Aloe vera as Promising Material for Water Treatment: A Review

Khadijah Mohammedsaleh Katubi 1, Abdelfattah Amari 2,3,*, Hamed N. Harharah 2, Moutaz M. Eldirderi 2, Mohamed A. Tahoon 4,5 and Faouzi Ben Rebah 4,6,*

Abstract: 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. Most of the used materials displayed significant pollutants removals depending on the used preparation methods. AV-based materials have been investigated and successfully used as coagulant/flocculant for water treatment at laboratory scale. Selected AV-based materials could reduce the solids (total suspended solids (TSS), suspended solids (SS), total dissolved solids (TDS), and dissolved solids (DS)), turbidity, chemical oxygen demand (COD), biochemical oxygen demand (BOD), heavy metals, and color, with removal percentages varied depending on the coagulant/flocculant materials and on the wastewater characteristics. In the same context, AV materials can be used as biological flocculant for wastewater sludge treatment, allowing good solid–liquid separation and promoting sludge settling. Moreover, using different methods, AV material-based biosorbents were prepared and successfully used for pollutants (heavy metal dyes and phenol) elimination from water. Related results showed significant pollutant removal efficiency associated with an interesting adsorption capacity comparable to other biosorbents derived from natural products. Interestingly, the enzymatic system of Aloe vera (carboxypeptidase, glutathione peroxidase, and superoxide dismutase) has been exploited to degrade textile dyes. The obtained results showed high promise for removal efficiencies of various kinds of pollutants. However, results varied depending on the methodology used to prepare the Aloe vera based materials. Because of its valuable properties (composition, abundance, ecofriendly and biodegradable), Aloe vera may be useful for water treatment.

Keywords: Aloe vera; water treatment; coagulation/flocculation; biosorbents; phytoremediation

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 [1–4]. 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. [7–10]. 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 polyelectrolytes 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 [13–15]. 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 [16–18]. 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. The literature reported the use of various methods to prepare AV-based materials. These AV materials have been adopted for water treatment, and various wastewater quality parameters (TSS, SS, TDS, DS, turbidity, COD, BOD, heavy metals concentration, color, etc.) were evaluated to determine their efficiencies in removing pollutants. In this context, a significant use of AV to remove various organic and inorganic pollutants was reported. This paper will review and discuss all the potential uses of AV for the removal of pollutants form wastewater.

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 [23–42] 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.

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 BOD₅, 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 flocculating 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]. Table 1 summarized the experiments conducted for the removal of various pollutants by the coagulation–flocculation using AV.

Table 1. Pollutants removal by coagulation–flocculation using Aloe vera.

| Effluents                  | Preparation                                      | Operating Conditions                              | Removal Efficiencies | Reference |
|----------------------------|--------------------------------------------------|--------------------------------------------------|----------------------|-----------|
| River water 7 NTU          | AV gel blended and mixed with H2O (1% v/v)        | AV as coagulant aid (10 mg/L) with Moringa oleifera (10 mg/L) | Turbidity: 42.85%    | [23]      |
| 21 NTU                     | AV gel blended and mixed with H2O (1% v/v)        | AV as coagulant aid (10 mg/L) with Moringa oleifera (50 mg/L) | Turbidity: 85.71%    | [23]      |
| 35 NTU                     | AV gel blended and mixed with H2O (1% v/v)        | AV gel as coagulant aid (10 mg/L) with Moringa oleifera (100 mg/L) | Turbidity: 91.42%    | [23]      |
| Drinking raw water Turbidity: 44.5 NTU Color: 375 UPt-Co, pH 7 | Sun dried AV                                    | 25 mg/L as flocculant                            | Turbidity: 92.74% Color: 95.73% | [24]      |
Table 1. Cont.

| Effluents                  | Preparation                                                                 | Operating Conditions                                                                 | Removal Efficiencies | Reference |
|---------------------------|-----------------------------------------------------------------------------|--------------------------------------------------------------------------------------|----------------------|-----------|
| Textile wastewater        | AV gel mixed H2O, stirred 30 min, strained (25 mm sieve) and filtrate         | Flocculant dose: 33 mL/L, mixing time 20 min, pH 7.3, 61 rpm                         | Turbidity: 92.3%     | [25]      |
| Turbidity: 190 NTU        | 37 °C                                                                        | COD: 410 mg/L                                                                        |                      |           |
| BOD5: 335 mg/L            | TSS: 380 mg/L                                                               | pH 5.1, 37 °C                                                                        |                      |           |
| Pb: mg/L                  |                                                                             | AV blended with magnesium sulphate (10:90%) at room temperature, 24 h                 | Dosage: 3000 mg/L as | 60–70%    | [27]      |
| pH 5.1, 37 °C             |                                                                             | coagulant, pH 12.5                                                                    |                      |           |
| Methylene blue            | AV blended with magnesium sulphate (10:90%) at room temperature, 24 h       | Dosage: 3000 mg/L as coagulant, pH 12.5                                               | 50–55%              | [27]      |
| Methylene blue            | AV leaves washed with deionized water, cut into small pieces, dried (333 K),| Dose of AV as coagulant: 2.0 mg/L, dose of polyaluminum chloride: 3 mg/L, pH 5        | 92.63%              | [28]      |
| Ground and sieved (100    | mesh)                                                                       |                                                                                       |                      |           |
| As(V) aqueous solution    | AV leaves washed with H2O, cut into small pieces, dried (333 K), ground and| 0.1 mg/L AV acasoglant versus 3 mg/L polyaluminun chloride pH 5                        | 21–93.1%.           | [28]      |
| (Na2HAsO4.7H2O) 0.2–1 mg/L| AV leaves washed with deionized water, cut into small pieces, dried (333 K),|                                                                       |                      |           |
| Ground and sieved (100    | mesh)                                                                       |                                                                       |                      |           |
| River water               | AV powder                                                                   | Coagulant dose: 1200 mg/L; settling time: 40 min, pH 8, 313 K                         | 30.59%              | [29]      |
| Cu: 2000 mg/L             |                                                                             |                                                                                       |                      |           |
| Indrayani stream water:   |                                                                              | 56 mg/L of alum with 5 mg/L of liquid AV as coagulation aid                          | Turbidity: 96.5%     | [31]      |
| Turbidity: 45.5 NTU       |                                                                             |                                                                                       |                      |           |
| Alkalinity: 70 mg/L       |                                                                             |                                                                                       |                      |           |
| pH 7.78                   |                                                                             |                                                                                       |                      |           |
| Indrayani stream water:   | 24 mg/L of alum with 14 mg/L of AV as coagulation aid                        | Turbidity: 98.5%                                                                       |                      | [31]      |
| Turbidity: 101 NTU        |                                                                             |                                                                                       |                      |           |
| Alkalinity: 65 mg/L       |                                                                             |                                                                                       |                      |           |
| pH 7.1                    |                                                                             |                                                                                       |                      |           |
| Indrayani stream water:   | 56 mg/L of alum with 10 mg/L of liquid AV as floculation aid                 | Turbidity: 96.2%                                                                       |                      | [31]      |
| Turbidity: 45.5 NTU       |                                                                             |                                                                                       |                      |           |
| Alkalinity: 70 mg/L       |                                                                             |                                                                                       |                      |           |
| pH 7.78                   |                                                                             |                                                                                       |                      |           |
| Indrayani stream water:   | 56 mg/L of alum with 10 mg/L of liquid AV as floculation aid                 | Turbidity: 96.2%                                                                       |                      | [31]      |
| stream:                   |                                                                             |                                                                                       |                      |           |
| Turbidity: 101 NTU        |                                                                             |                                                                                       |                      |           |
| Alkalinity: 65 mg/L       |                                                                             |                                                                                       |                      |           |
| pH 7.1                    |                                                                             |                                                                                       |                      |           |
| Surface water             | AV gel blended and mixed with H2O                                           | 4 mL/L, 308 K, pH 4–8                                                                  | Turbidity: 50–65%    | [32]      |
| Turbidity: 40–100 NTU     |                                                                             |                                                                                       |                      |           |
| Surface water             | AV gel                                                                      | 1 mL/L, pH 4.1, 303 K                                                                  | Turbidity: 58.33%    | [33]      |
| Turbidity: 12 NTU         |                                                                             |                                                                                       | TDS: 77.51%          |           |
| TDS: 1472 mg/L            |                                                                             |                                                                                       | Color: 50.36%        |           |
| Color: 137 TCU            |                                                                             |                                                                                       |                      |           |
| Surface water             | AV gel mixed with H2O, stirred and strained (25 mm mesh) and filtrate        | Dose: 10 mL/L as floculant                                                             | Turbidity: 72%       | [34]      |
| Turbidity: 186.8 NTU      |                                                                             |                                                                                       | SS: 91%             |           |
| SS: 163 mg/L              |                                                                             |                                                                                       | Color: 15%           |           |
| Color: 278 (Pt/Co)        |                                                                             |                                                                                       |                      |           |
| pH 7.37                   |                                                                             |                                                                                       |                      |           |
| Textile wastewater        | Powdered biofloculant extracted from dehydrated pieces of AV leaves (313 K) | Dosage: 60 mg/L, pH 5, contact time: 180 min                                          | FA: 82%             | [35]      |
| Turbidity: 54.1–66.1 NTU  |                                                                             |                                                                                       | COD: 90.53%         |           |
| TDS: 734.12–784.09 mg/L   |                                                                             |                                                                                       | TSS: 98.19%         |           |
| TSS: 3768 mg/L            |                                                                             |                                                                                       | TDS: 98.80%         |           |
| TDS: 3754 mg/L            |                                                                             |                                                                                       |                      |           |
| Municipal wastewater      | AV gel blended and mixed with H2O                                          | 150 mL of AV gel, 10 mL of alum as coagulant, pH 8                                    | Turbidity: 67.72%    | [35]      |
| Turbidity: 54.1–66.1 NTU  |                                                                             |                                                                                       |                      |           |
| TDS: 734.12–784.09 mg/L   |                                                                             |                                                                                       |                      |           |
| TSS: 3768 mg/L            |                                                                             |                                                                                       |                      |           |
| TDS: 3754 mg/L            |                                                                             |                                                                                       |                      |           |
| TSS: 218.22 to 239.10     |                                                                             |                                                                                       |                      |           |
| mg/L pH 7.2–8.4           |                                                                             |                                                                                       |                      |           |
Table 1. Cont.

| Effluents                              | Preparation                              | Operating Conditions                        | Removal Efficiencies      | Reference |
|----------------------------------------|------------------------------------------|---------------------------------------------|---------------------------|-----------|
| Electroplating industrial wastewater   | Frozen AV gel (277 K), extracted and lyophilized | AV polymer: 0.50–2.5 g/L, Aluminum sulphate: 500–1000 mg/L, pH: 2.5–3.5 | Cr(VI): 6.37–37.74% DS: 89.80–94.13% SS: 71.06–90.00% | [36]     |
| Dye industry effluent                  | AV gel                                   | 100 g of AV gel (20%, 40%, 60%, 80%, and 100%) added to water at boiling temperature | TDS: 1.8–3.5% COD: 3.23–33.05% BOD: 15.78–53.33% | [37]     |
| River water Cu: 2000 mg/L.             | AV powder                                | Coagulant dose: 1200 mg/L, settling time: 40 min, pH 8, 313 K | 30.59%                    | [29]     |
| River water Cu: 2 g/L.                 | AV powder                                | Coagulant dose: 1200 mg/L, settling time: 40 min, pH 8, 313 K | 30.59%                    | [29]     |
| Municipal wastewater                   | AV pulp blended, 1000 mg was mixed with 100 mL of H2O | Dosage of 3 mL (30% AV pulp), pH 6–7 | Turbidity: 77.05% TSS: 74% | [38]     |
| Synthetic water:                       | AV leaves gel                            | 1%, 2% and 5% of AV gel                     | Turbidity: 51.72% COD: 59.20% | [39]     |
| Tannery Wastewater                     | AV leaves gel                            | 5% of AV gel                               | Turbidity: 46.76% COD: 52.60% | [39]     |
| Artificial turbid water                | AV gel blended and mixed with H2O (1% v/v) | AV as coagulant aid (7%) with alum (10 mg/L) | Turbidity: 76–81%         | [40]     |
| Artificial turbid water                | AV gel blended and mixed with H2O (1% v/v) | AV as coagulant aid (7%) with alum (10 mg/L) | Turbidity: 60–65%         | [40]     |

AV: Aloe vera, TSS: total suspended solids, TDS: total dissolved solids, SS: suspended solids, DS: dissolved solids, FA: Flocculating activity. BOD: biochemical oxygen demand, COD: chemical oxygen demand.

Figure 1. The scheme of Aloe vera preparations and applications for wastewater treatment.
Generally, experiments related to the use of AV materials in the coagulation/flocculation process for wastewater treatment showed the variability of the efficiencies in removing pollutants. This variability could be related mainly to the method used to prepare AV polymer and to the characteristics of the wastewaters. The wastewater characteristics considerably controlled the process efficiency, as reported for other materials [15,17,18,30,41].

3. Aloe Vera as Biosorbent for Pollutant Removal

The beneficial characteristics of the adsorption process (efficiency, safety, technical feasibility, simple design, easy processing, etc.) allowed its application for the treatment of wastewater containing various pollutant types (dyes, metals, phenols, etc.). A material suitable as absorbent should be ecofriendly, cheap, resistant to toxic substances, able to remove various inorganic and organic pollutants, and offer high surface area and porosity [17,42]. In order to determine the suitability and the applicability of an adsorbent in removing pollutant, equilibrium modelling, kinetics and thermodynamic parameters should be determined based on experimental data [42,43]. Generally, Langmuir, Freundlich, Temkin, Dubinin-Radushkevicz, and the Halsey isotherm models were applied to analyze the equilibrium adsorption data. However, Elovich equation, intra particle diffusion pseudo first order, and pseudo second order models were used to describe the obtained kinetics results data [44–46]. In order to substitute the activated carbon, various renewable materials (plants, agricultural by-products, industrial wastes, etc.) were tested as adsorbents [17,47–49]. Among the studied materials, AV-based materials were considered as an adsorbent for water treatment. The removal of pollutants, mainly from aqueous solutions using AV as biosorbent, was examined by many researchers (Table 2).

### Table 2. Aloe vera as biosorbents for pollutants removal.

| Effluents                        | Aloe vera Preparation                                                                 | Removal Efficiency (R in %)/Biosorption Capacity (q in mg/g)/Used Conditions/Isotherm | References |
|---------------------------------|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|------------|
| Cd(II) aqueous solution (20–50 mg/L) | AV leaves crushed, powdered and sieved (200 mesh) and modified with carboxylated carbon nanotubes | R: 98%, q: 46.95 mg/g, dosage: 0.02 g, contact time: 30.45 min, pH 6.37 and initial cadmium concentration: 10.69 mg/L, Langmuir | [50]       |
| Ni(II) aqueous solution (20–200 mg/L) | AV leaf residue: steam-heated (40–50 Ka, 20–30 min), washed with H2O, dried (353 K, 24 h), grinded, sieved (100 mesh). The obtained powder mixed with Na2CO3 solution (250 rpm, 12 h), filtered, washed with H2O | q: 28.98 mg/g, 303 K, dosage: 600 mg/L, contact time: 90 min, pH 7. Pseudo-first-order, Langmuir | [51]       |
| Th and Ba aqueous solutions (5–200 mg/L) | AV gel dried (333 K), grounded, sieved (<125 µm), treated with H3PO4 (1.5 M), filtered, rinsed with H2O and dried (333 K). | Th: q: 96.2 mg/g, Langmuir Ba: q: 47.62 mg/g, Freundlich | [52]       |
| Aqueous solutions (Th and Ba: 5–200 mg/L) | AV gel dried (333 K), grounded, sieved (<125 µm), treated with H3PO4 (1.5 M), filtered, rinsed with H2O and dried (333 K). | Th: q: 170 mg/g, Langmuir Ba: q: 107.5 mg/g, Freundlich | [52]       |
| As aqueous solution (43,000 mg/L) | AV leaves | R: 100%, dosage: 30,000 mg/L, contact time: 4 h | [53]       |
| Cr(VI) aqueous solution (50 mg/L) | AV treated with H2SO4 | R: 98.66%, q: 58.83 mg/g, dosage 2000 mg/L, pH 1.23, 150 min, 150 rpm, 298 K, Langmuir | [54]       |
| Cr(VI) aqueous solution (50 mg/L) | AV HNO3 activated carbon | R: 98.89%, q: 59.88 mg/g, dosage 2000 mg/L, pH 1.21, 90 min, 150 rpm and 298 K, Langmuir | [54]       |
| Effluents                      | Aloe vera Preparation                                                                 | Removal Efficiency (R in %)/Biosorption Capacity (q in mg/g)/Used Conditions/Isotherm | References |
|-------------------------------|----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|------------|
| Pb(II) aqueous solution (400–2000 mg/L) | AV leaves dust and cut into small pieces, dried at room temperature (2 weeks), re-dried (323–333 K, 3 h), powdered, sieved (53–74 µm) and treated with H3PO4 (1 M), filtered and washed with distilled water                                                                 | R: 96.2% when the adsorbent amount was increased from 2000 to 6000 mg/L, for an agitation time of 30 min. Langmuir and Freundlich isotherms | [55]       |
| Cu(II) aqueous solutions (20,000–70,000 mg/L) | Leaves dried, grinded and sieved (0.2–0.3 µm)                                                                                             | q: 2.27 mg/g, dosage 2 g/L, contact time: 2 h, initial concentration 20,000 mg/L, pH 5, 318 K. Langmuir | [56]       |
| Hg(II) aqueous solution (5–15 mg/L) | Ethanolic AV extract reduced using AgNO3 (12 mM) at pH 7, in presence of air (stirred, 330 K, 3 h), then heated (353 K, 2 h) and filtered (0.45 µm).                                                                 | R: 95%                                                                                     | [57]       |
| Pd(II) aqueous solution (5–600 mg/L) | AV shell ash magnetic nanoparticles                                                                                                          | q: 47.2 mg/g, dosage: 2000 mg/L, contact time: 15 min, pH 5, 298 K, Freundlich            | [58]       |
| Textile wastewater (Pb: 0.11 mg/L) | AV gel dried (353 K for 24 h), redried using muffle furnace (673 K for 30 min)                                                               | R: 78%, dosage: 20 mg/L, contact time: 60–90 min                                             | [59]       |
| Cu (II) aqueous solutions (40–120 mg/L) | Zinc oxide AV nanoparticles: AV gel broth extracts (90%) mixed with zinc nitrate (94,000 mg/L), stirred (120 min) and left at rest (12 h), then dried (1023 K, 1 h)                                                                 | R > 95%, q: 20.425 mg/g, 298 K, pH 4, 150 min, Langmuir                                 | [60]       |
| U(VI) and Cd(II) aqueous solution (1000 mg/L) | Outer layer AV leaves was dried (333 K), ground, sieved (<125 µm), treated with H3PO4 (1.5) and NaOH (1.5) (24 h at room temperature), filtered, rinsed (H2O) and dried (353 K) | U (VI): q: 370.4 mg/g, dosage: 1.5 g/L, 6 h, pH 4. Cd(II): q: 104.2 mg/g, mg/g, dosage: 1.5 g/L, 6 h, pH 5–6, Langmuir and Freundlich | [61]       |
| Aqueous solutions: Ag (I) | AV shell ash supported Ni0.5Zn0.5Fe2O4 magnetic nanoparticles: AV shells were washed, dried (air oven, 353 K, 24 h), ground, sieved, then carbonized (973 K, 2 h), mixed with metal nitrates and dissolved in H2O. The extract mixed with the previous solution and stirring (30 min), evaporated (353 K), ground and calcined (823 K, 2 h). | R: 98.3%, q: 243.90 mg/g, dosage: 4000 mg/L, 30 min, pH 5, initial concentration: 100 mg/L Langmuir and Freundlich | [62]       |
| Aqueous solution of malachite green (50–250 mg/L) | Activated AV stems carbon: carbonized with concentrated sulphuric acid, washed with water and activated around (1273 K, 6 h)                                                                 | q: 334.61 mg/g, 303 K, 50 min, pH 6.5, Langmuir                                             | [63]       |
| Aqueous solution of methylene blue (4000 mg/L) | Reduced graphene oxide using AV                                                                                                              | R: 98%, dosage 20 mg, 298 K,150 rpm, pseudo second order                                   | [64]       |
| Aqueous solution of methylene blue (1000 mg/L) | Outer layer of AV leaves dried (353 K, overnight), crushed, and sieved (<180 µm)                                                              | q: 356 mg/g, 300 K Langmuir                                                                | [65]       |
| Aqueous solution of reactive red RR198 and reactive blue RB19 (10–160 mg/L) | AV leaves dried (378 K, 10 h), ash preparation (573 K, 2 h), sieved (149–74 µm)                                                               | RR-198: R: 80%, q: 80.152 mg/g/RB-19: R: 90%, q: 88.452 mg/g/pH 3, 20 min, 308 K Freundlich  | [66]       |
| Aqueous solution of Aqueous solution of reactive violet (RV8) and congo red (CR) (5.0–40 mg/L) | AV leaves washed (H2O and ethanol), dried (1 h), powdered, sieved (200 mesh), mixed with CuCl2 and Mg powder (stirred 60 min), filtered, washed (H2O and ethanol), dried (323 K, 1 h), ground and sieved (200 mesh) | CR: q: 36.90 mg/g/RV8: q: 25.19 mg/g/dosage: 100 mg/L, pH 5.5, 30 min, initial concentration: 10 mg/L Langmuir and Freundlich | [67]       |
Table 2. Cont.

| Effluents                                             | Aloe vera Preparation                                                                 | Removal Efficiency (R in %)/Biosorption Capacity (q in mg/g)/Used Conditions/Isotherm | References |
|-------------------------------------------------------|----------------------------------------------------------------------------------------|-----------------------------------------|------------|
| Aqueous solution of congo red (1000 mg/L)             | AV leaves dried, boiled (in H2O), extract mixed with copper sulphate and separation of CuO nanoparticles | Q: 1.1 mg/g, dosage: 5 mg/g, contact time: 10 min, pH 2, Langmuir         | [68]       |
| Synthesized wastewater (Titan Yellow: 10,000–100,000 mg/L) | Air-dried AV: AV leaves washed, cut into small pieces, air dried, dried in (323–325 K for 2 h), ground, and sieved (1 mm mesh) | R: 79.44%, q: 55.25 mg/g, dosage: 200 mg/50 mL, pH 9, contact time: 30 min, and initial concentration: 100,000 mg/L, Langmuir | [69]       |
| Synthesized wastewater (Titan Yellow: 10,000–100,000 mg/L) | Thermally treated AV: air-dried AV treated at 573–773 K (1 h)                          | R: 31.08–70.85%, q: 4.662–10.63 mg/g, dosage: 400 mg/L, pH 9, contact time: 30 min, and initial concentration: 100,000 mg/L | [69]       |
| Synthesized wastewater: aniline and methyl orange (MO) (20–100 mg/L) | AV leaves wastes-based sulfuric acid modified activated carbon: AV gel washed (H2O), dried (423 K, 24 h), crushed (30–60 µm), carbonization (823 K, 20 min), H2SO4 (0.1) treatment (12 h), filtered, washed (H2O), dried (423 K, 12 h), crushed and sieved (40-mesh) | aniline: q: 185.18 mg/g, MO: q: 196.07 mg/g, dosage: 1000 mg/L, contact time: 60 min, pH 3, 300 K Freundlich | [70]       |
| Solution of phenol (0.1–64 mg/L)                      | AV leaves dried (378 K, 3h), burned (973 K, 1 h), milled, converted to nanoscale (stearic acid 3%) | R > 96%, q: 71.73 mg/g, dosage: 80 mg/L, initial concentration: 32 mg/L, contact time: 60 min, 328 K, pH 7, Freundlich and Langmuir | [71]       |

As reported in Table 2, various metals were removed using AV gel and leaves (treated and untreated materials). The adsorption process is controlled by many factors including mainly the AV preparations and operating parameters (metal initial concentration, dosage, pH, temperature, contact time, etc.). For example, AV leaves were crushed, powdered, sieved (200 mesh) and modified with carboxylated carbon nanotubes to be used to remove Cd(II) from aqueous solution (20–50 mg/L). High level of adsorption (98%) was obtained at 20 mg, pH 6.37, and initial concentration of 10.69 mg/L. The adsorption process was found to fit with Langmuir model [51]. Furthermore, AV leaves treated with H2SO4 allowed high removal of Cr(VI) (98.66%), with maximum adsorption ability of 58.83 mg/g obtained with a dosage of 2000 mg/L and pH 1.23 [54]. Under the same condition, the treatment of AV with HNO3 activated carbon allowed the same removal rate (98.89%) for Cr(VI) [54]. Interestingly, total as removal was achieved using AV leaves with a dosage of 30,000 mg/L and a contact time of 4 h [54]. Another biosorbent was prepared by Malik et al. (2015), using AV leaves to remove Pb(II) from water. Leaves were cut, dried at room temperature (for 2 weeks), dehydrated (3 h at 323–333 K), powdered, sieved (53–74 µm), and activated with H3PO4 (1M), then filtered and washed with H2O. The obtained material reached an adsorption efficiency of 96.2% [55]. However, another AV preparation allowed the removal of only 78% of Pb(II) from textile wastewater. In this preparation, AV gel was washed, dried (1073 K for 24 h), and activated 30 min using muffle furnace (4273 K) [59]. Ni(II) removal was also investigated using steam-heated AV leaves (at 40–50 Ka for 20–30 min). After drying (353 K, 24 h), grinding, and sieving (100 mesh), the obtained powder was mixed with Na2CO3 solution, filtered, washed with distilled water (until pH constant) and dried (353 K for 24 h). Of this preparation, 600 mg reached a maximum adsorption capacity of 28.98 mg/g obtained at pH 7, 303 K, and contact time of 90 min. The adsorption process was found to fit with Langmuir model [51]. Likewise, the Th and Ba removal ability by AV gel modified with H3PO4 or NaOH was reported by Kapashi et al. (2019). Compared to H3PO4, the use NaOH enhances Th and Ba sorption capacity of AV gel. For Th, the adsorption capacity passed from 96.2 mg/g (with H3PO4 treatment) to 170 mg/g (with NaOH treatment). However, for Ba these values were 47.62 mg/g and 107.5 mg/g, respectively. The highest adsorption offered by AV gel
treated with NaOH, may be contributed to NaOH effect which may enhance the surface available for metal sorption more importantly than H$_3$PO$_4$ [52]. In another study, removal of Hg(II) from aqueous solution (5–15 mg/L) was assessed using AV ethanolic extract reduced with AgNO$_3$ (12 mM). This extract allowed 95% Hg(II) removal [57]. Generally, AV materials exhibit acceptable heavy metal removal while compared to other natural products (Table 3) and the result variability is related to biosorbent preparation methods and operating parameters (pH, temperature, contact time, biosorbent dose, heavy metal initial concentration, etc.).

Table 3. Maximum adsorption capacity of Aloe vera based biosorbents compared to other natural products for Ni(II), Cu(II), Cd(II) and Cr(VI).

| Adsorbents | Adsorption Capacity (mg/g) | References |
|------------|----------------------------|------------|
| Ni(II)     |                            |            |
| Steam-heated AV leaves (Na$_2$CO$_3$ treatment) | 28.98       | [51]       |
| *Inerata cylindrical* (H$_2$SO$_4$ treatment) | 19.13       | [72]       |
| Oak sawdust (HCl treatment) | 3.37        | [73]       |
| Dalbergia sissoo (NaOH treatment) | 10.47       | [74]       |

| Cu(II)     |                            |            |
|------------|----------------------------|------------|
| Dried AV leaves | 2.27                          | [56]       |
| Tobacco leaves | 17.182                         | [75]       |
| *Tectona grandis* L.f. leaves | 15.43                      | [76]       |
| *Ricinus communis* leaves | 127.27                | [77]       |

| Cd(II)     |                            |            |
|------------|----------------------------|------------|
| Outer layer of AV leaves (treatment with H$_3$PO$_4$ and NaOH) | 104.2        | [61]       |
| Sesame waste | 84.74                         | [78]       |
| *Ficus religiosa* leaves | 27.14                      | [79]       |

| Cr(VI)     |                            |            |
|------------|----------------------------|------------|
| AV leaves (treatment with HNO$_3$ activated carbon) | 59.88     | [54]       |
| *Melaleuca densifolia* leaves | 62.5                      | [80]       |
| *Ficus auriculata* leaves | 6.8                        | [81]       |

Adsorbent derived from AV are also evaluated for the removal of dyes. In this perspective, various preparations of AV were tested as biosorbents for dye decolorization. AV leaves were subject to treatments including simple air-drying, heat treatment, treatments with chemicals (ethanol, H$_2$SO$_4$, NaOH, stearic acid, etc.) and mixed with other components (CuCl$_2$, copper sulphate, etc.) as indicated in Table 2. For example, outer layer of AV leaves were subject to dehydration at 353 K (overnight) before being used for the removal of methylene blue from aqueous solution. The final adsorbent materials were crushed and sieved (<180 µm). The obtained adsorbent showed biosorption capacity of 356 mg/g [66]. For the same dye, significant removal efficiency (98%) was obtained with reduced graphene oxide using AV [64]. For the same purpose, AV leaves were used for the removal of reactive violet and congo red. Powdered leaves were mixed with CuCl$_2$ and Mg powder (stirred for 60 min), filtered, washed (H$_2$O and ethanol), dried (323 K, 1 h), ground, and then sieved (200 mesh). Hence, the prepared materials allowed better adsorption capacity for congo red (36.90 mg/g), than reactive violet 8 (25.19 mg/g) obtained at dose of 100 mg, pH 5.5, contact time of 30 min, and initial concentration of 10 mg/L [67]. However, lower adsorption capacity for congo red (1.1 mg/g) was obtained with the preparation suggested by Batool et al. (2019), in which AV leaves water extract was mixed with copper sulfate solution [68]. For the removal of titan yellow, two preparation methods (air-dried and thermally treated AV) were applied. Air-dried AV leaves (in an oven at 323–325 K, 2 h) were ground and sieved (1 mm), and then used to treat synthesized wastewater (10,000–100,000 mg/L). The obtained powder removed 79.44% of titan yellow with maximum sorption capacity of 55.25 mg/g obtained with a dosage of 4000 mg/L, pH 9, contact time of 30 min, and initial...
concentration of 100,000 mg/L [69]. However, for the thermally treated AV leaves, the removal efficiency did not exceed 70.85% under the same condition as reported before [69].

Furthermore, the removal of phenol from water was performed using dried AV leaves converted to nanoscale using stearic acid (3%). Interestingly, more than 96% of phenol was removed with an adsorption capacity of 71.73 mg/g achieved with a dosage of 80 mg/L, initial phenol concentration of 32 mg/L, contact time of 60 min at pH 7, and 328 K [71].

Generally, AV offered dye adsorption ability comparable to other biosorbents derived from natural products (Table 4). As indicated for heavy metals, the decolorization process is controlled by various factors including the preparation methods for the adsorbent materials and the parameters applied during the biosorption (dosage, contact time, pH, temperature, initial concentration, etc.). The adsorption process is related to the functional groups present over the biosorbent surface. Interestingly, the treatment process may enhance the specific surface area and the adsorption index of the material [82–84].

Table 4. Maximum adsorption capacity of Aloe vera based biosorbent compared to other natural products for methylene blue and methyl orange.

| Adsorbent Based Materials | Adsorption Capacity (mg/g) | References |
|---------------------------|----------------------------|------------|
| Methylene blue            |                            |            |
| Dried outer layer of AV leaves | 356                       | [65]       |
| Cactus (fruit peels treated with H₃PO₄) | 416                       | [82]       |
| Cactus (pear seed cake treated with H₃PO₄) | 260                       | [85]       |
| Cactus cladodes            | 3.44                       | [86]       |
| Cactus fruit peel          | 222                        | [87]       |
| Black stone cherries       | 321.75                     | [88]       |
| Walnut shell               | 315                        | [89]       |
| Hazelnut husks             | 204                        | [90]       |
| Wood apple rind            | 40                         | [91]       |
| Methyl orange              |                            |            |
| AV gel (dried and treated with H₂SO₄) | 196.07                    | [70]       |
| Untreated corn leaves      | 675.6                      | [92]       |
| Corn leaves (treated with HCl) | 4.54                      | [92]       |
| Sugar scum                 | 15.24                      | [85]       |
| Cork powder                | 16.66                      | [93]       |

4. Aloe vera Gel as Flocculant for Wastewater Sludge Treatment

Sludge gravity settling is improved using mineral salts and synthetic polymers. This process is called sludge conditioning. As reported for the coagulation/flocculation, the used chemicals are associated to various environmental problems [12,21]. Consequently, the use of natural products as bioflocculant for sludge conditioning constitutes a new strategy with sustainable impacts. To the best of our knowledge, the only study reporting the use of AV as biological flocculant for wastewater sludge treatment was conducted recently by Jaouadi et al. (2020) [94]. In this study, AV gel was blended and used freshly as bioflocculant. Interestingly, the gel allowed good sludge solid–liquid separation. Moreover, a combined treatment using AV gel and water glass (3%) enhanced the particles size and promoted sludge settling. At the same time, AV gel promoted the odor removal from the sludge, which was confirmed by volatile organic compounds analysis [94]. The use of AV materials as conditioner for wastewater sludge treatment represents a processing technology in line with the sustainable development goals. However, the applicability of this biomaterial should be confirmed by the evaluation of various parameters (dryness, residual turbidity and resistance of filtration) and compared to that obtained while using polyelectrolytes (FeCl₃, Al₂(SO₄)₃, etc.).
5. *Aloe vera* for Textile Dyes Biodegradation

Because *AV* contains enzymes, the degradation of dyes (congo red and malachite green) was examined using water extract of different plant parts (pulp, skin, and whole plant) by Rai et al. (2014), as the only group of researchers reporting this phytoremediation [95]. Dye decolorization rate varied depending on the extract origins. Malachite green decolorization reached the maximum in the presence of pulp extract (30%). However, skin extract allowed maximum decolorization for congo red (27%). Dye transformation is related to the presence of enzymes in *AV*, such as carboxypeptidase, glutathione peroxidase, as well as several isozymes of superoxide dismutase [96]. These enzymes are studied in different plants and microorganisms and are shown responsible for the degradation of dye molecules [97,98]. Consequently, *AV* enzymes can be considered as a biological option useful for treating textile wastewater. Similarly to various plants, *AV* exhibit phytoremediation potential for dyes remediation, as indicated in Table 5 for malachite green. The decolorization rate varied depending on the operating conditions applied for each experiment (pH, temperature, time, dye concentration, dose, etc.). Generally, more investigations are needed to explore the operating conditions for enzymatic system and to determine the compounds resulted from the biodegradation process.

| Textile Dyes         | Decolorization Rate (%) | References |
|----------------------|-------------------------|------------|
| AV pulp              | 30                      | [95]       |
| AV skin              | 10                      | [95]       |
| AV whole plant       | 9                       | [95]       |
| Cactus cladode       | 99                      | [99]       |
| Cactus callus        | 91                      | [99]       |
| *Azolla pinnata*     | 84.4                    | [100]      |
| *Lemna minor*        | 88                      | [101]      |
| *Spirodela polyrhiza*| 95                      | [102]      |

6. Factors Making *Aloe vera* a Promising Material for Water Treatment

*Aloe vera* is characterized by its original composition including enzymes, vitamins, carbohydrates lignin, proteins, and inorganic substances with beneficial utilization in various fields (food industry, pharmaceutical industry, cosmetics, etc.) [103,104]. The adsorption is related to the presence of high fiber content in *AV* gel, and hydroxyl and carboxyl groups allowed metal binding on *AV* materials [25]. Moreover, *AV* extract demonstrated its ability to play the role of metal reducing agent [105–107]. Glyco-aloeh-modinantherone and tannins are reported to be responsible of the coagulation property similar to other natural flocculants such as cactus juice [18]. In fact, *AV* gel is composed mainly of polysaccharide with low protein and lipid contents, and polysaccharide mucilage is involved in the flocculation/coagulation process. In this context, cactus carbohydrates (L-arabinose, D-galactose, L-rhamnose, D-xylose, and galacturonic acid) have been reported to be implicated as coagulant agent [108]. For example, galacturonic acid with its polymeric structure allowed the adsorption of particles via bridges. In addition to that, polysaccharide functional groups (carboxyl, hydroxyl, and amine) and hydrogen bonds are useful for the flocculation [109]. Furthermore, the mucilage property is controlled by the presence of Ca$^{2+}$ and K$,^{+}$, which enhance its water holding capacity [110]. This behavior is behind the use of this material for sludge dewatering. Interestingly, *AV* enzymatic system (carboxypeptidase, glutathione peroxidase, as well as several isozymes of superoxide dismutase) can be considered as a biological option useful for dyes biodegradation. However, the *AV* composition varied depending on various factors (species, origin, etc.), which may affect the coagulation property [111,112].
7. Conclusions

*Aloe vera* is an interesting plant that should be considered in water treatment. The possibility of using various AV reparations for pollutants removal from water was proved. It can be used as a flocculant/coagulant, as a biosorbent, and can substitute polymer in sludge dewatering. The use of AV materials in the coagulation/flocculation process for wastewater treatment has been verified at laboratory scale showing significant results in removing pollutants (suspended solids, turbidity, COD, BOD, dye, and heavy metals) from water. In some cases, the efficiency of pollutant removal exceeded 90% depending on the AV preparations used as coagulant/flocculant and on the wastewater characteristics. AV polymers are also useful for wastewater sludge conditioning. Furthermore, AV-based biosorbents were prepared using various methods, including sun-drying, heat treatment and chemical treatments. The resulted materials were tested for dye and metal removal. The adsorption capacity is controlled by various factors including the preparation techniques, the pollutant types, and the operating parameters (adsorbent dose, pH, temperature, contact time, etc). Experimental data showed promising removal values comparable to other materials reported in the literature. Interestingly, AV offered an enzymatic system able to degrade textile dyes. Generally, experiments were conducted at laboratory scale using aqueous solutions of pollutants. Consequently, more researches are needed to evaluate the applicability of AV materials for real wastewater at large scale. In this context, it is very important to optimize the operating conditions for each type of wastewater. Moreover, environmental study should be addressed taking into consideration the AV material properties useful as coagulant/flocculant or as biosorbent. Material properties include life cycle, storage condition, biodegradation, alteration, regeneration, etc. Finally, *Aloe vera* is abundant, ecofriendly, biodegradable, and environmentally sustainable. However, techno-economic assessment is required after confirmation of its applicability at real conditions.

**Author Contributions:** Writing—original draft preparation, K.M.K., A.A., H.N.H., M.M.E., M.A.T., and F.B.R.; writing—review and editing, K.M.K., A.A., H.N.H., M.M.E., M.A.T. and F.B.R.; visualization; F.B.R. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by Deanship of Scientific Research at King Khalid University.

**Acknowledgments:** The authors extend their appreciation to the Deanship of Scientific Research at King Khalid University for funding this work through General Research Project under grant number GRP/144/42. Also, this research was funded by the Deanship of Scientific Research at Princess Nourah Bint Abdulrahman University through the Fast-track Research Funding Program.

**Conflicts of Interest:** The authors declare no conflict of interest.

**References**

1. Jonathan, M.; Srinivasalu, S.; Thangadurai, N.; Ayyamperumal, T.; Armstrong-Altrin, J.; Ram-Mohan, V. Contamination of Uppanar River and coastal waters off Cuddalore, Southeast coast of India. *Environ. Geol.* 2008, 53, 1391–1404. [CrossRef]
2. Govil, P.; Sorlie, J.; Murthy, N.; Sujatha, D.; Reddy, G.; Rudolph-Lund, K.; Krishna, A.; Mohan, K.R. Soil contamination of heavy metals in the Katedan industrial development area, Hyderabad, India. *Environ. Monit. Assess.* 2008, 140, 313–323. [CrossRef] [PubMed]
3. Raju, N.J.; Ram, P.; Dey, S. Groundwater quality in the lower Varuna river basin, Varanasi district, Uttar Pradesh. *J. Geol. Soc. India* 2009, 73, 178–192. [CrossRef]
4. Kurniawan, T.A.; Lo, W.; Chan, G.; Sillanpää, M.E. Biological processes for treatment of landfill leachate. *J. Environ. Monit.* 2010, 12, 2032–2047. [CrossRef] [PubMed]
5. Cesaro, A.; Naddeo, V.; Belgiorno, V. Wastewater treatment by combination of advanced oxidation processes and conventional biological systems. *J. Bioremediat. Biodegrad.* 2013, 4, 1–8.
6. Amuda, O.; Alade, A. Coagulation/flocculation process in the treatment of abattoir wastewater. *Desalination* 2006, 196, 22–31. [CrossRef]
7. El-Gohary, F.; Tawfik, A.; Mahmoud, U. Comparative study between chemical coagulation/precipitation (C/P) versus coagulation/dissolved air flotation (C/DAF) for pre-treatment of personal care products (PCPs) wastewater. *Desalination* 2010, 252, 106–112. [CrossRef]
8. Jimenez, B.; Chavez, A.; Leyva, A.; Tchobanoglous, G. Sand and synthetic medium filtration of advanced primary treatment effluent from Mexico City. Water Res. 2000, 34, 473–480. [CrossRef]

9. Crini, G.; Lichtfouse, E. Advantages and disadvantages of techniques used for wastewater treatment. Environ. Chem. Lett. 2019, 17, 145–155. [CrossRef]

10. Xiong, B.; Loss, R.D.; Shields, D.; Pawlik, T.; Hochreiter, R.; Zydney, A.L.; Kumar, M. Polyacrylamide degradation and its implications in environmental systems. NPJ Clean Water 2018, 4, 1–9. [CrossRef]

11. Weston, D.P.; Lentz, R.D.; Cahn, M.D.; Ogle, R.S.; Rothert, A.K.; Lydy, M.J. Toxicity of anionic polyacrylamide formulations when used for erosion control in agriculture. J. Environ. Qual. 2009, 38, 238–247. [CrossRef]

12. Crini, G.; Badot, P.-M. Application of chitosan, a natural aminopolysaccharide, for dye removal from aqueous solutions by adsorption processes using batch studies: A review of recent literature. Prog. Polym. Sci. 2008, 33, 399–447. [CrossRef]

13. Agrawal, V.R.; Vairagade, V.S.; Kedar, A.P. Activated carbon as adsorbent in advance treatement of wastewater. IOSR J. Mech. Civ. Eng. 2017, 14, 36–40. [CrossRef]

14. Zhang, H. Regeneration of exhausted activated carbon by electrochemical method. Chem. Eng. J. 2002, 85, 81–85. [CrossRef]

15. Khadhraoui, M.; Sellami, M.; Zarai, Z.; Saleh, K.; Ben Rebah, F.; Leduc, R. Cacus juice preparation as bioflocculant: Properties, characteristics and application. Environ. Eng. Manag. J. 2019, 18, 137–146.

16. Amari, A.; Alalwan, B.; Eldirderi, M.M.; Mnif, W.; Ben Rebah, F. Cactus material-based adsorbs for the removal of heavy metals and dyes: A review. Mater. Res. 2019, 7, 01002. [CrossRef]

17. Ben Rebah, F.; Siddeeg, S. Cactus an eco-friendly material for wastewater treatment: A review. J. Mater. Environ. Sci. 2017, 8, 1770–1782.

18. He, W.; Xie, Z.; Lu, W.; Huang, M.; Ma, J. Comparative analysis on floc growth behaviors during ballasted flocculation by using aluminum sulphate (AS) and polyaluminium chloride (PACL) as coagulants. Sep. Purif. Technol. 2019, 213, 176–185. [CrossRef]

19. Wei, N.; Zhang, Z.; Liu, D.; Wu, Y.; Wang, J.; Wang, Q. Coagulation behavior of polyaluminum chloride: Effects of pH and coagulant dosage. Chin. J. Chem. Eng. 2015, 23, 1041–1046. [CrossRef]

20. Edzwald, J.K.; Haarhoff, J. Seawater pretreatment for reverse osmosis: Chemistry, contaminants, and coagulation. Water Res. 2011, 45, 5428–5440. [CrossRef]

21. Martyn, C.N.; Osmonda, C.; Edwardson, J.A.; Barker, D.J.P.; Harris, E.C.; Lacey, R.F. Geographical Relation Between Alzheimer’s Disease and Alcohol in Drinking Water. Lancet 1989, 333, 59–62. [CrossRef]

22. Nkurunziza, T.; Nduwayezu, J.B.; Banadda, E.N.; Nhapi, I. The effect of turbidity levels and Moringa oleifera concentration on the effectiveness of coagulation in water treatment. Water Sci. Technol. 2009, 59, 1551–1558. [CrossRef]

23. Gaikwad, V.; Munavalli, G. Turbidity removal by conventional and ballasted coagulation with natural coagulants. Appl. Water Sci. 2019, 9, 1–9. [CrossRef]

24. Daza, R.; Barajas Solano, A.F.; Epalza Contreras, J.M. Evaluation of the efficiency of bio-polymers derived from desertic plants as flocculation agents. Chem. Eng. Trans. 2016, 49, 361–366.

25. Adugna, A.T.; Gebreselassie, N.M. Aloe steudneri gel as a Natural Flocculant: Phytochemical Screening and Turbidity removal Trials of water by Coagulation flocculation. Water Sci. Technol. 2018, 36–40. [CrossRef]

26. Bazrafshan, E.; Mohammadi, L.; Mostafapour, F.K. Survey efficiency of coagulation process with polyaluminum chloride using allogenic and magnesium hybrid coagulants. Process optimization. Water Sci. Technol. 2016, 30, 59–62. [CrossRef]

27. Ezeamaku, U.; Chike-Onyegbula, C.; Eze, I.; Iheaturu, N.; Dunu, S.; Osueke, W.; Onuchukwu, S. Removal of Copper Ions from Drinking Water by Using Magnesium Chloride and Aloe Vera Leaves. Fusio J. Ser. 2019, 5, 117–126.

28. Jadhav, M.V.; Mahajan, Y.S. Assessment of feasibility of natural coagulants in turbidity removal and modeling of coagulation process. Desalin. Water Treat. 2014, 52, 5812–5821. [CrossRef]

29. Patil, H.S.; Shinde, S.A.; Raut, G.A.; Nawale, N.P.; Hakke, A.; Deosarkar, M. Use of Aloe-vera gel as natural coagulant in treatment of drinking water. Int. J. Adv. Sci. Res. Eng. Trends 2020, 5, 81–89.

30. Jinna, A.; Anu, M.; Krishnan, N.; Sanal, V.; Das, L. Comparative study of efficiency of local plants in water treatment. Int. Res. J. Eng. Technol. 2019, 6, 4046–4052.

31. Pallar, B.M.; Abram, P.H.; Ningsih, P. Analysis of Hard Water Coagulation in Water Sources of Kawatuna using Aloe Vera Plant. J. Acad. Kim. 2020, 9, 125–132. [CrossRef]

32. Irm, N.Y.A.E.; Philippe, S.; Abdoukarim, A.; Alassane, Y.A.K.; Pascal, A.C.; Daouda, M.; Dominique, S.K.C. Evaluation of Aloe vera leaf gel as a Natural Flocculant: Physicochemical Screening and Turbidity removal Trials of water by Coagulation flocculation. Res. J. Recent Sci. 2016, 5, 9–15.

33. Saratha Priya, S.; Kumar, M.K.S. Physio Chemical Treatment On Municipal Waste Water In Tuticorin Region Using Natural Coagulants. Int. J. Sci. Eng. Res. 2018, 6, 3221–5687.

34. Da Luz, T.G.; Sales, V.; da Rocha, R.D.C. Evaluation of technology potential of Aloe arborescens biopolymer in galvanic effluent treatment. Water Sci. Technol. 2018, 48–57. [CrossRef]
37. Abirami, P.; Devi, N.; Sharmila, S. Flocculant effect of Aloe vera L. in removing pollutants from raw and treated dye industry effluent. Asian J. Environ. Sci. 2010, 5, 5–7.

38. Zin, N.S.B.M.; Kamaruzaman, W.N.B.; Lee, C.S. Study the effectiveness of biofloculant between Aloe vera (L.). Burm. F and Okra mucilage in coagulation and flocculation Treatment. In e-Proceedings Seminar ENVIROPOLY 2016; Oleh, D., Penerbit, P., Eds.; Politeknik Sultan Idris Shah: Selangor, Malaisie, 2016.

39. Muruganandam, L.; Saravana Kumar, M.P.; Jena, A.; Gulla, S.; Godhwani, B. Treatment of waste water by coagulation and flocculation using biomaterials. IOP Conf. Ser. Mater. Sci. Eng. 2017, 263, 032006. [CrossRef]

40. Amruta, G.; Munavalli, G. Use of aloe vera as coagulant aid in turbidity removal. Int. J. Eng. Res. Technol. 2017, 10, 4362–4365.

41. Sellami, M.; Khadraoui, M.; Zarat, Z.; Jdidi, N.; Ben Rebaei, F. Cactus juice as flocculant in the coagulation-flocculation process for industrial wastewater treatment: Comparative study with polyacrylamide. Water Sci. Technol. 2014, 70(7), 1175–1181. [CrossRef] [PubMed]

42. Crini, G.; Badot, P.-M. Sorption Processes and Pollution: Conventional and Non-Conventional Sorbents for Pollutant Removal from Wastewaters; presses University Franche-Comté: Besançon, France, 2010.

43. Douven, S.; Paez, C.A.; Gommes, C.J. The range of validity of sorption kinetic models. J. Colloid Interface Sci. 2015, 448, 437–450. [CrossRef]

44. Malkoc, E.; Nuhoglu, Y. Determination of kinetic and equilibrium parameters of the batch adsorption of Cr (VI) onto waste acorn of Quercus ithaburensis. Chem. Eng. Process. Process Intensif. 2007, 46, 1020–1029. [CrossRef]

45. Matthäus, B.; Özcan, M.M. Habitat effects on yield, fatty acid composition and tocopherol contents of prickly pear (Opuntia ficus-indica L.) seed oils. Sci. Hortic. 2011, 131, 95–98. [CrossRef]

46. Tichaona, N.; Maria, M.N.; Emaculate, M.; Fidelis, C.; Upenygu, G.; Benias, N. Isotherm Study of the Biosorption of Cu (II) from Aqueous Solution by Vigna Subterranea (L.) Verdc Hull. J. Sci. Technol. Res. 2013, 2, 119–206.

47. Mahfoudhi, N.; Boufi, S. Nanocellulose as a novel nanostructured adsorbent for environmental remediation: A review. Cellulose 2017, 24, 1171–1197. [CrossRef]

48. Kyzas, G.Z.; Kostoglou, M. Green adsorbents for wastewaters: A critical review. Materials 2014, 7, 333–364. [CrossRef] [PubMed]

49. Sharma, P.; Kaur, H.; Sharma, M.; Sahore, V. A review on applicability of naturally available adsorbents for the removal of hazardous dyes from aqueous waste. Environ. Monit. Assess. 2011, 183, 151–195. [CrossRef]

50. Mahmoodi, Z.; Aghaie, H.; Fazaeli, R. Application of response surface methodology for optimization of cadmium removal by Aloe vera/carboxylated carbon nanotubes nanocomposite-based low-cost adsorbent. Mater. Res. Express 2020, 7, 065015. [CrossRef]

51. Gupta, S.; Sharma, S.; Kumar, A. Biosorption of Ni (II) ions from aqueous solution using modified Aloe barbadensis Miller leaf powder. Water Sci. Eng. 2019, 12, 27–36. [CrossRef]

52. Kapashi, E.; Kapnisti, M.; Dafnomili, A.; Noli, F. Aloe Vera as an effective biosorbent for the removal of thorium and barium from aqueous solutions. J. Radioanal. Nucl. Chem. 2019, 321, 217–226. [CrossRef]

53. Tripathi, V.; Srivastava, S.; Dwivedi, A. Aloe vera Burm. F. A potential botanical tool for bioremediation of arsenic. Sch. J. Agric. Vet. Sci. 2016, 3, 480–482.

54. Prajapati, A.K.; Das, S.; Mondal, M.K. Exhaustive studies on toxic Cr (VI) removal mechanism from aqueous solution using activated carbon of Aloe vera waste leaves. J. Mol. Liq. 2020, 307, 112956. [CrossRef]

55. Malik, R.; Lata, S.; Singhal, S. Removal of heavy metal from wastewater by the use of modified aloe vera leaf powder. Int. J. Basic Appl. Chem. Sci. 2015, 5, 6–17.

56. Singh, K.; Sharma, S.; Jain, A.; Mandal, M.; Pandey, P.K. Removal of copper ion from synthetic wastewater using Aloe vera as an adsorbent. Eur. J. Adv. Eng. Technol. 2017, 4, 249–254.

57. Vélez, E.; Campillo, G.; Morales, G.; Hincapié, O.; Osorio, J.; Arnache, O. Silver nanoparticles obtained by aqueous or ethanolic aloe Vera extracts: An assessment of the antibacterial activity and mercury removal capability. J. Nanomater. 2018, 4, 1–7. [CrossRef]

58. Namavari, S.; Moeinpour, F. Use of Aloe Vera Shell Ash Supported Ni 0.5 Zn 0.5 Fe2O4 Magnetic Nanoparticles for Removal of Pb (II) from Aqueous Solutions. Environ. Health Eng. Manag. J. 2016, 3, 15–21.

59. Sruhti, R.; Shabari, M. Removal of lead from textile effluent using Citrus aurantium peel adsorbent and Aloe barbadensis gel adsorbent. Int. Res. J. Environ. Sci. 2018, 5, 3881–3885. [CrossRef]

60. Primo, J.d.O.; Bittencourt, C.; Acosta, S.; Sierra-Castillo, A.; Colomer, J.-F.; Jaeger, S.; Teixeira, V.C.; Anaissi, F.J. Synthesis of Zinc Oxide Nanoparticles by Ecofriendly Routes: Adsorber for Copper Removal From Wastewater. Front. Chem. 2020, 8, 571790. [CrossRef]

61. Noli, F.; Kapashi, E.; Kapnisti, M. Biosorption of uranium and cadmium using sorbents based on Aloe vera wastes. J. Environ. Chem. Eng. 2019, 7, 102985. [CrossRef]

62. Beigzadeh, P.; Moeinpour, F. Fast and efficient removal of silver (I) from aqueous solutions using aloe vera shell ash supported Ni0.5Zn0.5Fe2O4 magnetic nanoparticles. Trans. Nonferr. Met. Soc. China 2016, 26, 2238–2246. [CrossRef]

63. Abuthahir, K.S.; Pragathiswaran, C.; Govindhan, P.; Abbubakkar, B.M.; Srivede, V. Adsorption of Malachite Green dye onto activated carbon obtained from the natural plant stem. Int. J. Res. Pharm. Chem. 2017, 7, 115–119.

64. Bhattacharya, G.; Sas, S.; Wadhwa, S.; Mathur, A.; McLaughlin, J.; Roy, S.S. Aloe vera assisted facile green synthesis of reduced graphene oxide for electrochemical and dye removal applications. RSC Adv. 2017, 7, 26680–26688. [CrossRef]
65. Hanafiah, M.A.K.M.; Jamaludin, S.Z.M.; Khalid, K.; Ibrahim, S. Methylene blue adsorption on Aloe vera rind powder: Kinetics, Isotherm and Mechanisms. Nat. Environ. Pollut. Technol. 2018, 17, 1055–1064.

66. Malakootian, M.; Jafari Mansoorian, H.; Alizadeh, M.; Baghbanian, A. Phenol Removal from Aqueous Solution by Adsorption Process: Study of The Nanoparticles Performance Prepared from Avo vera and Mesquite (Prosopis) Leaves. Sci. Iran. 2017, 24, 3041–3052.

67. Mahmoodi, Z.; Aghaie, H.; Fazaeli, R. Adsorption Study of Reactive Violet 8 and Congo Red Dyes onto Aloe Vera Micropowder Impregnated with Cu Atoms as a Natural Modified Sorbent and Related Kinetics and Thermodynamics. Phys. Chem. Res. 2019, 7, 547–560.

68. Batool, M.; Qureshi, M.Z.; Hashmi, F.; Mehbboob, N.; Shah, A.S. Congo red azo dye removal and study of its kinetics by aloe vera mediated copper oxide nanoparticles. Indones. J. Chem. 2011, 19, 626–637. [CrossRef]

69. El-Azazy, M.; Dimassi, S.N.; El-Shafie, A.S.; Issa, A.A. Bio-waste Aloe vera leaves as an efficient adsorbent for titan yellow from wastewatrer: Structuring of a novel adsorbent using Plackett-Burman factorial design. Appl. Sci. 2019, 9, 4856. [CrossRef]

70. Khanibadi, Y.O.; Heydari, R.; Nourmoradi, H.; Basiri, H.; Basiri, H. Low-cost sorbent for the removal of aniline and methyl orange from liquid-phase: Aloe vera leaves wastes. J. Taiwan Inst. Chem. Eng. 2016, 68, 90–98. [CrossRef]

71. Malakootian, M.; Mansoorian, H.J.; Yari, A.R. Removal of reactive dyes from aqueous solutions by a non-conventional and low cost agricultural waste: Adsorption on ash of Aloe Vera plant. Iran. J. Health Saf. Environ. 2014, 11, 117–125.

72. Li, Z.; Teng, T.T.; Alkarkhi, A.F.; Rafatullah, M.; Low, L.W. Chemical modification of imperata cylindrica leaf powder for heavy metal ion adsorption. WaterAir Soil Pollur. 2013, 224, 1–14. [CrossRef]

73. Argun, M.E.; Dursun, S.; Ozdemir, C.; Karatas, M. Heavy metal adsorption by modified oak sawdust: Thermodynamics and kinetics. J. Hazard. Mater. 2007, 141, 77–85. [CrossRef]

74. Shakirullah, M.; Ahmad, I.; Shah, S. Sorption studies of nickel ions onto sawdust of Dalbergia sissoo. J. Chin. Chem. Soc. 2006, 53, 1045–1052.

75. Çekim, M.; Yildiz, S.; Dere, T. Biosorption of copper from synthetic waters by using tobacco leaf: Equilibrium, inetic and thermodynamic tests. J. Environ. Eng. Landsc. Manag. 2015, 23, 172–182. [CrossRef]

76. Kumar, Y.P.; King, P.; Prasad, V. Equilibrium and kinetic studies for the biosorption system of copper (II) ion from aqueous solution. J. Taiwan Inst. Chem. Eng. 2015, 40, 1157–1177. [CrossRef]

77. Cheraghi, E.; Ameri, E.; Moheb, A. Adsorption of cadmium ions from aqueous solutions using sesame as a low-cost biosorbent: Kinetics and equilibrium studies. Int. J. Environ. Sci. Technol. 2015, 12, 2579–2592. [CrossRef]

78. Rao, K.S.; Anand, S.; Venkateswarlu, P. Adsorption of cadmium from aqueous solution by Ficus religiosa leaf powder and characterization of loaded biosorbent. Clean Soil Air Water 2011, 39, 384–391. [CrossRef]

79. Kuppusamy, S.; Thavamani, P.; Megharaj, M.; Venkateswarlu, K.; Lee, Y.B.; Naidu, R. Potential of Melaleuca diosmifolia leaf as a low-cost adsorbent for hexavalent chromium removal from contaminated water bodies. Process Saf. Environ. Prot. 2016, 100, 173–182. [CrossRef]

80. Rangabhashiyam, S.; Nakkeeran, E.; Selvaraju, N. Biosorption potential of a novel powder, prepared from Ficus auriculata leaves, for sequestration of hexavalent chromium from aqueous solutions. Res. Chem. Intermed. 2015, 41, 8405–8424. [CrossRef]

81. El-Azazy, M.; Dimassi, S.N.; El-Shafie, A.S.; Issa, A.A. Bio-waste Aloe vera leaves as an efficient adsorbent for titan yellow from wastewatrer: Structuring of a novel adsorbent using Plackett-Burman factorial design. Appl. Sci. 2019, 9, 4856. [CrossRef]

82. Nam, K.; Kim, T.; Yoon, J.; Lee, K.; Lee, H.; Song, H.; Lee, S. Adsorption of methyl orange from liquid-phase: Aloe vera leaves wastes. J. Taiwan Inst. Chem. Eng. 2016, 68, 90–98. [CrossRef]

83. Kumar, Y.P.; King, P.; Prasad, V. Equilibrium and kinetic studies for the biosorption system of copper (II) ion from aqueous solution. J. Taiwan Inst. Chem. Eng. 2015, 40, 1157–1177. [CrossRef]

84. Li, Q.; Qi, Y.; Gao, C. Chemical regeneration of spent powdered activated carbon used in decolorization of sodium salicylate for the pharmaceutical industry. J. Clean. Prod. 2015, 86, 424–431. [CrossRef]

85. El maguana, Y.; Elhadiri, N.; Benchanaa, M.; Chikri, R. Adsorption Thermodynamic and Kinetic Studies of Methyl Orange onto Sugar Scum Powder as a Low-Cost Inorganic Adsorbent. J. Chem. 2020, 2020, 9165874. [CrossRef]

86. Sakr, F.; Alahiane, S.; Sennnouaoui, A.; Dinne, M.; Bakas, I.; Assabanne, A. Removal of cationic dye (Methylene Blue) from aqueous solution by adsorption on two type of material from South Morocco. Mater. Today Proc. 2020, 22, 93–96. [CrossRef]

87. Abdelkarim, S.; Mohammed, H.; Nouredine, B. Sorption of methylene blue dye from aqueous solution using an agricultural waste. Trends Green Chem. 2017, 3, 1–7. [CrossRef]

88. Arana, J.M.R.R.; Mazzoco, R.R. Adsorption studies of methylene blue and phenol onto black stone cherries prepared by chemical activation. J. Hazard. Mater. 2010, 180, 656–661. [CrossRef]

89. Yang, J.; Qiu, K. Preparation of activated carbons from walnut shells via vacuum chemical activation and their application for methylene blue removal. Chem. Eng. J. 2010, 165, 209–217. [CrossRef]

90. Ozer, C.; Imamoglu, M.; Turhan, Y.; Boysan, F. Removal of methylene blue from aqueous solutions using phosphoric acid activated carbon produced from hazelnut husks. Toxicol. Environ. Chem. 2012, 94, 1283–1293. [CrossRef]

91. Malarvizhi, R.; Ho, Y.-S. The influence of pH and the structure of the dye molecules on adsorption isotherm modeling using activated carbon. Desalination 2010, 264, 97–101. [CrossRef]
92. Fadhil, O.H.; Eisa, M.Y. Removal of Methyl Orange from Aqueous Solutions by Adsorption Using Corn Leaves as Adsorbent Material. *J. Eng.* 2019, 25, 55–69. [CrossRef]

93. Krika, F.; Benlahbib, O.E.F. Removal of methyl orange from aqueous solution via adsorption on cork as a natural and low-cost adsorbent: Equilibrium, kinetic and thermodynamic study of removal process. *Desalin. Water Treat.* 2015, 53, 3711–3723. [CrossRef]

94. Jaouadi, T.; Hajji, M.; Kasmi, M.; Kallel, A.; Hamzaoui, H.; Mnif, A.; Tizaoui, C.; Trabelsi, I. Aloe sp. leaf gel and water glass for municipal wastewater sludge treatment and odour removal. *Water Sci. Technol.* 2020, 81, 479–490. [CrossRef] [PubMed]

95. Rai, M.S.; Bhat, P.R.; Prajna, P.; Jayadev, K.; Rao, P.V. Degradation of malachite green and congo red using Aloe barbadensis mill extract. *Int. J. Curr. Microbiol. Appl. Sci.* 2014, 3, 330–340.

96. Devis, P.; Robson, M. Anti-inflammatory and wound healing of growth substances in Aloe vera. *J. Am. Pediatr. Med. Assoc.* 1999, 84, 77–81. [CrossRef]

97. Oturkar, C.C.; Nemade, H.N.; Mulik, P.M.; Patole, M.S.; Hawaldar, R.R.; Gawai, K.R. Mechanistic investigation of decolorization and degradation of Reactive Red 120 by Bacillus lentus BL377. *Bioresour. Technol.* 2011, 102, 758–764. [CrossRef]

98. Gebresamuel, N.; Gebre-Mariam, T. Comparative physico-chemical characterization of the mucilages of two cactus pears (Opuntia spp.) obtained from Mekelle, Northern Ethiopia. *J. Biom. Nanobiotechnol.* 2012, 3, 79–86. [CrossRef]

99. Adki, V.S.; Jadhav, J.P.; Bapat, V.A. Exploring the phytoremediation potential of cactus (Nopalea cochenillifera Salm. Dyck.) cell cultures for textile dye degradation. *Int. J. Phytoremediat.* 2012, 14, 554–569. [CrossRef] [PubMed]

100. Kooh, M.R.; Lim, L.B.; Lim, L.H.; Dhari, M.K. Phytoremediation capability of Azolla pinnata for the removal of malachite green from aqueous solution. *J. Environ. Biotechnol. Res.* 2016, 5, 10–17.

101. Torbati, S. Feasibility and assessment of the phytoremediation potential of duckweed for triarylmethane dye degradation with the emphasis on some physiological responses and effect of operational parameters. *Turk. J. Biol.* 2015, 39, 438–446. [CrossRef]

102. Torbati, S. Artificial neural network modeling of biotreatment of malachite green by Spirodela polyrhiza: Study of plant physiological responses and the dye biodegradation pathway. *Process Saf. Environ. Prot.* 2016, 99, 11–19. [CrossRef]

103. Baruah, A.; Bordoloi, M.; Baruah, H.P.D. Aloe vera: A multipurpose industrial crop. *Ind. Crop. Prod.* 2016, 94, 951–963. [CrossRef]

104. Soltanizadeh, N.; Ghiasi-Esfahani, H. Qualitative improvement of low meat beef burger using Aloe vera. *Meat Sci.* 2015, 99, 75–80. [CrossRef]

105. Xie, J.Z.; Chang, H.-L.; Kilbane, J.J., II. Removal and recovery of metal ions from wastewater using biosorbents and chemically modified biosorbents. *Bioresour. Technol.* 1996, 57, 127–136. [CrossRef]

106. Maan, A.A.; Nazir, A.; Khan, M.K.I.; Ahmad, T.; Zia, R.; Murid, M.; Abrar, M. The therapeutic properties and applications of Aloe vera: A review. *J. Herb. Med.* 2018, 12, 1–10. [CrossRef]

107. Sharma, S. Chemical Constitution, Health Benefits and Side Effects of Aloe Vera. *Indian J. Res.* 2015, 4, 1–2.

108. Vijayaraghavan, G.; Sivakumar, T.; Kumar, A.V. Application of plant based coagulants for waste water treatment. *Int. J. Adv. Eng. Res. Stud.* 2011, 1, 88–92.

109. Sepúlveda, E.; Säenz, C.; Aliaga, E.; Aceituno, C. Extraction and characterization of mucilage in Opuntia spp. *J. Arid Environ.* 2007, 68, 534–545. [CrossRef]

110. Hamman, J.H. Composition and applications of Aloe vera leaf gel. *Molecules* 2008, 13, 1599–1616. [CrossRef] [PubMed]

111. Nidiry, E.S.J.; Ganeshan, G.; Lokesha, A. Antifungal activity of some extractives and constituents of Aloe vera. *Res. J. Med. Plant.* 2011, 5, 196–200.

112. Radha, M.H.; Laxmipriya, N.P. Evaluation of biological properties and clinical effectiveness of Aloe vera: A systematic review. *J. Tradit. Complement. Med.* 2015, 5, 21–26. [CrossRef]