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ORIGINAL RESEARCH ARTICLE

Evaluation of date-seed flocculation combined with solar disinfection for stormwater treatment in Dutse Urban, Nigeria

Catherine Iyabode Asaju[1,a], Aisha Usman[1], Adeniyi Olarewaju Adeleye[1,c], Afeez Oladeji Amoo[1,b], Maryam Ismail[1], Nureni Babatunde Amoo[2,d] and Muhammad Usama Sani[1]

[1]Department of Environmental Sciences, Federal University Dutse, Jigawa State, Nigeria
[2]Department of Surveying & Geo-informatics, Federal Polytechnic Ede, Osun State, Nigeria
Orcid ID: [a]0009-0000-9391-8002; [b]0000-0002-0412-9333; [c]0000-0001-9068-9398; [d]0009-0000-8518-4168

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ABSTRACT

Urban stormwater runoff in rapidly growing semi-arid cities such as Dutse Urban, Jigawa State, Nigeria, often contains elevated levels of suspended solids and pathogenic microorganisms, limiting its potential reuse and contributing to downstream pollution. Solar disinfection (SODIS) is hindered by high turbidity, while conventional chemical coagulants generate sludge and may leave residual metals. This laboratory-scale study evaluated the performance of date-seed powder (*Phoenix dactylifera*), an abundant agricultural residue, as a natural flocculant, both alone and in sequential combination with SODIS, for treating stormwater collected from open drainage channels in Dutse Urban. Stormwater samples were collected after rainfall events from mixed residential–commercial drainage channels. Jar-test experiments employed a 1 % (w/v) aqueous stock suspension of finely ground date-seed powder at doses of 0–6 mL per 250 mL sample (equivalent to 0–240 mg L^{-1}). Clarified supernatants and untreated controls were subsequently exposed to solar radiation in clear polyethylene terephthalate (PET) bottles under ambient conditions. Physicochemical parameters (turbidity, pH, electrical conductivity, total dissolved solids and temperature) and total coliform counts were measured before and after each treatment stage. All principal treatment sequences were performed in triplicate. Raw stormwater exhibited mean turbidity of 42.2 NTU and mean total coliform concentration of 960 CFU mL^{-1}. At the selected working dose of 4 mL stock (160 mg L^{-1}), date-seed flocculation alone reduced turbidity by approximately 14–27 % and total coliforms by approximately 50 % (principal comparative series; Table 2). Higher microbial reductions (up to ~77–88 %) were observed in dosage-screening series that used different raw-water batches. SODIS alone achieved ~51 % coliform reduction, while the sequential date-seed + SODIS treatment produced the highest microbial reduction among the four tested sequences (~59 %). Turbidity behaviour after the combined sequence was variable and depended on handling of the supernatant. These laboratory results indicate that modest pre-treatment with date-seed powder can improve the subsequent performance of SODIS under the conditions tested. Further optimization of dosing, mixing, settling and exposure parameters, together with multi-event field validation, will be required before community-scale application can be recommended.

Keywords: Natural coagulant; *Phoenix dactylifera*; Solar disinfection; SODIS; Stormwater treatment; Turbidity; Total coliform; Circular economy.

Introduction

Access to safe water is a problem in many urban centres of developing countries. Impervious surfaces (roads, buildings and pavements) can increase surface runoff volume and speed, contributing suspended solids, organic matter, nutrients, heavy metals, hydrocarbons and faecal microorganisms to the drainage system and receiving waters (Fletcher et al., 2015; Walsh et al., 2016; U.S. Environmental Protection Agency [EPA], 2023). The lack of open drains and proper solid waste management in Dutse Urban exacerbates storm water pollution, increasing environmental and health hazards, especially during dry seasons when pollutants can build up (Aderogba, 2012; NIMET, 2020).

The conventional treatment trains generally consist of aluminium or iron coagulants followed by disinfection. These chemicals are effective, but produce high amounts of chemical sludge, are expensive to operate and under specific exposure conditions residual metal ions have been linked to health risks (Bratby, 2016; Sillanpää et al., 2018). Therefore, the plant-derived, biodegradable and low-toxic coagulants that are locally available have become the focus of research (Yin, 2010).

Seeds from date palm (Phoenix dactylifera L.) are a big waste product for agriculture industry residue. They are composed of cellulose, hemicellulose, lignin, proteins and phenolics that can neutralise charges, form polymeric bridges and adsorb (Bouhlali et al., 2017; Adrin et al., 2024). Under optimized extraction conditions, the turbidity in textile and other industrial wastewaters was reduced by 62- 84 % and chemical oxygen demand (COD) reduced by 56-80 % by date-seed extracts (Adrin et al., 2024; Abdul-Rahman-Adrin et al., 2025). The microbial reductions of 75–88 % have also been reported in wastewater matrices (Kuhiyop, 2019; Kuhiyop et al., 2020). It is crucial to note that results from removal of contaminants in wastewater or drinking-water or textile-wastewater matrices do not necessarily translate to removal in urban stormwater, which contains significantly different particle and microbial assemblages.

Solar disinfection (SODIS) is a method that uses the UV-A radiation and high temperature to destroy pathogenic microorganisms and is recommended by the World Health Organization (WHO) as a method for treating drinking water in homes (2023; McGuigan et al., 2012). However, the efficacy of SODIS becomes significantly reduced when the turbidity is greater than ~30 NTU, as suspended particles will interfere with the UV and will provide protection to microorganisms (McGuigan et al., 2012; Dawney & Pearce, 2012). The pre-treatment which reduces turbidity is therefore likely to improve the subsequent solar inactivation.

Natural coagulation and SODIS processes have both been well documented, but their joint use in urban storm water treatment, especially when SODIS is applied sequentially to natural coagulation using date-seed waste under semi-arid climatic conditions in northern Nigeria has received little attention. The reason for the choice of stormwater as one of the matrices was that it is a significant, but relatively neglected, source of urban pollution in Dutse, and, unlike continuous wastewater flows, the events that cause stormwater occur intermittently.

The total coliforms were selected as the primary microbiological indicator because they are well-established in the studies of stormwater and surface waters, are relatively easy to enumerate in the laboratory under standard conditions, and are a conservative indicator of

faecal contamination (APHA, 2017). This present lab scale study however examined the performance of date-seed flocculation, SODIS and combined date-seed flocculation followed by SODIS treatment on selected physicochemical and microbiological parameters of stormwater collected from Dutse Urban.

Materials and methods

Study site and sample collection

The semi-arid climatic zone of Jigawa State in north-western Nigeria (lat. 11°42' N, long. 9°20' E) is where Dutse Urban is located. It has a well-defined wet season (May – October) and a long dry season. An artificial lake that is a few meters away from the mechanic village in Dutse urban receiving runoff from mixed residential and commercial surfaces was selected as the sampling site (Figure 1).

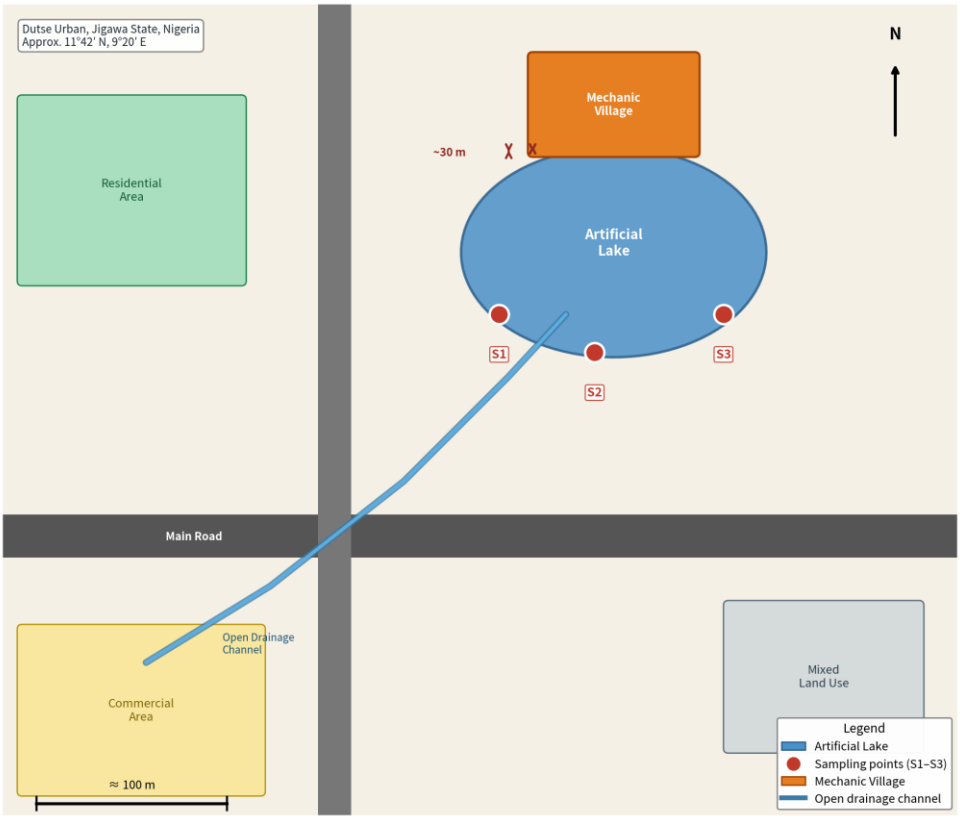


Figure 1: Map of the study site in Dutse Urban, Jigawa State, Nigeria (approx. 11°42′ N, 9°20′ E), showing the artificial lake and stormwater sampling points (S1–S3) located at the lake edge. Mechanic Village is situated a few meters away from the artificial lake.

Samples of stormwater were taken during the 2025 wet season at three different points after rainfalls occurred which resulted in continuous flow in the selected open drainage channels. In each case, the composite samples were taken from two to three accessible points draining mixed residential/commercial catchments. The experimental work was based on a total of three independent sampling events, therefore. Precipitation prior to each sampling event was not instrumentally recorded, but sampling was limited to those events that resulted in continuous flow in the channels for several hours or more, which local observers considered to be “major” precipitations. Samples were collected in clean, high-density polyethylene

containers, which were first rinsed with distilled water and then with the sample, per the procedures adapted from U.S. EPA (2023) and Walsh et al. (2016). Field observations (date, time, weather conditions and visible pollution indicators) were recorded. Samples for microbiological testing were taken in sterile bottles (American Public Health Association [APHA] 2017). To prevent changes in water quality, all samples were collected in insulated containers and processed in the laboratory within a few hours of collection.

Preparation of date-seed flocculant

The date palm (Phoenix dactylifera) seeds were collected from the local markets and date processing residues. The seeds were cleaned with clean water to wash off the pulp and surface dirt and afterwards sun dried to constant weight (Bouhlali et al., 2017; Adrin et al., 2024; Abdul-Rahman-Adrin et al., 2025). The dried seeds were milled in a laboratory mill (i.e. a mortar and pestle) to a fine powder and screened to collect a relatively uniform sample of particle size (Yin, 2010; Ndabigengesere et al., 1995). Powder was kept in clean, dry and labeled containers until use.

A stock suspension was prepared daily by accurately weighing 1.00 g of powder and dispersing this in 100 mL of distilled or de-ionised water by magnetic stirring for ~30 min until uniform (Bratby, 2016). It is not a true solution but a suspension as the lignocellulosic material is not dissolved completely. To minimize the effects of ageing, fresh stock was produced daily for each experimental day which would reduce coagulant activity (Ukanwa & Verstraete, 2010 as cited in Bate et al., 2023). The stock was re-suspended gently just prior to the dosing to avoid particle settling.

Experimental design, treatment matrix and jar-test procedure

The four treatment sequences for the laboratory experiments were: (i) untreated raw stormwater, (ii) date-seed flocculation only, (iii) SODIS only and (iv) sequential date-seed flocculation followed by SODIS treatment. Laboratory analytical replication was provided by the principal comparative series (the data reported in Table 2 and Figures 5-6), which was carried out three times using a single composite sample batch. Further series of dosages were made on other batches of the raw water to investigate dose–response relationships, and these are differentiated from the main comparative experiment in the Results section.

A standard jar-test apparatus (Bratby, 2016) was used for dosage determination and flocculation. Clean glass beakers were used for the deposition of homogenised stormwater (250mL). The 1 % stock suspension (0, 1, 2, 4 and 6 mL) were added which corresponds to 0–240 mg L^{-1} date-seed powder (Ndabigengesere & Narasiah, 1998; Khader et al., 2018). Immediately after dosing, rapid mixing (100-150 rpm, 1-2 min) was used to break up the coagulant and promote particle-polymer interaction, followed by slow mixing (30-50 rpm, 15-30 min) to encourage growth of the floc. The mixing process was then halted, and the suspensions were left to settle without disturbance for 30-60 min (Bratby, 2016; Yin, 2010). Care was taken to withdraw the settled solids and the supernatant was analysed. A blank having distilled water and the optimum stock volume was used to determine the contribution of the seed material itself to the measured turbidity (Ghebremichael, 2004; Yin, 2010).

Solar disinfection (SODIS) procedure and operating conditions

Supernatant (or raw stormwater for the SODIS-only arm) was transferred into clean, clear polyethylene terephthalate (PET) bottles with a capacity of 0.5–1.5 L following the protocol of McGuigan et al. (2012) recommended by WHO (2023). Bottles were filled to capacity and capped tightly and then set on a non-shaded, directly exposed to the sun, surface. The time of exposure was around 4-6 hours of peak daylight hours (usually 10:00-16:00 local time). Ambient air temperature during exposure ranged from approximately 28-36 °C and where a handheld meter was available, approximate solar intensity was noted. Both the SODIS-only and combined-treatment arms were exposed at the same time under the same conditions, so that direct comparisons can be made (McGuigan et al., 2012; Dawney & Pearce, 2012).

Analytical methods

Physicochemical parameters of the raw and treated samples were measured by using calibrated portable instruments based on standard laboratory procedure. Turbidity was measured using turbidity meter and expressed in nephelometric turbidity unit (NTU). The pH was determined using a calibrated pH meter, following the electrode's rinsing with distilled water. Measuring electrical conductivity (µS cm-1) and total dissolved solids (TDS, mg L-1) were done using conductivity/TS meter. The temperature was measured using a laboratory thermometer or the temperature probe of a multiparameter instrument.

Total coliform enumeration was carried out using a culture-based technique that is available in the laboratory: either membrane filtration or multiple-tube fermentation, and was expressed as colony forming units per millilitre (CFU mL-1). Sterile technique was used for all sample handling (APHA, 2017; WHO, 2023). Specimens that could not be stored were refrigerated and subsequently analysed as soon as possible (APHA, 2017).

Quality control, data treatment and statistical considerations

Quality-control measures included the use of clean (and, where required, sterile) apparatus, consistent mixing speeds and durations, thorough re-suspension of the stock suspension before each withdrawal, inclusion of untreated controls, and prompt recording of instrument readings (APHA, 2017; Bratby, 2016). Percentage reduction for each parameter was calculated relative to the mean raw-water value for that parameter:

$$\text{Reduction}\ (\%) = [(C_0 - C_t) / C_0] \times 100$$

where C_0 is the initial (raw) concentration and C_t is the concentration after treatment. Results are reported as means of laboratory replicates. Because the principal comparative series comprised only three laboratory replicates of a single composite sample, formal inferential statistical testing (e.g., ANOVA) was not performed; treatment sequences are compared descriptively by percentage reduction and by visual inspection of tabulated and graphical trends. Future multi-event studies with independent field replicates would permit robust statistical analysis.

Results

Physicochemical characteristics of raw stormwater

The untreated stormwater used in the principal comparative series had the following mean values (triplicate measurements): turbidity 42.2 NTU (range 38.8–45.7), pH 6.79, electrical conductivity 262.6 µS cm^{-1} (range 256.4–267.6), total dissolved solids 121 mg L^{-1} (range 116–123), and temperature 29.2 °C (range 28.8–29.5) (Table 1). These values indicate appreciable suspended material and served as the baseline for evaluating treatment performance.

Table 1: Physicochemical characteristics of raw stormwater (principal series, pretreatment).

Parameter	Replicate A	Replicate B	Replicate C	Mean
TDS (mg L^{-1})	120	121	121	121
Electrical conductivity (µS cm^{-1})	258	259	271	262.6
pH	6.88	6.76	6.73	6.79
Temperature (°C)	29.5	29.1	29.0	29.2
Turbidity (NTU)	38.8	42.1	45.7	42.2

Dosage screening

In a dosage-screening series performed on a separate raw-water batch, residual turbidity reached its lowest observed value (20.8 NTU) at the 4 mL stock addition (Figure 2). Microbial reduction increased with dose, reaching a maximum of approximately 77 % at 6 mL relative to a control mean of 486 CFU mL^{-1} in that series (Figure 3). On the basis of the turbidity response and practical dosage considerations, the 4–6 mL range was retained for further work, and 4 mL (160 mg L^{-1}) was adopted as the working optimum for the principal physicochemical and comparative series.

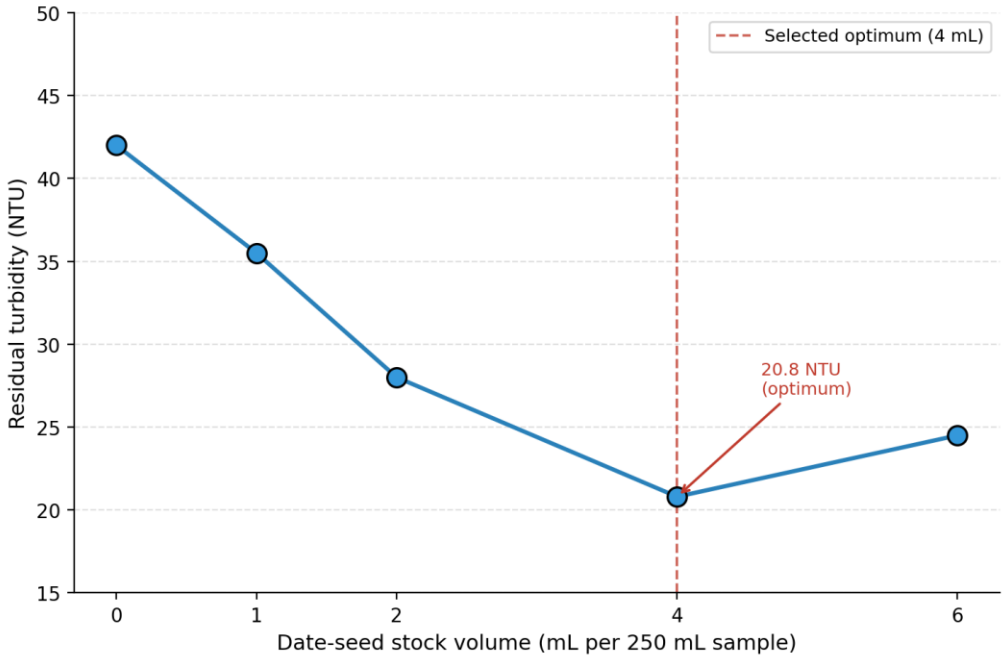


Figure 2: Effect of date-seed stock volume on residual turbidity during jar-test dosage screening. The 4 mL dose produced the lowest turbidity (20.8 NTU) and was selected as the working optimum.

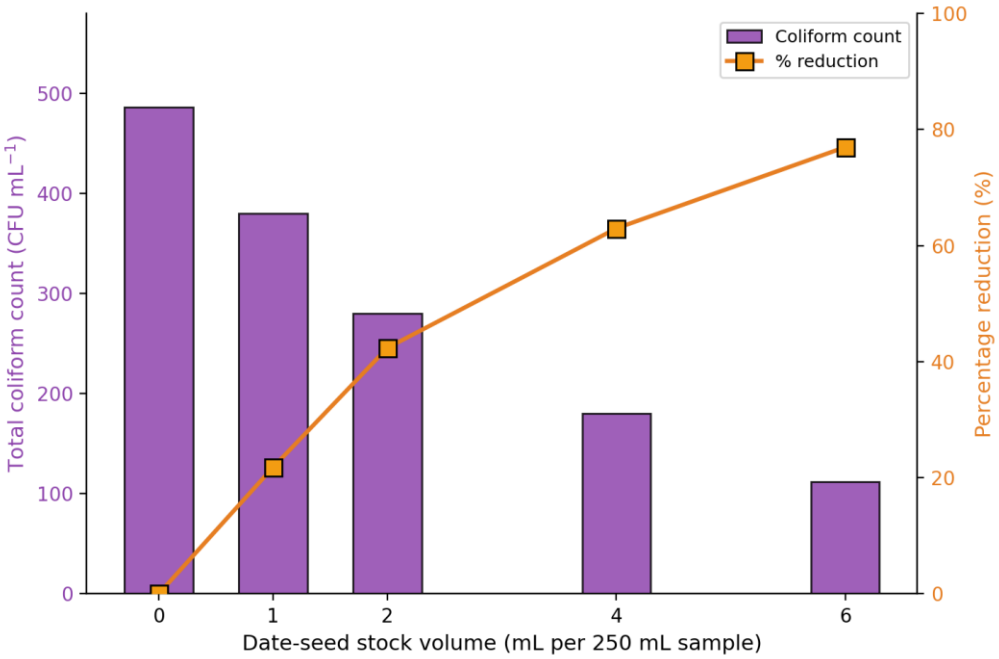


Figure 3: Dosage effect on total coliform count (left axis) and percentage reduction (right axis). Progressive microbial removal was observed with increasing date-seed dose up to 6 mL.

Performance of date-seed flocculation

The turbidity of raw water in principal series (around 36–42 NTU) was reduced to around 30.9 NTU at the selected dose of 4 mL (rough reduction of 14–27 % depending on the actual raw water turbidity value) (Figure 4. The pH was slightly lowered (to ~5.97) and EC and TDS were found to be almost the same (Figure 4). There were also reductions in the total coliform counts of the principal comparative series from a mean of 960 CFU mL^{-1} to 482 CFU mL^{-1} (49.8 %; Table 2). The dose-reduction series with the greater percentage reductions (50–88 %) were for different batches of raw water and greater absolute doses, so the 49.8 % from the principal triplicate series is the most appropriate value to compare directly with the other dose reduction arms.

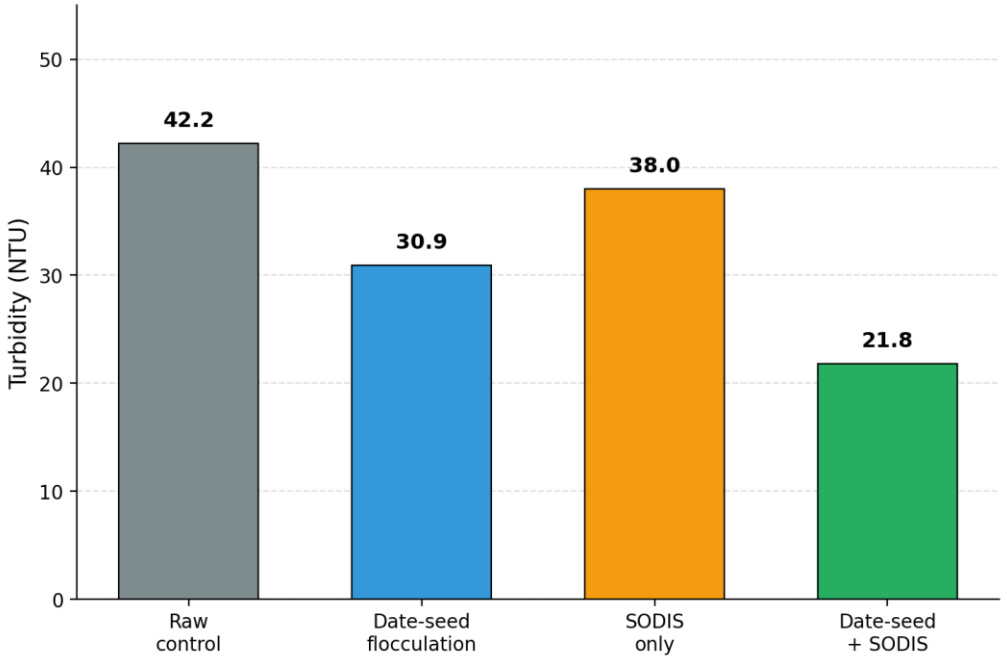


Figure 4: Turbidity of stormwater across the four treatment stages. Date-seed flocculation reduced turbidity relative to the raw control; residual turbidity after the combined treatment reached 21.8 NTU in one data set.

SODIS alone and combined treatment

SODIS alone produced a mean coliform reduction of approximately 51 % (Table 2). The sequential date-seed flocculation + SODIS treatment yielded the lowest mean coliform count among the four sequences (390 CFU mL^{-1} from a raw mean of 960 CFU mL^{-1}), corresponding to a 59.4 % reduction (Figures 5 and 6; Table 2). Turbidity after the combined sequence was variable: one data set showed a further decline to 21.8 NTU, while another showed an increase relative to the post-flocculation value. This variability underscores the importance of controlled settling, careful supernatant transfer and consistent bottle filling.

Table 2: Comparative total coliform performance of the four treatment sequences (principal triplicate series).

Treatment	Rep. 1	Rep. 2	Rep. 3	Mean (CFU mL^{-1})	Reduction (%)
Untreated control	962	956	964	960	0.0
Date-seed only	480	484	482	482	49.8
SODIS only	472	466	468	468	51.3
Date-seed + SODIS	392	388	390	390	59.4

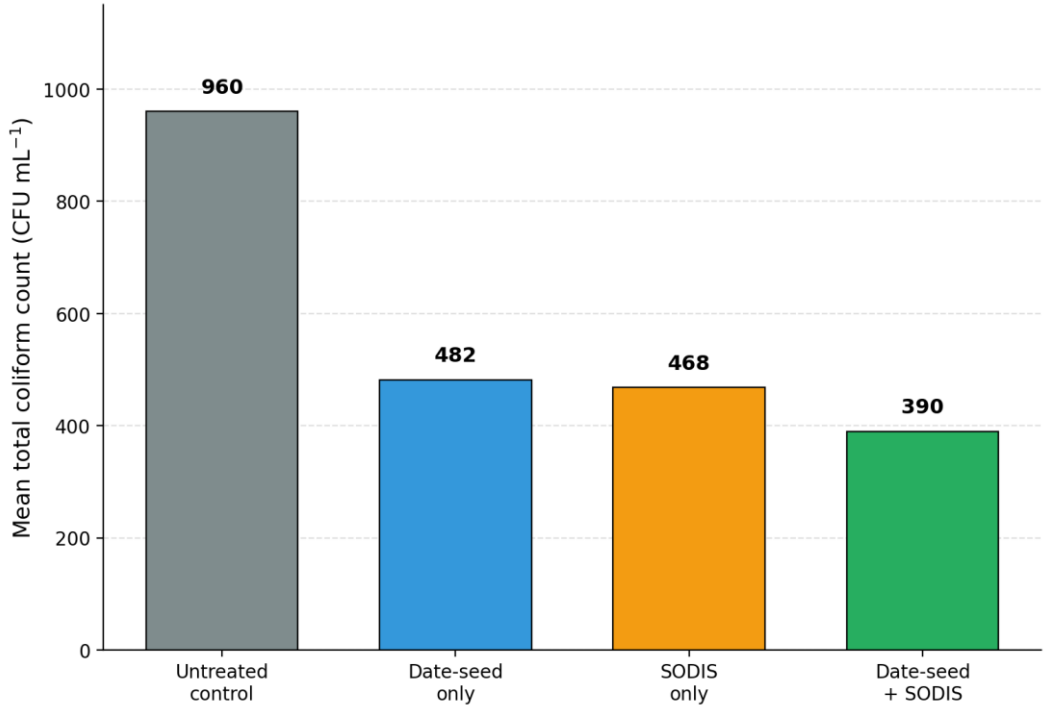


Figure 5: Mean total coliform counts (CFU mL^{-1}) for untreated control, date-seed flocculation only, SODIS only, and the combined date-seed + SODIS treatment (principal triplicate series).

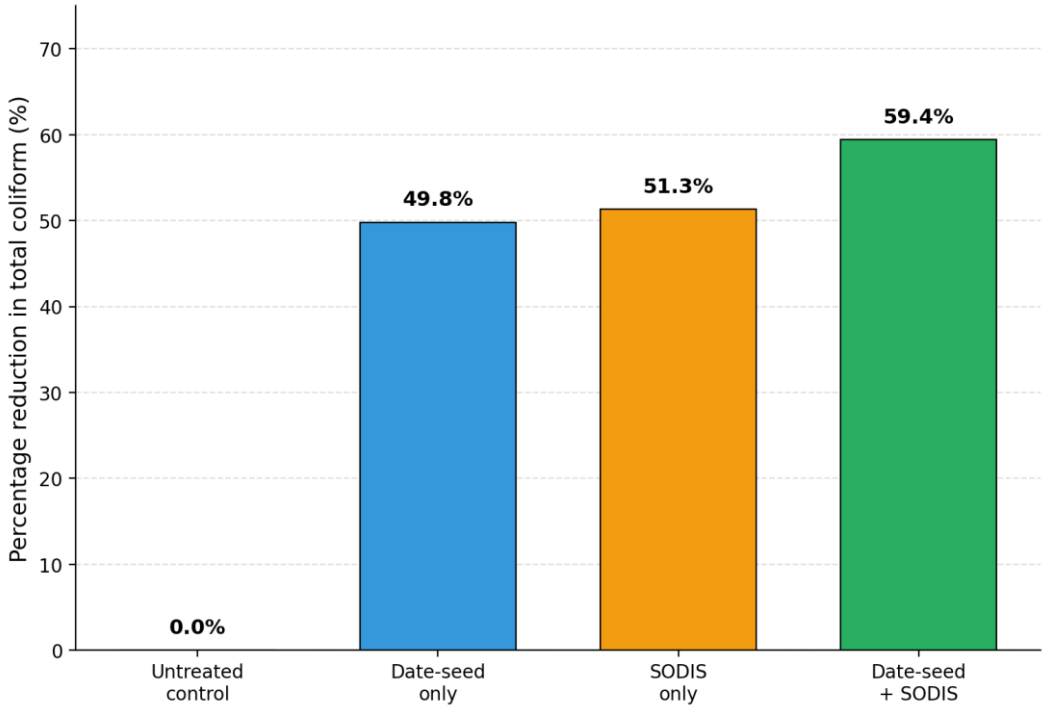


Figure 6: Percentage reduction in total coliform relative to the untreated control. The combined date-seed + SODIS treatment achieved the highest microbial removal efficiency (59.4 %).

Discussion

The turbidity reduction seen when using aqueous date-seed powder was relatively low (14-27 % in the main series), as compared to the reduction in turbidity on other matrices achieved under optimised saline extraction and higher doses of powder (Adrin et al., 2024; Abdul-Rahman-Adrin et al., 2025). The lower removal observed here is due to the complexity and

variability of the real stormwater, the aqueous (rather than saline) extraction method and relatively low initial turbidity. The mineral particle size distribution in stormwater often contains more diverse and varied mineral particles than controlled synthetic or industrial wastewaters, and may be less amenable to single natural polymers (Walsh et al., 2016; U.S. EPA, 2023).

Removal of around 50 % after flocculation only for the principal series is in line with the principle of particle associated bacteria being removed through coagulation–flocculation as reported by Kuhiyop (2019) and Kuhiyop et al. (2020). The percentage reduction varies, depending on the raw-water batch and the absolute dosages, as indicated by the average values obtained in the dosage-screening series (77–88 %). These values cannot be compared directly to the value obtained in the principal-series (49.8 %). Further incremental reduction was provided by subsequent SODIS, which further reinforces the multi-barrier rationale that the modest turbidity reduction can improve UV penetration and inactivation kinetics (McGuigan et al., 2012). The overall coliform reduction for the combined stages is 59.4 % which shows complementary action between two stages under the laboratory condition tested (Table 2).

Measureable pH depression may be caused by plant coagulants, which should be monitored, particularly for plant water to be used in sensitive end uses (Bratby, 2016; Yin, 2010). The process, under the current protocol, is considered more of a laboratory demonstration of a possible pre-treatment or non-potable polishing unit, rather than a full potable water treatment train.

In terms of environmental considerations, the method takes advantage of many agricultural residue, chemical sludge is not generated, and solar resources were used free, which aligns well with the objective of circular-economy and low-carbon water-management in northern Nigeria semi-arid cities (Bouhlali et al., 2017; Adrin et al., 2024). This technology of using a waste based natural flocculant in combination with solar disinfection is therefore a conceptually appealing approach to more sustainable urban stormwater management, where conventional infrastructure is restricted. These results, however, are based on lab-based experiments with a small number of sample batches, and have not yet been proven to be effective in the field or community.

Conclusion

Laboratory experiments show the date-seed powder can be used to remove the turbidity of Dutse Urban stormwater by around a tenth or so of the turbidity at the selected working dose in the principal comparative series, and also remove some coliforms (around 50 % at the selected working dose). The date-seed floccation + SODIS sequence gave the best microbial reduction (~59 %) of the sequences tested. It is easy to implement and does not require expensive equipment or any imported materials, thus it is worth further studying as a technology that can be adopted at a community level as a pre-treatment process.

Recommended future work includes:

(i) systematic optimization of seed preparation (particle size, extraction solvent, dosage), mixing intensity and settling time;

(ii) inclusion of *Escherichia coli,* enterococci and additional indicator organisms;

(iii) testing across larger volumes and multiple independent storm events with fully documented rainfall and catchment characteristics;

(iv) assessment of residual or ganic matter and possible secondary effects; and

(v) techno-economic and life-cycle comparison with conventional coagulants.

Only after such work can the date-seed + SODIS train be confidently advanced toward practical application in resource-limited urban settings.

Declarations

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

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References

Abdul-Rahman-Adrin, M. H., Ngadiman, N., Abdullah, N. H., Hamdan, R., & Abdullah, M. S. (2025). Evaluating the effectiveness of different masses of date seeds as natural coagulants in the process of treating textile wastewater. IOP Conference Series: *Earth and Environmental Science,* 1453(1), Article 012052. https://doi.org/10.1088/1755-1315/1453/1/012052

Kuhiyop, E. A., Adie, D. B., & Abubakar, U. A. (2020). Application of Mangifera indica (mango) and *Phoenix dactylifera* (dates) seeds powders as coagulants in wastewater treatment. *Nigerian Journal of Technology,* 39(1), 269–277. https://doi.org/10.4314/njt.v39i1.30

Adrin, M. H. A. R., Ngadiman, N., Hamdan, R., Abdullah, N. H., & Siddiqui, Z. (2024). Effectiveness of date dry seed as a natural coagulant in wastewater treatment process. International *Journal of Sustainable Construction Engineering and Technology,* 15(3), 168–177.

Aderogba, K. A. (2012). Global warming and challenges of floods in Lagos Metropolis, Nigeria. *Academic Research International,* 2(1), 448–468.

American Public Health Association. (2017). Standard methods for the examination of water and wastewater (23rd ed.). American Public Health Association.

Bate, G. B., Adeleye, A. O., Amoo, A. O., Ijanu, E. M., Asaju, C. I., & Mohammed, H. S. (2023). Comparative assessment of *moringa oleifera* seed extract and aluminum sulfate solution efficiency as coagulants for storm water treatment. *Journal of Bangladesh Academy of Sciences,* 47(1), 119–125. https://doi.org/10.3329/jbas.v47i1.61838

Bouhlali, E. D. T., Alem, C., Ennassir, J., Benlyas, M., Mbark, A. N., & Zegzouti, Y. F. (2017). Phytochemical compositions and antioxidant capacity of three date (Phoenix dactylifera L.) seeds varieties grown in the South East Morocco. *Journal of the Saudi Society of Agricultural Sciences*, 16(4), 350–357. https://doi.org/10.1016/j.jssas.2015.11.005

Bratby, J. (2016). Coagulation and flocculation in water and wastewater treatment (3rd ed.). IWA Publishing.

Dawney, B., & Pearce, J. M. (2012). Optimizing the solar water disinfection (SODIS) method by decreasing turbidity with NaCl. Journal of Water, Sanitation and Hygiene for Development, 2(2), 87–94. https://doi.org/10.2166/washdev.2012.043

Fletcher, T. D., Shuster, W., Hunt, W. F., Ashley, R., Butler, D., Arthur, S., Trowsdale, S., Barraud, S., Semadeni-Davies, A., Bertrand-Krajewski, J.-L., Mikkelsen, P. S., Rivard, G., Uhl, M., Dagenais, D., & Viklander, M. (2015). SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. Urban Water Journal, 12(7), 525–542. https://doi.org/10.1080/1573062X.2014.916314

Ghebremichael, K. A. (2004). Moringa seed and pumice as alternative natural materials for drinking water treatment (Doctoral dissertation). Royal Institute of Technology (KTH).

Khader, E. H., Mohammed, T. J., & Mirghaffari, N. (2018). Use of natural coagulants for treatment of industrial wastewater: A review. *Journal of Engineering and Sustainable Development*, 22(2), 1–12.

Kuhiyop, E. A. (2019). The use of mango (Mangifera indica) seeds and dates (Phoenix dactylifera) seeds as coagulants in wastewater treatment (Master's thesis). Ahmadu Bello University.

McGuigan, K. G., Conroy, R. M., Mosler, H.-J., du Preez, M., Ubomba-Jaswa, E., & Fernandez-Ibañez, P. (2012). Solar water disinfection (SODIS): A review from bench-top to roof-top. *Journal of Hazardous Materials*, 235–236, 29–46. https://doi.org/10.1016/j.jhazmat.2012.07.053

Ndabigengesere, A., & Narasiah, K. S. (1998). Quality of water treated by coagulation using *Moringa oleifera* seeds. *Water Research,* 32(3), 781–791. https://doi.org/10.1016/S0043-1354(97)00295-9

Ndabigengesere, A., Narasiah, K. S., & Talbot, B. G. (1995). Active agents and mechanism of coagulation of turbid waters using Moringa oleifera. *Water Research*, 29(2), 703–710. https://doi.org/10.1016/0043-1354(94)00161-Y

Nigerian Meteorological Agency. (2020). Seasonal rainfall prediction. NIMET.

Sillanpää, M., Ncibi, M. C., Matilainen, A., & Vepsäläinen, M. (2018). Removal of natural organic matter in drinking water treatment by coagulation: A comprehensive review. *Chemosphere*, 190, 54–71. https://doi.org/10.1016/j.chemosphere.2017.09.113

U.S. Environmental Protection Agency. (2023). Urban stormwater runoff. https://www.epa.gov/

Walsh, C. J., Booth, D. B., Burns, M. J., Fletcher, T. D., Hale, R. L., Hoang, L. N., Livingston, G., Rippy, M. A., Roy, A. H., Scoggins, M., & Wallace, A. (2016). Principles for urban stormwater management to protect stream ecosystems. *Freshwater Science,* 35(1), 398–411. https://doi.org/10.1086/685284

World Health Organization. (2023). Guidelines for drinking-water quality (4th ed., incorporating the 1st and 2nd addenda). WHO.

Yin, C.-Y. (2010). Emerging usage of plant-based coagulants for water and wastewater treatment. *Process Biochemistry,* 45(9), 1437–1444. https://doi.org/10.1016/j.procbio.2010.05.030