Aloe vera

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Aloe vera plant offers a sustainable solution for the removal of various pollutants from water. Due to its chemical composition, Aloe vera has been explored as coagulant/flocculant and biosorbent for water treatment.

Keywords: Aloe vera ; water treatment

1. Introduction

Industrial development generates large amounts of polluted effluents. Released in the environment, pollutants damage the soil, the ground, and the surface water—leading to ecosystem degradation and causing health risks [1][2][3][4]. In order to reduce the environmental problems associated with these effluents, industries utilize various methods of wastewater treatments. Depending on the characteristics of the wastewater, a combination of a number of physical, chemical, and biological processes can be applied to remove various pollutants (carbon, nitrogen, turbidity heavy metals, dyes, etc.) [5][6]. The physical methods include mainly the adsorption, ion exchange, and membrane technologies. The chemical treatment induces chemical reactions, coagulation, precipitation, oxidation, advanced oxidation, ion exchange, neutralization, and stabilization, etc. However, the biological treatment systems involve membrane bioreactors, biofilter, sequential batch reactor, activated sludge, etc. [7][8][9][10]. Although their ability to efficiently remove pollutants from various effluents, these processes may have some disadvantages such as the use of chemicals in the coagulation–flocculation technique. For example, aluminum salts and polyacrylamides remain in water after treatment and may cause health concerns (genotoxicity, neurotoxicity, etc.) for organisms [11][12]. Besides, the activated carbon used as adsorbent for wastewater treatment is expensive, non-selective, and needs regeneration after rapid saturation [13][14][15]. Therefore, depending on the characteristics of the industrial effluent, the applied process to remove pollutants may not be economically justified and sustainable, with a high environmental cost related to the adverse effects of its secondary effluent on the environment. In order to be sustainable, wastewater treatment should involve biological materials aiming to minimize energy consumption and negative impacts on the environment. As reported in the literature, the sustainable strategy involving the use of biological materials constitutes a promising solution for pollutants removal. For example, biological natural materials such as cactus, moringa, *Aloe vera*, bean, etc. have been explored for their eventual use for pollutants removal [16][17][18]. Interestingly, the removal of various pollutants (dyes, turbidity, metals, etc.) by *Aloe vera* (AV) via its utilization in many processes (adsorption, coagulation–flocculation, degradation, etc.) was reported. AV is biodegradable, safe, and abundant in various regions over the world.

2. *Aloe vera* as Coagulant/Flocculant for Wastewater Treatment

Coagulation/flocculation is a common process used for the removal of various pollutants (suspended solids, organic, and inorganic materials). In this operation, chemicals such as aluminum salts, acrylamides are added to water to destabilize colloidal materials and allow the agglomeration of small particles into larger settleable flocs [19][20]. However, these chemicals remain in treated water leading to various health problems (neurotoxicity, genotoxicity, etc.) [12]. Furthermore, during the treatment, these chemicals may react with other compounds producing new products with unknown health risks. Various diseases such as Alzheimer are reported to be related to the use of alum [21]. Therefore, it is necessary to consider alternative flocculants/coagulants. These alternative materials should be available, cost effective, biodegradable, and without health risks. Various parts (seeds, leaves, pieces, roots, fruits, etc.) of plants (cactus, moringa, etc.,) were used as potential sources of flocculants/coagulants [18][22]. Interestingly, the use of AV as a promising natural material to substitute chemicals in the coagulation/flocculation process [23][24][25][26][27][28][29][30][31][32][33][34][35][36][37][38][39][40][41][42] has been reported. Various investigations reported the use of AV as coagulant, flocculant, or coagulant/flocculant aid for water treatment. Figure 1 shows the scheme of *Aloe vera* preparations and applications for wastewater treatment using various processes.

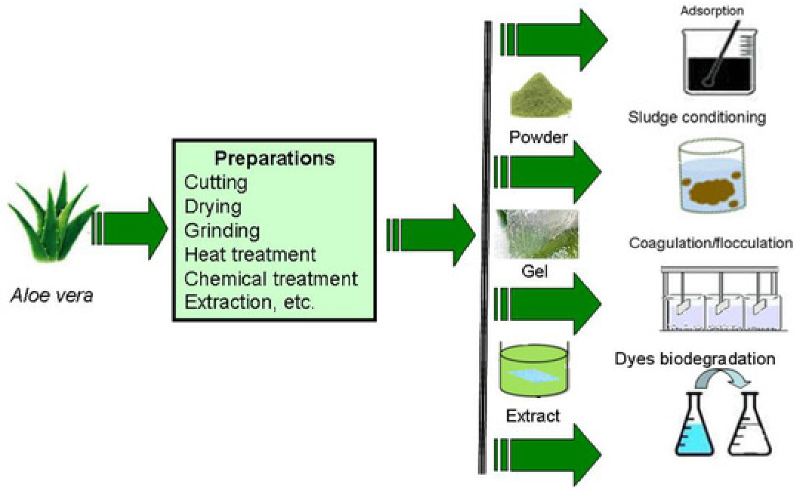

Figure 1. The scheme of *Aloe vera* preparations and applications for wastewater treatment.

To determine the process efficiency, various water quality parameters (solids, turbidity, color, COD, BOD, dyes, heavy metal, etc.) were measured. As reported in the literature, biopolymer investigations were designed and implemented in many stages, including mainly the material preparation and the optimization of the operating parameters (dosage, pH, temperature, mixing speed, contact time, etc.). Essentially, dosage is an important parameter to be studied and inadequate dosage could result in low performance of the coagulation/flocculation process [20]. In recent research conducted on AV, leaves gel was tested as coagulant aid for turbid water (35 NTU) treatment. For this purpose, the gel was blended and mixed with water (1%) in the presence of *Moringa oleifera*. The obtained results showed higher level of turbidity removal (91.42%) [23]. Similarly, 96.5% turbidity removal from Indrayani stream water was reached with 5 mg/L of liquid AV used as coagulation aid in the presence of alum (56 mg/L). However, for the same water and using the same quantity of alum (56 mg/L), the use of AV liquid as flocculant aid (10 mg/L) allowed the removal of 96.2% of the turbidity. Therefore, the use of liquid AV as coagulant aid offers more advantages (higher efficiency and lower quantity) than its use as flocculant aid. As indicated in the literature, many AV materials were prepared using different methods and applied for pollutants removal from waters. Sun dried AV offered a good potential as flocculant in reducing the turbidity (92.74%) and color (95.73%) from crude drinking water [24]. Likewise, textile wastewater was treated using flocculant recuperated after filtration of mixture of AV gel with distilled water [25]. The use of flocculant dose of 33 mL/L at pH 7.3, under mixing speed of 61 rpm for 20 min, allowed the removal of 92.3% of turbidity, 76.8% of COD, 83.5% of BOD_5, and 57.9% of TSS [25]. Similar work was conducted with high-loaded textile wastewater (1215 mg/L COD and 593.33 mg/L BOD) using powdered bioflocculant extracted from dehydrated pieces of AV leaves. The treatment of this effluent using bioflocculant dosage of 60 mg/L (at pH 5 and contact time of 180 min) removed 90.53% of COD, 98.19% of TSS, and 98.80% of TDS. Interestingly, the powdered bioflocculant exhibited significant flocculanting activity (82%) [26]. In the same perspective, methylene blue was partially removed (50–55%) using a coagulant obtained by physical blending of AV with aluminum sulphate (10:90%) performed at room temperature for 24 h. The removal rates were obtained at coagulant optimal dosage of 3000 mg/L and pH 6. The replacement of aluminum sulphate by magnesium sulphate for the preparation of AV coagulant allowed an enhancement of the removal efficiency of 60–70%, obtained at pH 12.5 and with the same dosage (3000 mg/L) [27]. Simultaneously to the removal of organic pollutants by the coagulation/flocculation process with AV, the removal of heavy metal was reported in few studies. For example, the AV powder (AV dried at 330 K) was tested for the removal of arsenic from aqueous solution (with initial concentration ranging from 0.2 to 1 mg/L). The use of 2 mg/L of the AV preparation as coagulant in the presence of polyaluminum chloride (3 mg/L) at pH 5 removed 92.63% of As (V) [28]. Similar preparation (AV powder used as coagulant) removed only 30.59% of Cu from river water (initial concentration 2000 mg/L). This removal rate was obtained with coagulant dose of 1.20 g/L, settling time of 40 min, pH 8, and at 313 K [29]. Interestingly, filtrate of AV gel was effective in the coagulation/flocculation of Pb (II) ions from textile wastewater. A removal rate of 77% was obtained with flocculant dosage of 33 mL/L at pH 7.3 [25]. Interestingly, results were comparable to those achieved when using cactus and *Moringa oleifera*. Moreover, the optimum AV coagulant/flocculant dose was found to be comparable to that reported for other used materials [18][30].

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