Valorization of potato peel residues to produce a biofloculant to be used in the treatment of liquid effluents

Fatima Zohra CHOUMANE 1,2*, Fatiha ZAOUI 3, Fatma KANDOUCI 1, Bouhana MAACHOU 1 and Belkacem BENBUELFA 2

1 Department of Process engineering, Faculty of Technology. University of Saida- Dr Moulay Tahar, Algeria
2 Laboratory of Inorganic Chemistry and Environment, Department of Chemistry, Faculty of Sciences. University of Tlemcen - Abou Bakr Belkaid, Algeria
3 Department of Chemistry, Faculty of Science. University of Saida- Dr Moulay Tahar, Algeria

fatimazohra.choumane@univ-saida.dz

Abstract. The present study aims primarily to investigate the flocculation capacity of a novel potato peel-based bioflocculant in wastewater treatment. The analysis of wastewater revealed high COD and BOD₅ contents that could respectively reach the values 529.08 mg O₂/l and 317.03 mg O₂/l. In addition, the effect of experimental parameters such as the pH, coagulant/flocculant dosage, and contact time, was studied using the coagulation-flocculation treatment technique. The experiments were carried out with a lab-scale jar-test apparatus where aluminum chloride (AlCl₃) was used as a coagulant agent. It should be noted that the optimal dose of AlCl₃ was equal to 0.6 g at 10 mn, with turbidity reduction of 99.01%. Moreover, the flocculation tests showed higher turbidity removal (98%), for a flocculant dosage of 0.2g. The results obtained in this study indicated that using the natural potato peel-based flocculant, in the presence of a coagulant, provides an effective and environmentally friendly coagulation option for wastewater treatment.

Keywords: coagulation-flocculation, wastewater, turbidity, treatment

1. Introduction

No one denies that industrial sites throughout the world remain the primary cause of water pollution due to the diversity of industries (textiles, paints, pharmaceuticals, metal coatings, corrosion inhibition, etc.) [1-5]. Nowadays, various wastewater treatment technologies, such as adsorption, oxidation, chemical precipitation, etc., with different degrees of effectiveness and success, are available to control and minimize water pollution [6, 7]. Each one of these techniques, when applied, showed some advantages and limitations [8]. However, many of these methods have not been widely used due to high costs, formation of hazardous by-products and intensive energy requirements [9]. It is worth noting that the coagulation-flocculation process is being widely applied in raw water treatment, and in particular wastewater treatment. This technique is broadly used because it relatively low-cost, robust and environmentally friendly [10].

The coagulation-flocculation technique has been widely used in multiple industry sectors so far. This process is generally applied for the removal of colloidal particles, soluble compounds, and very fine solids suspended in solutions by colloid destabilization which leads to the formation of larger particles that are commonly referred to as flocs [11, 12]. Currently, this technique can be effectively achieved through the use of inorganic coagulants and fossil-based organic flocculants. Note that
Flocculants are particularly advantageous because they are efficient at low dosages and able to form quite large flocs [13, 14].

However, it was shown that the use of synthetic flocculants causes serious environmental damage and health problems. In addition, this method generates a great deal of controversy related to the production of large volumes of toxic sludge and the dispersion of acrylamide oligomers, which engenders serious health hazard due to its harmful carcinogenic and neurotoxic effects on human beings [15-17]. For these reasons, as an alternative, bioflocculants have attracted increasing attention for water treatment due to their biodegradability, non-toxic properties, and remarkable flocculation performances that are sometimes comparable to those of synthetic flocculants [18-22]. This eco-friendly approach involves biodegradability and sustainability with the exploitation and utilization of byproducts derived from human activities such as fishing, agriculture, industry, and others. It is worth citing some examples of bioflocculants like alginate, cellulosic materials, starch, chitosan, xanthan gum, Moringa oleifera, okra, guar gum and Cassia tora gum, and tannins, which represent economical, viable, and safe substitutes for synthetic flocculants [15-17]. It is widely admitted that potato peel waste causes much environmental pollution when stored outside without any appropriate and safe disposal. In addition, potato peel processing can release potential pollutants that cause serious environmental problems. Consequently, due to the multifunctional nature of potato peels, it is highly urgent and essential to design and develop environmentally friendly processing procedures to deal with these wastes [23].

On the other hand, it is important to indicate that some food byproducts, like potato peels, possess essential organic matter. In this context, Gebrechristos et al. (2018) [23] indicated that potato peel residues can potentially be used as a food preservative, pharmaceutical ingredient, animal food for the purpose of promoting eco-friendly food industries; they also reported that potato peels can also be employed in renewable energy. Similarly, the author [24] found out that potato peel waste is an interesting low cost adsorbent which is quite efficient in the adsorption of the methylene blue (MB) dye from aqueous solutions. Indeed, the results obtained showed that the percentage of elimination of this dye can go from 61.4 to 87.6% while increasing the adsorbent mass. Based on these findings, it can be said that potato peels could be effectively used as an eco-friendly adsorbent material for the removal of methylene blue dye from an aqueous solution. Therefore, potato peel residues can be valorized to produce a flocculant agent for the treatment of wastewater through the coagulation-flocculation procedure.

The primary purpose of this paper is to investigate the effect of some operational factors on the treatment of water using potato peel waste as a bioflocculant. It is worth indicating that, over the past few years, biopolymer-based flocculants have been attracting increasing interest from many researchers because they are easily biodegradable and are highly environmental friendly. However, natural flocculants, which are characterized by a moderate flocculating efficiency and short shelf life, should be used at large doses [13]. Moreover, factors such as the pH, coagulant dose and coagulant type, play an essential role in the coagulation and flocculation operations. These factors were investigated in order to determine the optimal efficiency under the best experimental conditions and to identify the most appropriate mechanisms that could be involved in the treatment process. These flocculants turned out to be highly efficient in removing COD, turbidity, color and metals, depending on the types of contaminant and coagulant/flocculant used [25].

2. Materials and Methods

2.1. Preparation of potato Peel

Nowadays, food processing industries are producing huge amounts of waste. In particular, potato processing factories are rapidly expanding and are generating enormous volumes of potato peel waste. When decomposed, this potato byproduct can cause serious environmental pollution [23]. For this reason, potato peel has been investigated by many researchers as a good source for biopolymer production. In addition, it was found that potato peel waste represents an interesting source of vegetable starch. It should also be noted that this type of starch swells well and possesses high viscosity.
For the purpose of understanding the physicochemical properties of potato peels, it is required to determine their physical and chemical composition.

It was revealed that potato peels contain various polyphenols and phenolic acids, which are responsible for its antioxidant activities, as well as fatty acids and lipids, which exhibit interesting antibacterial activities [26, 27]. In addition, potato peels contain starch (25%), non-starch polysaccharides (30%), proteins (18%), acid-soluble and acid-insoluble lignin (20%), lipids (1%) and ash (6%) on dry matter basis [28]. Furthermore, the lipid fraction includes long-chain fatty acids, alcohols, triglycerides and sterol esters. Moreover, lignin units were also found in the cell wall of potato [29]. It was also found that potato peel waste is rich in starch (52% dry weight), but the content of fermentable reducing sugar is quite low (0.6% dry weight) [30].

In this study, potato peel is used as a bioflocculant without any modification or prior purification. For this, the potato peels to be tested were first washed with tap water and then dried in the open air for several days. Afterwards, they were cut into small pieces and finely crushed to powder. Then, the samples thus obtained were placed in bottles and stored at room temperature.

3. Experimental

3.1. Characterization

In order to characterize the potato peels, to be used as a bioflocculant, Fourier-transform infrared spectroscopy analyses were carried out to study the surface functional groups of this material using potassium bromide pellets. The infrared analysis was performed with a PerkinElmer Spectrum One FT-IR Spectrometer version 10.4.1.

3.2. Wastewater

The wastewater used in this study was brought from the wastewater treatment plant in the small town of Rebahia, located near wadi Saida, in the northwestern part of the City of Saida. The procedures applied for the physicochemical measurements were carried out in accordance with the Standards described by the French national organization for standardization (AFNOR).

The turbidity is expressed in nephelometric turbidity units. In addition, factors such as the pH, conductivity and turbidity were measured using a Hanna Instruments pH meter, a conductivity meter and an infrared AQUA LYTIC Model AL250T-IR turbidity meter, respectively. The results of the physicochemical measurements of the wastewater under study are summarized in Table 1.

Table 1. Results of the characteristics of wastewater analyzed

| Parameter      | Units | Average values | AFNOR standards | Algerian standards |
|----------------|-------|----------------|-----------------|-------------------|
| pH             | -     | 8.12           | NF T90-008      | 5.5 - 8.5         |
| Turbidity      | NTU   | 350            | NF T90-033      | -                 |
| Conductivity   | mS/cm | 2.410          | NF T90-031      | -                 |
| Suspended solids | mg/l | 233.89         | NF EN 872       | 35                |
| BOD₅           | mg/l  | 317.03         | NF EN:1899-2    | 30                |
| COD            | mg/l  | 529.08         | ISO15705        | 125               |
| Oxidation by KMnO₄ | mg/l | 29             | NF EN ISO 8467  | -                 |

3.3. Coagulation experiments

Coagulation and flocculation processes proved to be essential in a number of diverse disciplines, including raw water and wastewater treatment. In this study, these two procedures were carried out using the jar-test apparatus. To do this, the coagulant was first injected at the beginning of the rapid mixing phase, at the speed of 150 rpm, for 10 min, 20 min, 30 min and 1 h to ensure complete dispersion, followed by slow stirring, at 50 rpm, for 10 min. It should be noted that all the experiments were conducted at neutral pH. Moreover, aluminum chloride was selected to be used as a coagulant in the chemical treatment.

Afterwards, the coagulant was introduced into wastewater with different amounts (0.1, 0.2, 0.4, 0.6, 0.8, 1, 1.2, 1.6 and 2 g). In the next step, the samples were allowed to decant for a period ranging between 30 and 60 minutes. It should be noted that flakes were observed during and after agitation. After decantation, some samples were taken from each beaker in order to measure physical parameters.
such as the pH, turbidity, COD and BODs. The coagulant dose was chosen so as to obtain the highest percentages of removal of each of the above mentioned parameters.

4. Results and discussions

4.1. Characterization of the bioflocculant potato peel

Figure 1 clearly shows the FTIR spectra of the potato peel powder. The FTIR spectrum of potato peel exhibits a broad band around 3421.5 cm\(^{-1}\) due to the presence of hydroxyl groups in cellulose, lignin and adsorbed water [31]. Another band, recorded at 2925.8 cm\(^{-1}\), is attributed to C-H vibrations of the CH\(_2\) group. With regard to the band at 1647.1 cm\(^{-1}\), it corresponds to the stretching vibrations of the C = C carbonyl functions.

In addition, close examination of the spectrum reveals the presence of two bands at 1537.2 and 1548.7 cm\(^{-1}\) which are characteristic of the deformation of the C-H bond vibration. On the other hand, several bands are observed between 1388 and 1157.2 cm\(^{-1}\), which confirms the lignin structure of the material. Finally, another peak was noted at 1026 cm\(^{-1}\); it is attributed to the C-O-C elongations of the cellulose functions present in the potato peel [32].

![Figure 1. FTIR spectra of potato peel](image)

4.2. Physicochemical characteristics of wastewater

The results of the physicochemical analyses of wastewater before treatment are summarized in table 1. It can be seen that the pH is equal to 8.12. It is worth also noting that the wastewater under study has an unpleasant odor. This bad odor is probably due to the presence of some chemicals or decomposing organic matter, or may be to Clostridium perfringens that give off hydrogen sulfide (H\(_2\)S). One may clearly note that the chemical oxygen demand (COD) and biochemical oxygen demand (BOD\(_5\)) values are much higher than those of other pollutants. Further, the results show that the pollution level of this wastewater is quite high; the turbidity is equal to 350 UNT as a result of the high presence of solid materials, especially suspended solids. It is important to mention that this parameter is essential in the coagulation processes primarily because it is easy to measure and is quite sensitive to coagulation processes.

4.3. Coagulation-flocculation treatment method

4.3.1. Optimization of coagulant dosage

The coagulant used in this study is aluminum chloride (AlCl\(_3\)), with doses ranging from 0.1 to 2g. Also, the variation of the turbidity rate (%) in terms of doses of coagulant (AlCl\(_3\)) is presented in...
Figure 2 in order to determine the optimum coagulant dose. The same figure depicts the coagulation performance of aluminum chloride in terms of turbidity reduction of the wastewater samples.

![Figure 2: Evolution of the turbidity rate as a function of the dose of the coagulant aluminum chloride](image)

This figure indicates that the turbidity continuously decreases as the quantity of the coagulant added increases. It is observed that turbidity starts decreasing after the addition of 0.1 g of aluminum chloride; it then continues declining. It should be noted that the optimal coagulant dose can be determined by measuring the turbidity and also considering the stirring time. On the basis of the results obtained, it can be seen that in the absence of flocculant, the mass of 0.6 g of aluminum chloride coagulant allows achieving a very good flocculation with a turbidity rate equal to 99.01% after for a stirring period of 10 mn. This represents the first step in wastewater treatment. The next step consists in adding the flocculant.

4.3.2. Effect of pH on coagulation efficiency

It is broadly acknowledged that the pH is a fundamental parameter. Figure 3 clearly displays the evolution of the pH as a function of the dosage of aluminum chloride coagulant, for different time periods. This figure shows that an increase in aluminum chloride dosage results in a lower pH value. In addition, depending on the characteristics of the water under study, there is an optimum pH value that allows achieving the best coagulation. It should also be noted that this pH is often within the range where the solubility of the coagulant used is minimal; this should therefore give good precipitation. Consequently, the most adequate pH value, which gives the optimal turbidity rate of 4.1, leads to the best coagulation efficiency. Note also that controlling the pH allows improving coagulation when the temperature of water is low [33].
4.3.3. Influence of the bioflocculant dosage on the coagulation-flocculation treatment

The coagulation-flocculation treatment was carried out through the addition of a constant dose of aluminum chloride (0.6g) to wastewater samples kept under continuous stirring. Next, various masses of potato peel powder, ranging between 0.1 and 1 g, were added to the resulting coagulated product. The results obtained suggested that potato peel powder with the optimum dose of 0.2g allowed flocculating wastewater efficiently, with a turbidity reduction of 98% (Figure 4). In addition, the BOD$_5$ dropped from 317.03 mg of O$_2$ / l to 0 mg of O$_2$ / l, which represents a 100 % reduction.

The pH is another critical factor affecting the coagulation-flocculation process. Aluminum chloride is among the most common coagulants that are used to achieve flocculation and clarification of water as well. The combination of the aluminum chloride coagulant with potato peels results in a slight drop, followed by a rise and then a decrease in pH (Figure 5). This fluctuation is primarily due to the hydrolysis of the salts used.
Figure 5. Evolution of pH of wastewater as a function of biofloculant dosage, in the presence of coagulant

5. Conclusions

This work was an attempt to recover and valorize potato peel waste, which is largely available, to be used as a low cost flocculation agent for the treatment of wastewater in the City of Saida through the coagulation-flocculation process.

The results obtained indicated that the optimum dose of aluminum chloride coagulant of 0.6 g allowed achieving high turbidity removal efficiency (99.01%) for a contact time of 10 mn. The biofloculant dosage used was quite efficient in reducing the suspended solids, color, COD, BOD$_{5}$ and turbidity of wastewater. The findings confirmed the successful flocculation process, which led to a 100% BOD$_{5}$ reduction. It was therefore concluded that the coagulation-flocculation process can be viewed as a viable technique for the treatment of wastewater.

References

[1] Said Benkhayaa, Souad Mrabetb and Ahmed ElHarf 2020, A review on classifications, recent synthesis and applications of textile dyes, Inorg. Chem. Commun. 115 107891.
[2] Rachid Hsissoua, Bouchra Benzidiab, Najat Hajjajib and Ahmed Elharfia 2018, Elaboration and electrochemical studies of the coating behavior of a new nanofunctional epoxy polymer on E24 steel in 3.5 % NaCl, Portugaliae Electrochimica Acta, 36 (4), 259-270.
[3] Rachid Hsissoua, Bouchra Benzidiab, Najat Hajjajib and Ahmed Elharfia 2019, Elaboration, electrochemical investigation and morphological study of the coating behavior of a new polymeric polyepoxide architecture: crosslinked and hybrid decaglycidyl of phosphorus pentamethylene dianiline on E24 carbon steel in 3.5% NaCl, Portugal. Electrochim. Acta 37, 179-191.
[4] Rachid Hsissou, Said Abbout, Rajaa Seghiri, Malak Rehioui, Avni Berisha, Hamid Erramli, Mohammed Assouag and Ahmed Elharfi 2020, Evaluation of corrosion inhibition performance of phosphorus polymer for carbon steel in [1M] HCl: computational studies (DFT, MC and MD simulations), J. Mater. Res. Technol., 9 (3), 2691-2703.
[5] Hanane Arroub, Rachid Hsissou and Ahmed Elharfi 2020, Investigation of modified chitosan as potential polyelectrolyte polymer and eco-friendly for the treatment of galvanization wastewater using novel hybrid process, Results in Chemistry 2, 100047.
[6] Giusy Lofrano 2012, emerging compounds removal from wastewater, Natural and Solar Based Treatments, Springer, Netherlands.
[7] Sabino De Gisi, Giusy Lofrano, Mariangela Grassi and Michele Notarnicola 2016, Characteristics and adsorption capacities of low-cost sorbents for wastewater treatment: a review. Sustain. Mater. Technol., 9, 10-40.
[8] Bai-Yu Gao, Qin-Yan Yue, Yan Wang and Wei-Zhi Zhou 2007, Color removal from dye-containing wastewater by magnesium chloride, J. Environ. Manage. 82, 167-172.

[9] Faisal Ibnay Hai, Kazuo Yamamoto and Kensuke Fukushima 2007, Hybrid treatment systems for dye wastewaters. Crit. Rev. Environ. Sci. Technol. 37, 315-377.

[10] Fatima Zohra Choumane, Belkacem Benguella, B Maachou and N Saadi 2017, Valorisation of a bioflocculant and hydroxyapatites as coagulation-flocculation adjuvants in wastewater treatment of the steppe in the wilaya of Saida (Algeria), Ecological Engineering, 107,152-159.

[11] John Brathy 2008, Coagulation and Flocculation in Water and Wastewater Treatment, second ed, IWA publishing, London.

[12] Pang FongMoi, Teng SheaPing, Teng TjoonTow and Omar A K M 2009, Heavy metal removal by hydroxide precipitation and coagulation-flocculation methods from aqueous solutions, Water Qual. Res. J. Can. 44 (2) 174-182.

[13] Chai Siah Lee, John Robinson and Mei Fong Chong 2014, A review on application of flocculants in wastewater treatment, Process Saf. Environ. Prot. 92, 489-508.

[14] Victor Ajao, Remco Fokkink, Frans Leermakers, Harry Bruning, Huub Rijnaarts and Hardy Temmink 2021, Bioflocculants from wastewater: Insights into adsorption affinity, flocculation mechanisms and mixed particle flocculation based on biopolymer size-fractionation, Journal of Colloid and Interface Science, 581, 533-544.

[15] T Nharingo and M Moyo 2016, Application of Opuntia Ficus-Indica in Bioremediation of Wastewaters. A Critical. Review. J. Environ. Manage, 166, 55-72.

[16] Lorenzo A Picos-Corrales, Juan I Sarmiento-Sanchez, Jose P Ruelas-Leyva, Gregorio Crini, Eduardo Hermosillo-Ochoa and J Ariel Gutierrez-Montes 2020, Environment-friendly approach toward the treatment of raw agricultural wastewater and river water via flocculation using chitosan and bean straw flour as bioflocculants, American Chemical Society (ACS) Omega, 5, 3943-3951.

[17] Grégorio Crini, Eric Lichtfouse, Lee Wilson and Nadia Morin-Crini 2019. Conventional and Non-Conventional Adsorbents for Wastewater Treatment. Environ. Chem. Lett, 17, 195-213.

[18] A Mishra and M Bajpai 2005, Flocculation behaviour of model textile wastewater treated with a food grade polysaccharide, J. Hazard. Mater. 14 (118) 213-217.

[19] T Suopajärvi, H Liimatainen, O Hormi and J Niinimäki 2013, Coagulation-flocculation treatment of municipal wastewater based on anionized nanocelluloses, Chem. Eng. J. 231,59-67.

[20] C Wu, Y Wang, W Zhao, Z Yanxia and Q Yue 2012, Coagulation performance and floc characteristics of aluminum sulfate using sodium alginate as coagulant aid for synthetic dyeing wastewater treatment, Sep. Purif. Technol, 95,180-187.

[21] V Ajao, H Bruning, H Rijnnaarts and H Temmink 2018, Natural flocculants from fresh and saline wastewater: Comparative properties and flocculation performances, Chem. Eng. J. 349, 622-632.

[22] F Renault, B Sancey, J Charles, N Morin-Crini, PM Badot, P Winterton and G. Crini 2009, Chitosan flocculation of cardboard-mill secondary biological wastewater, Chem. Eng. J. 155,775-783.

[23] H Y Gebrechrisstos and W Chen 2018, Utilization of potato peel as eco-friendly products: A review. J. Food Sci and Nutr, 6 (6), 1352-1356.

[24] S Boumchita, A Lahrichi, Y Benjelloun, S Lairini, V Nenov and F Zerrouq 2016, Removal of cationic dye from aqueous solution by a food waste: potato peel. J. Mater. Environ. Sci. 7(1), 73-84.

[25] Mohini Verma and R Naresh Kumar 2016, Can coagulation-flocculation be an effective pre-treatment option for landfill leachate and municipal wastewater co-treatment?, Perspectives in Science, 8, 492-494.

[26] AFS Maldonado, E Mudge, MG Ganzle and A Schieber 2014, Extraction and fractionation of phenolic acids and glycoalkaloids from potato peels using acidified water/ethanol-based solvents. Food Res Int, 65, 27-34.

[27] KB Jeddou, F Chaari, S Makoutou, O Nouri-Elouz , CB Helbert and R E Ghorbel 2016, Structural, functional, and antioxidant properties of water-soluble polysaccharides from potatoes peels. Food Chem, 205, 97-105.
[28] S Liang and AG McDonald 2014, Chemical and thermal characterization of potato peel waste and its fermentation residue as potential resources for biofuel and bioproducts production. *J Agric Food Chem*, **62**, 8421-8429.

[29] S Liang, AG McDonald and ER Coats 2014, Lactic acid production with undefined mixed culture fermentation of potato peel waste. *Waste Manag*, **34**, 2022-2027.

[30] Ahsan Javed, Awais Ahmad, Ali Tahir, Umair Shabbir, Muhammad Nouman and Adeela Hameed 2019, Potato peel waste-its nutraceutical, industrial and biotechnological applications”. *AIMS Agriculture and Food*, **4**(3),807-823.

[31] N Wibowo, L Setyadhi, D Wibowo, J Setiawan and S Ismadji 2007. Adsorption of benzene and toluene from aqueous solution onto activated carbon and its acid heat treated forms: Influence of surface chemistry on adsorption. *Journal of Hazardous Materials*, **146**, 237-242.

[32] K Bouhadjra, W Lemlikchi and N Oubagha 2017, Application of potato peels for the removal of reactive blue 72 from aqueous solutions, *J. Wat. Env. Sci*, Vol **1**, (Numéro spécial ICWR 2), 219-229.

[33] R JULIEN1983, *Etude de la coagulation-floculation-décantation d'une eau colorée froide de faible alcalinité*. Mémoire de maîtrise - Département de Génie Civil, École Polytechnique de Montréal, Canada, 157p.