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Original Research

Enhancing Electrocoagulation Process Efficiency Using Astraglus Gossypinus Tragacanth in Turbidity Removal from Brackish Water Samples

Amin Zarei[1], Hamed Biglari[2*], Mohammad Mobini[3], Gholamreza Ebrahimzadeh[4], Ahmad Reza Yari[5], Mohammad Reza Narooie[6], Ehsan Abouee Mehrizi[7], Abdollah Dargahi[8], Mohammad Mehdi Baneshi[9], Mohammad Javad Mohammadi[10], Sajad Mazloomi[11]

[1]Department of Environmental Health Engineering, School of Health, Torbat Heydariyeh University of Medical Sciences, Torbat Heydariyeh, Iran
[2]Department of Environmental Health Engineering, School of Public Health, Gonabad University of Medical Sciences, Gonabad, Iran
[3]Department of Environmental Health Engineering, School of Health, Rafsanjan University of Medical Sciences, Rafsanjan, Iran
[4]Department of Environmental Health Engineering, School of Public Health, Zabol University of Medical Sciences, Zabol, Iran
[5]Research Center for Environmental Pollutants, Qom University of Medical Sciences, Qom, Iran
[6]Department of Environmental Health Engineering, School of Public Health, Iranshahr University of Medical Sciences, Iranshahr, Iran
[7]Department of Environmental Health Engineering, Faculty of Public Health, North Khorasan University of Medical Sciences, Bojnurd, Iran
[8]Department of Environmental Health Engineering, School of Health, Kermanshah University of Medical Sciences, Kermanshah, Iran
[9]Social Determinants of Health Research Center, Yasuj University of Medical Sciences, Yasuj, Iran
[10]Student Research Committee, Department of Environmental Health Engineering, School of Public Health and Environmental Technologies Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
[11]Department of Environmental Health Engineering, Faculty of Health, Ilam University of Medical Sciences, Ilam, Iran

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*e-mail: biglari.h@gmu.ac.ir

Abstract

Colloidal particles are the main cause of turbidity in an aquatic environment. Water turbidity maintains pathogenic microorganisms against disinfection. In addition to increasing the consumption of antiseptic substances, mainly it causes a lot of aesthetic and non-sanitary problems such as the formation of toxic and carcinogenic side constituents in the treatment of water. In this study we investigated the efficiency of the use of tragacanth of Astraglus gossypinus (Catira) on the effectiveness of the electrocoagulation process in the removal of turbidity from brackish water. In this descriptive-analytic study, direct bentonite injections of 2 to 8 g/L were used to provide opacity. In the following, the effect of applying coagulant aid of Tragacanth of Astraglus gossypinus plant with values of 0.25 to 1.5 g/L on the efficiency of the electro-coagulation process equipped with iron electrodes in the removal of opacity from brackish water samples were examined in potential difference from 5 to 30 volts, and pH from 2 to 9 over a period of 60 min. Variation of turbidity was determined using the turbidity sensor in accordance with standard reference methods. The results showed that the highest opacity removal efficiency is about 99% for each 1 kg of opacity due to the addition of 7 g/L bentonite under neutral pH conditions, Tragacanth dose of 1.5 g/L, 8 g/L dose of NaCl, and voltage of 30 V for 30 min, along with the average consumption of iron and electrical energy of 0.18 kg and 0.53 Kwh, respectively. Thus, the use of Astraglus gossypinus tragacanth for removing turbidity as a natural coagulant aid dramatically improves the electrocoagulation process efficiency in the removal of turbidity from brackish water samples and reduces current costs of the electro-coagulation process.

Keywords: turbidity, aid coagulant, Astraglus gossypinus, Tragacanth, electrocoagulation, brackish water, catira

Introduction

Health promotion and environmental protection are always dependent on the availability of clean water [1-5]. Today the topic of optimal and affordable water purification is one of the most serious problems of researchers in the world [6-8]. This issue threatens the health and safety of citizens in developing countries at macro levels of management due to the inability to fully control water purification and the crisis of non-sanitary problems [9-12]. Removing suspended particles and colloids is one of the most significant stages of water purification that is performed during the set of processes and operations, including coagulation, flocculation, and sedimentation [13-15]. High water turbidity can cause microorganisms to be maintained against the effect of antiseptic substances and lead to the growth of bacteria, as well as increase the amount of needed antiseptic substances. For effective disinfection, it is better to have less opacity than one NTU. Also, turbidity of more than NTU 5 is detectable and leads to consumer complaints [16-18]. Turbidity in the water is generally created by suspended matter like soil and mud, fine organic and mineral substances, soluble colored organic compounds, plankton, and other microorganisms [19]. In recent years, attention to the removal of turbidity has become more important because of the connection between opacity factors with microorganisms such as giardia and cryptosporidium [20].

Coagulation and flocculation play an important role in surface water treatment. This process enhances the efficiency of following processes by reducing opacity in water purification, including filtration and disinfection [21]. Using coagulant in addition to the primary coagulant and improving the quality of treated water has other benefits such as water enrichment, more successful disinfection, and the resulting sludge density [22-23]. In order to eliminate health problems and reduce production costs as well as the use of synthetic coagulants, numerous research regarding the use of natural coagulants has been carried out so far [14, 24].

The history of using different parts of plant materials such as bark, roots, stems, and seeds for water clarification is related to a book written in Sanskrit 4,000 years ago in India. Indians implemented the seeds of a nirmali tree to clear up turbid water of rivers [25]. Also, water was cleared up traditionally in Peru by a slimy sap of cactus leaves with optimum efficiency [26]. So far, the effectiveness and usability of banana peel, cumin plant, guar gum, Chinese hibiscus, fenugreek and lentils, okra, tea, rice, chitosan, etc. have been examined in water purification and as coagulant aids in various studies [27-32]. Several processes like electro-coagulation (EC) have been introduced [33]. The EC process is one of the most common processes that relies on the foundation coagulation and flocculation. It is an electrochemical process that uses direct current (DC) for the production of original metal coagulants [33]. In the EC process, coagulant is produced by direct flow from the anode electrode during the reaction of electrolytic oxidation [34]. EC is an electrochemical process that uses DC for the production of primary metal coagulants [33]. In the EC process, the coagulant is produced through the DC of the anode electrode during the reaction of electrolytic oxidation [34]. The type of produced metal coagulant is dependent on the electrode material and generally is made of iron or aluminum [35]. In this process, pollutants are removed under a set of chemical and physical processes, especially the coagulation process and sedimentation from the water environment [19].

In the meantime, it seems that its coagulant properties are worthy of review due to the jelly tragacanth nature of the Astraglus gossypinus plant. Moreover, its shrub reaches up to a maximum height of one m and it often grows in mountainous regions and arid meadows in a self-propelled way. Gum materials in stem tissue of the plant species, which are collected and leaked automatically, or due to the creation of a gap are called Tragacanth. Productive species of Tragacanth grow in warm and mountainous areas. More than 900 different species grow in different parts of Iran. Generally, productive varieties of Tragacanth gum are acanaceous, which are referred to as Astrakanta [36]. Tragacanth is counted as one of the most important pasture products. Since ancient times, people have been familiar with its properties and used it in various industries [37-38]. In various studies, the effects of using natural coagulants on the efficiency of the EC process in the removal of various pollutants has been investigated [39-41]. Given that large quantities of tragacanth are produced and collected in different places especially in Iran currently, initial and processing costs are negligible. So it should be considered to be a naturally inexpensive coagulant from this perspective. Therefore, efficiently using tragacanth of Astraglus gossypinus plant as a natural coagulant was investigated in this study on the efficiency of the electro-coagulation process for removing turbidity from brackish waters.

Materials and Methods

All chemicals used in this study were provided from the Merck brand in Germany. Applied coagulant aids in this study are a gum plant with the scientific name of Astraglus gossypinus. Design, manufacture, and operation of an electro-coagulation reactor was conducted in bipolar form by a closed method. The reactor was manufactured in dimensions of 13*12*13 cm from unbreakable and acid corrosion-resistant glass (buccal) with an effective volume of one l. Then it was used after being equipped with 4 plate electrodes of iron with thickness of 2 mm, area 121 cm^2, and spacing of 2 cm from each other. Required voltage was supplied to convert urban electric power alternating current (AC) to DC by a transformer with a maximum power of 30 V and 5 amps current. Turbidity removal in the process of EC was investigated by changing the parameters of 2-10 pH by H_2SO_4 and NaOH of 0.1 normal, 2-7g/L dose of bentonite to make opacity, electric conductivity by adding sodium chloride 2-8 g/L, and the dose of Tragacanth was 0.25 to 1.5 g/L for a reaction time of maximum 60 min. 100 g of Astraglus gossypinus Tragacanth was dried and powdered to prepare the solution of Tragacanth, and it was weighed accurately. It reached a volume of 100 mL after mixing with 10 mL of chloride acid of 0.1 mol using distilled water. Then it was kept in the refrigerator as long as needed. Each one mL of this solution contained one g of tragacanth [42].

To provide brackish water and examine the effect of other parameters as well as to provide minimal electrical conductivity of solvent, the specified amount of pure NaCl was added to all samples at the beginning of the process. After beginning the process and passing certain amount of time, samples were taken from the middle of the reactor. Variation of opacity values in accordance with standard methods using the portable turbidity meter (AL250T model, Aqualytic, made in Germany) was investigated after applying sedimentation time for 30 min. All experiments were performed discontinuously with 3 repetitions. It has been reported in some studies that pH adjustment during the process of clots' production makes hydroxyl different. Therefore, no pH adjustment was made after the onset of the process in this study [43]. Considering the importance of the amount of electrical energy as well as the weight of the used electrode from economic and system performance aspects, the rate was calculated and presented using the following formulas [41]:

$$E = \frac{I.\int_0^t U.dt}{V.C_0.\frac{Y_t}{100}} \quad (1)$$

...where E is the consuming energy (kWh/kg), I is current intensity (A), voltage (V), t is time (h), V is the volume of the treated solution (L), and Y_t is color removal efficiency at time t (%).

$$M = \frac{3600.I.t.A}{n.F.V.C_0.\frac{Y_t}{100}} \quad (2)$$

...where M is the unit electrode material demand (kg/kg), t is time (h), n is the number of electrons involved in the oxidation/reduction reaction, F is Faraday's constant (C/mol), and A is atomic mass of the electrode material (g/mol).

Results and Discussion

Effect of Primary pH Change

Each coagulant substance with a certain concentration in an optimum pH in the process of coagulation and flocculation has the highest rate of efficiency in the shortest possible time with the significant possible returns. Thus, examining the pH effect of aqueous solutions is considered one of the key and effective factors in chemical coagulation processes [27]. In many studies, the effect of pH on the efficacy of removing pollutants in the process of chemical coagulation and its effect depending on the type of pollutant as well as the used process were mentioned [44]. The efficiency of simultaneously using the tragacanth and the EC process are shown Fig. 1 in removing the opacity at different pH values. Results indicate that the highest rate of opacity removal efficiency from aqueous solution occurred at neutral pH, and that efficiency at lower or higher pH was decreased. Based on the study carried out by Bazrafshan et al. [35], clots are significantly larger at optimal pH and the process of coagulation-sedimentation is more efficient. Hence, the dominant mechanism of coagulation-sedimentation in a sweep coagulation mechanism is the trapping of suspended particles in the polymer chains of a coagulant substance.

It has also been reported in other studies that most iron ions at neutral pH are effectively gelatinous clots of sedimentary $Fe(OH)_3$ [33, 45]. Findings of the study by Bazrafshan et al. [35] specify that the formation of iron hydroxide clots is decreased at a pH below and above the optimal pH and, consequently, efficiency is also reduced. Removing a hydrocarbon pollutant from Sewage using the electrical coagulation process was investigated by Tir et al. [46], whose findings indicate that efficiency of the process was almost constant at pH 6 and 7, while reducing efficiency was very significant outside of this range. Removing oily sewage from a restaurant by electrical coagulation process was examined by Xu et al. [47], and the best removal efficiency was achieved and stated in the neutral pH range. It was also reported in a study by De Carvalho et al. [41] that the most effective combination of EC and Moringa oleifera seeds in removal of acid black 1 and basic red 2 colors occurred in the neutral pH range. It was believed by Abuzaid et al. [48] that although the mechanism of coagulation using iron salts occurred in the pH range, the formless hydrocarbon ferric clots were obtained at pH 8 and they have the least solubility. Therefore, the pH increase caused by the exhaust of hydrogen gas will increase the efficiency of the EC process. In this study, adding tragacanth to solution did not cause any change in the pH environment, but during the electrical coagulation process over time in addition the temperature rise from 19 to 25ºC and the average pH increased about 0.26 with a standard deviation of 1.03 units. The pH was augmented from about 7 to about 9.1 (after 60 min, from the beginning of process). The findings of this study are consistent with the outcomes of other studies [40-41, 43, 48].

The Effect of Changing the Reaction Time

The effect of changes in reaction time on opacity removal efficiency is shown in Fig. 2. Based on the outcomes, increases in the time spent for turbidity removal up to 30 min was done linearly up to about 99% and then dropped to about 61%. This can be due to the growth of pH as well as the outflow of hydrogen gas and, as a result, floating of the material [48]. On the other hand, increasing pH may have disrupted the environment of producing iron hydroxyl clots [41]. Since temperature was also continuous during the process and increased by about 6ºC, that also could lead to dissolution of deposited substances [35]. It was believed by Abuzaid et al. [48] that the large amount of coagulant in the process of EC at long-term exposure was produced, which resulted in the induction of charge reversal and the re-stabilization of some of the colloids in the process environment.

Effect of Change on Primary Conductivity and Voltage

The effect of change of primary electrical conductivity and voltage on opacity removal efficiency was investigated. Maximum efficiency was observed in 30, 15, and 5 V by about 0.99, 0.90, and 0.82%, respectively. Results show that removal efficiency increased dramatically with increasing electrical conductivity and voltage. In this study, the effect of

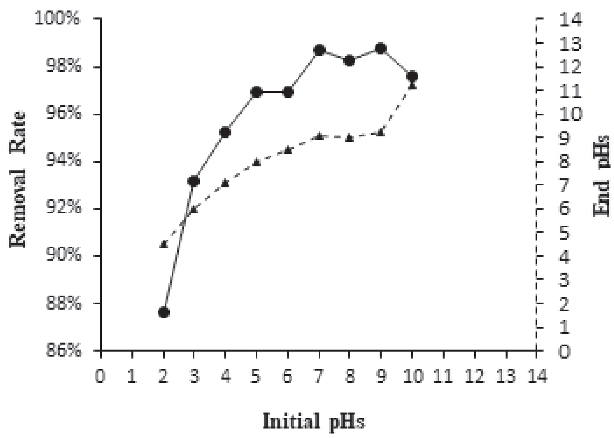

Fig. 1. Effect of pH on turbidity removal efficiency and pH changes (bentonite 7 g/L, tragacanth 1.5 g/L, NaCl 8 g/L, voltage 30 V, and time 30 min).

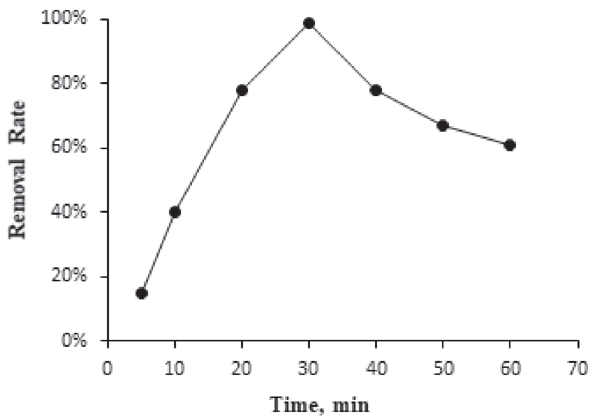

Fig. 2. Effect of reaction times on turbidity removal efficiency (bentonite 7 g/L, pH 7, tragacanth 1.5 g/L, NaCl 8 g/L, and voltage 30 V).

changing the initial electrical conductivity was checked out by adding specific amounts of sodium chloride and, in accordance with other parameters, holding other variables constant (Fig. 3). There is always a direct correlation between the amount of produced coagulant of electrodes and the parameter of electrical conductivity as well as voltage. Increased electrical conductivity facilitates the flow of electricity between the electrodes (reduction in resistance), which leads to the production of more coagulants and reduces the current costs of the process [40]. Natural water resources contain different compounds and ions.

In the case of creating an electrical bridge in such water environments, available ions cause transmission of electrical current within the bridge. The greater the ionic strength of these species, the more the stream transfer at constant voltage. In a steady stream, the voltage level is reduced with increasing electrical conductivity and vice versa [23]. According to Faraday's law, the production of metal hydroxyls is augmented by increasing the current density. Thus, more active venues will be formed to attract more efficient pollutants [34]. Based on the perspective of Baneshi et al. [33], coagulant production leads to augmentation of electrical conductivity by increasing the reaction time in the process of EC, which has a good effect on improving process efficiency. It has been stated in some studies that high amounts of sodium chloride cause more hydrogen gas to flow out of the system under process. As a result, the pH of the environment has increased and the dissolution of the metal clot is dropped. Moreover, the removal efficiency is also boosted [48]. It is believed by Adjeroud et al. [40] that adding sodium chloride to provide electrical conductivity in the process of EC by producing chloride ions significantly reduces the adverse effects of bicarbonate and sulfate ions on the process. In the current research, increases in the rate of sodium chloride to solution not only causes growth in removal efficiency but also leads to a decline in current system costs by reducing the amount of electrical power consumption, which is consistent with the findings of the above studies and other research [49-50].

Effect of Change on Tragacanth Dosage (Catira)

Removal turbidity efficiency for catira and the EC/catira process in the case of using different doses is shown in Fig. 4. The results indicated that adding tragacanth to the solution in the EC/catira process at concentrations of less than 0.75 g/L are sufficient for optimal efficiency. However, improving effectiveness and achieving a high rate of efficiency has been intensified in concentrations greater than this amount over a shorter period of time. When using a dose of 0.75 g/L of tragacanth in the process of EC/catira, removal efficiency reached about 94% after about 30 min. While the removal efficiency reached up to 94% using a dose of 1.5 g/L only during 20 min and more than 99% of the turbidity was removed from the solution after 30 min. Therefore, if the reaction time is increased, a lower rate of doses can be used to achieve optimal efficiency. Using a dose of 1.5 mg/L of tragacanth can dramatically remove about 46% of opacity only after a period of 30 min.

In the study of coagulation of azo dyes using the Olivier Moringa seed extract by Beltrán-Heredia et al. [51], it was thought that the use of high doses of natural coagulant aids might remain in the environment and process in form of a solution without coagulation in solution, which could cause secondary problems in the process. Also, the use of doses of less than 0.6 g/L of the absorber of Olivier Moringa seed extract along with the EC process was considered effective and sufficient by De Carvalho et al. [41], to remove the acid black 1 and basic red 2 colors. It was believed by Nawel et al. [40] that the capacity of a natural coagulant depends on the activity of its mucilage. Therefore, they examined the effect of simultaneous use of cactus extract and the process of EC on the purification of wastewater. The outcome of their study represented the use of small amounts of this

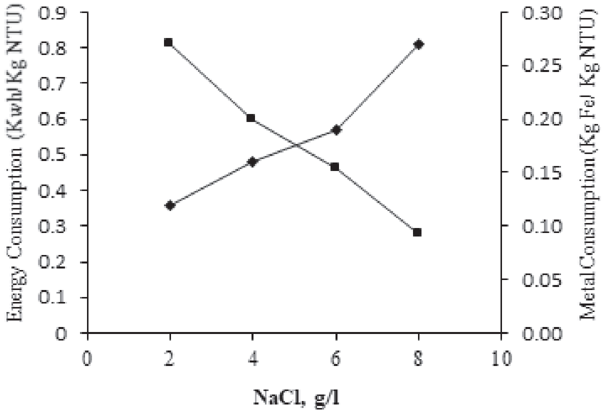

Fig. 3. Effect of energy and metal consumed in different initial electrical conductivity (bentonite 7 g/L, pH 7, tragacanth 1.5 g/L, voltage 30 V, and 30 min).

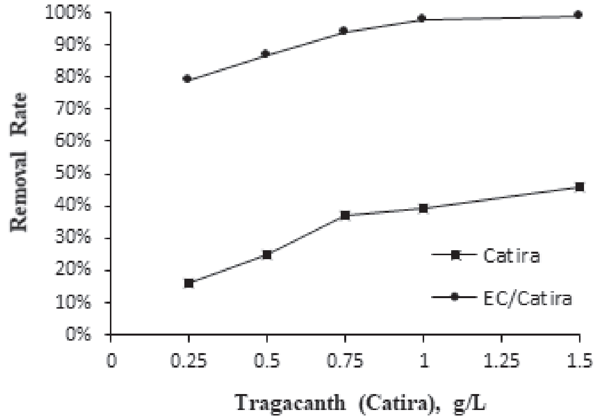

Fig. 4. Effect of the catira dosage on turbidity removal efficiency (bentonite 7 g/L, pH 7, NaCl 8 g/L, voltage 30 V, and 30 min).

plant extract has improved the efficiency of wastewater treatment so that in the case of using only 0.016 ml/L of Opuntia ficus indica extract in initial pH condition of 8.2, electrical conductivity of 3.04 mS/cm, and current density of 43.6 mA/cm^2, removal efficiency of turbidity has improved from 72% to about 87%. It was pointed out in some studies that such natural coagulants using physical absorption methods due to mucilage spreading in the water environment remove opacity agents. Removal efficiency also increases by increasing the amount of mucilage, and the findings of this study are consistent with their findings [40, 52-53].

Effect of Primary Bentonite Change (Initial Turbidity)

In this study, process efficiency was examined by changing initial turbidity due to the addition of 3, 5, and 7 g/L bentonite to the solution which was subjected to the process. The results displayed the integration system of tragacanth and EC in more turbid volumes was more efficient and thus removal efficiency was improved. So that removal efficiency of turbidity in quantities of 5 and 7 g/L bentonite 2 reached 82, 94, and 99%, respectively.

Efficiency of the Moringa oleifera seeds and poly-aluminum Chloride on removing turbidity from the water was examined by Bina et al. [54], who found that increasing the unit of turbidity led to augmentation in its efficiency of removal by Moringa seed extract. Based on their point of view, the cause of this occurrence was a mechanism of absorbing and neutralizing loads. Efficiency of the EC process in the removal of opacity due to the use of bentonite was investigated by Abuzaid et al. [48], and it was reported that increasing the initial values of opacity (swelling the initial values of bentonite) leads to improvement in process efficiency because of overcoming sedimentation mechanisms. The results of these studies are in line with the results of the current study. Using biological coagulant of tragacanth instead of synthetic ones minimizes serious damage to the environment.

Conclusions

The results showed that using astraglus gossypinus tragacanth as a natural coagulant is effective for the electrocoagulation process in turbidity removal from brackish water samples. The highest removal efficiency was about 99% for each 1 kg NTU due to the addition of 7 g/L bentonite under neutral pH conditions, tragacanth dose of 1.5 g/L, 8 g/L dose of NaCl, voltage of 30 V for 30 min, and average consumption of iron and electrical energy of 0.18 kg and 0.53 Kwh, respectively. The use of Astraglus gossypinus tragacanth in removing turbidity as a natural coagulant aid dramatically improves electrocoagulation process efficiency in the removal of turbidity from brackish water samples and reduces current costs of the electro-coagulation process. The use of these bio-coagulants instead of synthetic suppliers could reduce the risk of serious damage to the environment.

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Ethical Clearance

Taken from the ethical committee of Gonabad University of Medical Science with grant Nos. 94/58 by the Student Research Committee.

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