Removal of Natural Organic Matter and Turbidity in Drinking Water by Modified Flaxseed Husk

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Annotation

In the present study, the removal of turbidity and natural organic matter (NOM) by modified flaxseed husk (MFH) were investigated. The characterization of MFH revealed high specific surface area (125.18 m^2/g) with average pore diameter of 26.28 μm. Moreover, FTIR spectra indicated the existence of large number of amino groups. Flaxseed husk was mixed with aluminum sulphate to increase the efficiency of coagulation. The optimum ratio for removal of NOM was (40%:60%). The NOM was quantified in this study by the UV light absorbance at wavelength of 254 nm (UV254). Using a MFH dosage of 50 mg/L attained a removal efficiency of 97.7 % for turbidity and 98.4 % for UV254. The experimental results revealed the favorability of treatment of raw water contaminated with NOM by MFH

Keywords: Coagulation; Flaxseed husk; Natural organic matter (NOM); Turbidity

Abbreviations: NOM: Natural Organic Matter; MFH: Modified Flaxseed Husk; FTIR: Fourier Transform Infrared Spectroscopy; BET: Brunauer-Emmett-Teller.

Introduction

The existence of natural organic matter (NOM) in drinking water has received considerable attention in recent decades, because it may cause, color and taste problems in addition to the formation of disinfection by-products (DBPs) [1]. NOM is detected in most of water sources such as lakes and rivers [2]. It has been reported that most of NOM in surface and ground water are in the form of humic and fulvic acids [3]. Humic and fulvic acids react with the chlorine based materials during the disinfection process and hence DBPs are formed. DBPs are carcinogenic and cause many health and environmental problems to human and aquatic life [4,5]. Chemical coagulation using aluminum sulphate followed by sedimentation and filtration are the most prevalent sequence in water treatment plants. These basic processes are efficient for the removal of colloidal or suspended particles, but the removal of NOM is limited [6]. Some researchers enhanced the coagulation process to remove NOM by adjusting the water pH and increasing the amount of coagulant, but the high amount of chemical addition was a concern [7]. Lieknes investigated the micro-filtration by metal membranes as a post process after coagulation for NOM removal [8]. However, the cost of micro-filtration was not considered.

Many researchers have used the adsorption by activated carbon and advanced oxidation processes for removal or degradation of different organics from water [9-12]. While, other researchers have developed low cost adsorbent materials that prepared from agricultural residues such as wheat straw [13], rice husk [14], peanut hull coconut husk [15], black gram husk [16], Sawdust [17], sugarcane bagasse [14], banana pith [18], and pine grape stalk [16]. In this paper, chemically modified flaxseed husk (MFH) was used for drinking water treatment. MFH was prepared by addition of aluminum sulphate. The removal of turbidity and NOM by coagulation and adsorption using MFH were deeply investigated.

Materials and Methods

Materials and Raw Water

Flaxseed was purchased from a local market and stored at room temperature, ($Al_2 (SO_4)_3.16H_2O$, n-hexane, what man filter paper grad 1, $NaHCO_3$ were purchased from Somat-co, El- Riyad City. The raw water was collected from different wells in Skaka, Al Jouf, and Saudi Arabia. The characteristics of raw water are illustrated in (Table 1). All the experiments were conducted without prior modifications of samples.

Table 1: Physicochemical characteristics of raw water.

Temperature 0C	pH	Turbidity (NTU)	UV254 (cm^{-1})	T.D.S (mg.l^{-1})	Conductivity (μs.cm^{-1})
20 - 23	7.0 - 7.8	4.0 - 9.5	0.05 - 0.44	975 - 989	1400 - 1408

Experimental Work

MFH was prepared according to Tehrani et al. [19] with modification. First 50 gm of the seeds were washed with distilled water and treated with 0.5 M NaHCO$_3$ (1:8 w/v, 40°C) under vigorous stirring for 1 hr. The seeds were then washed several times with distilled water and dried by remaining at room temperature for 24h. After removing of mucilage, the dried seeds were crushed by a general lab grinder and the resulting matter was stirred with n-hexane (1:5, w/v) for 6 h at 4°C. Hexane was renewed every 2 h by paper filtration of the suspension. Following final filtration, the treated matter was kept in dark to be air dried and then stored at 4°C. The resulted material was called (FH-OUT M,O). Fourier transform infrared spectroscopy (FTIR) spectra were recorded on a PerkinElmer "Spectrum BX" spectrometer in the range of 4000-400 cm^{-1} using KBr pellets for sample preparation. Surface area and pore size were determined by Brunauer-Emmett-Teller (BET) analysis using Belsorp-max automated apparatus using liquid N2 adsorption at temperature of 77 K. (FH-OUT M,O) was then used with aluminum sulphate (AS), as a mixed coagulant with different dosages as specified in (Table 2).

Table 2: Coagulants dosage combinations.

Point	% Coagulant (Al$_2$(SO$_4$)$_3$.16H$_2$O/ FH-OUT$_{M,O}$)	Coagulant dosage (mg.L^{-1}) Al$_2$(SO$_4$)$_3$.16H$_2$O	FH-OUT$_{M,O}$
1	0%, 100%	0	50
2	20%, 80%	5	40
3	40%, 60%	10	30
4	60%, 40%	15	20
5	80%, 20%	20	10
6	100% , 0%	25	0

Operational conditions of coagulation/flocculation and sedimentation process used in the association of seeds of (FH-OUT M,O) and alum coagulants are presented on (Table 3). After completing the coagulation/flocculation and sedimentation process, samples was taken 3 cm under the water surface and filtered by what man filter paper grad 1 (pore size of 0.6 μm). Finally, the residual turbidity and UV254 were quantified by 2100 P Turbidimeter Hach Co, and spectrophotometer DR 5000 Hach Co respectively. For evaluation of coagulation efficiency, 1000 ml of raw water was transferred into a beaker with a certain dosage of MFH. The process included 3 min of rapid mix at 350 rpm, 30 min of slow mixing at 60 rpm for flocculation, and 30 min for settling. Adsorption experiments were executed by mixing MFH with raw water using a magnetic stirrer at 150 rpm for 120 min without heat. Subsequently, MFH was removed by filtration through a what man filter paper grad 1 (pore size of 0.6 μm) for measurements. Hybrid process including coagulation and adsorption was carried out as follows: first: coagulation followed by adsorption, second: adsorption followed by coagulation. Coagulation and subsequent adsorption tests were performed after collection of samples after sedimentation, and then different doses of MFH were added. Adsorption followed by coagulation experiments were executed by adding a certain dosage of coagulants with mixing stirring similar to coagulation experiments. Then, a sample was taken using the same procedure.

Table 3: Operational conditions of coagulation/flocculation and sedimentation process for point 3, 4.

Assay	1	2	3	4	5	6
RMV (rpm)	200	300	350	250	300	350
RMT (min)	1	1	1	3	3	3
SMV (rpm)	60	60	60	60	60	60
SMT(min)	15	20	30	15	20	30
ST (min)	15	15	15	30	30	30

RMV: rapid mixing velocity; RMT: rapid mixing times; SMV: slow mixing velocity; SMT: slow mixing times; ST: sedimentation times.

Results and Discussion

Characterization of the FH

The specific surface area of FH was found to be 125.18 m^2/g. The average pore diameter of FH was found to be 26.28 μm indicating reasonable adsorption capacity. FTIR spectra results are shown in (Figure 1). Ketone and alkane groups (C-H) were detected by the band intensity at 2850 c m^{-1} and 2925 cm^{-1}, and the band at 1650 c m^{-1} was associated with the special vibration of aromatic cyclic groups. The intense vibration at 1350 cm^{-1} further indicated that large number of amino groups has been grafted into the FH structure.
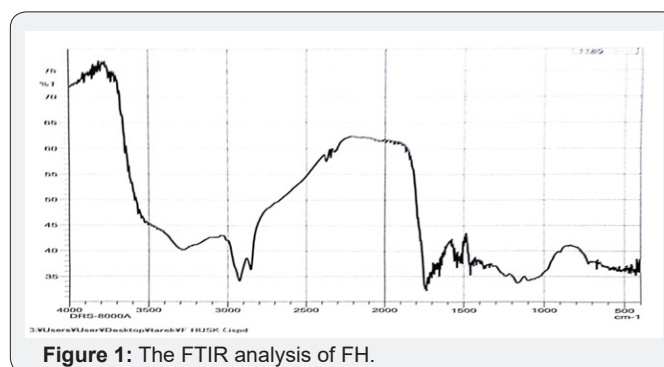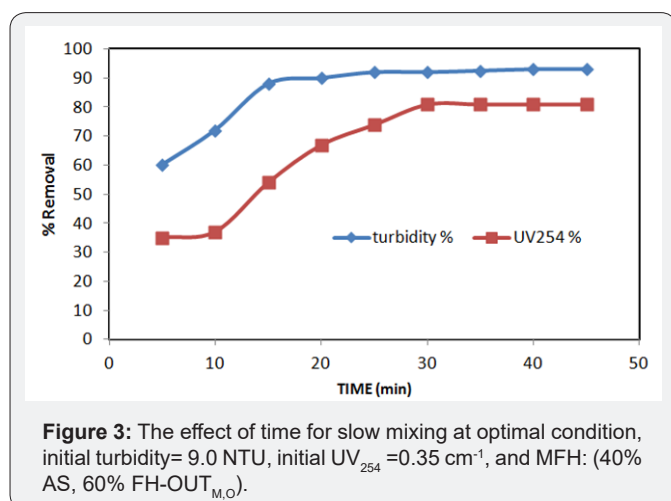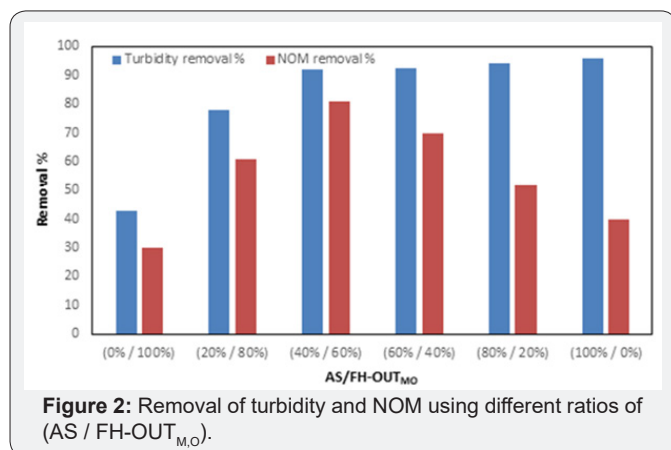

Figure 1: The FTIR analysis of FH.

Removal of Turbidity and NOM

The removal efficacies of turbidity and NOM at different percentages of AS / FH-OUTM, O are shown in (Figure 2). The higher percentage of AS leads to better removal of turbidity due to the abundance of dissolved positively charged aluminum ions which neutralize the suspended particulates and increase the potential of agglomeration and floc formation [5]. On the other hand, the optimal ratio of (AS / FH-OUTM, O) for removal
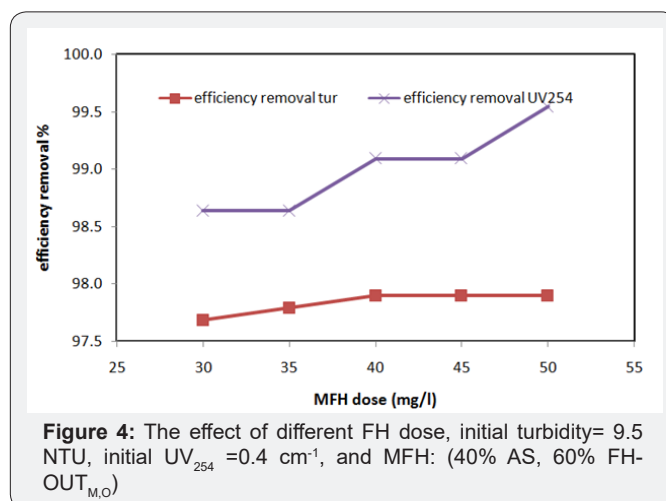
of NOM was (40/60) which attained a removal efficiency of 81%. The higher percentage of AS leads to smaller surface area of coagulant/polymer which inhibit the adsorption of NOM on FH-OUTM,O. In addition, the lower percentage of AS decreases the efficiency of agglomeration and precipitation of suspended particulates which reduce the NOM removal.

Figure 2: Removal of turbidity and NOM using different ratios of (AS / FH-OUT$_{M,O}$).

Figure 3: The effect of time for slow mixing at optimal condition, initial turbidity= 9.0 NTU, initial UV$_{254}$ =0.35 cm^{-1}, and MFH: (40% AS, 60% FH-OUT$_{M,O}$).

The effect of slow mixing time on the removal of turbidity and NOM is shown in (Figure 3). It is clear that increasing the slow mixing time improved the removal of both turbidity and NOM. This improvement was attained because the particulates have adequate time to agglomerate and form stable flocs [20]. The maximum removal efficiency of turbidity was achieved after about 20 min of slow mixing, and additional time did not improve the removal of turbidity because the coagulant dose may be consumed at this stage and additional dosage may be required [21]. The optimum removal of NOM was attained after 30 min of mixing, while additional time did not significantly improve the removal. Such a trend could be attributed to the consumption of aluminum ions and the occupation of all active sites on FH-OUTM,O surface[22]. Accordingly, the optimum slow mixing time is considered 30 min in this study. The adsorption of organic molecules may be attributed to the electrostatic attraction forces with amino groups of flaxseed husk which have been detected in FTIR spectra [9].

Effect MFH Dosage and Initial NOM

Different dosages of MFH were tested to investigate the optimum dosage for NOM and turbidity removal as shown in (Figure 4). It is clear that increasing the dosage more than 30 mg/L slightly improve both turbidity and NOM removal. This finding is due to the agglomeration of most of suspended particulates and/or adsorption of dissolved organic matter on MFH particles [23]. Accordingly, excess MFH amount will not significantly improve the efficiency.

Figure 4: The effect of different FH dose, initial turbidity= 9.5 NTU, initial UV$_{254}$ =0.4 cm^{-1}, and MFH: (40% AS, 60% FH-OUT$_{M,O}$)

The removal efficiency of NOM at different initial concentrations was investigated and exhibited in (Figure 5). The removal efficiency results ranged from 98.4% to 100%, using the optimum dosage of MFH. The removal efficiency was between 98.8 % and 100 % for initial concentration of UV254 between 0.05 to 0.18 mg/l, and between 98.4 % and 99.3 % for initial concentration of UV$_{254}$ between 0.19 and 0.44 mg/l. The high efficiency is due to the attractive of NOM to the functional groups in FH and to the high surface area which suggests high adsorption capacity [11]. This finding indicates that the MFH could be used for removal of high concentration of NOM from water.

Figure 5: The effect of different concentrations at optimal condition, MFH: (40% AS 60% FH-OUT$_{M,O}$).
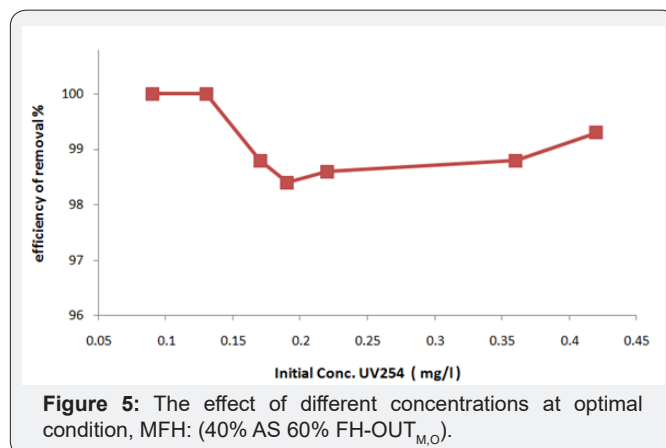
Conclusion

In this study, flaxseed husk was modified and used for removal of turbidity and NOM from drinking water. The

characterization of FH reveals high adsorption capacity due to the high surface area and the existence of large number of amino groups. The optimal ratio of (AS / FH-OUTM,O) for removal of NOM was (40% / 60%) which attained a removal efficiency of 81%. Increasing the dosage of MFH to 50 mg/L significantly improved the removal efficiency to 97.7 % for turbidity and 98.4 % for UV254. Moreover, the MFH revealed high removal efficiency at higher initial UV254 value which suggests the favorability for treatment of raw water contaminated with NOM.

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