

Performance Evaluation of Orange Seeds and Peels as Natural Coagulants for Surface Water Treatment

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Abstract. The increasing demand for alternative water treatment methods has led to growing interest in natural coagulants for purifying surface water particularly in low-resource communities. In this study, the coagulation performance of orange (*Citrus sinensis*) seeds and peels as natural alternatives to alum for surface water treatment was investigated. Coagulant dosages ranging from 2–10 g/L were evaluated for their effectiveness in reducing turbidity, total suspended solids (TSS), total dissolved solids (TDS), chemical oxygen demand (COD) and biological oxygen demand (BOD). The results showed that orange seeds achieved maximum reductions of 73.6% turbidity, 61.7% TSS, 36.2% TDS, 65.5% COD and 48.3% BOD at an optimal dosage of 8 g/L, outperforming orange peels across all parameters. In comparison, alum at 2 g/L demonstrated higher treatment efficiency, with turbidity, COD and BOD reductions of 81.5%, 69.7%, and 55.6%, respectively. While reductions in turbidity and organic matter were substantial, TDS removal was limited thus suggesting the need for additional treatment stages to meet WHO drinking water standards. These findings suggest that orange seeds and peels are promising alternatives to conventional coagulants for surface water treatment and supports the application of natural and biodegradable alternatives for water treatment practices.

1. Introduction

Access to safe and clean water is a fundamental human right, yet millions of people in developing regions continue to face challenges in obtaining potable water. The quality of surface water bodies such as rivers, lakes and streams has declined significantly due to increased urbanization, agricultural runoff, industrial discharges, and domestic wastewater [1, 2]. These contaminants contribute to high levels of turbidity, organic load, and microbial contamination, making raw surface water unsafe for human consumption. Traditional water treatment systems, which commonly rely on chemical coagulants like alum and ferric chloride, though effective, are often unaffordable and inaccessible for rural and low-income communities. Furthermore, residual aluminum in treated water has been associated with neurological disorders and other health risks [3].

In recent years, natural coagulants have emerged as sustainable alternatives to chemical counterparts [4–6]. Plant-based coagulants such as *Moringa oleifera* seeds, cactus extracts and tannin-rich materials have shown considerable potential in water treatment due to their biodegradability, renewability, and low toxicity [5, 7–11]. Agricultural by-products such as fruit peels and seeds, which are typically discarded as waste, have also been explored for their coagulating properties. These natural materials contain active compounds including polysaccharides, proteins, and polyphenols that facilitate floc formation and sedimentation [12–14]. Orange (*Citrus sinensis*), a widely consumed fruit, generates significant amounts of waste in the form of peels and seeds, which are rich in pectin and limonoids—bioactive components known for their coagulating ability [15, 16].

This study investigated the effectiveness of orange seeds and peels as natural coagulants for the treatment of surface water. By examining their performance in reducing key water quality parameters such as turbidity, total suspended solids (TSS), total dissolved solids (TDS), chemical oxygen demand (COD), biochemical oxygen demand (BOD) and pH, the study seeks to validate their potential as

low-cost and eco-friendly alternatives to alum. Studies have demonstrated the promising roles of fruit-derived coagulants, but comparative evaluations of different parts of the same plant, such as seeds versus peels, are limited [6, 17–20]. This research aims to fill that gap and contribute to the growing body of knowledge that promotes sustainable water treatment approaches suitable for use in low-resource settings.

2. Materials and Methods

Surface water used in this study was collected from a tributary of the Ala River in Akure, South Western Nigeria, using clean 10-liter plastic containers. The collected samples were immediately transported to the laboratory for analysis and were characterized for turbidity, total suspended solids (TSS), total dissolved solids (TDS), chemical oxygen demand (COD), biological oxygen demand (BOD) and pH, following standard procedures outlined by the American Public Health Association [21]. TSS was determined by filtering a known volume of the water sample through a pre-weighed glass fiber filter, drying the filter at 103–105°C and calculating the mass of solids retained. TDS was measured by evaporating the filtrate from the TSS test and drying the residue at 180°C. COD was analyzed using the closed reflux method with dichromate digestion followed by colorimetric determination and BOD was determined by incubating the sample at 20°C for 5 days and measuring the oxygen consumed using a dissolved oxygen meter.

Natural coagulants were prepared from orange seeds and peels. These materials were thoroughly washed to remove dirt and adhering impurities, then air-dried under shade to prevent the loss of bioactive compounds. After drying, they were pulverized into fine powders using a laboratory grinder and stored in airtight containers until use. Coagulant solutions were prepared by dissolving known quantities of the powders in distilled water to achieve dosages of 2 g/L, 4 g/L, 6 g/L, 8 g/L, and 10 g/L. For comparison, alum (aluminum sulfate) was used as a control coagulant at a fixed dosage of 2 g/L.

Jar test experiments were conducted to simulate the coagulation-flocculation process in a batch mode. For each test, 500 mL of the raw water sample was poured into six beakers, and the respective coagulant doses were added. The contents were rapidly mixed at 120 rpm for 2 minutes to disperse the coagulants, followed by slow mixing at 40 rpm for 20 minutes to promote floc formation. The samples were then allowed to settle undisturbed for 30 minutes. After sedimentation, the supernatants were carefully collected and analyzed for residual turbidity, TSS, TDS, COD, BOD and pH using the same standard methods applied to the raw water.

The percentage reduction of contaminants was calculated using equation 1 as described in [19]

$$\text{Percentage Reduction (\%)} = \frac{C_{\text{initial}} - C_{\text{final}}}{C_{\text{initial}}} \times 100 \quad (1)$$

Where: C_{initial} is concentration of the parameter (turbidity, TSS, TDS, COD, BOD) before treatment (mg/L or NTU)

C_{final} is concentration of the parameter after treatment with the coagulant (mg/L or NTU).

3. Results and Discussion

3.1 Initial parameters

The quality of the initially collected surface water before treatment is presented in Table 1. It shows that the raw surface water sample exceeded the WHO recommended limit for turbidity, thus indicating significant presence of suspended particles that may harbor pathogens. Although TDS is within acceptable limits, the elevated levels of COD and BOD suggest high organic pollution, which could lead to oxygen depletion and microbial contamination [22]. The slightly acidic pH of 6.4 is just below the WHO guideline range, this indicates the need for pH adjustment for safe consumption.

Table 1. Surface water quality before treatment

Parameter	Raw Water Value	WHO (2017) Standard for Potable Water	Unit
Turbidity	52.7	≤ 5	NTU
TSS	5.6	Not specified (should be as low as possible)	mg/L
TDS	162	≤ 1000	mg/L
COD	368.7	Not specified (used as pollution indicator)	mg/L
BOD	42.1	Not specified (used as pollution indicator)	mg/L
pH	6.4	6.5–8.5	—

3.2 Percentage Reduction of Contaminants

Figures 1 and 2 show a consistent trend of increasing treatment efficiency with higher dosages of orange seed and peel, up to 8 g/L, after which a slight decline is observed—indicating optimal performance at this dosage. Orange seeds outperformed orange peels across all parameters with maximum turbidity, TSS, TDS, COD, and BOD reductions of 73.6%, 61.7%, 36.2%, 65.5%, and 48.3%, respectively, at 8 g/L. In contrast, orange peels achieved peak reductions of 66.7%, 55.4%, 32.8%, 57.9%, and 41.6%, also at 8 g/L, suggesting comparatively lower coagulation efficiency due to fewer active phytochemicals [23]. The pH of the treated water remained within the acceptable WHO range (6.5–8.5) across all dosages. There was a slight but consistent increase with higher coagulant concentrations, indicating that the natural coagulants had a mild alkalizing effect [24]. When compared to alum treatment (Figure 3), which at 2 g/L achieved superior reductions—81.5% in turbidity, 69.2% in TSS, 40.3% in TDS, 69.7% in COD, and 55.6% in BOD—both natural coagulants showed moderate performance, with orange seeds being a closer alternative. This aligns with findings by [25] who noted that while alum often demonstrates higher removal efficiency, natural coagulants offer safer and more sustainable options. TDS reductions were modest for both coagulants, but remained well within the WHO limit of 1000 mg/L [1, 26]. The COD and BOD were considerably lowered by both coagulants, indicating their effectiveness in reducing organic pollutants [27]. The orange-based coagulants significantly reduce contaminants, they may require further polishing treatment to meet potable standards [28]. TDS reductions were the least among all parameters for all treatments, with orange seed showing a maximum of 36.2% compared to alum's 40.3%, reinforcing findings by [7] that natural coagulants have limited effect on dissolved solids. The optimal performance at 8 g/L for both seed and peel followed by a drop at 10 g/L could be attributed to particle restabilization due to overdosing, a phenomenon previously reported by [29]. The results suggest that orange seeds are better suited as a sustainable coagulant for surface water treatment, particularly in rural or decentralized water systems. While not as efficient as alum, orange-based coagulants could provide a viable, low-cost and eco-friendly alternative that can be further optimized and integrated with complementary treatment steps [29].

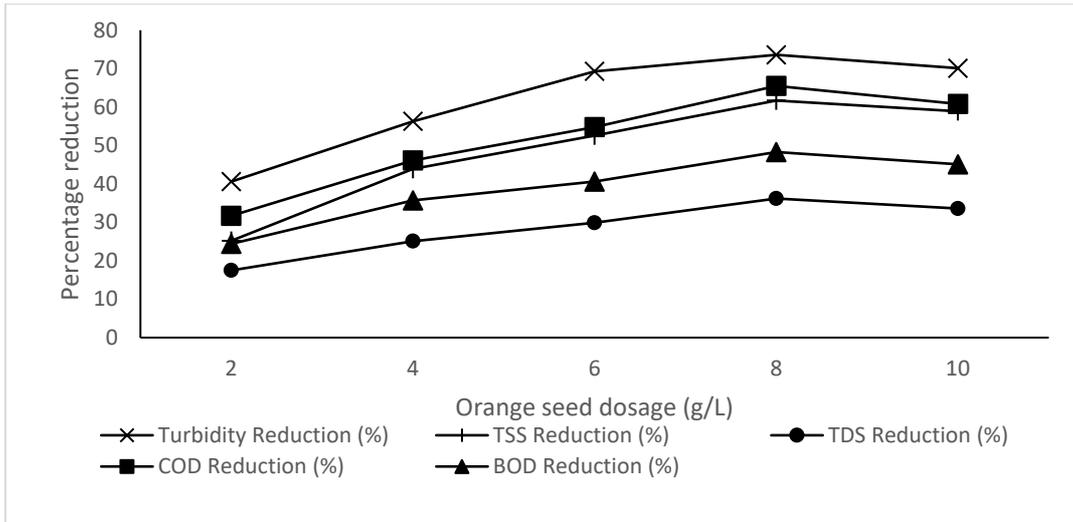


Fig. 1. Orange Seed Treatment

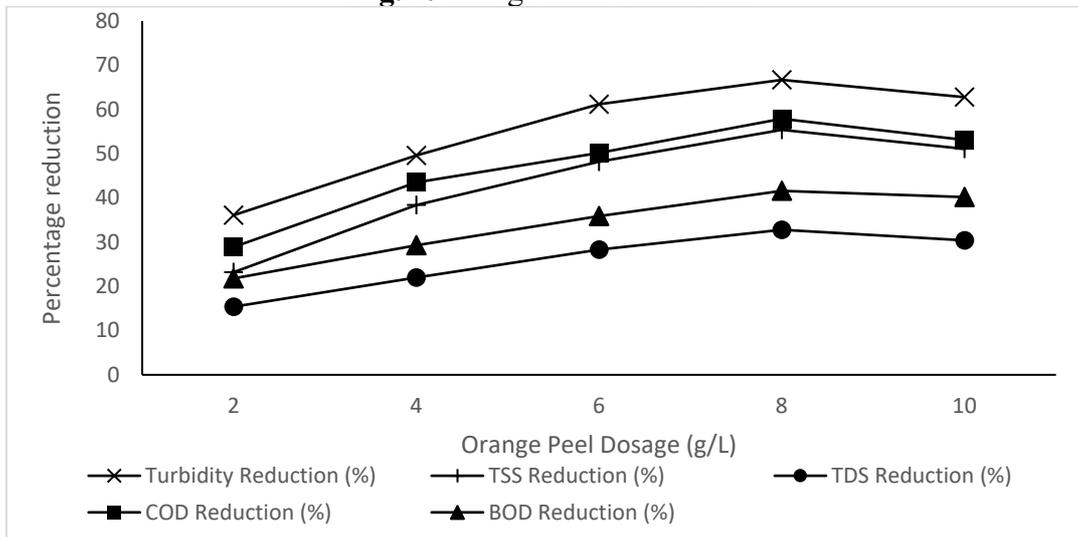


Fig. 2. Orange Peel Treatment

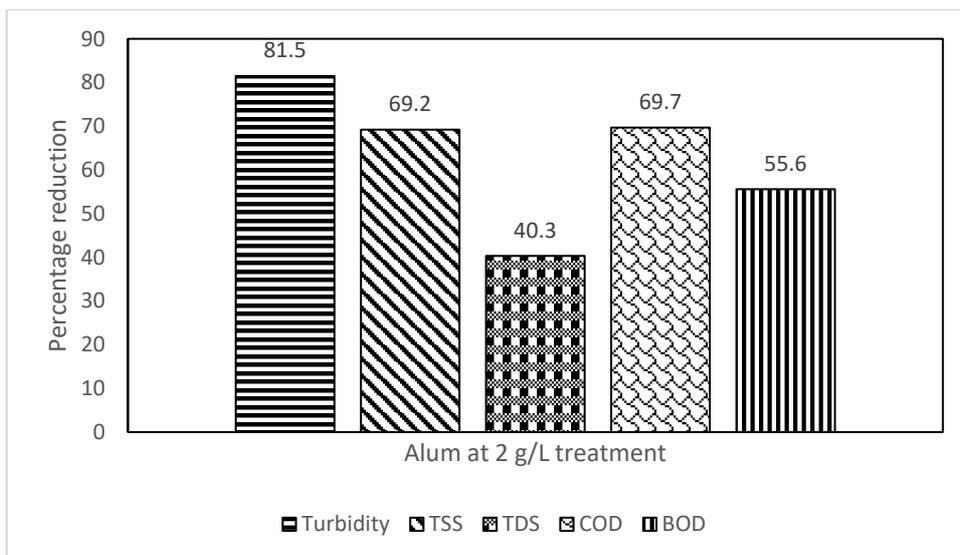


Fig. 3. Performance of Alum (2 g/L) as a Control Coagulant in Surface Water Treatment

4. Conclusion

Orange seeds showed slightly better performance than peels across all the parameters. The effectiveness peaked at 8 g/L, beyond which a slight decline was observed; this indicates potential overdosing. While alum outperformed both natural coagulants in terms of absolute reductions, the gap was not substantial at optimal natural dosages. These findings affirm the potential of orange-based coagulants as environmentally friendly alternatives in household and community-level water treatment.

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