs at many locations in Egypt. Such polluted waters must be treated for removal of heavy metals before use by humans and animals. Heavy metal pollutants may come directly from industrial wastewater disposal, or may be released from soil layers of groundwater aquifers, especially clay layers. Many clay deposits naturally contain some heavy metals inherited from their parent rocks. In many cases, Manganese and Iron are the heavy metals that are found in Egypt's polluting clay deposits (Ibrahim, 2016). Usually, when parent rocks of the clay deposits are Mica and metamorphic rocks, the clay is rich in manganese. Meanwhile, when parent rocks are sandstone or pyrite, the clay is usually rich in iron. (ECHW, 2007).

Some slow processes release the heavy metals contained in clay deposits to surface and groundwater (AWWA, 1990). When aquifer clay layers

around an old drinking water well release these heavy metals, the pumped polluted water poses great threat to human and animal health. Wastewaters from some industries are also polluted with Manganese and Iron, which may reach surface and groundwater. Removal of heavy metal pollutants from these waters is necessary before use; especially as drinking water (Babel and Kurniawan, 2003; Nurchi and Villaescusa, 2008).

Many works focused on the removal of other heavy metals that are more toxic to biota such as: zinc, copper and nickel which mainly come from industrial wastewater (Sun and Shi 1998), while more work is needed for removal of manganese(II) and iron(II) from polluted waters. This is particularly important because this type of pollution to groundwater cannot be controlled by prevention from the source as in case of industrial wastewaters. Therefore, this work focuses on procedures for removal of Mn (II) and Fe (II) from polluted water.

Generally, groundwater pollution levels with Manganese (II) or Iron (II) are around the mean of 1.09 mg/l for Mn(II), and the mean value of 4.03 mg/l for Fe(II) (Elsayed & Salem 2015.; EHCW, 2007; USEPA, 2001; USEPA, 2018).

The World Health Organization (WHO) established maximum permissible values for Mn(II) and Fe(II) in drinking water at 0.05 mg/l and 0.3 mg/l; respectively (WHO, 2003). Egypt adopted these values in the national standards for drinking water (EHCW, 2007).

Dakahlia Governorate, in the Delta of Egypt, is known for polluted groundwater that is used for drinking, exceeding the permissible limits for Mn(II) and Fe(II). Waters polluted with manganese or iron develop reddish rust color, with bad odor and unpleasant taste. Pollution of waters with above-limit concentrations of manganese and iron lead to major health and economic problems if used as a source for drinking water (EHCW, 2007; Elsayed, & Salem 2015). Water pollution with manganese causes major neurological disorders to the human brain such as Parkinson's disease (Volesky and Holan, 1995; Vimala and Karthika, 2008). Meanwhile, iron pollution causes bad metallic odor and taste, as well as spoilage of laundry, which leads to making the water unfit for human use. In addition, dark sludge is deposited on the walls of drinking water pipes due to activity of manganese and ferric bacteria, which cause pipe corrosion (Sun and Shi, 1998; Igwe and Abia, 2006).

There are many methods in wastewater treatment for removal of polluting heavy metals. These treatments include: chemical process (Wan Ngah and Hanafiah, 2008; Ghimire *et al.*, 2007, coagulation/ flocculation (Biswas *et al.*, 2008; Rodriguez, A.Z., Wange, H., Hu, L., Zhang, Y., Xu, P., 2020., clay mineral process (Kour *et al.*, 2013; Homagai *et al.*, 2011), cementation (Nieto *et al.*, 2010; Demirbas, 2008), precipitation (Mahvi *et al.*, 2005; Chen *et al.*, 2010, electrochemical process (Shamaei, L., Khorshidi, B., Perdicakis, B., Sadzadeh, M. 2018., biological methods (Islam *et al.*, 2009),

vocalization (Shrestha *et al.*, 2012, filtration (Sankaramakrishnan and Sanghi, 2006), ion selective membranes (Moussavi and Khosravi, 2010), and adsorptive removal (Kusworo , T.D., Qudratun, N.A., Utono, D.P., 2018 and Latif , S., Reham, R., Imran, M., Hussain, M.S., Iqbal, S., Mitu, L., 2020.

In this work, removal of Fe(II) and Mn(II) from polluted water is examined experimentally by adsorption technique. Trunk wood of *Salix aegyptiaca* (known as “Al-Sefsaaf” tree) is treated to produce activated charcoal as a new adsorbent material. It is introduced as a new cheap, environmentally friendly adsorbent material to remove heavy metals from polluted water using fixed bed column technique. The objectives of this work are: (1) to prepare the adsorbent material from *Salix aegyptiaca* trunk wood, and then (2) to experimentally determine the optimal parameter values for highest efficiency removal of Manganese (II) and Iron (II) from polluted water.

These variables are: (1) Concentration of treatment solution components for preparation of activated charcoal, (2) Contact time between the polluted solution and the activated charcoal, (3) pH of the polluted solution, (4) Dose (weight) of activated charcoal material. Adsorption capacity of the activated charcoal determines how long it can be used before disposal, or re-activation to remove the adsorbed pollutants and re-use it. Adsorption is affected by the concentration of the polluted solution, and by the un-occupied sites on the adsorbent surface. Thus, (5) Two experiments are done to determine the

adsorption capacity of the activated charcoal material: (5-a) Adsorption capacity under higher initial pollutant concentrations, and (5-b) Adsorption capacity under repeated experimental runs using the same activated charcoal mass and under the same initial concentration of pollutant. The objective of this work is to determine experimentally the adsorption capacity of activated carbon from *Salix aegyptiaca* and the corresponding optimal parameter values for the removal of Mn II and Fe II from polluted waters at that adsorption capacity.

MATERIALS AND METHODS:

A number of laboratory experiments are conducted using fixed bed column technique to obtain the targeted parameter values for highest pollutant removal efficiency. Laboratory experiments are done to obtain the desired values of the parameters as mentioned above. All these experiments are done in a fixed bed column that is described below:

1) Preparation of Activated Charcoal as Adsorbent Material: *Salix aegyptiaca* specimens were collected locally from the trunk of Al-Sefsaaf' tree at Kafr al-Amar; al-Qalyubia Governorate; Egypt. The *Salix aegyptiaca* to remove soluble materials, impurities and dust. The specimens were then dried in oven (model of LHT 5/120 WITH 2416 CONTROLLER Carbolite Gero) for 12 hours. A mechanical grinder was used to choose the fraction 50-300 mesh. *Salix aegyptiaca* specimens.

The ground *Salix aegyptiaca* specimens were sieved to reach the softest image, which is estimated at 250-300 mesh to be more appropriate in their use to remove heavy elements from contaminated water. Preparation of activated charcoal carbon from *Salix aegyptiaca* trees was done using solution of zinc chloride together with 15 % hydrochloric acid solution, following the procedure of Heidarinejad *et al.* (2020). The obtained activated charcoal was treated several times, each time with different values for HCl and ZnCl₂ concentrations, and each treated specimen was used in an adsorption test to determine the best concentrations for the treatment process.

Treatment of charcoal with HCl and ZnCl₂ washes away the cations on the charcoal surface, leaving the negatively charged functional groups that are ready to adsorb the metal cations from the polluted solution.

2) Fixed Bed Column Experiment Set-Up: A fixed bed column of 120 cm height and 8 cm radius was used. It was fixed by a metal fixture 100 cm above the floor surface. The fixed bed column contains a glass window to monitor the test steps easily. There is a valve near the bottom of the column to control flushing/draining the solution from the column after each experimental run. A sufficient amount of activated charcoal that may reach 1000 g can be placed in the column, according to experimental needs. The added amount is easily seen through the glass window of the column. Polluted water is poured at the column top by gravity. The

concentrations of manganese and iron are measured before and after adding the solution to the activated charcoal. The shimadzu atomic absorption unit is used to measure the concentrations of iron and manganese before treatment (before pouring at the top of column), and after treatment (after releasing from the valve at the column bottom).

3) Calculations of the Adsorption Uptake by Charcoal (Q) and Percent Adsorption Removal Efficiency (R) of Pollutants: The adsorption uptake by charcoal (Q), and the percent adsorption removal efficiency (R) of Mn(II)/Fe(II) from polluted solution using activated charcoal carbon are calculated using the following two equations below (De Gisi et al., 2016):

$$Q = (C_i - C_o) \times \frac{V}{m} \quad (1)$$

$$R = \frac{(C_i - C_o)}{C_i} \times 100 \quad (2)$$

Where

Q – is adsorption uptake by activated charcoal (mg/g),

C_i – Initial concentration of pollutant in solution (Mn(II) or Fe(II)); (mg/l)

C_o – Output concentration of pollutant in solution after adsorption (Mn(II) or Fe(II)); (mg/l)

V – Volume of polluted solution; (liter)

m – Mass of the sorbent (activated charcoal carbon from *Salix aegyptiaca*); (g)

R (%) – is the percent adsorption removal efficiency; (%).

4) Scanning Electron Microscope and X-Ray Diffraction: Scanning electron microscopy (SEM) is one of the fundamental techniques for surface characterization as it gives the morphology and topography data of the prepared material. Furthermore, SEM can be used to determine the pore size in the case of a porous surface. SEM works similarly to an optical microscope but in SEM, electrons are used instead of light. A beam of concentrated electrons is sent to the sample and this releases secondary electrons. The electrons are collected by a detector and then analyzed to produce an image. Compared to a light microscope which gives a maximum magnification of 1500 times, the magnification in SEM can reach up to 1 million times (Bibaj *et al.*, 2019).

Diagnostic scanning for the *Salix aegyptiaca* activated charcoal carbon transcripts was conducted using the morphology examiner Scanning Electron Microscope (SEM). Two images were taken: for *Salix aegyptiaca* before the activation treatment, and for the activated charcoal carbon.

X-ray diffraction (XRD) is one of the most important nondestructive instruments used to analyze all kinds of matter ranging from fluids, to powders and crystals. Crystals are regular arrays of atoms which are diagnosed by X-rays that can be considered waves of electromagnetic radiation. Atoms scatter X-ray waves, primarily via the atoms' electrons. X-ray radiation demonstrates a wavelength that is of the order of the usual interatomic spacing that exists in crystalline solids, and thus is used to

determine the crystal domain size and the structure of materials. Similarly, it is used to determine surface properties of objects. XRD is an indispensable technique for materials' surface properties characterization (Nasrollahzadeh, 2019).

Salix Charcoal contains Sulfur, Phosphorus, Carbon, Nitrogen and other compounds, bound with cations. Some of the anions are bonded together in bi- and tri-bonds that result in excess electrons. When the charcoal is activated by leaching with acid, cations on the surface compounds are leached away, leaving behind groups with broken mono- bi- and tri-bonds with plentiful negative charges on the activated surface. Each of these groups appears at a certain wavelength, and its intensity appears in the 'pulse' on the transmittance axis.

5) Preparation of Mn (II) and Fe (II) Stock Solutions: All chemicals used were from the analytical class. Different concentrations of Iron (II) and manganese (II) ranging from 2 mg/l to 100 mg/l were prepared using iron sulfate tetrahydrate $\text{FeSO}_4 \cdot 4\text{H}_2\text{O}$ and manganese sulfate tetrahydrate, $\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$. Iron (II) and manganese (II) concentrations were measured before and after adsorption experiments using the analysis device shimadzu atomic absorption spectrophotometer, aas 6880 specifications model.

Some preliminary experiments were done to determine appropriate parameter values to start with, which were confirmed by doing the actual

experiments below. Most of the experiments below were done in replicates of ten times to examine the variability of behavior of the charcoal material.

6) Determination of the Best Preparation Treatment to Obtain Activated

Charcoal as Adsorbent Material: Charcoal resulting from each of the treatments mentioned above was examined for adsorption of Mn(II) and Fe(II) from polluted water in fixed bed cylinder. In these tests, the pollutant initial concentration in the solution was fixed at the most common pollutant concentration in polluted groundwater in Egypt :1.204 and 4.081 mg/l for Mn(II) and Fe(II); respectively (Elsayed, & Salem (2015). EHCW, 2007; USEPA, 2001; USEPA, 2018). For these experimental runs, only the concentrations of the activation solution components' (HCl and ZnCl₂) were changed to determine the best combination of the treatment solutions' concentrations. Meanwhile, all other variables were fixed (Mn(II)/Fe(II) initial concentration, contact time, solution pH, solution volume, adsorbent (activated charcoal) weight/dose).

7) Determination of the Effect of Contact Time Between Polluted Solution and Activated Charcoal on Mn(II) and Fe(II) Adsorption:

In this experiment, only the contact time between the polluted solution (Mn(II)/Fe(II)) was set at a different value for each experimental run, ranging from 5 minutes to 480 minutes (8.0 hours). All other variables were set unchanged during all the experimental runs (Mn(II)/Fe(II) initial

concentration, Solution pH, Solution volume, Adsorbent (activated charcoal) weight/dose). The values of these parameters were chosen based on preliminary experiments, which were confirmed by the following experiments. Each of the experimental runs (for a certain contact time) was run in ten replicates (using different charcoal material) to test the effect of activated charcoal variability. The initial pollutant (Mn(II)/Fe(II)) concentration was fixed at the common values

in polluted groundwater levels at 1.09 mg/l and 4.03 mg/l for Mn(II) and Fe(II); respectively (Elsayed, & Salem, (2015).; EHCW, 2007; USEPA, 2001; USEPA, 2018).

9) Determination of the Effect of pH on Mn(II) and Fe(II) Adsorption: In this experimental runs, the polluted solution pH was set at a certain value for each experimental run, ranging from 2.0 to 7.0. Each pH value was run for 10 replicates, using different charcoal material in each run. All other variables were unchanged during this experiment.

10) The Effect of Activated Charcoal Dose (Weight) on Mn(II)/Fe(II) Adsorption: The target of this experiment is to determine the amount (dose/weight) of activated charcoal needed for removal of Mn(II)/Fe(II) from the solution to reach the permissible limit. Thus, the adsorption experiment is done with variation of the amount of activated charcoal, until the increase in amount doesn't improve the output concentration. All

other factors are fixed. Each step is done in ten replicates to examine the charcoal variability.

11) Determination of the Activated Charcoal Adsorption Capacity

(mg/g): The charcoal adsorption capacity (mg pollutant/g charcoal) determines the limit the charcoal can be used before being disposed, or reactivated by removal of adsorbed cations. Adsorption is controlled by the pollutant concentration in solution, and the empty adsorption sites on the charcoal surface, if all other factors are fixed. So, this test is done in two steps:

- **Adsorption under Higher Initial Pollutant Concentrations:** Increase the pollutant concentration to much higher values and determine charcoal adsorption values at these concentrations (using new charcoal mass in every run). This experiment was also done in 10 replicates to examine the charcoal variability.
- **Cumulative Adsorption Under Repeated Runs Using Same Charcoal and Same Initial Pollutant Concentration:** The experiment is re-run several times using the same amount of charcoal and the same initial pollutant concentration, in order to determine the cumulative adsorption on charcoal surfaces.

RESULTS AND DISCUSSION

1) Determination of the Best Preparation Treatment to Obtain Activated Charcoal as Adsorbent Material: Charcoal specimens that were activated using solutions with different ratios between HCl and ZnCl₂ concentrations (as mentioned in section 2.3 above) were tested by adsorption of Mn(II) and Fe(II) to determine the best treatment solution concentration. Table (1) shows the experimental results, with Mn(II) initial concentration of 1.204 mg/l, and Fe(II) of 4.081 mg/l, which are the most common concentrations in polluted groundwater in Egypt (Elsayed, & Salem (2015).; EHCW, 2007; USEPA, 2001; USEPA, 2018). Figures (1 – a, b, c) show the graphical presentation of Mn(II) and Fe(II) adsorption results for pollutant output concentration (C_o – mg/l), adsorption uptake by charcoal (Q – mg/g) and percent adsorption removal efficiency R (%). In this experiment, only the concentrations of the activation solutions components were changed. Meanwhile, all the other variables were fixed: (weight of activated charcoal = 60 g, polluted solution volume = 5.0 liters, pH left unchanged, contact time between the charcoal and the polluted solution was set at a relatively high value of 60 minutes (1.0 hour), which was determined from a preliminary experiment.

It is important to note that components' concentrations of the treatment solution that are lower than the examined range were ineffective (i.e. HCl <

15%, and $\text{ZnCl}_2 < 2.0 \text{ N}$). Meanwhile, higher concentrations destroyed the entire adsorbent material (i.e. $\text{HCl} > 20\%$, and $\text{ZnCl}_2 > 15.0 \text{ N}$).

From table (1), it is realized that for the same initial pollutant concentration (C_i), the output pollutant concentration after adsorption treatment (C_o) decreases with higher treatment components' concentration up to a certain value. Beyond that value, there is no significant change in C_o and there is no improvement in adsorption uptake (q) nor in the percent removal efficiency (R). This value (20 % hydrochloric acid and 6.0 N zinc chloride) is taken as the best treatment for charcoal activation, as highlighted/shaded in table (1).

Table(1): Effects of preparation treatment components' concentrations on the activated charcoal adsorption efficiency for Mn(II)/Fe(II). (Ci : Initial Concentration (mg/l); Co : Output Concentration after adsorption (mg/l))

Activation Solution Components' Concentrations		Mn(II) Adsorption				Fe(II) Adsorption			
HC I	Zn Cl2	Initial Concentration Ci (mg/l)	Output Concentration Co (mg/l)	Mn(II) Adsorption Uptake (mg/g)	Mn(II) Adsorption Removal Efficiency R (%)	Ci Initial Concentration mg/l	Co Output Concentration mg/l	Fe(II) Adsorption Uptake (mg/g)	Fe(II) Adsorption Removal Efficiency R (%)
15 %	2.0 N	1.24	0.521	56.92	56.73	4.18	0.815	272.17	80.03
15 %	4.0 N	1.24	0.435	64.08	63.87	4.18	0.752	277.42	81.57
15 %	6.0 N	1.24	0.395	67.42	67.19	4.18	0.692	282.42	83.04
15 %	8.0 N	1.24	0.318	73.83	73.59	4.18	0.621	288.33	84.78
15 %	10.0 N	1.24	0.316	74.00	73.75	4.18	0.608	289.42	85.10
15 %	15.0 N	1.24	0.323	73.42	73.17	4.18	0.684	283.08	83.24
20 %	2.0 N	1.24	0.081	93.58	93.27	4.18	0.415	305.50	89.83
20 %	4.0 N	1.24	0.064	95.00	94.68	4.18	0.315	313.83	92.28
20 %	6.0 N	1.24	0.035	97.42	97.09	4.18	0.21	322.58	94.85
20 %	8.0 N	1.24	0.021	98.58	98.26	4.18	0.205	323.00	94.98
20 %	10.0 N	1.24	0.021	98.58	98.26	4.18	0.208	322.75	94.90
20 %	15.0 N	1.24	0.021	98.58	98.26	4.18	0.216	322.08	94.71

1) SCANNING ELECTRON MICROSCOPE (SEM) and X-RAY DIFFRACTION (XRD) ANALYSIS RESULTS FOR THE

ACTIVATED CHARCOAL CARBON : Figure (1- a, b) shows the Scanning Electron Microscope (SEM) images with the enlargement of the adsorption sites in the treated activated charcoal specimen (b) as compared to the untreated charcoal specimen (a). The properties of activated charcoal surface are: Surface area (700-950 m²/g), radii of microspores were 4.15 Å – 8.23Å, and microspore volume (1.23~1.35 cm³ g⁻¹).

Figure (2) shows the x-ray diffraction results of activated charcoal carbon and shows a band at section from 945 to near 4000, which confirms the presence of negative charges inside the activated charcoal components due to anion groups.

XRD profiles displayed four broad diffuse bands centered around 940 to near 3500 nm. The IR spectrum of activated carbon is shown below (table 2, figure 3). Note the strong bands in the 3000-3460 nm region due to O-H and N-H stretch. The C-H scissoring and S=O (1430), sulfate group and carbon-carbon triple bond (1940), long-chain C=C, (954) are noted on this spectrum. All the above function groups have strong negative charges that easily attracted and adsorbed the studied positively charged heavy metal cations of iron (II) and zinc (II).

In Table (2) and Figure (2), the first band in the curve at 954 nm indicates Carbon=Carbon (double bond) and P-OR esters groups. The second

at 1430 nm is at C–H and S=O, and sulfate anion groups. The third pulse at 1940 nm is at Carbon≡Carbon triple bond. The fourth band at 3460 indicates O-H and N-H multiple bond anion groups.

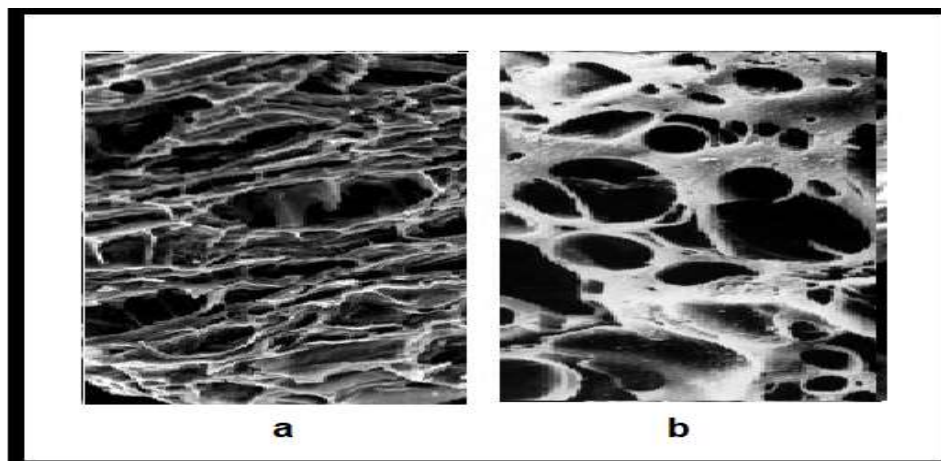


Figure (1). The scanning electron microscopy (SEM) image of activated charcoal carbon: (a) before treatment (raw *Salix aegyptiaca* tree trunk wood), and (b) after the activation treatment.). The properties of activated charcoal are: Surface area (700-950 m²/g), radii of microspores were 4.15 Å – 8.23Å, and microspore volume (1.23~1.35 cm³ g⁻¹).

Table (2): The distributions of negative charges on activated carbon surface as they appear in the XRD profile.

Position nm (Wave Length; nm)	Intensity a.u. (transmittance)	Functional groups
954	0.48	C=C, have characteristic peaks based on bond strengths, and P-OR esters
1430	0.49	C-H and S=O, sulfate group
1940	0.68	Carbon-carbon triple bond C≡C
3460	0.52	O-H 3400 to 3650 cm ⁻¹ Usually broad and intense v N-H 3300 to 3500 cm ⁻¹
a.u.: absorption units; percent absorbance of x-ray beam reflected on activated charcoal surface		

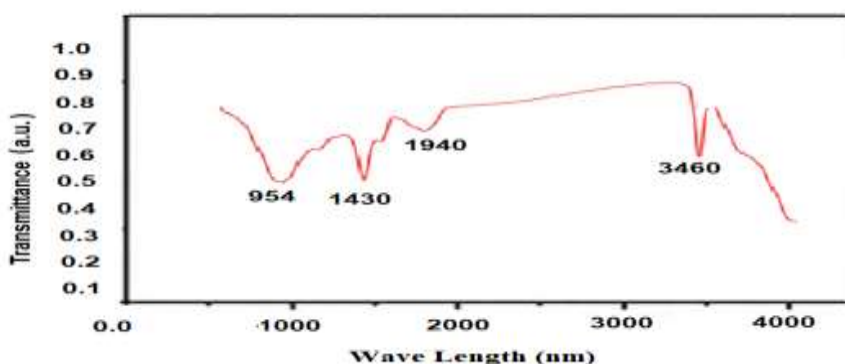


Figure (2): X-Ray Profile of Activated charcoal Carbon surface. The first pulse in the curve at 954 nm indicates Carbon=Carbon (double bond) and P-OR esters groups. The second at 1430 nm is at C-H and S=O, and sulfate anion groups. The third pulse at 1940 nm is at Carbon≡Carbon triple bond. The fourth pulse at 3460 indicates O-H and N-H multiple bond anion groups.

2) The Effect of Contact Time Between Polluted Solution and Activated Charcoal on Mn(II) And Fe(II) Adsorption: Tables (3–a, b) show the experimental results for Mn(II)/Fe(II) adsorption; respectively. They show Mn(II)/Fe(II) results for output solution concentration C_o (mg/l), adsorption uptake by charcoal Q (mg/g) and percent adsorption removal efficiency R (%). Contact time varied from 5 minutes to 480 minutes (8 hours), while all other variable values were left unchanged. These parameters are: initial pollutant concentration (1.24 mg/l and 4.18 mg/l for Mn(II) and Fe(II); respectively), charcoal dose (60 g), solution pH (around 8; left unchanged), and solution volume).

Results show that 40 minutes is the best contact time, and that longer experimental time will not increase the adsorption value. Each contact time was done in 10 replicates. Tables (3–a, b) show that the standard deviation values are very small, and are almost negligible.

Table (3-a): Effect of contact time between polluted solution and activated charcoal on Mn(II) Adsorption.

Replicate No.	Mn(II) Output Concentration (Co : mg/l)										Mean Co	Standard Deviation	Q (mg/g)	R (%)	
	1	2	3	4	5	6	7	8	9	10					
Contact Time (Minutes)	5	0.082	0.085	0.09	0.088	0.084	0.087	0.084	0.081	0.082	0.083	0.085	0.003	1155.40	93.18
	10	0.052	0.053	0.051	0.054	0.053	0.057	0.057	0.053	0.053	0.054	0.054	0.002	593.15	95.67
	20	0.041	0.047	0.042	0.043	0.043	0.044	0.043	0.041	0.042	0.041	0.043	0.002	299.33	96.56
	30	0.034	0.032	0.034	0.037	0.033	0.036	0.037	0.034	0.033	0.031	0.034	0.002	200.98	97.25
	40	0.021	0.025	0.022	0.021	0.022	0.021	0.02	0.021	0.029	0.02	0.022	0.003	152.23	98.21
	60	0.024	0.022	0.024	0.021	0.023	0.026	0.027	0.024	0.023	0.021	0.024	0.002	101.38	98.10
	120	0.025	0.021	0.026	0.022	0.02	0.021	0.02	0.021	0.024	0.02	0.022	0.002	50.75	98.23
	180	0.024	0.022	0.024	0.027	0.023	0.026	0.027	0.024	0.023	0.021	0.024	0.002	33.78	98.06
	240	0.027	0.025	0.02	0.021	0.02	0.022	0.029	0.028	0.02	0.02	0.023	0.004	25.35	98.13
	300	0.027	0.02	0.02	0.026	0.02	0.021	0.023	0.022	0.023	0.02	0.022	0.003	20.30	98.21
	360	0.02	0.025	0.021	0.024	0.022	0.026	0.029	0.028	0.02	0.02	0.024	0.003	16.90	98.10
	480	0.021	0.028	0.022	0.029	0.026	0.02	0.021	0.022	0.021	0.025	0.024	0.003	12.67	98.10
	Contact time varies from 5 minutes to 480 minutes (8.0 hours) Fixed initial Concentration of Mn(II) in polluted solution (Ci) = 1.24 mg/l Maximum permissible level for Mn(II) in drinking water (Co) = 0.05 mg/l Fixed pH = 7.61 for all experimental runs Fixed polluted solution total volume = 5.0 liters Fixed bed glass column: radius = 15 cm; Height = 1.5 m Fixed weight of activated charcoal = 60 g Q (mg/g): adsorption uptake by charcoal. R (%): pollutant removal efficiency from solution.														

Table (3–b): Effect of contact time between polluted solution and activated charcoal on Fe(II) Adsorption.

Replicate No.	Fe(II) Output Concentration (C _o : mg/l)										Mean C _o	Standard Deviation	Q (mg/g)	R (%)	
	1	2	3	4	5	6	7	8	9	10					
Contact Time (Minutes)	5	3.122	3.158	3.178	3.14	3.152	3.178	3.102	3.108	3.144	3.105	3.139	0.029	1041.30	24.91
	10	0.875	0.825	0.879	0.815	0.829	0.815	0.874	0.819	0.879	0.819	0.843	0.029	1668.55	79.83
	20	0.458	0.5	0.472	0.415	0.426	0.418	0.428	0.419	0.427	0.427	0.439	0.028	935.25	89.50
	30	0.215	0.221	0.201	0.215	0.212	0.215	0.208	0.209	0.215	0.215	0.216	0.013	660.63	94.83
	40	0.215	0.201	0.203	0.208	0.213	0.214	0.211	0.221	0.211	0.213	0.211	0.006	496.13	94.95
	60	0.211	0.213	0.221	0.233	0.213	0.231	0.251	0.205	0.204	0.211	0.219	0.015	330.06	94.75
	120	0.211	0.205	0.208	0.222	0.211	0.231	0.213	0.251	0.261	0.281	0.229	0.026	164.61	94.51
	180	0.215	0.251	0.208	0.231	0.251	0.255	0.215	0.261	0.231	0.222	0.234	0.019	109.61	94.40
	240	0.251	0.221	0.231	0.214	0.215	0.215	0.231	0.251	0.235	0.251	0.232	0.015	82.26	94.46
	300	0.214	0.241	0.281	0.211	0.201	0.215	0.212	0.261	0.205	0.204	0.225	0.027	65.93	94.63
	360	0.241	0.254	0.274	0.264	0.218	0.217	0.208	0.208	0.207	0.258	0.235	0.026	54.79	94.38
	480	0.215	0.207	0.209	0.215	0.246	0.284	0.265	0.248	0.246	0.247	0.238	0.026	41.06	94.30
	Contact time varies from 5 minutes to 480 minutes (8.0 hours) Fixed initial Concentration of Fe(II) in polluted solution (C _i) = 4.18 mg/l Maximum permissible level for Fe(II) in drinking water (C _o) = 0.30 mg/l Fixed pH = 7.62 for all experimental runs Fixed polluted solution total volume = 5.0 liters Fixed bed glass column: radius = 15 cm; Height = 1.5 m Fixed weight of activated charcoal = 60 g Q (mg/g): adsorption uptake by charcoal. R (%): pollutant removal efficiency from solution.														

3) The Effect of Polluted Solution pH on Mn(II) and Fe(II) Adsorption:

In this experiment, the solution pH was changed in each run from 2.0 to 8.0, while all other factors were fixed. Highest percent removal efficiency were at pH values of 7.82 and 7.62 for Mn(II) and Fe(II) at 98.1% and 94.8%; respectively. However, pH range from 7.0 to 8.0 is considered appropriate for highest adsorption efficiency. This is consistent with the findings of Ruiti and Thayer (2015). This is elaborated in tables (4–a, b), especially with Fe(II) adsorption results that show pronounced variation with changes in pH.

Table (4-a): Effect of polluted solution pH on Mn(II) Adsorption.

Replica No.	Mn(II) Output Concentration (Co: mg/l)										Mean Co	Standard Deviation	Q (mg/g)	R (%)	
	1	2	3	4	5	6	7	8	9	10					
pH	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.004	96.4	93.
	2	82	82	84	83	81	86	87	83	75	78	82			
	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	103.	94.
	8	66	62	65	62	64	63	61	64	61	63	63			
	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.004	103.	95.
8	55	53	52	53	51	53	54	63	58	53	55				
5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.003	103.	97.	
2	39	33	41	34	38	36	37	35	34	37	36				
7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	103.	97.	
65	31	32	29	28	32	31	32	32	30	28	29				
pH varies from 2.0 to 12.0 Fixed Initial Concentration of Mn(II) in polluted solution (Ci) = 1.24 mg/l Maximum permissible level for drinking water (Co) = 0.05 mg/l Fixed Polluted solution total volume = 5.0 liters Fixed bed glass column: radius = 15 cm; Height = 1.5 m Fixed Weight of activated charcoal = 60 g Fixed Contact time = 40 minutes															

Table (4-b): Effect of polluted solution pH on Fe(II) Adsorption.

Replicate No.	Fe(II) Output Concentration (Co : mg/l)										Mean Co	Standard Deviation	Q (m g/g)	R (%)	
	1	2	3	4	5	6	7	8	9	10					
pH	2.37	1.952	1.925	1.925	1.902	1.928	1.908	1.935	1.907	1.953	1.987	1.932	0.026	187.32	53.78
	3.53	1.252	1.208	1.258	1.208	1.258	1.235	1.292	1.278	1.253	1.262	1.250	0.027	244.13	70.09
	4.84	0.854	0.825	0.841	0.845	0.815	0.894	0.851	0.825	0.843	0.809	0.840	0.024	278.32	79.90
	6.01	0.321	0.358	0.325	0.308	0.358	0.321	0.389	0.324	0.371	0.318	0.339	0.027	320.06	91.88
	7.62	0.212	0.222	0.223	0.221	0.218	0.218	0.218	0.219	0.220	0.200	0.217	0.007	330.24	94.81
	8.35	0.292	0.275	0.246	0.248	0.246	0.321	0.278	0.249	0.295	0.219	0.267	0.031	326.09	93.61
<p>pH varies from 2.0 to 12.0 Fixed Initial Concentration of Fe(II) in polluted solution (Ci) = 4.18 mg/l Maximum permissible level for drinking water (Co) = 0.30 mg/l Fixed Polluted solution total volume = 5.0 liters Fixed bed glass column: radius = 15 cm; Height = 1.5 m Fixed Weight of activated charcoal = 60 g Fixed Contact time = 40 minutes</p>															

4) The Effect of Activated Charcoal Weight (Dose) on Mn(Ii) And Fe(Ii)

Adsorption: The amount of charcoal that is put in the fixed column was changed from 10 g up to 100 g to determine the optimum dose (amount/weight) in solution, with the other parameters fixed (Solution volume at 5.0 liters, Contact time at 40 minutes, pH at about 8.0 and

Mn(II)/Fe(II) initial concentrations at 1.24 and 4.18 mg/l; respectively). Each step was done in 10 replicates to examine the charcoal variability.

Tables (5–a, b) show the experimental results for the effect of activated charcoal weight (dose) on Mn(II) and Fe(II) adsorption. Standard deviations of the output concentration results were very small, indicating no significant variability in activated charcoal behavior. Increasing the charcoal dose above 10 g resulted in decreasing the pollutant concentration in the output solution (Co) until 60 g of charcoal, and there was no significant improvement above this value. So, 60 g of activated charcoal is the best amount (dose) for 5.0 liters of the polluted solution at the used initial concentrations of 1.24 and 4.18 mg/l for Mn(II) and Fe(II); respectively.

Table (5-a): Effect of activated charcoal weight on Mn(II) Adsorption.

Replicate No.	Mn(II) Output Concentration (Co : mg/l)										Mean Co	Standard Deviation	Q (mg/g)	R (%)	
	1	2	3	4	5	6	7	8	9	10					
Activated Charcoal Weight (g)	10	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.012	108.100	17.435
	20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	287.750	92.823
	30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	193.450	93.605
	40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	146.338	94.411
	50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	119.040	96.000
	60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	101.375	98.105
	70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.005	86.736	97.927
	80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.004	76.013	98.081
	90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.004	67.706	98.282
	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.005	60.915	98.250
		Variable Weight of activated charcoal = 10 – 100 g Fixed Initial Concentration of Mn(II) in polluted solution (Ci) = 1.24 mg/l Maximum permissible level for drinking water (Co) = 0.30 mg/l Fixed pH at 8.0 Fixed Polluted solution total volume = 5.0 liters Fixed bed glass column: radius = 15 cm; Height = 1.5 m Fixed Contact time = 40 minutes													

Table (5-b): Effect of activated charcoal weight on Fe(II) Adsorption.

Replicate No.	Fe(II) Output Concentration (Co: mg/l)										Mean Co	Standard Deviation	Q (mg/g)	R (%)	
	1	2	3	4	5	6	7	8	9	10					
Activated Charcoal Weight (g)	10	2.2	2.2	2.2	2.2	2.0	2.2	2.2	2.2	2.2	2.2	2.2	0.059	981.100	46.94
	20	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.026	836.100	80.01
	30	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.029	608.100	87.29
	40	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.033	479.538	91.78
	50	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.031	394.050	94.27
	60	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.035	328.142	94.20
	70	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.034	280.914	94.09
	80	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.024	245.719	94.06
	90	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.030	218.556	94.11
	100	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.040	196.355	93.95
	Variable Weight of activated charcoal = 10 – 100 g Initial Concentration of Fe(II) in polluted solution (Ci) = 4.18 mg/l Maximum permissible level for drinking water (Co) = 0.05 mg/l Fixed pH at 8.0 Polluted solution total volume = 5.0 liters Fixed bed glass column: radius = 15 cm; Height = 1.5 m Contact time = 40 minutes														

5) Determination of the Activated Charcoal Adsorption Capacity (mg/g):

As mentioned above, the charcoal adsorption capacity (mg pollutant/g charcoal) determines the limit the charcoal can be used before being

disposed, or reactivated by removal of adsorbed cations. Adsorption is controlled by the pollutant concentration in solution, and the empty adsorption sites on the charcoal surface, if all other factors are fixed. So, this test is done in the following two steps:

- **Adsorption under Higher Initial Pollutant Concentrations:** The pollutant initial concentration was increased step-by-step from 1.24 mg/l to 30.72 mg/l for Mn(II), and from 2.48 mg/l to 30.52 mg/l for Fe(II), using new charcoal material for every run. Adsorption uptake by charcoal increased with higher pollutant concentrations, and reached 2347.7 and 2421.0 mg/g for Mn(II) and Fe(II); respectively. Tables (6–a, b) show the experimental results, with the ten replicates that had no significant differences. Pollutant concentrations up to about 10.0 mg/l for both Mn(II) and Fe(II) resulted in output concentrations within the permissible limit for drinking water use (as highlighted/shaded in tables 6–a, b). At higher input concentrations, the pollutant output concentration exceeded the permissible limit for drinking water use, while percent removal efficiency (R) declined slightly from 98.15% and 96.32% down to 91.71% and 95.19% for Mn(II) and Fe(II); respectively. The increasing trend in adsorption uptake Q in figure (7–b) suggests that the charcoal adsorption capacity is higher than the values obtained in this experiment at 2347.7 and 2421.0 mg/g for Mn(II) and Fe(II); respectively. As shown in tables

(6-a, b), replicates showed non-significant variability in charcoal performance.

Table (6-a): Effect of pollutant initial concentration on Mn(II) Adsorption.

Replicate No.	Mn(II) Output Concentration (Co : mg/l)										Mean Co	Standard Deviation	Q (mg/g)	R (%)	
	1	2	3	4	5	6	7	8	9	10					
Polluted Solution Initial Mn(II) Concentration (mg/l)	1.24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	101.4	98.145
	5.21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	431.2	99.328
	7.08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	586.5	99.417
	10.09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	836.7	99.518
	15.21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	1263.092	99.652
	20.21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	1677.217	99.587
	24.26	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	0.026	1909.708	94.462
	27.31	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0.032	2147.825	94.375
	30.72	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	0.031	2347.700	91.707
	Variable Initial Concentration of Mn(II) in polluted solution (Ci) mg/l Variable Mn(II) Initial Concentration range = 1.24 – 30.72 mg/l Fixed amount of activated charcoal = 60 g Maximum permissible level for drinking water (Co) = 0.05 mg/l Fixed pH at 8.0 Fixed Polluted solution total volume = 5.0 liters Fixed bed glass column: radius = 15 cm; Height = 1.5 m Fixed Contact time = 40 minutes														

Table (6-b): Effect of pollutant initial concentration on Fe(II) Adsorption.

Replica No.	Fe(II) Output Concentration (Co: mg/l)										Mean Co	Standard Deviation	Q (mg/g)	R (%)	
	1	2	3	4	5	6	7	8	9	10					
Polluted Solution Initial Fe(II) Concentration (mg/l)	2.48	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	199.050	96.315
	4.18	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.017	329.058	94.467
	10.23	0.2	0.2	0.2	0.2	0.2	0.2	0.5	0.2	0.2	0.2	0.2	0.084	829.033	97.247
	15.34	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.030	1250.317	97.808
	17.52	0.3	0.3	0.39	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.012	1427.708	97.788
	19.89	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.025	1612.642	97.294
	22.35	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.008	1796.683	96.466
	25.15	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.002	2005.483	95.689
	26.45	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	0.003	2107.800	95.628
	30.52	1.4	1.4	1.4	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	0.056	2421.008	95.190
	Variable Initial Concentration of Fe(II) in polluted solution (Ci) mg/l Variable Fe(II) Initial Concentration range = 2.48 – 30.52 mg/l Fixed amount of activated charcoal = 60 g Maximum permissible level for drinking water (Co) = 0.3 mg/l Fixed pH at 8.0 Fixed Polluted solution total volume = 5.0 liters Fixed bed glass column: radius = 15 cm; Height = 1.5 m Fixed Contact time = 40 minutes														

- **Adsorption Under Repeated Runs Using Same Charcoal and Same Initial Pollutant Concentration:** As mentioned above, the experiment was re-run several times using the same amount of charcoal and the same initial pollutant concentration, in order to find the cumulative adsorption on charcoal surfaces. Tables (7–a, b) show the experimental results. As shown in tables (7–a, b), the output concentrations were within the permissible limit for drinking water use after 9 runs and 6 runs for Mn(II) and Fe(II); respectively. After 20 runs, adsorption removal efficiency declined from 98.25% and 94.68% down to 52.36% and 31.94% for Mn(II) and Fe(II); respectively. Meanwhile, the current run adsorption uptake (Q) declined over the 20 runs from 107.75 and 327.58 mg/g down to 57.42 and 110.50 mg/g for Mn(II) and Fe(II); respectively. However, cumulative adsorption uptake increased all along the experimental runs, and went up from 107.75 and 327.57 mg/g to reach 1871.42 and 5016.50 mg/g for Mn(II) and Fe(II); respectively. Although the increasing trend went milder after 20 runs, it still shows the possibility of increase with more runs. By far, 1871.42 and 5016.50 mg/g for Mn(II) and Fe(II); respectively are the highest adsorption uptake values obtained during all the experiments of this work. Note that, adsorption uptake should be higher at higher pollutant concentration.

Upon the practical use of the activated charcoal from *Salix aegyptiaca* (obtained from trunk wood of Al-Sefsaaf tree), it is advisable to use it up to

reaching its adsorption capacity (i.e. all the adsorption sites on its surface are occupied with pollutant cations). The above results, together with further experimentation should be used to determine the optimal use of the charcoal before disposal or leaching (re-generation) for re-use.

Table (7-a): Mn(II) adsorption under repeated experimental runs using the same charcoal and the initial concentration.

	Mn(II) Initial Conc. Ci (mg/l)	Mn(II) Output Conc. Co (mg/l)	Mn(II) Adsorption Removal Efficiency R (%)	Permissible Level for Drinking Water Use	Mn(II) Current Run Adsorption Uptake Q (mg/g)	Mn(II) Cumulative Adsorption Uptake Q (mg/g)	
Experimental Runs	1	1.316	0.023	98.25	Within PL	107.75	107.75
	2	1.316	0.027	97.95	Within PL	107.42	215.17
	3	1.316	0.031	97.64	Within PL	107.08	322.25
	4	1.316	0.038	97.11	Within PL	106.50	428.75
	5	1.316	0.041	96.88	Within PL	106.25	535.00
	6	1.316	0.044	96.66	Within PL	106.00	641.00
	7	1.316	0.048	96.35	Within PL	105.67	746.67
	8	1.316	0.05	96.20	Within PL	105.50	852.17
	9	1.316	0.052	96.05	Within PL	105.33	957.50
	10	1.316	0.061	95.36	OUT PL	104.58	1062.08
	11	1.316	0.123	90.65	OUT PL	99.42	1161.50
	12	1.316	0.152	88.45	OUT PL	97.00	1258.50
	13	1.316	0.172	86.93	OUT PL	95.33	1353.83
	14	1.316	0.242	81.61	OUT PL	89.50	1443.33
	15	1.316	0.345	73.78	OUT PL	80.92	1524.25
	16	1.316	0.412	68.69	OUT PL	75.33	1599.58
	17	1.316	0.402	69.45	OUT PL	76.17	1675.75
	18	1.316	0.485	63.15	OUT PL	69.25	1745.00
	19	1.316	0.488	62.92	OUT PL	69.00	1814.00
	20	1.316	0.627	52.36	OUT PL	57.42	1871.42
Fixed Initial Concentration of Mn(II) in polluted solution (Co) mg/l = 1.316 mg/l Fixed amount of activated charcoal = 60 g (non-replaced for all runs) Maximum permissible level for drinking water (Cf) = 0.3 mg/l Fixed pH at 7.61 Fixed Polluted solution total volume = 5.0 liters Fixed bed glass column: radius = 15 cm; Height = 1.5 m Fixed Contact time = 40 minutes							

Table (7–b): Fe(II) adsorption under repeated experimental runs using the same charcoal and the initial concentration.

		Fe(II) Initial Conc. Ci (mg/l)	Fe(II) Output Conc. Co (mg/l)	Fe(II) Adsorption Removal Efficiency R(%)	Permissible Level for Drinking Water Use	Fe(II) Current Run Adsorption Uptake Q (mg/g)	Fe(II) Cumulative Adsorption Uptake Q (mg/g)
Experimental Runs	1	4.152	0.221	94.68	Within PL	327.58	327.58
	2	4.152	0.256	93.83	Within PL	324.67	652.25
	3	4.152	0.271	93.47	Within PL	323.42	975.67
	4	4.152	0.292	92.97	Within PL	321.67	1297.33
	5	4.152	0.3	92.77	Within PL	321.00	1618.33
	6	4.152	0.305	92.65	Within PL	320.58	1938.92
	7	4.152	0.346	91.67	OUT PL	317.17	2256.08
	8	4.152	0.425	89.76	OUT PL	310.58	2566.67
	9	4.152	0.752	81.89	OUT PL	283.33	2850.00
	10	4.152	0.827	80.08	OUT PL	277.08	3127.08
	11	4.152	1.002	75.87	OUT PL	262.50	3389.58
	12	4.152	1.125	72.90	OUT PL	252.25	3641.83
	13	4.152	1.354	67.39	OUT PL	233.17	3875.00
	14	4.152	1.654	60.16	OUT PL	208.17	4083.17
	15	4.152	1.851	55.42	OUT PL	191.75	4274.92
	16	4.152	2.002	51.78	OUT PL	179.17	4454.08
	17	4.152	2.184	47.40	OUT PL	164.00	4618.08
	18	4.152	2.287	44.92	OUT PL	155.42	4773.50
	19	4.152	2.562	38.29	OUT PL	132.50	4906.00
	20	4.152	2.826	31.94	OUT PL	110.50	5016.50
Fixed Initial Concentration of Fe(II) in polluted solution (Co) mg/l = 4.152 mg/l Fixed amount of activated charcoal = 60 g (non-replaced for all runs) Maximum permissible level for drinking water (Cf) = 0.3 mg/l Fixed pH at 7.73 Fixed Polluted solution total volume = 5.0 liters Fixed bed glass column: radius = 15 cm; Height = 1.5 m Fixed Contact time = 40 minutes							

SUMMARY

This work examined the activated charcoal that is obtained from the trunk wood of *Salix aegyptiaca* (“Al-Sefsaaf” tree) as adsorbent material. It is newly introduced as a cheap, environmentally friendly adsorbent material to remove heavy metals from polluted water using fixed bed column technique. The objective of this work was to experimentally investigate the appropriate parameter values for preparation and use of this adsorbent material for efficient removal of Mn(II) and Fe(II) from polluted water.

Experimental results showed that (20% hydrochloric acid and 6.0 N zinc chloride) are the best combination for preparation treatment of the activated charcoal. In a fixed column bed, with 5.0 liters solution volume, and 1.24 and 4.18 mg/l concentrations of Mn(II) and Fe(II); respectively, the obtained values for best adsorption removal efficiency are: contact time of 40 minutes, pH at 7.0 to 8.0, and charcoal dose of 60 g.

Experiments were also done to explore the adsorption removal capacity of the activated charcoal (mg pollutant/g charcoal), which is useful in designing the economic use. Experiments were done at higher pollutant concentration that went up to 30 mg/l using new charcoal material in every run, and were also done with repeated runs using the same charcoal material at the same concentrations above. Experiments with higher pollutant initial concentrations resulted in adsorption uptake values of 2347.7 and 2421.0 mg/g for Mn(II) and Fe(II); respectively. Meanwhile, repeated runs using the

same initial pollutant concentration as above and the same amount of charcoal resulted in 1871.42 and 5016.50 mg/g for Mn(II) and Fe(II); respectively.

Results also show that adsorption capacity of the activated charcoal are thought to be higher than the obtained values, and it is recommended for further investigation. It is concluded that the newly introduced activated charcoal from *Salix aegyptiaca* is appropriate for use in adsorption removal of iron (II) and manganese (II) from polluted waters at normal pollution levels, and even higher pollutant concentrations up to 10 mg/l. At higher pollutant concentrations, the polluted water should go through more than one run to reach the permissible limits for use.

REFERENCES

- AWWA. A., & SCE, A., (1990): Water Treatment Plant Design. 2nd. New York: McGraw Hill.
- Babel, S. and Kurniawan, T.A. (2003): Low Cost Adsorbents for Heavy Metals Uptake from Contaminated Water: A Review. *Journal of Hazardous Materials*, 97: 219-243. [http://dx.doi.org/10.1016/S0304-3894\(02\)00263-7](http://dx.doi.org/10.1016/S0304-3894(02)00263-7)
- Biswas, B.K., Inoue, K., Ghimire, K.N., Harada, H., Ohto, K. and Kawakita, H. (2008): Removal and Recovery of Phosphorus from Water by Means of Adsorption onto Orange Waste Gel Loaded with Zirconium. *Bioresource Technology*, 99 : 8685-8690. <http://dx.doi.org/10.1016/j.biortech.2008.04.015>
- Bibaj, E., Lysigaki, K., Nolan, J.W. . Seyedsalehi M, Deliyanni E. A. Mitropoulos, A. C. & Kyzas G. Z. (201⁹): Activated carbons

from banana peels for the removal of nickel ions *International Journal of Environmental Science and Technology* 16: 667–680, 10.1007/s13762-018-1676-0. 2019

Chen, S., Yue, Q., Gao, B. and Xu, X. (2010): Equilibrium and Kinetic Adsorption Study of the Adsorptive Removal of Cr (VI) Using Modified Wheat Residue. *Journal of Colloid and Interface Science*, 349: 256-264.

<http://dx.doi.org/10.1016/j.jcis.2010.05.057>

De Gisi, Sabino, Giusy Lofrano, Mariangela Grassi, Michele Notarnicola (2016): Characteristics and adsorption capacities of low-cost sorbents for wastewater treatment: A review, *Sustainable Materials and Technologies*, 9: 10-40,

Demirbas, A. (2008): Heavy Metal Adsorption onto Agrobased Waste Materials: A Review. *Journal of Hazardous Materials*, 157: 220-229.

<http://dx.doi.org/10.1016/j.jhazmat.2008.01.024>

EHCW, (2007): Standards and Specifications of Water for Drinking and Domestic Use. Decree of the Minister of Health and population Ministry of Health and Population. 10: 458,, <https://doi.org/10.1016/j.desal.2009.05.006>

Elsayed, S., & Salem W.M. (2015). Hydro-chemical assessment of surface Nile water and groundwater in an industrial area – South West Cairo. *Egyptian Journal of Petroleum*, 24: 277-288.

<https://doi.org/10.1016/j.desal.2009.05.006>

Ghimire, K.N., Inoue, K., Ohto, K. and Hayashida, T. (2007): Adsorptive Separation of Metallic Pollutants onto Waste Seaweeds, *Porphyra yezoensis* and *Ulva japonica*. *Separation Science and Technology*, 42: 2003-2018.

<http://dx.doi.org/10.1080/15363830701313461>

- Heidarinejad, Zoha & Dehghani, Mohammad Hadi & Heidari, Mohsen & Javedan, Gholamali & Ali, Prof. Imran & Sillanpää, Mika. (2020): Methods for preparation and activation of activated carbon: a review. *Environmental Chemistry Letters*. 18: 1-23. 10.1007/s10311-019-00955-0.
- Homagai, P.L., Ghimire, K.N. and Inoue, K. (2011): Preparation and Characterization of Charred Xanthated Sugarcane Bagasse for the Separation of Heavy Metals from Aqueous Solutions. *Separation Science and Technology*, 46: 330-339. <http://dx.doi.org/10.1080/01496395.2010.506903>
- Ibrahim, N., (2016): The relations between Concentrations of Iron and the pH in Groundwater, *International Journal of Environmental Monitoring and Analysis*. 4 (6): 140-145.
- Igwe, J.C. and Abia, A.A. (2006): A Bio-separation Process for Removing Heavy Metals from Wastewater Using Bio-sorbents—Review. *African Journal of Biotechnology*, 5: 1167-1179.
- Islam, T.A., Begum, H.A., Hossain, M.A. and Rahman, M.T. (2009): Removal of Pb(II) from Aqueous Solution by Sorption on Used Tea Leaves. *Journal of Bangladesh Academy of Sciences*, 33: 167-178.
- Kour, J., Homagai, P.L., Cagnin, N., Masi, A., Pokhrel, M.R. and Ghimire, K.N. (2013): Adsorption of Cd(II), Cu(II), and Zn(II) from Aqueous Solution onto Nitrogen-Functionalized *Desmostachya bipinnata*. *Journal of Chemistry*,. <http://dx.doi.org/10.1155/2013/649142>
- Kusworo , T.D., Qudratun, N.A., Utono, D.P., (2018): Oilfield produced water treatment to clean water using integrated activated carbon-bentonite adsorbent and double stages membrane process, *Chem.l Eng. J.*, 347: 462-471

Latif , S., Reham, R., Imran, M., Hussain, M.S., Iqbal, S., Mitu, L., (2020): Removal of Cadmium (II) and Lead (II) from water by chemically treated citrullus lanatus peels as biosorbent in cost effective way, *Rev. Chim.*, 71: 182-192

Mahvi, A.H., Naghipour, D., Vaezi, F. and Nazmara, S. (2005): Tea-waste as an Adsorbent for Heavy Metal Removal from Industrial Wastewaters. *American Journal of Applied Sciences*, 2: 372. <http://dx.doi.org/10.3844/ajassp.2005.372.375>

Moussavi, G. and Khosravi, R. (2010): Removal of Cyanide from Wastewater by Adsorption onto Pistachio Hull Wastes: Parametric Experiments, Kinetics and Equilibrium Analysis. *Journal of Hazardous Materials*, 183: 724-730.

<http://dx.doi.org/10.1016/j.jhazmat.2010.07.086>

Nasrollahzadeh, Mahmoud, Monireh Atarod, Mohaddeseh Sajjadi, S. Mohammad Sajadi, Zahra Issaabadi (2019): Chapter 6 - Plant-Mediated Green Synthesis of Nanostructures: Mechanisms, Characterization, and Applications, Editor(s): Mahmoud Nasrollahzadeh, S. Mohammad Sajadi, Mohaddeseh Sajjadi, Zahra Issaabadi, Monireh Atarod, *Interface Science and Technology*, Elsevier, Volume 28: 199-322,

ISSN 1573-4285, ISBN 9780128135860.

Nieto, L.M., Alamia, S.B.D., Hodaifab, G., Faurc, C., Rodrigueza, S., Gimeneza, J.A. and Ochando, J. (2010): Adsorption of Iron on Crude Olive Stones. *Industrial Crops and Products*, 32: 467-471.

<http://dx.doi.org/10.1016/j.indcrop.2010.06.017>

Nurchi, V.M. and Villaescusa, I. (2008): Agricultural Biomasses as Sorbents of Some Trace Metals. *Coordination Chemistry Review*, 252, 1178-1188.

<http://dx.doi.org/10.1016/j.ccr.2007.09.023>

- Rodriguez , A.Z., Wange, H., Hu, L., Zhang, Y., Xu, P., (2020): Treatment of produced water in the permian basin for hydraulic fracturing: comparison of different coagulation processes and innovative filter media, *Water (Basel)*, 12: 770-781
- Ruiti, Manel and Béchir Ben Thayer (2015): Removal of iron from artificial groundwater by adsorption on charcoal. *International Journal of Scientific Research & Engineering Technology (IJSET)*, 3: 133-137
- Sankaramakrishnan, N. and Sanghi, R. (2006): Preparation and Characterization of a Novel Xanthated Chitosan. *Carbohydrate Polymers*, 6: 160-167.
<http://dx.doi.org/10.1016/j.carbpol.2006.02.035>
- Shrestha, B., Homagai, P.L., Pokhrel, M.R. and Ghimire, K.N. (2012): Adsorptive Removal of Toxic Metal from Aqueous Solution by Using a Bio-waste Used Tea Leaves. *Nepal Journal of Science and Technology*, 13: 109-114.
- Shamaei, L., Khorshidi, B., Perdicakis, B., Sadzadeh, M., (2018): Treatment of oil sands produced water using combined electrocoagulation and chemical coagulation techniques, *Sci. Total Environ.*, 645: 560-572
- Sun, G. and Shi, W. (1998): Sunflower Stalks as Adsorbents for the Removal of Metal Ions from Wastewater. *Industrial & Engineering Chemistry Research*, 37: 1324-1328.
<http://dx.doi.org/10.1021/ie970468j>
- USEPA. (United States Environmental Protection Agency) (2001): Office of water. National secondary drinking water regulations. In Code of Federal Regulations, 612-614.
- USEPA. (2018): Edition of the Drinking Water Standards and Health Advisories, EPA 822-F-18-001, Office of Water, U.S. Environmental Protection Agency Washington,

Vimala, Das, N. R. and P. Karthika (2008): Bio-sorption of Heavy Metals—
An Overview. *Indian Journal of Biotechnology*, 7: 159-169.

Volesky, B. and Holan, Z.R. (1995): Bio-sorption of Heavy Metals.
Biotechnology Progress, 11: 235-250.
<http://dx.doi.org/10.1021/bp00033a001>

Wan Ngah, W. S., & Hanafiah, M. A. K. M. (2008): Removal of heavy metal
ions from wastewater by chemically modified plant
wastes as adsorbents: A review. *Bio-resource Technology*, 99:
3935-3948.

<http://dx.doi.org/10.1016/j.biortech.2007.06.011>.

WHO (2003): Guidelines for Drinking Water Quality. World Health
Organization, Germany.

إزالة المنغنيز والحديد من المياه الملوثة عن طريق الأدمصاص على سطح كربون الفحم المنشط والمستخلص من أشجار الصفصاف المصري

سعد محمد السيد^(١) - نبيل محمد أنور^(٢)

(١) كليات عينزة الأهلية المملكة العربية السعودية (٢) معهد أبحاث البيئة والمناخ المركز القومي
لبحوث المياه

المستخلص

يعد تلوث مياه الابار الجوفية بالمعادن الثقيلة من المنغنيز والحديد مشكلة خطيرة تحدث في
العديد من المواقع في مصر حيث تحتوي العديد من رواسب الطين بشكل طبيعي على هذين المعدنين
الثقلين. يتم إطلاق المنغنيز والحديد من رواسب الطين ومنها الى المياه الجوفية حيث يحدث اتلوث
المياه. من الضروري إزالة المنغنيز والحديد من هذه المياه قبل الاستخدام، خاصة كمياه الشرب.
يفحص هذا العمل الفحم النشط الذي يتم الحصول عليه من جذع شجرة (الصفصاف) كمادة مدمصه.
تم استخدام شجر الصفصاف بالذات كونه مادة ماصة رخيصة وصديقة للبيئة لإزالة المعادن الثقيلة

من المياه الملوثة باستخدام تقنية عمود السرير الثابت. تم تحضير الكربون المنشط من شجرة الصفصاف بواسطة التنشيط الكيميائي باستخدام حمض الهيدروكلوريك ومحلول كلوريد الزنك. أظهرت النتائج التجريبية أن (٢٠٪ حمض الهيدروكلوريك و ٦,٠ نورمال كلوريد الزنك) هي أفضل خليط لتحضير ومعالجة الفحم المنشط في قاع العمود الثابت، مع حجم المحلول ٥,٠ لتر، وتركيزات ١,٢٤ و ٤,١٨ ملغم / لتر من المنجنيز والحديد على التوالي. القيم التي تم الحصول عليها لأفضل كفاءة لإزالة الامتزاز هي: وقت التلامس ٤٠ دقيقة، ودرجة الحموضة من ٧,٠ إلى ٨,٠، وجرعة الفحم ٦٠ جم. أظهرت النتائج أن السعة الامتصاصية للفحم المنشط يُعتقد أنها أعلى من القيم التي تم الحصول عليها، ويوصى بمزيد من التجارب والابحاث. اثبتت النتائج التي تم الحصول عليها أن الفحم المنشط الذي تم تحضيره من شجرة الصفصاف مناسب للاستخدام في إزالة امتصاص الحديد والمنغنيز من المياه الملوثة بمستويات تلوث طبيعية، وحتى تركيزات أعلى من الملوثات تصل إلى ١٠ مجم / لتر. في حالة وجود تركيز أعلى من الملوثات، يجب أن تمر المياه الملوثة بأكثر من مسار للوصول إلى الحدود المسموح بها للاستخدام

الكلمات المفتاحية: المياه الملوثة - الحديد والمنجنيز -الادمصاص - الفحم المنشط - الصفصاف المصري