Performance Evaluation of Tamarindus Indica Seeds Powder in the Treatment of Dye Wastewater

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DOI: 10.22178/pos.93-17

LCC Subject Category: TA1-2040

Received 27.05.2023
Accepted 28.06.2023
Published online 30.06.2023

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Abstract. A large amount of dye wastewater is generated after the local dyeing process. It contains high concentrations of organic and inorganic contaminants. Furthermore, the composition of the wastewater varies according to the type and number of textiles and the water requirements of the process. Hence, its treatment before discharge is necessary to protect the environment. This study investigated the use and effectiveness of Tamarindus indica seeds powder from agricultural waste for removing some recalcitrant target compounds in the dye wastewater. A batch test was performed to examine the use of this adsorbent as a potential replacement for the advanced treatment methods. Varying adsorbent dosages determined the maximum adsorption capacity at 30, 35, 40, 45, and 50 g and at 24, 48, 72, 96 and 120 hr reaction times. The optimum dosage, reaction time and percentage removal of various parameters were found to be; Turbidity (no significant effect), TDS (40 g/l, 72 hrs, 54.42%), EC (35 g/l, 72 hrs, 4.46%), Phosphate (35 g/l, 24 hrs, 38.49 %), Total suspended solid (no significant effect), Nitrate (30 g/l, 96 hrs, 15.26%), COD (no considerable impact) and BOD (30 g/l, 48 hrs, 63.38%) respectively. The results showed that adsorption efficiency increased with decreased adsorbent dosage, even at different reaction times. Hence, low-cost adsorbents such as Tamarindus indica seeds can treat dye waste water to a certain level for safe disposal.

Keywords: Dye Wastewater; Tamarindus Indica Seeds; Agricultural Waste; Physio-Chemical Analysis.

INTRODUCTION

Many factors can cause water contamination. Industrial waste and sewage from cities dumped into the rivers are the most polluting [1]. Waste produced by manufacturing or industrial activities is called industrial waste [2]. The dye business uses a lot of water [3]. Water is needed Throughout production to clean the raw materials and perform many flushing operations [3]. The wastewater produced throughout the various production phases must be cleaned of fat, oil, colour, and other chemicals [4]. The type of wastewater and the amount of water utilised affect the cleansing process [3]. Textile dye extraction from wastewater has become a major global environmental problem. Water contamination poses a severe ecological and human health hazard [5]. It can also lead to some chronic disorders. By examining dye side effects such as toxicity and mutagenicity, bacteria and other living things embedded a prelude to releasing metals into the environment.

The dye business uses raw materials, equipment, and methods to manipulate the finished product's shape and qualities [6]. The primary source of this industry's strength is its robust production, which is based on various fibres and yarns, including both natural and synthetic/man-made ones, including polyester, viscose, nylon, and acrylic [7]. Textile mills and their wastewater have been growing proportionally with the rise in textile product demand, which has led to a significant increase in global pollution [8]. Dye wastewater contains various compounds, and dyes are one of those chemicals [9]. The majority of the environmental issues that the textile industry causes on a global scale have to do with water contamination brought on by the release of untreated wastewater and, therefore, by using hazardous chemicals, particularly during processing [10]. If dye wastewater is released into the environment without adequate treatment, it may cause significant environmental damage. Thus, removing colours from textile effluents before disposal becomes essential to prevent ecological harm.

Pre-treatment, dyeing, finishing, and other technologies are used in textile printing and dyeing processes [11]. Desizing, scouring, washing, and other procedures are included in pre-treatment [12]. To produce coloured fabric under specific circumstances, dying seeks to dissolve the dye in water [13]. A branch of dyeing known as printing is localised dyeing or dyeing restricted to a specific area of the fabric that makes up the design. It is dying in which the fundamental chemical processes are identical [8, 14]. Significant environmental issues are being created by some enterprises' improper and unmanaged wastewater discharges [15]. Dye, metal, and other contaminants are present in the effluents released from textile manufacturing [16]. Natural and artificial dyes can be used as colourants [17]. The ease of production, availability in various colours, and fastness of synthetic dyes make them more popular than natural dyes [18]. According to their chemical makeup (e.g., azo, anthraquinone, sulfur, phthalocyanine, and triaryl methane) and method of use (e.g., reactive, direct, disperse, essential, and vat dying), synthetic dyes are divided into various classes [19].

The dye effluents have high levels of salts, metals, temperature, pH, suspended solids (SS), chemical oxygen demand (COD), and biological oxygen demand (BOD) [20]. Therefore, before releasing the appropriate effluent to the receiving water body during the treatment procedures, it is crucial to check and compare these values with the standard concentrations. It is also necessary to monitor the treatment's effectiveness concerning additional measures, including total organic carbon (TOC), ammonia-nitrogen (NH4-N), nitrate-nitrogen (NO3-N), and ortho-phosphate-phosphorus (PO4-P) [22]. Without a doubt, humanity's future largely depends on the importance of pollution control and treatment. The loss of dissolved oxygen caused by high COD and BOD levels, particulate matter and sediments, and oil and grease in the effluent hurt the aquatic biological system [23]. Chromium, which has a cumulative effect and increased chances of getting into the food chain, is also present in dye effluent [24]. The turbidity of the water body is increased by the effluents' dark colour, which is caused by using dyes and chemicals [25]. The organic contaminants, colour, and heavy metal ions should be considered when dyeing wastewater [26]. Recently, the recovery of wastewater should be taken into consideration due to the lack of water. As a result, the dyeing wastewater's decolourisation was significantly enhanced.

Tamarind (Tamarindus indica, Fabaceae), a tropical fruit in Africa and Asia, is highly valued for its pulp [27]. The tamarind fruit pulp has a sweet acidic taste due to a combination of high contents of tartaric acid and reducing sugars [28]. The pulp is used for seasoning, in prepared foods, to flavour confections, curries and sauces, and as a significant ingredient in juices and other beverages [29]. Several nations produce commercial tamarind-based drinks [28]. A by-product of the tamarind pulp business is tamarind seed [29]. The whole seed cannot be consumed directly due to the testa's presence of tannin and other colouring material [28]. However, after soaking and boiling in water to remove the seed covering, the seeds are then edible [29]. Even now, sources that might be processed into palatable cattle feed have been wasted in the past [30]. The tamarind kernel powder (TKP), a significant sizing material used in the textile, paper, and jute industries, is the leading industrial product of tamarind seed [29].

Additionally, tamarind seeds are used as a raw material to produce tannin, glue, and polysaccharide (jellos) [30]. Two Indian scientists reported that decorticated kernels contained 46-48% of a component that forms gels in 1942. A stabiliser for ice cream, mayonnaise, and cheese, as well as an element or agent in several medicinal goods, has been suggested for usage as this polysaccharide (pectin) with carbohydrate character and gelly forming capabilities, known as "jellose" [31]. Cake and bread may be produced using seed flour [32]. It is asserted that roasted seeds' flavour is superior to groundnuts [28].

Given the overall nutrient and chemical composition, tamarind seeds may be adopted as an inexpensive alternative protein source to alleviate protein malnutrition among traditional people living in developing countries. The powdered seed of Tamarindus Indica has adsorption properties that have been used in various aspects of Turbidity, PH, Total Dissolved Solids and Total Suspended Solids removal [33]. Consequently, the use of these low-cost Tamarindus indica seeds forms the main focus of the study. To reduce the risk of pollution problems from such effluents, it is necessary to accurately treat them before discharging them into the environment. This research focuses on determining the physical and chemical composition of pollutants present in industrial wastewater, metallic content and using Tamarindus indica seeds powder as an adsorbent. To treat and minimise the effect of hazardous contaminants present in dye wastewater, it becomes necessary to treat them accurately before discharging them into the environment.

MATERIALS AND METHODS

The following materials were used; wastewater sample, Tamarindus indica seeds powder, distilled water, Sulphuric acid, Potassium permanganate, Hydrochloric Acid, Sieves of different sizes, PH/EC/TDS meter MODEL HI 9813-5, Colorimeter HACH MODEL DR/890, 753N UV-Visible Spectrophotometer, and Titration Apparatus.

Preparation of adsorbent. The Tamarindus indica were soaked in water for two days and washed with water to remove dust and pulp, and the clean seeds were dried in the shade for 24 hours and then removed from the coat. Afterwards, the seeds were powdered with the grinder and sieved through a size 402 micrometre standard BS sieve, which takes up to 210 grams of the powdered natural adsorbent.

Collection of wastewater. The sample dye wastewater was collected from the Dansokoto Local Dye Industry in Bauchi, Bauchi State, Nigeria. The collected wastewater was kept as a stock solution, and the sample used for studies was prepared by diluting some of the stock solutions to avoid fault results.

Batch Adsorption Study and Procedure. Batch adsorption studies were performed at a temperature range of (24–27 °C) to obtain the equilibrium data required for the design and operation for treatment of the wastewater/effluent. For equilibrium studies, a series of 2 Litre containers were employed. Each container was filled with 2000 ml of effluent and was placed in a flocculate-controlled assembly. A known amount of adsorbent (30, 35, 40, 45 and 50 g/l) was added into each container except for the blank solution/sample or control (effluent sample without adsorbents) with all well labelled. The containers were covered and agitated intermittently for the desired periods (24, 48, 72, 96, and 120 hr). The contact time and other conditions (e.g. adsorbent dosage) were selected based on preliminary experiments. The solutions of the specified tubes were separated from the adsorbent and analysed to determine COD, BOD, pH, dissolved solids, Suspended solid, Electric conductivity, Nitrate, Phosphate, and Turbidity.

RESULTS AND DISCUSSION

The initial test was performed on the raw wastewater before applying any adsorbent, as shown in Table 1.

Table 1 – Initial concentration of dye wastewater

No	Parameter	Initial Concentration
1	PH	12.2
2	Turbidity (NTU)	5200
3	Total Dissolved Solids, ppm	37300
4	Electric Conductivity, Siemens/m	8.09
5	Chemical Oxygen Demand, mg/l	27.61
6	Biochemical Oxygen Demand, mg/l	609
7	Phosphate PO4, mg/l	408.4
8	Total Suspended Solid	9
9	Nitrate	0.511

Effect of Adsorbent on measured parameters. The highest pH reduction was found at 120 hrs at an optimum dosage of 30, 35, 45, and 50 g/l, having an initial value of 12.2 to a final value of 11.6 (Figure 1).

A reduction rate of 5.74% was recorded. pH is a measure of the acidity or alkalinity of a solution. In dye wastewater treatment, pH is crucial in determining the efficiency of various treatment processes.

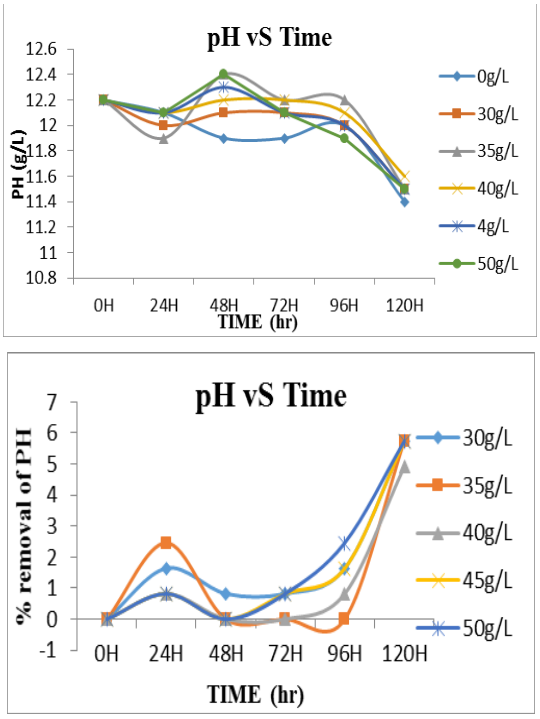

Figure 1 – PH measurement and percentage removal by TISP

PH modification is frequently required to maximise the effectiveness of the coagulation, flocculation, and biological treatment procedures.

Electrical Conductivity. 4.21% was the highest removal percentage at 48 hrs, and the optimum dosage of 45 g/l had an initial value of 8.09 Ms/m to a final value of 7.73 Ms/m (Figure 2).

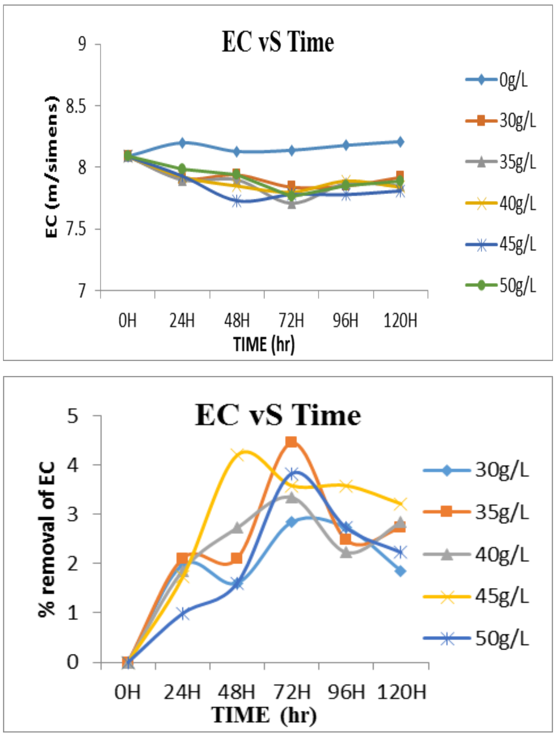

Figure 2 – EC measurement and percentage removal by TISP

Electrical conductivity gives a clue as to the overall concentration of dissolved pollutants in dye wastewater treatment. A high concentration of dissolved salts or other ionic contaminants may cause high electrical conductivity levels, affecting treatment effectiveness and calling for particular treatment strategies.

Total Dissolved Solids. 54.42% was the highest percentage of removal at 72 hrs and an optimum dosage of 40 g/l, having an initial value of 37300 ppm to a final value of 17000 ppm. TDS measurement aids in determining the overall concentration of dissolved pollutants in dye wastewater.

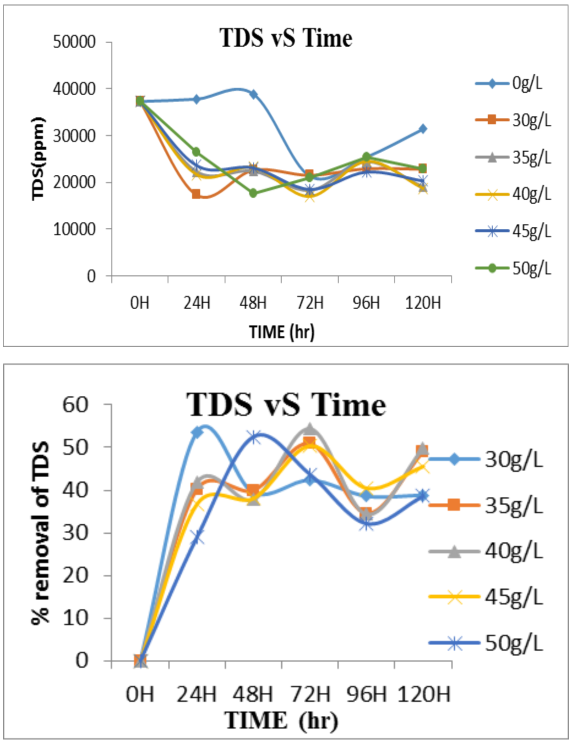

Figure 3 – TDS measurement and percentage removal by TISP

High TDS levels can hinder the effectiveness of treatment procedures and necessitate using particular treatment techniques, like membrane filtration or evaporation, to produce the appropriate water quality.

Temperature. 6.99% was the highest percentage of removal at 120 hrs and an optimum dosage of 50 g/l, having an initial value of 27.7 to a final value of 25.5. The measurement of temperature is essential because most wastewater treatment schemes include biological processes that are temperature dependent. In treating dye wastewater, temperature impacts the speed of chemical reactions and physical activity.

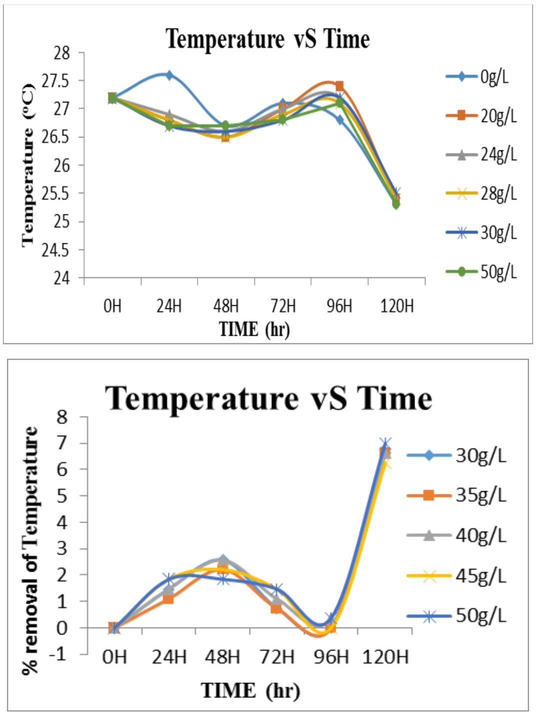

Figure 4 – Temperature measurement and percentage removal by TISP

Higher temperatures typically speed up reactions and boost microbial activity, which can improve the efficacy of treatment methods).

Biochemical Oxygen Demand. 63.38% was found to be the highest percentage of removal at 48 hrs and an optimum dosage of 30 g/l having an initial value of 609 ppm to a final value of 223 ppm.

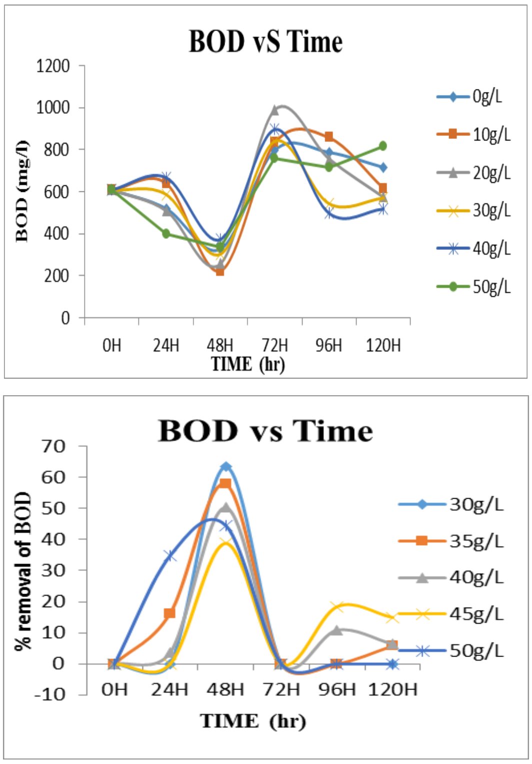

Figure 5 – BOD measurement and percentage removal by TISP

Over the years, several tests have been developed to determine the organic content of wastewater. BOD is the most widely used parameter to quantify the organic pollution of water. BOD measures the dissolved oxygen microbes' use in the biochemical oxidation of organic matter.

Phosphate. 38.49% was found to be the highest percentage of reduction at 24 hrs and an optimum dosage of 30 g/l, having an initial value of 408.4 mg/l to a final value of 251.2 mg/l. Phosphates are phosphorus and oxygen chemical compounds.

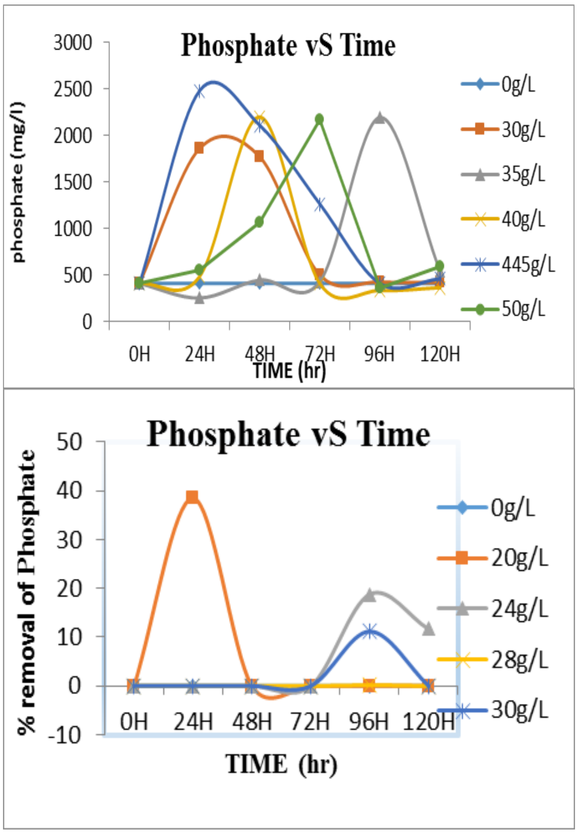

Figure 6 – Phosphate measurement and percentage removal by TISP

Phosphates are regarded as contaminants in the dye wastewater treatment process and, when released into aquatic bodies, can cause eutrophication. To reduce the environmental impact of phosphates in dye effluent, phosphorus removal techniques, such as chemical precipitation or biological nutrient removal, may be necessary. Using TISP may be a viable option for removing phosphates in wastewater based on its performance.

Nitrate. 15.26% was found to be the highest percentage of removal at 96 hrs and an optimum dosage of 30 g/l, having an initial value of 0.511mg/l to a final value of 0.433 mg/l.

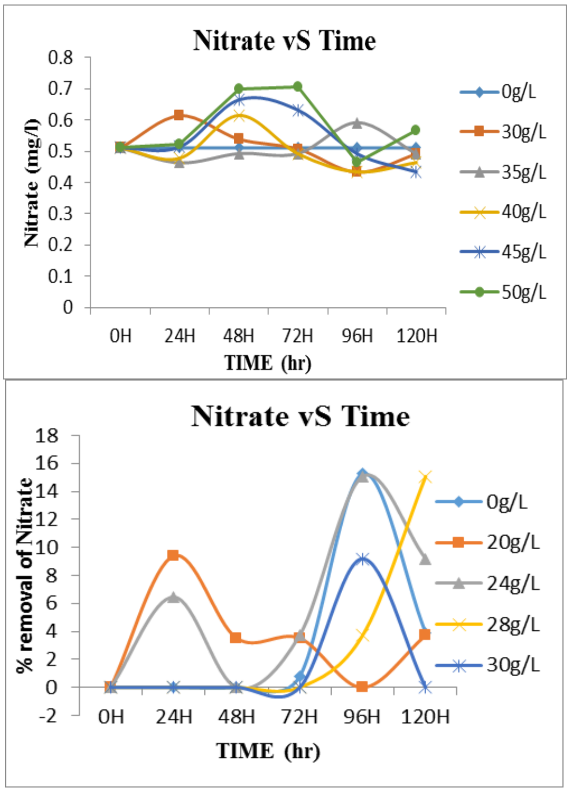

Figure 7 – Nitrate measurement and percentage removal by TISP

Nitrogen and oxygen are the two elements that makeup nitrates. They are frequently discovered in effluent from dyeing processes or other industrial sources. Water pollution and environmental concerns, including groundwater contamination and algal blooms, can result from wastewater with high nitrate concentrations.

Turbidity, Chemical Oxygen Demand and Total Suspended Solids. Though the tests for these parameters were carried out, it was found that the adsorbent did not affect any of them.

Based on the result, the TISP was partially effective in treating dye wastewater to a certain level for safe disposal. Physical and chemical parameters of the dye wastewater were tested for 24, 48, 72, 96 and 120 H at different adsorbent dosages of 30, 35, 40, 45, and 50 g/l. The results of the parameters were found to be undulating at other times and dosages. Varying adsorbent dosages determined the maximum adsorption capacity at 30, 35, 40, 45, and 50 g and at 24, 48, 72, 96 and 120 hr reaction times. The optimum dosage, reaction time and percentage removal of each parameter are presented in Table 2.

Table 2 – Summary of the effect of TISP on measured parameters

No	Parameter	Optimum dosage, g	Contact time, hrs	Percent removal, %
1	PH	50	12	5.74
2	Temperature	50	96	6.99
3	EC	45	48	4.21
4	TDS	40	72	54.4
5	Phosphate	30	24	38.49
6	Nitrate	30	96	15.26
7	BOD	30	48	63.38

CONCLUSIONS

In this study, the physicochemical parameters of the dye wastewater were determined. The results showed that the percentage removal of the various parameters measured even though sometimes sinusoidal increases with an increase in Tamarindus indica seeds powder dosage. Considering the results obtained from the investigation, it is clearly found that powder from Tamarindus indica seeds was influential in treating dye wastewater to a certain level before safe disposal. Though, the results obtained for each parameter tested were found to be dependent on the time and dosage of the adsorbent. But almost all the target parameters like EC, BOD5, NH3-N, PO4, TDS and pH had higher removal efficiency at a relatively lower adsorbent concentration (i.e. 30g). Therefore, the optimum amount of 30g of TISP was more effective in dye wastewater treatment.

The approach used in this study has given a promising result. To improve the adsorption capacities of the studied low-cost adsorbent of Tamarindus indidica seeds powder, the following recommendations are made; less adsorbent dose needs to be employed in further research to improve adsorption capacity. The reaction time can be kept constant since there is variation in determining the optimum reaction time for adsorption capacity. Experiments need to be conducted on other parameters, like heavy metals not measured in this research, to know and record their adsorption capacity. It could also be of particular interest to study the adsorption performance of Tamarindus indica seeds powder from different sources and use a different preparation mode like the activated carbon technique.

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