

Article

Evaluation of Purification and Disinfection Potentials of Plant-Based Biomass from Wild Sesame Plant

Adeyemi O. Adeeyo ^{1,*} , Hlavangwani N. Eulendah ², Mercy Alabi ³ , Joshua A. Oyetade ⁴ , Titus A. M. Msagati ¹  and Rachel Makungo ² 

- ¹ Institute for Nanotechnology and Water Sustainability, College of Science, Engineering and Technology (CSET), University of South Africa, The Science Campus, Cnr Christiaan De Wet and Pioneer Avenue, Roodeport, Johannesburg 1709, South Africa; msagatam@unisa.ac.za
 - ² Department of Earth Science, Faculty of Science, Engineering and Agriculture, University of Venda, Private Bag X5050, Thohoyandou 0950, South Africa; hlvangwanieulendah@gmail.com (H.N.E.); rachel.makungo@univen.ac.za (R.M.)
 - ³ Discipline of Microbiology, School of Life Sciences, University of KwaZulu-Natal, Durban 4041, South Africa; alabimercy14@gmail.com
 - ⁴ School of Materials, Energy, Water and Environment Sciences, Nelson Mandela African Institution of Science and Technology, Arusha P.O. Box 447, Tanzania; joshuaoyetade@gmail.com
- * Correspondence: eadeeyao@unisa.ac.za

Abstract

The limitations reported for conventional approaches in the treatment and disinfection of water have led to a recent exploration in the use of plant-based water treatment solutions. This technique leverages natural, renewable, and often locally available resources with appreciable environmentally friendly features, cost-effectiveness, and a sustainable nature compared to chemical and energy-intensive conventional methods. Therefore, the current study aimed to evaluate the water purification and disinfection potential of Sesame plant biomass. The experimental process entails the use of plant fibre, leaf dry matter, and ash for the treatment of sampled water from the river and spring source at concentrations of 1–5 g/L. The physicochemical and microbial properties of river and spring water were evaluated after 30 min and 24 h of treatment. Raw river water showed higher pH, conductivity, salinity, total dissolved solids, and turbidity than spring water. Treatment increased pH in both sources (river 6.86–7.94; spring 6.46–8.28), remaining within regulatory limits. The greatest salinity reduction (79.03 mg/L) occurred with dry leaf matter in river water. Sesame ash showed the strongest antimicrobial effect, inhibiting *E. coli* by 99% in river water and completely in spring water. The reduction in total coliforms by 98% also highlights its potential for sustainable water purification.

Keywords: disinfection; plant-based; ash; purification; biomass



Academic Editor: Ligang Zhou

Received: 17 September 2025

Revised: 11 November 2025

Accepted: 20 November 2025

Published: 25 November 2025

Citation: Adeeyo, A.O.; Eulendah, H.N.; Alabi, M.; Oyetade, J.A.; Msagati, T.A.M.; Makungo, R. Evaluation of Purification and Disinfection Potentials of Plant-Based Biomass from Wild Sesame Plant.

Microbiol. Res. **2025**, *16*, 246. <https://doi.org/10.3390/microbiolres16120246>

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Over the years, there have been thriving challenges across various regions, specifically the rural settlements lacking access to clean drinking water, especially those in developing countries. At least, about 2 billion people globally use contaminated water sources [1]. Potable water access has decreased significantly in developing nations, resulting in poor sanitation and impacting human health [2]. The increasing population, specifically in countries like South Africa, has caused a significant increase in water pollution, leading to the unavailability of potable water [3]. Furthermore, climate change, severe droughts, population growth, demand increase, and poor management all contribute to the insufficiency

of water in all countries around the world [4]. Additionally, inefficient water treatment contributes to the unavailability of potable water [5,6]. Polluted water that has not been efficiently treated cannot be used for drinking, agriculture, or industry, and this decreases the quantity of accessible water within a given area.

As the population continues to grow, fewer households will have access to potable water in many countries [4]. This will lead to health dangers and the emergence of lethal diseases [7]. In contribution to the United Nations' goal (SDG 6), there is a need for research focusing on reducing the amount of unsafe water [8] and making clean water available for human and industrial use. This concern necessitates new research focused on the purification of water to meet the needs of the rising global population [9]. Furthermore, the presence of faeces and urine discharged in many watercourses contributes greatly to the high levels of pathogen loads in water bodies [10]. Since this is common practice, there is a need for effective means of disinfection of water before use and consumption [11].

Although studies have demonstrated that conventional chemical-based coagulants are effective for water treatment, this practice can pose health risks. Treated water may contain residues associated with health risk, such as cancer, anaemia, and liver problems [12]. While coagulants made of aluminium have become a popular choice for treating water in several nations, aluminium contributes to the development of neurological conditions like Alzheimer's disease and presbycusis dementia [13]. Chlorine toxicity is also becoming well known, necessitating an immediate cessation of its use in the treatment of water. Hence, there is a need for the replacement of chemical disinfectants with greener options or for existing chemical options to be modified into safer versions [14]. Aside from the problem of health risks of chemical disinfectants, most chemicals are sourced outside the local markets, making them difficult to acquire. When available, they are often comparatively expensive. Therefore, cost-effective alternatives such as plant-based coagulants are to be sought [15]. Water treatment with the use of plant-based coagulants will decrease water purification costs and reduce the health risks caused by chemical coagulants.

Plant-based coagulants have been used in different communities for many years, and scientists have explored them as a sustainable alternative to the current water treatment practices [16,17]. These coagulants are natural, water-soluble, organic, ionic, and nonionic polymers with a range of molecular weights produced from different plant components [18]. They are non-corrosive, reducing the danger of pipe erosion, and may be carbon-neutral in the manufacturing process [19]. As a sustainable, non-hazardous, and degradable alternative to conventional coagulants, plant-based materials are becoming increasingly popular [20,21]. Furthermore, the shift to more sustainable alternatives from the use of conventional coagulation–flocculation methods is associated with the limitations of non-biodegradability and a generation of secondary pollutants when coagulants such as alum salts, ferrous salts, and organic polymers are applied for water treatment [22,23]. Thus, studies have explored the use of various plant parts such as seeds, fruits, and leaves such as lime seeds [24], pods seeds of tamarind [25], leaves of a corn [26], pads from cactus [27], among others. Furthermore, studies have established the use of plant-based cationic, anionic, and nonionic coagulants with great prospect of commercialization, see Saleem and Bachmann [17], while Mohd-Salleh et al. [28] critically reviewed the use of over 16 plants species having natural aid potential as sustainable composite coagulants. The limitations of crude plant biomasses, as reported in the studies, and others are those impacting turbidity and suspended solids. Hence, there is a need to further innovate these materials into products, like eco-friendly filters and other innovative products, that could eliminate these limitations and improve lifespan, regeneration, and large-scale applications. The materials can be regenerated through desorption or acid/base treatment.

Among recently studied plant biomasses, Sesame (*Sesamum* spp.) is an annual plant believed to have originated in Africa, with various species also found in India, China, and Malaysia [29]. It is used primarily for extracting oils, preparing milk-like beverages, and extensively for producing confectionery, bakery products, and Sesame butter [30]. However, it has recently gained attention in water treatment applications [6]. Sesame seeds have been used in the treatment of turbid surface water [31], and their other parts have potential as sources of good coagulating materials. Other plants and plant parts, including mongo seeds, okra, cactus, oak leaves, acorn leaves, moringa seeds, pine cones, and banana peels, have been reported to reduce the total suspended solids, total oxygen demand, and organic matter in water systems [26]. Therefore, this study aims to evaluate the coagulation and disinfection potentials of plant-based biomass from wild Sesame plant materials and to investigate their treatment performance using raw river and spring water.

Also, the plant parts selectively investigated are the leaf and the stem parts. This choice is based on the high amount of lignocellulosic materials (cellulose, hemicellulose, and lignin) present in the selected part. This corresponds to the functional groups such as hydroxyl, carboxyl, and phenolic functional groups present in the materials which provide high affinity to metals and organic pollutants [32]. Thus, the leaf and stem are more chemically reactive and hydrophilic, giving them appreciable purification of use in water purification in contrast to the seeds. As an addendum, the seed is reported to have a high amount of oil and, consequently, has low wettability and poor sorption potentials [3,33]. Also, upon ashing, as similarly reported with the for the sickle bush plant, the inorganic residue mainly comprises oxides and carbonates (Ca, K, Mg, Si, Fe, etc.) which can act as active sites for chemical adsorption and the precipitation of pollutants [6,34].

Also, there is the choice of the targeted plant species (Sesame) as compared to a plant such as *Moringa* with notable coagulant potentials due to its cationic proteins. Sesame exhibits multifaceted potentials of adsorption and coagulation as sustainable antimicrobial agent. Additionally, Sesame plant residues are abundant, low-cost, and environmentally sustainable for large-scale water purification applications. Thus, the study focused on harnessing the leaf and stem part of Sesame plant and their corresponding ash comprising the mixture of stem and leaf as a natural agent for the treatment of water in comparison with the conventional coagulating agent (potash alum). In addition, the study investigated their antimicrobial potential via the respective evaluation of their performance for the remediation of *Escherichia coli* and the total coliform at respective treatment time.

2. Methodology

2.1. Collection of Plant Samples and Plant Preparation

The Sesame plant was collected at Xitlhelani village in the Vhembe district as described by previous studies in Figure 1. with described geological coordinates. It was then analysed both at the School of Agricultural Science, University of Venda, and UNISA College of Agriculture and Environmental Science laboratory in Florida, Johannesburg, for compositional analysis. For preparation, the plant was washed to remove foreign material such as soil. Excessive washing was avoided to minimise leaching. The various parts were divided and dried at room temperature for 7 days to avoid breakdown or weight loss due to respiration [6].

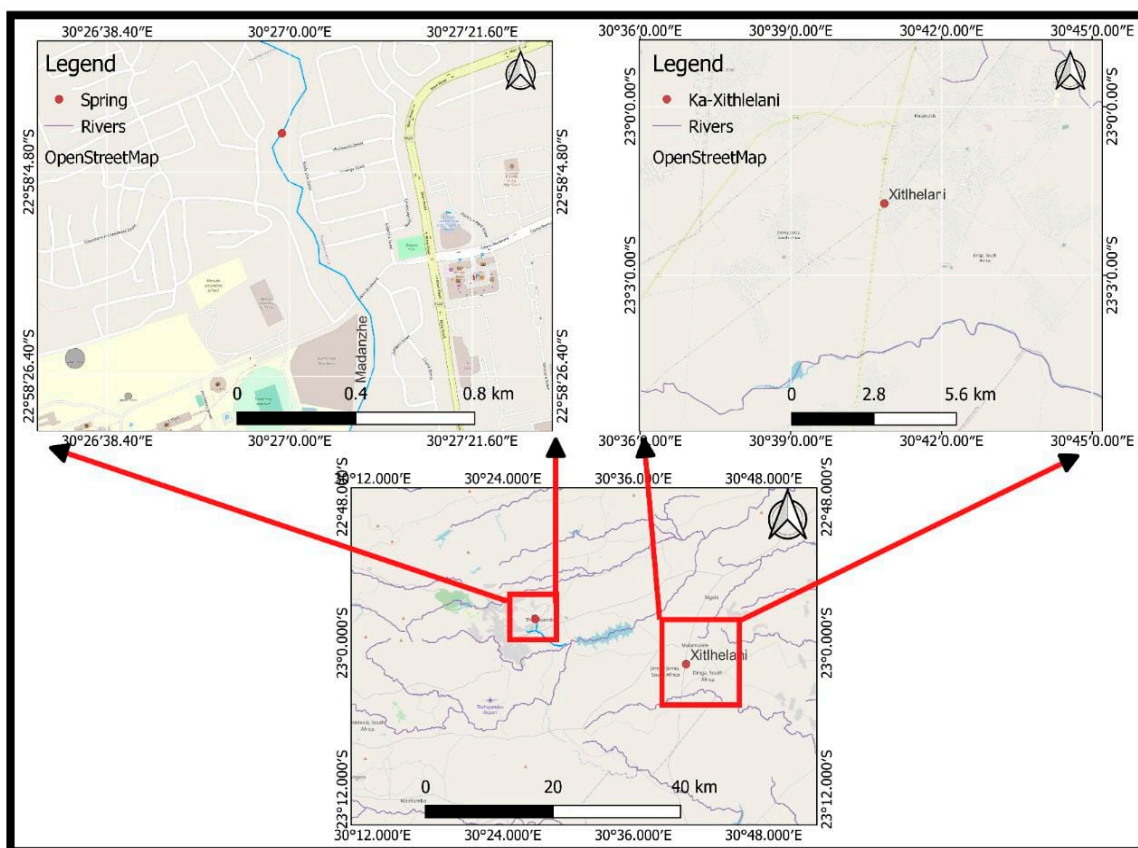


Figure 1. Location of the study area.

2.2. Preliminary Analysis of Water Samples

The river water sample was collected at the Madanzhe River, and the spring water sample was collected from a spring along the river in Ngovhela village near Thohoyandou as described in Figure 1. The samples were collected in sterile containers and transported to the laboratory for further analysis. The physicochemical parameters of the water samples were tested at the collection points using an Extech multi-metre (EC 400 Extech instruments, Nashua, NH, USA) and a turbidimeter (TB 4000 instrument, Nashua, NH, USA) in triplicate [6].

2.3. Preparation of Plant Materials

For the preparation of ash content, the mixture of stem and leaf was milled at 1000 rpm for 5 min, and the powder was stored in a moisture-free container for ash preparation [35]. Ten grams (10 g) of ground Sesame biomass comprising the stem and leaf, respectively, was added to a crucible. The crucible was placed in a muffle furnace (CNW, SXL-1208, Meditry Instrument Co. Ltd., Jiangyin, China) at 500 °C for 8 h. It was cooled in a desiccator and stored in an airtight container for further use. For the preparation of fibre material, the stem was ground by a Wiley mill at 1000 rpm for 3 min, steam-treated, and washed with hot distilled water to separate pigmented and other loose components of the plant, obtaining the plant fibre material. The plant fibre was then dried at room temperature for 24 h. For the preparation of leaf dry matter, the plant leaf materials were ground using a Maxwell and Williams mortar and pestle. The powdered leaf sample was stored in a closed container for water treatment analysis.

2.4. Preparation of Alum Coagulant Stock Solution

This study used industry-grade aluminium sulphate ($\text{Al}_2(\text{SO}_4)_3 \cdot 18 \text{H}_2\text{O}$) as a test control. One gram of alum was dissolved in 100 mL of distilled water to obtain the 1% (10 g/L) stock solution.

2.5. Screening of Plant Materials for Water Purification and Disinfection Potential

Each plant material (ash, fibre, and leaf dry matter) was prepared and tested at concentrations of 1–5 g/L. A volume of 10 mL of the plant material solution at each concentration was shaken for 5 min and decanted into 90 mL of river and spring water samples, which were further agitated for 25 min. The coagulated particles were allowed to settle to the bottom, and results were taken after 30 min and 24 h. The supernatant was poured through filter paper to ensure that any suspended coagulant was captured. Following that, physicochemical and corresponding microbial analyses of the supernatants were performed. Alum solution was used as a control at standard concentration [36]. All experimental data were carried out in triplicates to ensure its reproducibility and the results expressed as mean $\pm$ standard deviation (SD), and error bars represent the standard deviation. Also, the statistical comparisons were carried out among the treatment agents and dosages using one-way analysis of variance (ANOVA) to evaluate the significant differences ($p < 0.05$) between groups.

2.6. Bacteriological Analysis of Water

Bacteriological analysis of water samples was carried out using the colony enumeration method by the pour plating technique. This was used to determine the antibacterial potential of the plant materials against *Escherichia coli* and total coliforms in the water samples. A volume of 1 mL of raw and treated water samples was added into sterile Petri dishes and overlaid with sterile MacConkey and Nutrient Agar. After solidification, the Petri dishes were incubated at 37 °C for 24 h. The colonies in each plate were enumerated, and a mean count was determined. Each sample was tested in duplicate. The antibacterial potential was calculated and reported as the percentage of the difference between the mean colony count of the control and treated plates [37].

3. Results and Discussion

Table 1 shows the results of the analysis of the raw river and spring water samples before treatment. The effect of the treatment on the river water sample with different plant materials after 30 min and 24 h is presented in Figures 2–4. There was an increase in the pH after 30 min of adding alum across the different concentrations, which is not as expected, considering that alum is an acidic salt. However, there was a reduction in the pH after 24 h.

Table 1. Physicochemical analysis of river and spring water samples at collection sites.

Parameters	Raw River Water	Raw Spring Water
pH	6.3 $\pm$ 0.315	4.8 $\pm$ 0.24
EC ($\mu\text{S}/\text{cm}$)	230.0 $\pm$ 11.5	160.9 $\pm$ 8.45
Salinity (mg/L)	102.0 $\pm$ 5.1	76.5 $\pm$ 3.825
TDS (mg/L)	151.0 $\pm$ 7.77	112.6 $\pm$ 5.63
Turbidity (NTU)	11.4 $\pm$ 0.57	0.5 $\pm$ 0.025

Treatment with ash, fibre, and dry leaf matter increased the pH after 30 min and after 24 h (Figure 2a,b). Although the pH of the treated river water samples with alum and Sesame plant materials was within the limits for drinking water of 6.5–8.5 and 5.0–9.7, respectively, the salinity of the water samples reduced with an increase in time of exposure to plant materials and alum in Figure 2c,d [38,39].

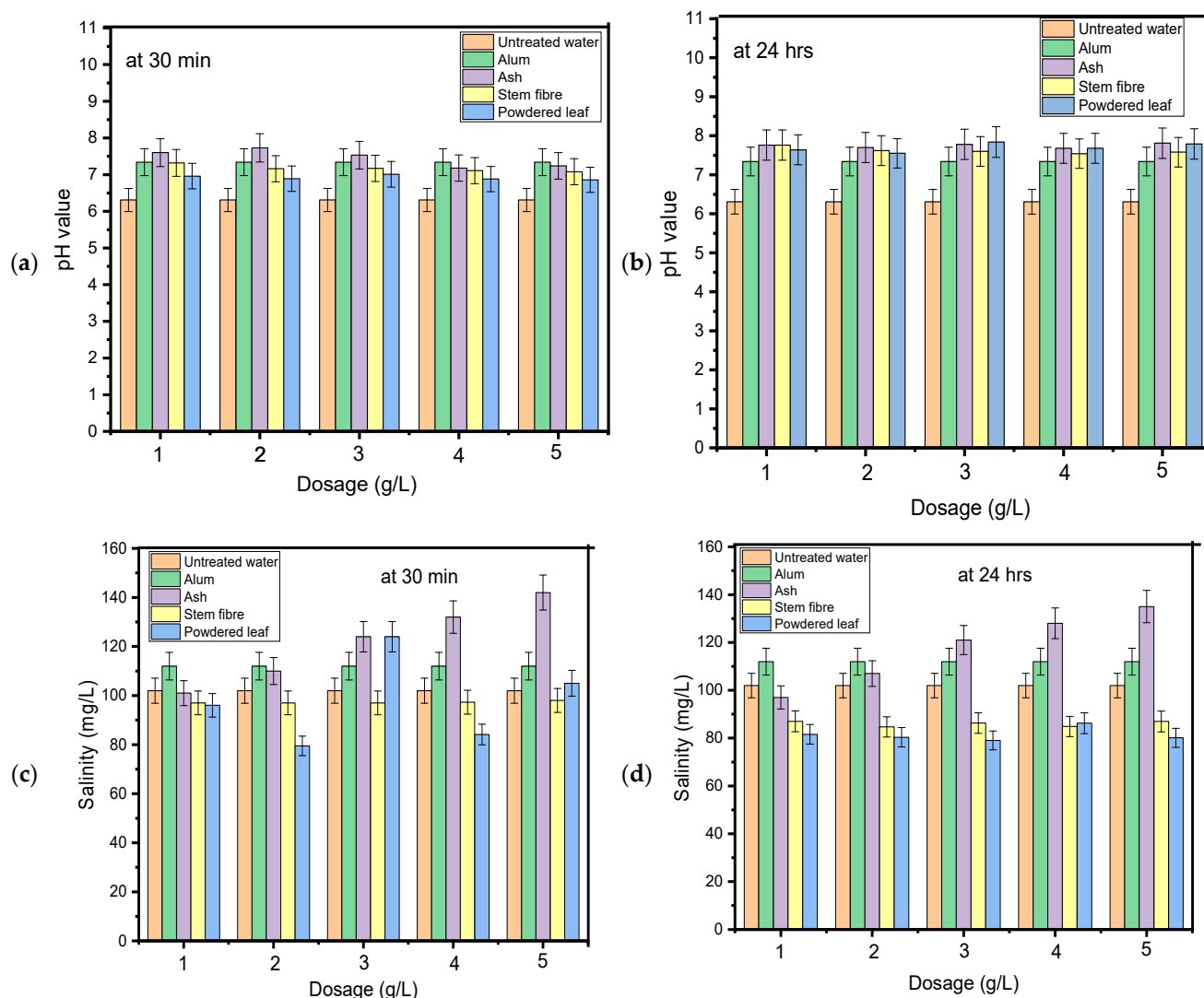


Figure 2. Effect of Sesame plant materials and alum on the pH (a,b) and salinity (c,d) of river water after 30 min and 24 h of treatment.

The highest reduction in salinity was observed in dry leaf matter after 24 h of treatment at 3 g/L. Generally, the plant materials performed better than alum at reducing the salinity of the water samples. All the salinity values were within the guidelines of 600–900 mg/L and 0–200 mg/L, respectively [38,39]. There was an increase in electrical conductivity following the treatment of the river water sample with alum and powdered leaf, but a reduction after treatment with ash and stem fibre for 24 h in Figure 3a,b. The highest reduction in conductivity was observed with the river water sample treated with dry leaf after 24 h. The electric conductivity values of the raw and treated river water samples did not fall under the guideline standards of SANS (2015) of 0–17 μL but fell under the standards of 0–600 μL for drinking water [39]. The treatment with ash increased the amount of total dissolved solids, which increased with an increase in concentration as described by Figure 3c,d.

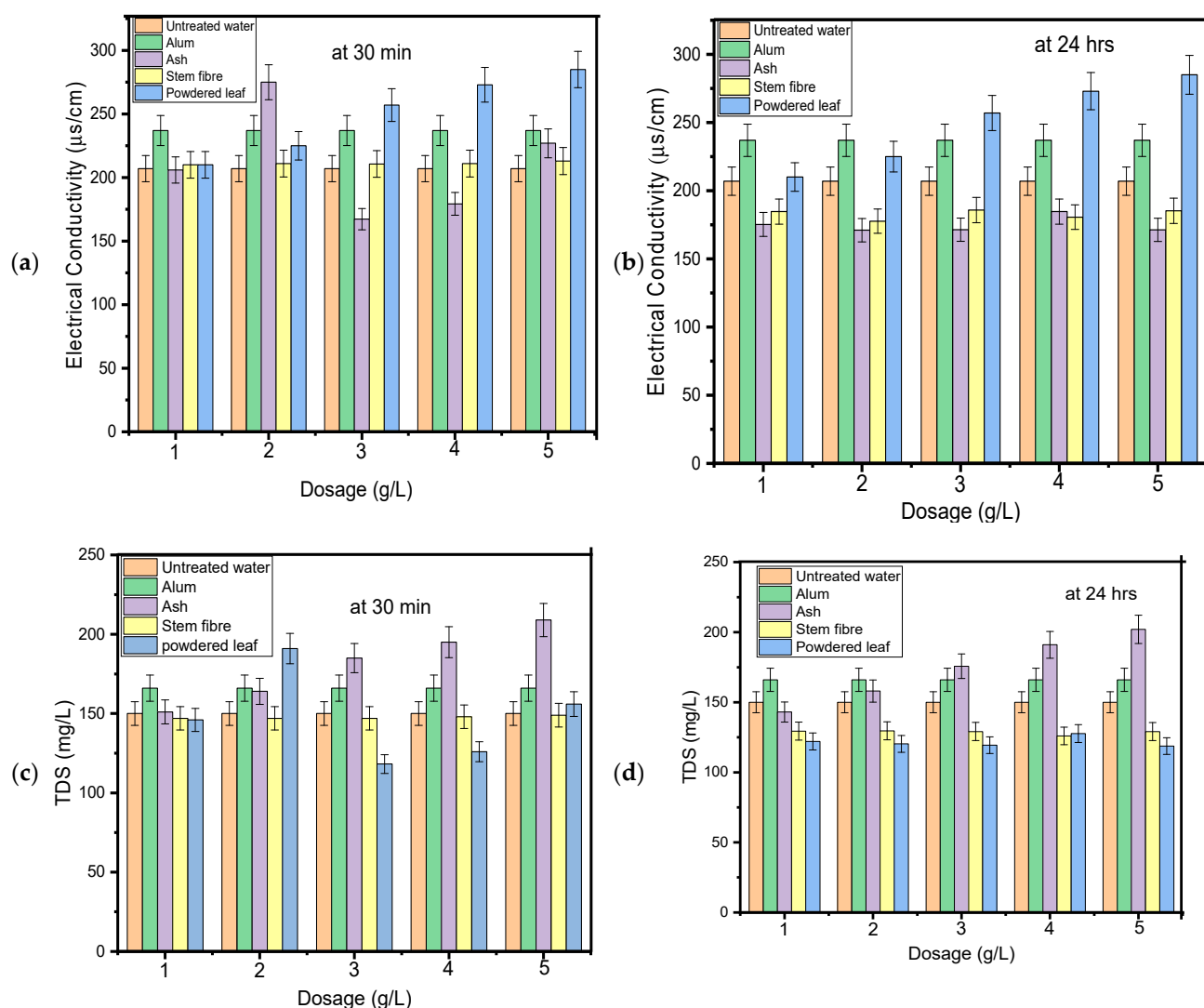


Figure 3. Effect of Sesame plant materials and alum on the electrical conductivity (a,b) and TDS (c,d) of river water after 30 min and 24 h of treatment.

Furthermore, there was a notable reduction in the total dissolved solids in the river water sample after 24 h of treatment with fibre and dry leaf matter. There was a significant reduction in the turbidity of water samples when treated with plant materials, Figure 4a,b. More specifically, at 30 min (Figure 4a), the stem fibre and powdered leaf were most effective with a significant reduction in the turbidity of the treated water from an initial value of 11.36 NTU to 1.57 NTU at 0.03 g and 0.035 NTU at 0.05 g amount of stem fibre. However, at 24 hrs treatment for the same dosage, a noticeable increase in the turbidity (3.20 NTU) was observed, similar to the stem fibre, which was 2.49, which could be due to organic matter leaching, release, or particle re-dispersion; however, these values are the lowest reported values after the treatment [40]. This implies that this biomass is more effective for rapid treatment of water to be consumed within a shorter period, but not suitable for storage over long periods, except combined with other treatments. Thus, more reduction after 30 min of treatment than after 24 h of treatment across all the materials except for ash treatment.

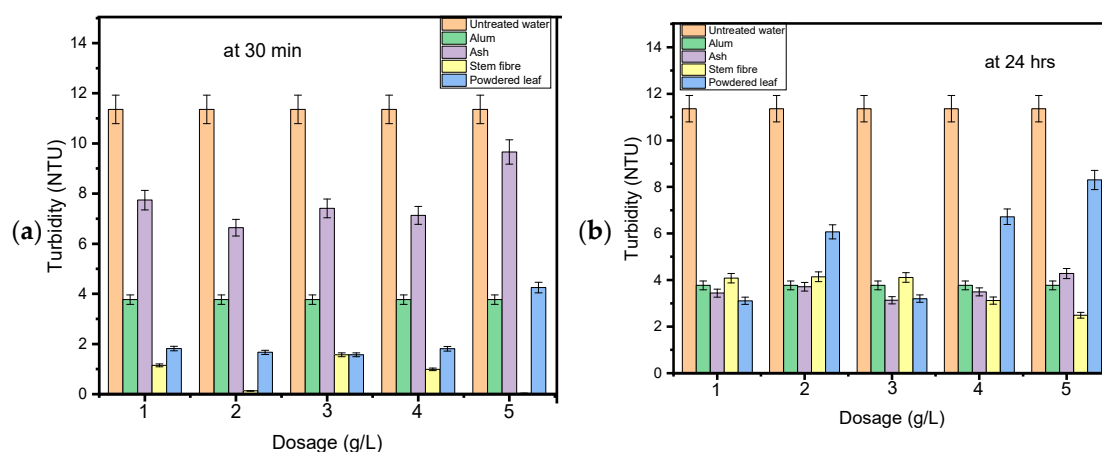


Figure 4. Effect of Sesame plant materials and alum on the turbidity (a,b) of river water after 30 min and 24 h of treatment.

Similarly, the effect of the treatment of the spring water sample with different plant materials on the physicochemical properties after 30 min and 24 h is presented in Figures 5 and 6. An increase in pH was observed for all materials compared to the untreated Figure 5a,b. However, the values of the treated spring water with alum and the plant materials were within WHO [38] and SANS [39] for drinking water of 6.5–8.5 and 5–9.7, respectively. As observed in the salinity value in Figure 5c,d, similarly, the treatment with fibre for 24 h significantly increased the electric conductivity of the water sample, and a slight increase was observed for treatment with ash and dry leaf matter, see Figure 5e,f.

The electric conductivity values did not fall under the guideline standards of SANS [39] of 0–17 μL but fell under the WHO [38] standards of 0–600 μL for drinking water, aside from the treatment with fibre for 24 h. There was an increase in the total dissolved solids after treatment with fibre for 24 h in Figure 5g,h, but both the treated and untreated spring water values fall within the WHO [38] and SANS [39] of 0–1200 ppm and 0–500 ppm, respectively. The treatment of the spring water sample with plant materials increased the turbidity of the water samples, Figure 6a,b. Generally, the plant materials worked better at treating more turbid water, as applicable to the river water sample, than the spring water sample, which is less turbid. The treatment of water with fibre and dry leaf matter induced the highest change in physicochemical properties. There is no patterned difference in the effect of plant materials in relation to concentration.

Different Sesame plant materials have been reported for water purification [6,20,41]. In this study, the Sesame ash, stem fibre, and powdered leaf materials were tested for their water purification potential, as measured by physicochemical parameters including pH, salinity, electric conductivity, total dissolved solids, and turbidity. The slight decrease in the pH of the water sample after 24 h of treatment in comparison to the 30 min treatment with alum can be explained as a result of hydrolysis, as alum reacts with the natural alkalinity in water to form aluminium hydroxide floc and release hydrogen ions. This reduction in pH agrees with the reports of the effect of alum on the alkalinity of water [12]. The increase in the pH of the water samples after treatment with natural products, as observed in this study, can be a result of the protein content of the samples, as explained by Fida et al. [42], who also reported an increase in pH of water samples after treating with *M. oleifera* leaves and *Cicer arietinum* seed extracts. According to WHO [38] and SANS [39], the desirable pH range of drinking water is 6.5–8.5 and 5.0–9.7, respectively. While pH does not directly affect health, it may impact the taste and acidity of water, sometimes rendering it unfit for drinking. The pH of water samples after treatment with all materials falls within

the regulated values, which makes the Sesame plant materials acceptably useful in the purification process, as it does not affect the pH of the water sample.

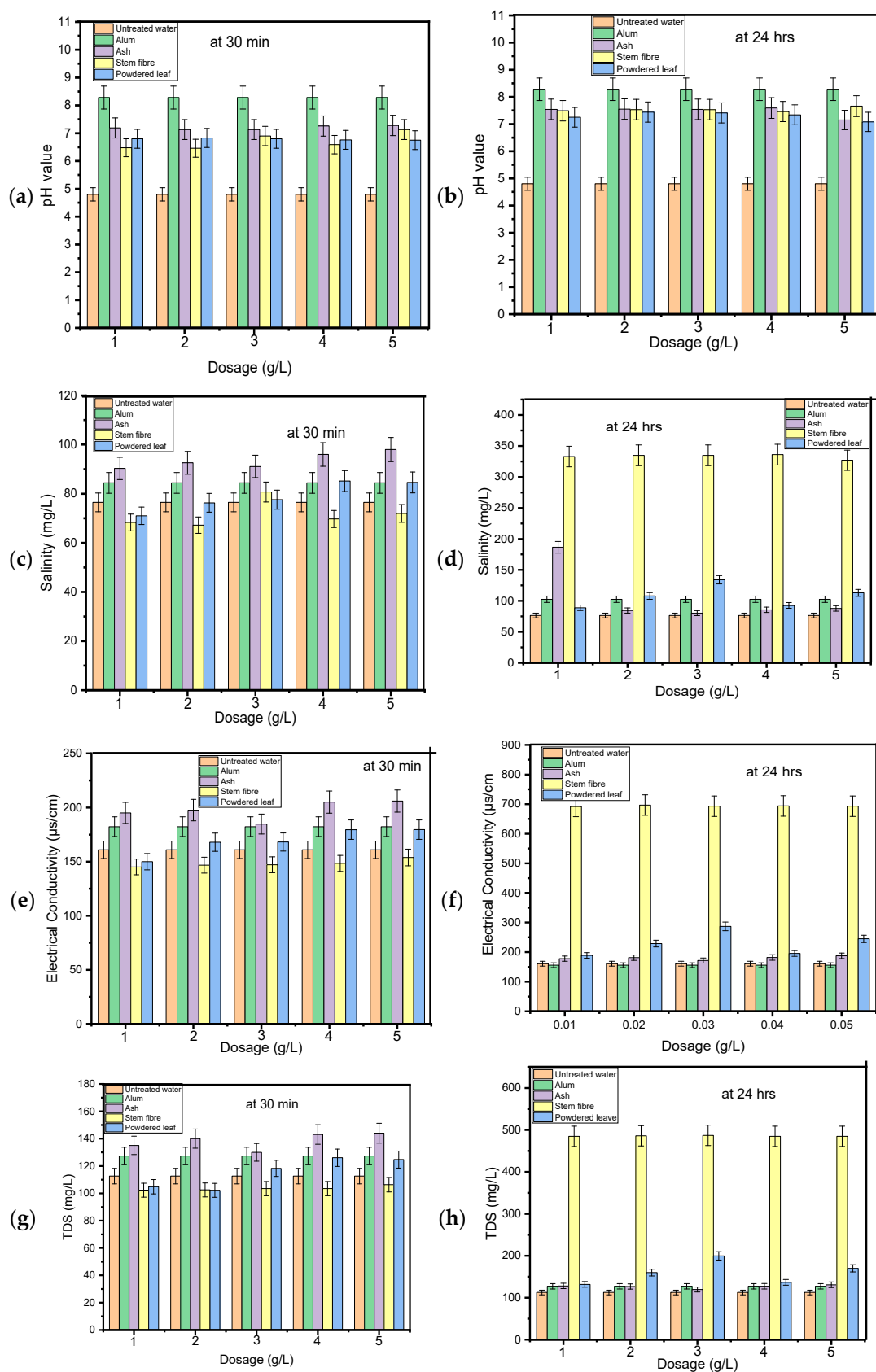


Figure 5. Effect of Sesame plant materials and alum on the pH (a,b), salinity (c,d), electrical conductivity (e,f) and TDS (g,h) of spring water after 30 min and 24 h of treatment.

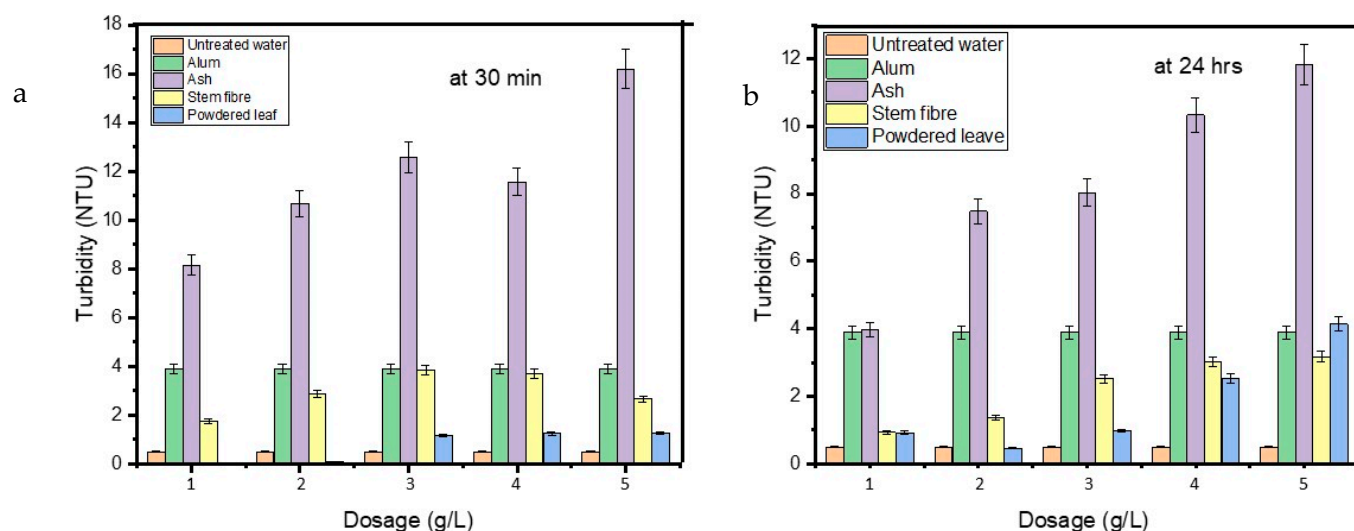


Figure 6. (a,b): Effect of Sesame plant materials and alum on the turbidity of spring water after 30 min and 24 h of treatment.

The stem fibre and powdered leaf material from the Sesame plant had effects in reducing the salinity of the untreated river water, and the ash and stem fibre materials were effective in reducing the electrical conductivity of the river water sample. Maurya et al. [43] reported that banana peels, papaya seeds, and lemon seeds powders used as natural coagulants in their study were effective for the treatment of water samples collected from rivers, ponds, lakes, and canals in Pratapgarh District, Uttar Pradesh, India, which agrees with the findings of this study. Electrical conductivity is a measure of a water sample's ability to conduct electricity and is a crucial indicator of water quality, reflecting the presence and concentration of dissolved ions and salts. High conductivity suggests a higher concentration of these impurities, potentially indicating some sort of contamination [44]. The conductivity of water is a very important index to measure water quality as it is a pointer to the presence of inorganic acids, alkali, and salt [45]. Hence, the capacity of Sesame plant materials to reduce salinity and electrical conductivity is an indication of their water purification potential.

Increased concentration of total dissolved solids is related to increased density of water. The total dissolved solids parameter of water also reduces dissolved gases present in water, thereby hampering the water quality [46]. The reduction in total dissolved solids observed in this study agrees with the finding of Pandey et al. [46], who reported a reduction in total dissolved solids in water samples by *Moringa* leaf extract (525–279 mg/L) and a combination of *Moringa* and neem leaf extract (525–201 mg/L). All the materials tested had a significant effect on the reduction in the turbidity of the river water sample. Ahmed et al. [47] reported the effectiveness of the Sesame material in reducing the turbidity of a water sample from 75 NTU to 2.88 NTU after treatment, which agrees with the findings of this study. Deleegn et al. [48] also reported the water purification potential of *Moringa* leaves. Rasheed [49] reported the effect of *Moringa oleifera* seed extracts in treating turbid water. The coagulation of the extract for removing colloidal particles varied depending on the initial turbidity of the water and the concentration of the added coagulant extract. In their experiment, *M. oleifera* seed powder at 0.016 g/L reduced turbidity from 129.00 NTU to 16.8 NTU (86.98%) for the Angereb and from 208.3 NTU to 33.66 NTU (83.84%) for the Shinta River water. Alnawajha et al. [50] also reported the capacity of the water extract of *Leucaena leucocephala* seeds for turbid water treatment, which agrees with the findings of this study.

A higher purification potential of the Sesame plant materials was observed in the treated river water than in the spring river water. No significant treatment effect was observed for the ash, stem fibre, and powdered leaf, considering the pH, salinity, electric conductivity, and turbidity of spring water. However, the stem fibre slightly reduced the total dissolved solids in the spring water sample. This difference in the treatment effect can be linked to the nature of the water samples. Plant materials have been opined to have lesser treatment potential with less turbid water samples [51]. River water contains higher levels of suspended solids and other contaminants, which natural coagulants can effectively bind to and remove, resulting in higher purification activity. On the other hand, spring water is typically clearer with fewer suspended particles [52]. Additionally, the observed increase in turbidity of spring water samples in this study agrees with the finding of Ahmed [47], who explained that higher concentrations of *M. oleifera* seed powder resulted in increased turbidity in water samples. A similar result was reported by Rasheed et al. [49] for the treatment of less turbid water. Therefore, it could be opined that if tested at lower concentrations, the Sesame plant materials may reduce the turbidity of spring water samples. This opinion is supported by Alnawajha et al. [50], who explained that a further increase in the dosage of coagulant does not have a significant change in the coagulation potential of a material and that higher dosage gives an adverse effect because excessive coagulants lead to an increase in repulsive force. Additionally, when the concentration of a coagulant exceeds the optimum dosage, the turbidity of water increases because all colloids have been neutralised and settled down with an optimum dosage. Thus, the excess coagulants cause turbidity in the water as they do not interact with oppositely charged colloidal particles [51].

Generally, the Sesame plant materials were able to improve water quality with measures of parameters including pH, salinity, electric conductivity, total dissolved solids, and turbidity, making them potential materials in the purification of water. These crude samples can be further processed to increase their efficiency and explored on a larger scale. Hence, the Sesame plant materials hold promising applications in the purification and treatment of water.

The antibacterial activity of the various materials against *Escherichia coli* and total coliforms in sampled river and spring water is presented in Figure 7a–d and e–h, respectively. In the river water sample, fibre and ash had increasing inhibition of *E. coli* with an increase in dose in Figure 7a,b. However, there was an increase in the cell number of *E. coli* as the time of treatment increased for the stem fibre. Ash material had the highest inhibitory activity against *E. coli* (99%) after 24 h of exposure.

In the inhibition of total coliforms, leaf dry matter had no inhibitory effect at any of the concentrations tested. Using ash, there was 100% inhibition of total coliforms at 4 g/L and 5 g/L after 24 h, as depicted in Figure 7c,d. Ash materials had the best inhibitory activity on *E. coli* and total coliforms in the river sample. During the treatment of the spring water sample, 30 min was the optimum time of treatment with a notable reduction in *E. coli* cells during treatment with ash and fibre. The cell count, however, increased after 24 h of treatment in Figure 7e,f. Treatment of spring water with ash reduced *E. coli* count by 100% after 30 min. There was also a high inhibition of total coliform by ash and fibre, up to 98% and 99%, respectively. Generally, ash and fibre material had good *E. coli* and total coliform removal activity as reflected in Figure 7g,h.

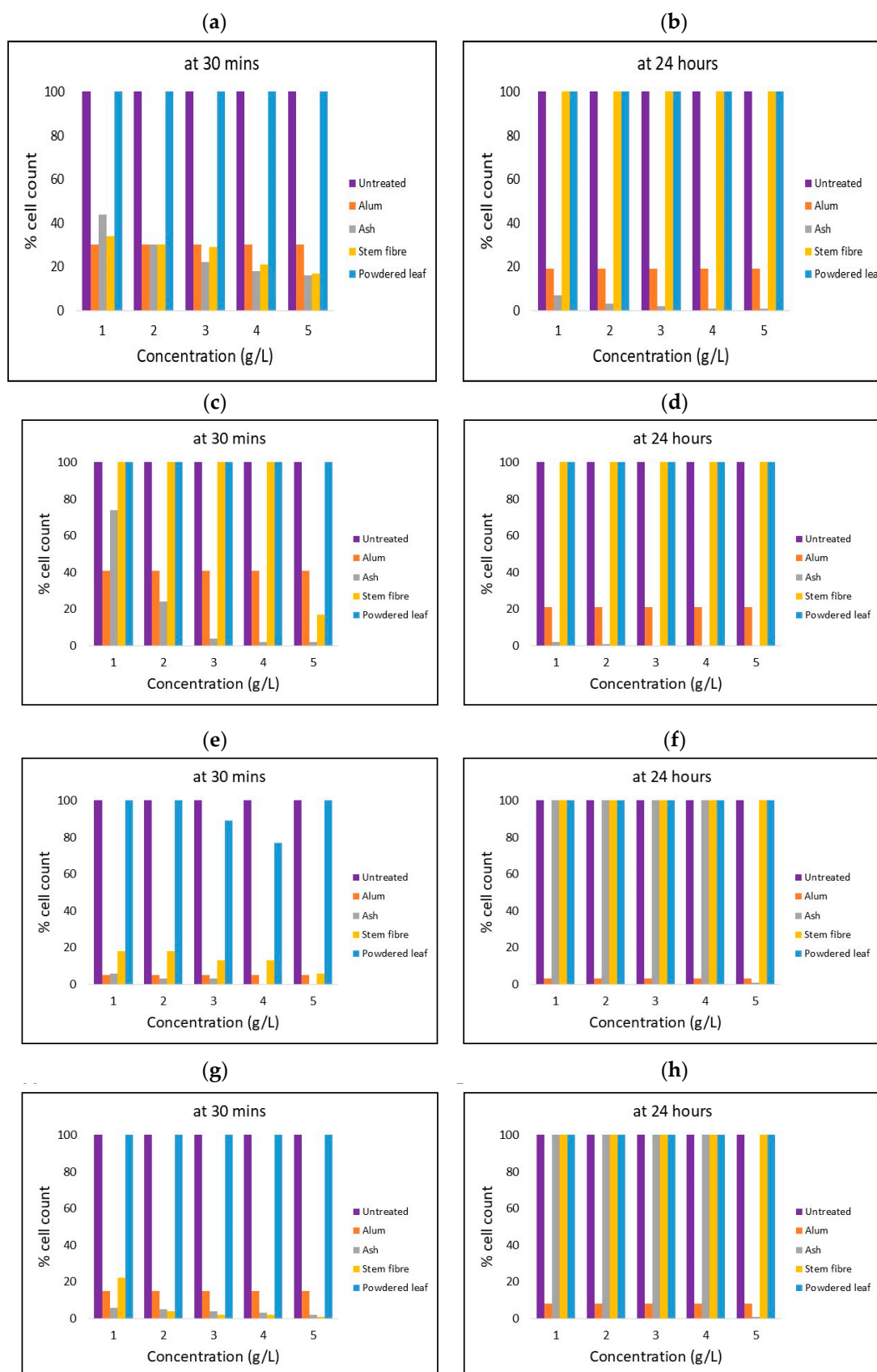


Figure 7. Percentage cell count of *E. coli* in river (a,b), spring water (c,d), water and percentage cell count of total coliforms after 30 min and 24 h treatment of river (e,f), and spring water (g,h) with Sesame plant materials and alum.

Concerning the disinfection potential of Sesame materials against *E. coli* and total coliforms in treated river and spring water samples, the ash and stem fibre materials were effective in reducing the microbial load of both *E. coli* and the total coliforms in both water samples. This finding agrees with reports in the literature. *Azadirachta indica*, *Dolichos lablab*, and *Moringa oleifera* plant materials have all been reported to be effective in reducing the cell count of *E. coli* and total coliforms in water samples. Okunlola et al. [36] also reported the effect of the *M. oleifera* plant in eliminating bacteria in water samples. Mili et al. [29] reported the reduction in cell count of *E. coli* after treatment of water with *M. oleifera* (95.23%) and *Boscia senegalensis* seeds (85%), which agrees with the findings from this study for the fibre and ash materials. However, the observed increase in the number of bacterial isolates after longer exposure to plant materials in this study may be a result of regrowth of bacteria or reactivation of dormant bacteria, as well as plant material serving as a nutrient source for coliform bacteria, allowing them to grow and reproduce [53–55].

Aziza [56] and Konkono et al. [57] reported the antibacterial effect of Sesame leaf, stem, and fruit extracts in relation to the phytochemicals present in the plant samples. This established that the plant materials possess phytochemicals with antibacterial potential, responsible for the reduced cell count of *E. coli* and total coliforms observed. Plants are rich in a wide variety of secondary metabolites, such as tannins, terpenoids, alkaloids, flavonoids, etc., which have been found to have antimicrobial properties in vitro [15]. Natural coagulants have been demonstrated to possess antibacterial qualities and can be used to purify water [33]. This study therefore established Sesame plant materials as a potential choice for such an application towards industrial use.

4. Conclusions

Safe drinking water has become a scarce resource in many parts of the world due to reasons like soil and water contamination, prolonged droughts, and population growth. In the current era of water shortage, effective water treatment is essential for survival, health advancement, and economic progress. It is also one of the most significant Sustainable Development Goals (SDGs) that the United Nations has established to be accomplished by 2030. In this study, the Sesame plant materials were effective in reducing the pH, salinity, electric conductivity, total dissolved solids, and turbidity of river water samples. The plant material was also effective in reducing the microbial load of *E. coli* and total coliforms. These indicate the capacity of the materials for the purification and disinfection of water. Plant-based coagulants have been reported for water purification and disinfection and should be harnessed as greener alternatives to water treatment. Natural coagulants exhibit certain limitations that can hinder their industrial application, including low solubility in water, low stability (shelf life), weak surface charge, and moderate efficiency. To increase the efficiency of plant-based coagulants, they can be used in combination with other materials and treatment processes, such as in biological treatment. Improved extraction method and purification of natural coagulants will also increase their efficiency. Hence, plant-based materials, such as those studied, hold promising potential in the purification of water, making them useful in the quest for improved water quality towards meeting the Sustainable Development Goals and the increasing demand for safe water by the growing human population.

Author Contributions: A.O.A.: conceptualization, laboratory analysis, initial drafting, final proof-reading; H.N.E., M.A. and J.A.O.: processing, data analysis and formatting; T.A.M.M. and R.M.: supervision and final draft proofreading. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author(s).

Conflicts of Interest: The authors declare no conflicts of interest.

References

- Okesanya, O.J.; Eshun, G.; Ukoaka, B.M.; Manirambona, E.; Olabode, O.N.; Adesola, R.O.; Okon, I.I.; Jamil, S.; Singh, A.; Lucero-Prisno, D.E.; et al. Water, sanitation, and hygiene (WASH) practices in Africa: Exploring the effects on public health and sustainable development plans. *Trop. Med. Health* **2024**, *52*, 68. [\[CrossRef\]](#)
- Adeeyo, A.O.; Odiyo, J.; Odelade, K. Chemical Profiling and Antimicrobial Properties of Phyto-Active Extracts from *Terminalia glaucescens* Stem Against Water Microbial Contaminants. *Open Biotechnol. J.* **2018**, *12*, 1–15. [\[CrossRef\]](#)
- Edokpayi, J.N.; Enitan-Folami, A.M.; Adeeyo, A.O.; Durowoju, O.S.; Jegede, A.O.; Odiyo, J.O. Recent trends and national policies for water provision and wastewater treatment in South Africa. In *Water Conservation and Wastewater Treatment in BRICS Nations*; Elsevier: Amsterdam, The Netherlands, 2020; pp. 187–211. [\[CrossRef\]](#)
- Salehi, M. Global water shortage and potable water safety; Today's concern and tomorrow's crisis. *Environ. Int.* **2022**, *158*, 106936. [\[CrossRef\]](#) [\[PubMed\]](#)
- Mercy, M.; Mkangombe, K.F.; Yongji, Z. Water Availability, Quality and Treatment Methods in Malawi: A Review. *Int. J. Sci. Res. Publ.* **2021**, *11*, 542–553. [\[CrossRef\]](#)
- Adeeyo, A.O.; Oyetade, J.A.; Msagati, T.A.; Colile, N.; Makungo, R. Performance of a Wild Sesame (*Sesamum* spp.) Phytochemical Extract for Water Disinfection. *Water Air Soil Pollut.* **2025**, *236*, 108. [\[CrossRef\]](#)
- Bazaanah, P.; Mothapo, R.A. Sustainability of drinking water and sanitation delivery systems in rural communities of the Lepelle Nkumpi Local Municipality, South Africa. *Environ. Dev. Sustain.* **2023**, *26*, 14223–14255. [\[CrossRef\]](#)
- Ejiohuo, O.; Onyeaka, H.; Akinsemolu, A.; Nwabor, O.F.; Siyanbola, K.F.; Tamasiga, P.; Al-Sharify, Z.T. Ensuring water purity: Mitigating environmental risks and safeguarding human health. *Water Biol. Secur.* **2025**, *4*, 100341. [\[CrossRef\]](#)
- Saxena, R.; Gupta, H.; Dhiman, S.; Gupta, H.; Dhiman, S. Availability and Minimization of Nitrogenous Disinfectant By-Products in Drinking Water. In *Drinking Water Disinfection By-Products*; Madhav, S., Mazhar, M.A., Ahmed, S., Kumar, P., Mishra, P.K., Eds.; Springer Nature: Cham, Switzerland, 2024; pp. 239–262. [\[CrossRef\]](#)
- Bwapwa, J.K. Review on Main Issues Causing Deterioration of Water Quality and Water Scarcity: Case Study of South Africa. *Environ. Manag. Sustain. Dev.* **2018**, *7*, 14–34. [\[CrossRef\]](#)
- Adeeyo, A.O.; Odiyo, J.O.; Enitan, E.M.; Odelade, K.A.; Edokpayi, J.N. Towards indigenous ecological waste bio-disinfection: Ethanolic extract from *T. glaucescens*, *Z. zanthoxyloides*, *G. latifolium* as effective biocide against water microbial pollutant. Innovations and Technologies for Sustainable Management of Natural Resources. In Proceedings of the International Conference in Sustainable Management of Natural Resources, Polokwane, South Africa, 15–17 October 2018; pp. 132–139.
- Krupińska, I. Aluminium Drinking Water Treatment Residuals and Their Toxic Impact on Human Health. *Molecules* **2020**, *25*, 641. [\[CrossRef\]](#)
- Cutipa-Díaz, Y.M.; Huanacuni-Lupaca, C.; Limache-Sandoval, E.M.; Mamani-Huanca, D.Y.; Sánchez-Esquivel, W.M.; Rubira-Otarola, D.G.; Gutiérrez-Cueva, R.N.; Sacari, E.J.S. Exposure to Aluminum in Drinking Water and the Risk of Developing Alzheimer's Disease: A Bibliometric Analysis and Systematic Evaluation. *Water* **2024**, *16*, 2386. [\[CrossRef\]](#)
- Ghernaout, D.; Elboughdiri, N. Is Not It Time to Stop Using Chlorine for Treating Water? *OALib J.* **2020**, *7*, 1–11. [\[CrossRef\]](#)
- Lwasa, A.; Mdee, O.J.; Ntalikwa, J.W.; Sadiki, N. Performance analysis of plant-based coagulants in water purification: A review. *Discov. Water* **2024**, *4*, 108. [\[CrossRef\]](#)
- Adeeyo, A.; Ojelade, B.; Alabi, M.; Makungo, R. Disinfectants of plant origin: Emerging application, standardization and meta-analysis. *Desalination Water Treat.* **2023**, *313*, 125–129. [\[CrossRef\]](#)
- Saleem, M.; Bachmann, R.T. A contemporary review on plant-based coagulants for applications in water treatment. *J. Ind. Eng. Chem.* **2019**, *72*, 281–297. [\[CrossRef\]](#)
- Righetto, I.; Al-Juboori, R.A.; Kaljunen, J.U.; Mikola, A. Multipurpose treatment of landfill leachate using natural coagulants—Pretreatment for nutrient recovery and removal of heavy metals and micropollutants. *J. Environ. Chem. Eng.* **2021**, *9*, 105213. [\[CrossRef\]](#)
- El Bouaidi, W.; Libralato, G.; Douma, M.; Ounas, A.; Yaacoubi, A.; Lofrano, G.; Albarano, L.; Guida, M.; Loudiki, M. A review of plant-based coagulants for turbidity and cyanobacteria blooms removal. *Environ. Sci. Pollut. Res.* **2022**, *29*, 42601–42615. [\[CrossRef\]](#)

20. Adeeyo, A.O.; Odelade, K.A.; Msagati, T.A.; Odiyo, J.O. Antimicrobial potencies of selected native African herbs against water microbes. *J. King Saud Univ. Sci.* **2020**, *32*, 2349–2357. [\[CrossRef\]](#)
21. Karnena, M.K.; Saritha, V. Contemplations and investigations on green coagulants in treatment of surface water: A critical review. *Appl. Water Sci.* **2022**, *12*, 150. [\[CrossRef\]](#)
22. Irfan, S.; Li, L.; Saleemi, A.S.; Nan, C.-W. Enhanced photocatalytic activity of La 3+ and Se 4+ co-doped bismuth ferrite nanostructures. *J. Mater. Chem. A* **2017**, *5*, 11143–11151. [\[CrossRef\]](#)
23. Othmani, B.; Rasteiro, M.G.; Khadhraoui, M. Toward green technology: A review on some efficient model plant-based coagulants/flocculants for freshwater and wastewater remediation. *Clean Technol. Environ. Policy* **2020**, *22*, 1025–1040. [\[CrossRef\]](#)
24. Seghosime, A.; Awudza, J.A.M.; Buamah, R.; Ebeigbe, A.B.; Kwarteng, S.O. Effect of locally available fruit waste on treatment of water turbidity. *Civ. Environ. Res.* **2017**, *9*.
25. Buenaño, B.; Vera, E.; Aldás, M.B. Study of coagulating/flocculating characteristics of organic polymers extracted from biowaste for water treatment. *Ing. Investig.* **2019**, *39*, 24–35.
26. Benalia, A.; Derbal, K.; Amrouci, Z.; Baatache, O.; Khalfaoui, A.; Pizzi, A. Application of Plant-Based Coagulants and Their Mechanisms in Water Treatment: A Review. *J. Renew. Mater.* **2024**, *12*, 667–698. [\[CrossRef\]](#)
27. Kumar, M.R.; Istalingamurthy, D.B. Natural bio-flocculant in water treatment: Investigation of the performance of cactus extracts as a natural flocculant. *Int. J. Innov. Res. Sci. Eng. Technol.* **2017**, *5*, 12609–12614.
28. Mohd-Salleh, S.N.A.; Mohd-Zin, N.S.; Othman, N. A Review of Wastewater Treatment using Natural Material and Its Potential as Aid and Composite Coagulant. *Sains Malays.* **2019**, *48*, 155–164. [\[CrossRef\]](#)
29. Mili, A.; Das, S.; Nandakumar, K.; Lobo, R. A comprehensive review on *Sesamum indicum* L.: Botanical, ethnopharmacological, phytochemical, and pharmacological aspects. *J. Ethnopharmacol.* **2021**, *281*, 114503. [\[CrossRef\]](#) [\[PubMed\]](#)
30. Wan, Y.; Zhou, Q.; Zhao, M.; Hou, T. Byproducts of Sesame Oil Extraction: Composition, Function, and Comprehensive Utilization. *Foods* **2023**, *12*, 2383. [\[CrossRef\]](#) [\[PubMed\]](#)
31. Jubril, A.; Giwa, S.O.; Giwa, A. The Use of Sesame Seed as a Coagulant for the Treatment of Turbid Surface Water. *J. Environ. Sci. Comput. Sci. Eng. Technol.* **2015**, *4*, 543–554.
32. Adeeyo, A.O.; Odiyo, J.O.; Enitan, A.M.; Motsa, M.M.; Msagati, T.A.; Mkoyi, H.D.; Makungo, R. Morphometric and structural properties of a sustainable plant biomass with water purification Potentials. *Sustainability* **2021**, *13*, 11075. [\[CrossRef\]](#)
33. Gojiya, D.; Barad, A.; Gohil, V.; Dabhi, M.; Dhamsaniya, N.; Naliapara, V.; Sapariya, P. Quantification of design associated engineering properties of sesame (*Sesamum indicum* L.) seed varieties as a function of moisture content. *J. Am. Oil Chem. Soc.* **2023**, *100*, 663–678. [\[CrossRef\]](#)
34. Zhou, H.; Margenot, A.J.; Li, Y.; Si, B.; Wang, T.; Zhang, Y.; Li, S.; Bhattarai, R. Phosphorus pollution control using waste-based adsorbents: Material synthesis, modification, and sustainability. *Crit. Rev. Environ. Sci. Technol.* **2022**, *52*, 2023–2059. [\[CrossRef\]](#)
35. Bharali, P.; Gamo, Y.; Das, A.K.; Tag, H.; Baruah, A.M.; Kakati, D. Phytochemical and Biochemical Study of Four Legume Plants with Detergent and Anti-Lice Properties from the Eastern Himalayan Region of India. *Curr. Sci.* **2017**, *113*, 1434–1439. [\[CrossRef\]](#)
36. Okunlola, M.B.; Ijah, U.J.J.; Yisa, J.; Abioye, P.O.; Ariyelo, D.S.; Ibrahim, J.N. Purification efficacy of different parts of *Mangifera indica* on water samples from contaminated drinking water sources in chanchaga local government area of Niger State, Nigeria. *Appl. Water Sci.* **2020**, *10*, 102. [\[CrossRef\]](#)
37. Sandle, T. Microbiology laboratory techniques. In *Pharmaceutical Microbiology*; Elsevier: Amsterdam, The Netherlands, 2016; pp. 63–80. [\[CrossRef\]](#)
38. World Health Organization. *Guidelines for Drinking-Water Quality: Fourth Edition Incorporating First Addendum*, 4th ed.; World Health Organization: Geneva, Switzerland, 2017.
39. SANS 241-1:2015; Drinking Water Specification. International Organization for Standardization: Geneva, Switzerland, 2015.
40. Chaukura, N.; Chiworeso, R.; Gwenzi, W.; Motsa, M.M.; Munzeiwa, W.; Moyo, W.; Chikurunhe, I.; Nkambule, T.T. A new generation low-cost biochar-clay composite ‘biscuit’ ceramic filter for point-of-use water treatment. *Appl. Clay Sci.* **2020**, *185*, 105409. [\[CrossRef\]](#)
41. Sadeghy, S.; Pormazar, S.M.; Ghaneian, M.T.; Ehrampoush, M.H.; Dalvand, A. Modeling and optimization of direct dyes removal from aqueous solutions using activated carbon produced from sesame shell waste. *Sci. Rep.* **2024**, *14*, 24867. [\[CrossRef\]](#) [\[PubMed\]](#)
42. Fida, Z.; Tanoli, M.A.; Mahmood, Q.; Alamgir, M.S.; Sajjad, D. Evaluation of Plant-Based Natural Extracts as Coagulants for Surface Water Treatment. *Environ. Eng. Geosci.* **2024**, *30*, 77–90. [\[CrossRef\]](#)
43. Maurya, S.; Saxena, A.; Pate, A. Evaluation of plant based natural coagulants for surface water treatment of Pratapgarh District Uttar Pradesh, India. *J. Trop. For. Environ.* **2024**, *13*. [\[CrossRef\]](#)
44. Gapparov, A.; Isakova, M. Study on the characteristics of water resources through electrical conductivity: A case study of Uzbekistan. *IOP Conf. Ser. Earth Environ. Sci.* **2023**, *1142*, 012057. [\[CrossRef\]](#)
45. Xianhong, Y.; Shijun, L.; Jian, H.; Jie, X. Application Analysis of Conductivity in Drinking Water Quality Analysis. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *784*, 012028. [\[CrossRef\]](#)

46. Pandey, P.; Khan, F.; Ahmad, V.; Singh, A.; Shamshad, T.; Mishra, R. Combined efficacy of *Azadirachta indica* and *Moringa oleifera* leaves extract as a potential coagulant in ground water treatment. *SN Appl. Sci.* **2020**, *2*, 1300. [\[CrossRef\]](#)
47. Ahmed, N.A.S.; Mohamed, N.Y. Using Natural Coagulants for Reduction of Turbidity of Water. *Int. Res. J. Eng. Technol.* **2021**, *8*, 1453–1456.
48. Delelegn, A.; Sahile, S.; Husen, A. Water purification and antibacterial efficacy of *Moringa oleifera* Lam. *Agric. Food Secur.* **2018**, *7*, 25. [\[CrossRef\]](#)
49. Rasheed, F.A.; Alkaradaghi, K.; Al-Ansari, N. The Potential of *Moringa oleifera* Seed in Water Coagulation-Flocculation Technique to Reduce Water Turbidity. *Water Air Soil Pollut.* **2023**, *234*, 250. [\[CrossRef\]](#)
50. Alnawajha, M.M.; Abdullah, S.R.S.; Abu Hasan, H.; Othman, A.R.; Kurniawan, S.B. Effectiveness of using water-extracted *Leucaena leucocephala* seeds as a coagulant for turbid water treatment: Effects of dosage, pH, mixing speed, mixing time, and settling time. *Biomass Convers. Biorefinery* **2024**, *14*, 11203–11216. [\[CrossRef\]](#)
51. Sha'Arani, S.; Azizan, S.N.F.; Akhir, F.N.M.; Yuzir, M.A.M.; Othman, N.; Zakaria, Z.; Noor, M.J.M.M.; Hara, H. Removal efficiency of Gram-positive and Gram-negative bacteria using a natural coagulant during coagulation, flocculation, and sedimentation processes. *Water Sci. Technol.* **2019**, *80*, 1787–1795. [\[CrossRef\]](#)
52. Putri, A.I.; Arisalwadi, M. Analysis of The Influence Between Turbidity Value on Total Suspended Solid (TSS) Value At The River Water Surface In Kutai Kartanegara. *Front. Adv. Appl. Sci. Eng.* **2023**, *1*, 14–20. [\[CrossRef\]](#)
53. Kesari, K.K.; Soni, R.; Jamal, Q.M.S.; Tripathi, P.; Lal, J.A.; Jha, N.K.; Siddiqui, M.H.; Kumar, P.; Tripathi, V.; Ruokolainen, J. Wastewater Treatment and Reuse: A Review of its Applications and Health Implications. *Water Air Soil Pollut.* **2021**, *232*, 208. [\[CrossRef\]](#)
54. Adeeyo, A.O.; Edokpayi, J.N.; Alabi, M.A.; Msagati, T.A.M.; Odiyo, J.O. Plant active products and emerging interventions in water potabilisation: Disinfection and multi-drug resistant pathogen treatment. *Clin. Phytosci.* **2021**, *7*, 31. [\[CrossRef\]](#)
55. Kandimalla, R.; Vallamkondu, J.; Corgiat, E.B.; Gill, K.D. Understanding Aspects of Aluminum Exposure in Alzheimer's Disease Development. *Brain Pathol.* **2016**, *26*, 139–154. [\[CrossRef\]](#) [\[PubMed\]](#)
56. Aziza, A.S. Chemical and Microbiological Studies on Some Agricultural Waste of Sesame (*sesamum indicum*) Plant. *Food Technol. Res. J.* **2024**, *6*, 70–82. [\[CrossRef\]](#)
57. Konkobo, F.A.; Savadogo, P.W.; Diao, M.; Dakuyo, R.; Dicko, M.H. Evaluation of the effectiveness of some local plant extracts in improving the quality of unsafe water consumed in developing countries. *Front. Environ. Sci.* **2023**, *11*, 1134984. [\[CrossRef\]](#)

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.