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Combined coagulation and disinfection efficiencies of *Mangifera indica*, *Carica papaya* and solar disinfection on synthetic agro - waste water

[1] Dokubo Chinweike Unoma, [2] Uba Bright Obidinma, [3] Nnaji Ijeoma Genevieve
[1] Department of Science and Laboratory Technology, Delta State Polytechnic Ogwashi - Uku, Nigeria
[2, 3] Department of Microbiology, Chukwuemeka Odumegwu Ojukwu University, P.M.B Uli, Anambra State, Nigeria

Corresponding Author: **Uba Bright Obidinma**

Abstract
Solar disinfection (SODIS) proves to be both economical and eco-friendly technique particularly in rural areas in waste water treatment. Natural coagulants applications have been posed in many evaluation assays through many years owing to the difficulties raised by usage of chemical coagulants. It is indispensable to optimize process variables such as turbidity and coliforms counts accuracy to raise the efficiency of coagulation and disinfection operations via employing Mangifera indica and Carica papaya. In this study, an investigation on the combined coagulation and disinfection efficiencies of M. indica and C. papaya as well as solar disinfection on synthetic waste water was conducted using turbidity and membrane filtration techniques. The results revealed that the removal efficiency for turbidity was culminated up to a higher percentage by incorporation of M. indica and C. papaya seeds at lower dosages of coagulant about 0.1 – 1 mg/L in combination with SODIS for about 6 hours in comparison to the control set up. Also, the highest efficiency of solar disinfection system possessed to fell the sunlight exposure period time by up to 6 h with 100 % removal of coliforms at different plastic capacities (0.75 – 1.5 L). Therefore, the M. indica and C. papaya seeds powder as natural coagulant supported by solar disinfection composed a combined or integrated practice which can be utilized in rural areas to turbid water treatment operations.

Keywords: *M Indica*, *C Papaya*, SODIS, Phyto - Disinfectant, Waste Water Treatment

1. Introduction

Water remains a strategic resource for the integration of economic, social and environmental concerns and it is the key to sustainable development. It sustains human productivity and livelihoods and plays a crucial role in integrating world's ecosystems. Water is under increasing and competing demands from agricultural, industrial and domestic uses with increasing pollution threatening this scarce resource [1].

The world health organization has estimated that up to 80 % of all diseases and sickness in the world is caused by inadequate sanitation, polluted water or unavailability of water however, 10% could be prevented by improvements related to drinking water, sanitation, hygiene and water resource management. Despite the wide recognition of the importance of improved water and sanitation and heavy investment by international donors and governments in developing countries in extending water supply systems, over 780 million people are still without access to improved sources of drinking water and success still leaves more than 605 million people without access to safe water in 2015 mainly in sub–Saharan Africa [2]. The people at greatest risk due to unsafe water are children, people living under unsanitary conditions and the elderly. But this can be reduced through the provision of household water treatment techniques and potentially billions of people can benefit from effective household water treatment. Household water treatment applications are any of a range of technologies, devices or methods employed for the purposes of treating water at the household level or at the point [3].

Water treatment techniques such as filtration, boiling, chlorination and ultra violet radiation, while effective may be too costly to use in developing countries or emergency situations [4]. Plant extracts which are natural have been exploited for water purification by many nations from ancient times. Majority of them are derived from the fruits of trees and plants, roots, bark or sap, seeds and leaves [5]. The earlier studies on the coagulation and disinfection efficiency with Tuberregium sclerotium, Moringa oleifera, Hibiscus sabdariffa, Jatropha curcas, Pleurotus and Alum were evaluated on wastewater samples for removal of turbidity. Coagulation efficiency of approximately 90 % was achieved for the M. oleifera with a significant rise in disinfection efficiency. Moringa oleifera seeds are widely regarded for nontoxic, eco-friendly and simplified water treatment operations for people who are accommodated in extreme poverty. With regard to many assays published to some of the waterborne pathogens, M. oleifera seeds have exhibited sufficient resistance [6]. Solar water disinfection (SODIS) is one of the household water treatment and safe storage (HWTS) methods recommended for water treatment in emergencies and in the camps of internally displaced persons (IDP). SODIS has been recognized as a simple, low-cost method that is ideally suited for the poorest members of the world's population, especially where there are no other methods for ensuring safe drinking water. SODIS harnesses energy from the sun to kill pathogenic microorganisms in drinking water. It basically involves storing small quantities of water in transparent containers, preferably Polyethylene Terephthalate (PET) bottles and exposing them to the sun for a period that depends on the intensity and duration of the sun [7]. SODIS exploits the germicidal action of heat and UV components of solar radiation to destroy microbial pathogens through thermal denaturation of cell proteins and UV-induced formation of reactive oxygen species (ROS) that attack cell DNA [8]. ROS are potent oxidants and can cause irreversible damage to microorganisms. SODIS has demonstrated a capacity for reducing the incidence of diarrhoeal diseases and infant mortality substantially in several field trials and health impact assessment studies [9, 10]. More than 4.5 million people in 55 countries are now using SODIS as their daily household water treatment and safe storage (HWTS) option [7].

Several studies indicated that solar disinfection in synergism with plant disinfectants may be an alternative, low- cost, effective and simple method of water purification for use at the household level. Most of those studies focus on treatment efficiencies of SODIS without exploring the potentials on different local environmental conditions. There is limited database on SODIS technology in synergism with plant disinfectants in Nigeria using coliform or other water-related pathogens as most studies conducted were outside Nigeria and may not permit the development of model for optimal disinfection potentials. Also, PET bottles can be found at negligible cost and this system can potentially have zero capital and operational costs during water treatment. This study was aimed at investigating the combined turbidity and disinfection efficiencies of M. indica, C. papaya and solar disinfection on synthetic waste water.

2. Materials and methods

2.1 Sample Collection

Cow dung sample will be collected using clean disinfectant hand trowel into a sterile polyethylene bag**.** Fresh healthy Moringa seeds will be purchased at Ogwashikwu market, Delta State, Nigeria and packaged into sterile polyethylene bags. Both will be transported to the laboratory for further study.

2.2 Processing of the Plant Seed Sample

Seeds will be selected and dried under shade for 10 days. The seeds will be de-shelled by hand, crushed and converted to powdered form using a blender and sieved using a strainer with a pore size of 2.5 mm^2 to obtain a fine powder according to Adeoti *et al*. [11]. The powder will be stored in a sealed plastic container with cover at room temperature (25 °C) prior to processing and use.

2.3 Simulation of Synthetic Waste Water

Synthetic water will be simulated by deliberately contaminating 1 L of distilled water with 10 g of the collected cow dung sample and finally used as raw waste water [12].

2.4 Preliminary Physicochemical and Microbiological Analysis

The following test will be conducted on the synthetic waste water sample.

2.4.1 Turbidity

The turbidity of the samples will be determined after calibrations of the instrument with blank and standard solutions and triplicate measurements were taken [13].

2.4.2 Bacteriological analysis of water

Membrane filtration technique was employed to determine microbial quality of the water samples in accordance with American Public Health Association [13]. A sterile filtration apparatus was put in position and connected to a vacuum pump. The apparatus was rinsed by passing small amount of sterile water and the water sample to be analyzed through the funnel using the vacuum pump. The water samples were thoroughly mixed after which one hundred milliliters (100 mL) of it was poured into the funnel containing the filter paper and slowly filtered through the membrane filter with the aid of the vacuum pump. Using sterile forceps, the membrane filters were removed from the filtration cup and transferred facing up on the surface of the Petri dishes containing the named medium for the culture of bacteria of interest. For total coliform, the plates were incubated at 37 ºC for 48 hr using MacConkey agar. After incubation, number of bacterial colonies were enumerated and expressed as colony per 100 mL of sample.

2.4.3 Testing the efficiency of coagulant with SODIS under different parameter

The efficiency of SODIS in combination with the phyto-disinfectant will be tested under different water depths in bottles, photo-coagulant and phyto-disinfectant and solar exposure time by adopting the modified method of Dessie *et al*. [12] and Unnisa and Bi [6]. To determine the effect of water depth on SODIS, bottles having 0.75 L of water depth, 1.0 L of water depth and 1.5 L of water depth were filled with raw water having initial bacterial load and exposed under direct sunlight. The effects of coagulant and disinfectant on SODIS efficiency were determined by exposing the bottles to different concentrations of 0.1, 0.5 and 1.0 g/L, respectively. The effect of solar exposure time on SODIS was determined by exposing them to sunlight for 6 h and analyzed in 3 h intervals to determine the effect of exposure time turbidity and coliform inactivation, respectively. This helps to identify optimum SODIS efficiency levels for direct applicability of the technology.

2.5 Biostatistical management

The results were considered statistically significant if $P < 0.05$ when two way of variance (ANOVA) was implemented for mean of treatment groups comparism as well as Post Turkey's multiple comparism test using GraphPad Prism Statistical Software Version 9.0.0 (GraphPad Software Inc.

San Diego CA) [14].

3. Results and discussion
3.1 Results

Table 1: Turbidity value (NTU) of SODIS - M. indica treated water after 3 hr

Seed mass (g)	Water depth (L)		
	0.75	1	1.5
0	271.99	271.99	271.99
0.1	39.46	140.62	30.23
0.5	33.12	44.85	161.96
1.0	237.35	42.73	240.23

Key: NTU = Nephelometric Turbidity Units; SODIS = Solar disinfection; g = Gram; L = Litre; hr = Hour

Table 2: Turbidity value (NTU) of SODIS- C. papaya seed treated water after 3 hr

Seed mass (g)	Water depth (L)		
	0.75	1	1.5
0	271.99	271.99	271.99
0.1	12.15	33.08	21.00
0.5	15.23	32.54	20.23
1.0	31.00	19.08	46.77

Key: NTU = Nephelometric Turbidity Units; SODIS = Solar disinfection; g = Gram; L = Litre; hr = Hour

Table 3: Turbidity value (NTU) of SODIS - *M. indica* treated water after 6 hr

Seed mass (g)	Water depth (L)		
	0.75	1	1.5
0	271.99	271.99	271.99
0.1	47.54	38.5	43.69
0.5	237.54	58.37	55.23
1.0	43.31	119.46	37.54

Key: NTU = Nephelometric Turbidity Units; SODIS = Solar disinfection; g = Gram; L = Litre; hr = Hour

Table 4: Turbidity value (NTU) of SODIS- *C. papaya* seed treated water after 6 hr

Seed mass (g)	Water depth (L)		
	0.75	1	1.5
0	271.99	271.99	271.99
0.1	27.92	12.15	25.62
0.5	7.54	32.92	14.85
1.0	17.54	13.69	61.38

Key: NTU = Nephelometric Turbidity Units; SODIS = Solar disinfection; g = Gram; L = Litre; hr = Hour

Table 5: Bacterial count (CFU/100mL) of SODIS – M. indica treated water after 3 hr

Seed mass (g)	Water depth (L)		
	0.75	1	1.5
0	41	41	41
0.1	10	0	14
0.5	8	10	11
1.0	4	36	8

Key: CFU/100mL = Colony forming unit per 100 mL; SODIS = Solar disinfection; g = Gram; L = Litre; hr = Hour

Table 6: Bacterial count (CFU/100mL) of SODIS-C papaya seed treated water after 3 hr

Seed mass (g)	Water depth (L)		
	0.75	1	1.5
0	28	28	28
0.1	11	0	15
0.5	8	5	10
1.0	7	12	13

Key: CFU/100mL = Colony forming unit per 100 mL; SODIS = Solar disinfection; g = Gram; L = Litre; hr = Hour

Table 7: Bacterial count (CFU/100mL) of SODIS - *M. indica* treated water after 6 hr

Seed mass (g)	Water depth (L)		
	0.75	1	1.5
0	41	41	41
0.1	0	6	7
0.5	0	2	5
1.0	0	0	0

Key: CFU/100mL = Colony forming unit per 100 mL; SODIS = Solar disinfection; g = Gram; L = Litre; hr = Hour

Table 8: Bacterial count (CFU/100mL) of SODIS- *C. papaya* seed treated water after 6 hr

Seed mass (g)	Water depth (L)		
	0.75	1	1.5
0	28	28	28
0.1	3	3	9
0.5	0	1	5
1.0	0	0	0

Key: CFU/100mL = Colony forming unit per 100 mL; SODIS = Solar disinfection; g = Gram; L = Litre; hr = Hour

3.2 Discussion
Nowadays, the application of environmentally friendly natural coagulants is getting more publicity which is mentioned as ubiquitous alternative for water treatment targets. Organic polymers which are natural are called as biopolymers which are generated or released from many resources such as microorganisms, animals and plant tissues which are safe for human and biodegradable in nature. Their exploitation as coagulants is getting some advantageous because they are efficient in low dosage, produces less sludge quantity and have negligible impact on pH and alkalinity [6].

In this study, in order to treat turbid water, natural coagulants and solar disinfection were used and the results are depicted in tables. Tables 1 – 8 showed the turbidity value and bacterial count on SODIS - *M. indica* and *C. papaya* treated waters, respectively. According to Table 1 - 4, the turbidity was detected in high ranges in treated water samples, which might be reasonable because of the dissolving the dissolved solids ions and salts. Turbidity can influence and alter the organoleptic properties of water and also protect pathogens in the distribution system that can be major causes of waterborne diseases [15].

Natural sunlight has been confirmed to confer germicidal properties. It was revealed that natural light exposure of approximately 2000 kJ/m^2 or 555 Wh/m^2 led to 3-log inactivation of *E. coli*. Viruses withstand this process more resistant than bacteria for the same inactivation exposures. Experimentally, the solar irradiance was implemented and conducted for 3-day utilization so that the disinfection operation. Solar light is an indicative of the amounts of both available $UV_{315-415\ nm}$ and visible irradiation for disinfection operation, so it is one of the major factors influencing solar treatment efficiency [16]. Tables 5-8 displays the solar disinfection employed by the current research.

The natural E. coli made up approximately 0.05 – 5 % of the natural total coliforms (TCs) probable numbers or concentrations. The presence of colonies on MacConkey agar confirmed probable presence of typical coliforms with the absence of spores. No coliform species emerged after 6 h exposure period for 0.75 L of plastic containers and 1.0 g of M. indica and C. papaya experiment, respectively. The results generally proved strongly that natural materials applied had strong ability to purify turbid water. Despite the materials alone cope with treating water and wastewater, incorporation of the material with solar disinfection has a further advantage in treating turbid water as demonstrated according to Table 5 - 8. Dawney *et al*. [17] utilized table of NaCl to remove turbidity in water as a pretreatment step for colloidal clay particles supported by Jar tests resulted to about 92 % particle removal efficiency in South Sudan. It has also been suggested that complementary process use very low amounts of bentonite to raise the turbidity removal and solar system for microorganism elimination targets. Giannakisa *et al.* [18] reported that using solar system procured the highest disinfection efficiencies for both of water and wastewater treatments applications. The microbial load in the water can be reduced by solar disinfection practice, making it potable. The results proved that water samples from various rural water resources met the drinking water standards with a significant decline in microbial loads by Devi and Lalitha [19]. Also, the study done by Fernandez - Ibanez *et al.* [20] is in full agreement and conformity with results and findings of present study.

4. Conclusion

Promotion and development of *M. indica* and *C. papaya* seeds as a natural coagulant offered many diverse advantages to many countries of the developing world. Therefore, it created us a sustainable, useful, effective and robust water treatment product. Turbidity was removed up to highly significant proportion after treatment. As the natural coagulant remediated turbidity of the water additionally sunlight as a renewable energy demanded for disinfection, so it is recommended. It was found that seeds as natural coagulants procured 100 % reduction in coliform counts with SODIS after 6 h at different plastic capacities (0.75 – 1.5 L). Employing seeds powder to purify turbid water created some positive attentions such as being eco-friendly and cheap products to use. The seeds as natural coagulant supported by solar disinfection composed a combined or integrated practice which can be utilized in rural areas to turbid water treatment operations.

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