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Optimizing Wastewater Treatment Using Endophytic Fungi Isolated from *Acacia saligna* L. Bark

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Abstract

Endophytic fungi's application in biological wastewater treatment is a cost, clean, and eco-friendly. This study aimed to assess the efficiency of three *Aspergillus* species in the mycoremediation of industrial (I) and agricultural (A) wastewater. These species were *Aspergillus flavipes, Aspergillus niger, and Aspergillus flavus* isolated from the bark of a medicinal plant (*A0cacia saligna*). *Aspergillus* species were subculture on potato dextrose broth at 28 °C for 7 days on a rotatory shaker at 180 rpm until fungal pellets were formed. Before and after treatment with fungi, all wastewater samples were examined for pH, TDS, salinity, EC, COD, BOD, TP, TN, and turbidity. According to the results, *Aspergillus flavipes* has a good removal efficiency of total phosphorus, removing 78% of it from sample (I) after 25 days, and turbidity removing 91% after 20 days in (A) sample. *Aspergillus niger* has a high chemical oxygen demand removal efficiency of 99% and 99.8% in (I and A) samples after the 15th and 10th day, respectively, in addition to total nitrogen removal efficiency of 99% in (A) sample after the 25th day; and turbidity removal efficiency of 99.7% in the same sample. Also, *Aspergillus flavus* recorded high removal of biological oxygen demand by 76% and 66% in (I and A) samples after the 10th day of each, respectively; total nitrogen by 69% after the 10th day in (I) sample; total phosphorus by 23% after 10th day in (A) sample; electrical conductivity by 10.7% after 10th day in (I) sample; and total dissolved salts by 1.3% after 5th day in (I) sample. The results explained that *Aspergillus niger* and *Aspergillus flavus* were the most efficient in the removal of chemical oxygen demand and biological oxygen demand which represented indicators of pollution in wastewater. The obtained results will be useful for optimal management of agricultural and industrial wastewater.

Keywords Biosorption, Endophytic fungi, Biological oxygen demand, Water quality, Wastewater, Removal efficiency

1 Background

Water is a vital resource for sustainable development. The population increase, climate change, and using water by various fields, such as industry, agricultural activities, and energy, make water resource management more difficult. To promote sustainable development, it must achieve a balance between the supply and demand of water, which is the aim of an integrated water resources management approach [1]. The irrigation and drainage water were affected and contaminated by factors such as high population density, increased agricultural practices, land degradation, and discharge of improper waste disposal. On the global level, unique, ecologically friendly, and low-cost methods of mycoremediation procedure were used for wastewater treatment due to the lack of available drinking water [2]. Many pollutants were dumped into irrigation and drainage canals together with agricultural and industrial effluents such as various organic pollutants [3, 4]. Biosorption is consider a viable technique for cleaning up

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and recovering pollutants from wastewater effluents [5, 6]. The key to bioremediation is choosing the best fungal species for removing particular contaminants. The essential role of fungi in the ecosystem is the breakdown of organic materials and substrates. In addition, endophytic fungi can remove the nutrients, which have been studied by numerous researchers [4, 7–15]. Endophytic fungi isolated from *Acacia saligna* for wastewater treatment is relatively novel compared to other mycoremediation studies. It may be due to its symbiotic relationships with host plants as it provides metabolic diversity that may facilitate the wastewater treatment [16]. In addition to such, these fungi are low-cost, sustainable, and eco-friendly. The motivation for using endophytic fungi is also due to its efficiency in increasing plant growth and introducing new approaches for wastewater treatment. Utilizing fungi to remediate wastewater due to its ability to break down organic matter more rapidly. Fungal cell walls rich in polysaccharides such as chitin with their cations exchange properties and glucans with hydroxyl groups which can bind to organic compounds, play important roles in pollutant adsorption in wastewater treatment. In addition, some fungi such as *Aspergillus niger* produce extracellular enzymes such as manganese peroxidase, which catalyzes the oxidation of manganese ions using hydrogen peroxide as a co-substrate, are crucial in the biosorption of hazardous chemicals during wastewater treatment [17–19]. Fungal culture converts organic compounds found in wastewater into simple fungal biomass, which is then use as a source of food for humans and animals [20]. Several fungi's filamentous mycelia hyphae can entrap and compress waste and mineral materials [21]. *Aspergillus species as Aspergillus niger* can transform toxicants compounds into less harmful compounds and become easier to be removed from wastewater as removal of nutrients by consuming nitrogen and phosphorus as a source of nutrients [15, 22, 23]. Therefore, this study aimed to monitor and evaluate the performance of some fungal endophytes in mycoremediation and remove some pollutants from industrial and agricultural wastewater during wastewater treatment.

2 Methods

2.1 Study area

New Damietta city lies north of Damietta Governorate and extends about 5 km along the Mediterranean Sea coast and approximately 4.5 km west of the Damietta port. It covers an area of 18 km ^{2} and extends from latitude 31° 24′ 2.40″ N to 31° 28′ 24.61″ N and longitude 31° 37′ 10.13″ E to 31° 44′ 9.49″ E. The city has two industrial zones and five residential districts (Fig. 1) [24].

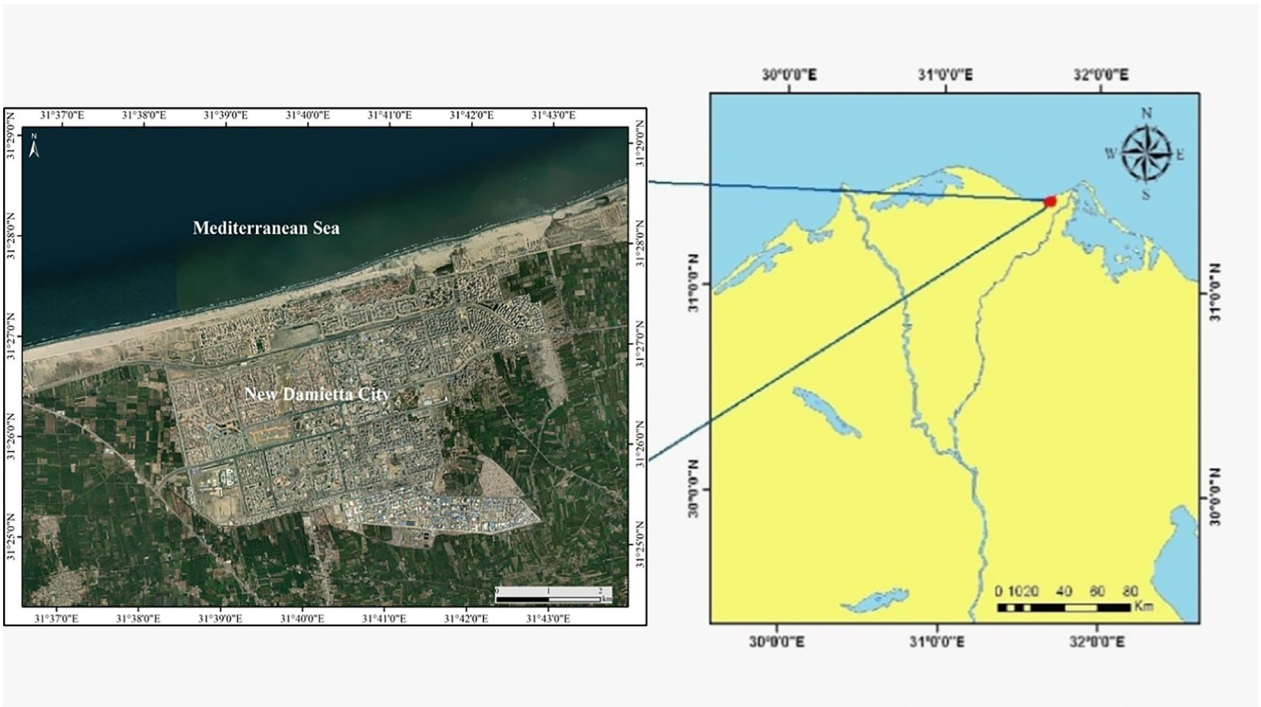


Fig. 1 Location map showing the drain of New Damietta where water samples were collected (Land sat image, 2000)

2.2 Water Sampling and analysis

Six wastewater samples were collected from six separate locations between November 2021 and December 2022, representing industrial (I) and agricultural (A) effluents from the New Damietta drain. Samples were collected in sterile containers and refrigerated at 4 °C. Five liters of wastewater for each sample were taken from 20 cm beneath the water's surface by plunging the plastic bottle that had been acid-washed into the water.

The wastewater samples were analyzed twice, before the treatment and after using fungi for 25 days, with samples taken every 5 days in addition to the control sample (wastewater without fungi). After filtering the wastewater samples with Whatman No. 1 filter paper, 1000 ml of each sample was examined for pH, total dissolved solids (TDS), salinity, electrical conductivity (EC), chemical oxygen demand (COD), biological oxygen demand (BOD), total nitrogen (TN), total phosphorus (TP), and turbidity. The pH value was determined using the electrometric method with a pH Meter (model 211 HANNA, USA) [25]. The Digital Portable TDS/Conductivity meter Model 8033 HANNA, USA, was used to measure salinity, TDS, and EC. TDS was reported as ppm (mg/L), EC as Ms/cm, and salinity as percentage. The samples' BOD was measured according to Adams [26] whereas the samples' COD was determined by Manual Method: Dichromate Reflux according to EPA [27]. In addition, the Rump and micro-Kjeldahl method was used to determine TN [28], but total phosphorus (TP) of the samples was detected according to Ascorbic Acid Method [25]. The Nephelometric Method (Al1000 Turbidimeter, Aqualytic, Germany, measuring 0-200 NTU) was used to determine the turbidity of the samples [25]. The adsorption parameters, biomass dosage, pH value, and retention time, were optimized for three different fungus species to achieve the equilibrium conditions. The optimization experiment was accomplished using a jar test according to the Rump method [28], which depends on turbidity measurement. The turbidity performance was related to the lower turbidity value and the most optimum parameter value of (dose, pH, and time); the results were shown in (Table 1).

2.3 Preparation of fungal species

Eight fresh bark samples were harvested from *Acacia saligna* tree using a sterilized knife. The bark was cut at a height of 1–2 meters above ground and a depth of 1–1.5 cm. The collected bark pieces were transferred to a laboratory where they were surface sterilized by soaking the samples in 70% alcohol (v/v) for 1 to 2 minutes, then another minute or two in 3–5 % sodium hypochlorite solution. The treated and small-teased bark samples were inoculated in potato dextrose broth, and chloramphenicol (100 µg/ml) was added to prevent bacterial contamination. On a shaker, incubate the flask for 21 days at 28 °C [6]. Identification of these fungal strains: *Aspergillus flavipes, Aspergillus niger*, and *Aspergillus flavus,* which were isolated from the bark, was done based on their cultural and microscopic characteristics. Identification based on phenotypic characters had been processed, and the report has been generated using morphological characters.

2.4 Biosorption by free fungal biomass

A. flavipes, A. niger, and *A. flavus* were selected based on their frequent occurrence as they are naturally occurring in Egypt. The fungi were subcultured in potato dextrose broth at 28 °C for 7 days on a rotatory shaker at 180 rpm until fungal pellets were formed and washed twice in sterile second distilled water. Dry at 60 °C for constant weight. Then, ground with a mortar and pestle before evaluating the water adsorption [29].

2.5 Statistical Analysis

Analysis of variance ANOVA (Two-way) for water quality parameters of (I and A) samples was examined in addition to linear regression analysis. Excel 2013 and IBM SPSS Statistics 25.0 software have been used for the statistical analysis of the data.

3 Results

Physicochemical parameters of both industrial and agricultural wastewater samples before treatment with values of 8.3±0.19, 44.2±0.0 NTU, 13.08±0.0 g/L, 25.1±0.0 µs/cm, 13.5±0.01%, 12880±5.6 mg/L, 119±1.0 mg/L, 1.38±0.04 mg/L, and 0.936 ±0.01 mg/L of pH, turbidity,

Table 1 Optimum conditions of fungal species in (I) and (A) wastewater samples

Optimum conditions of fungal species in wastewater samples						
Parameters Fungal sp.	**pH (I)**	**pH (A)**	**Biomass (I) g/L**	**Biomass (A) g/L**	**Time (hour) (I)**	**Time (hour) (A)**
A. flavipes	4.0	4.0	0.4	0.4	1	1
A. niger	5.1	5.5	1.2	1.2	24	24
A. flavus	5.0	5.0	0.4	0.4	48	48

TDS, EC, salinity, COD, BOD, TP, and TN, respectively, for (I) sample. And with values of 8.6±0.01, 5.4±0.16 NTU, 1.25±0.0 g/L, 2.27±0.0 Ms/cm, 1.3±0.0%, 41920±1.5 mg/L, 109±0.6 mg/L, 0.069±0.0 mg/L, and 0.468±0.01 mg/L of pH, turbidity, TDS, EC, salinity, COD, BOD, TP, and TN, respectively, for (A) sample (Table 2). Figure 2 shows that the pH value of (I) wastewater sample with *A. flavipes* increased from 4 at the beginning of the treatment to 4.5±0.00 after the 5th day and reached 4.2±0.00 after the 25th day. In the (A) sample, the pH value increased from 4 to 5.5±0.01 on the 10th day but decreased to 3.8±0.01 in 20 days. With *A. niger* pH value of (I) decreased from 5.1 to 4.3±0.00 after the 5th day, while it increased to 7.9±0.00 on the 25th day. In the (A) sample, the pH value decreased from 5.5 to 3.9 ± 0.00 after 5 days while increasing gradually and reached 8.3±0.01 on the 25th day. The pH value of (I) sample with *A. flavus* decreased from 5.0 to 4.6 ±0.01 on the 5th day, while increased to 8.3±0.01 in 20 days while increase gradually in (A) sample until reached to 8.2±0.01 after 25th day.

Results in Fig. 3 revealed that the removal percentage of BOD of (I) sample was in the order of *A. flavus*> *A. niger*> *A. flavipes*> control with percent of 76%, 71%, 29%, and 16% after 10th, 15th, 10th, and 10th day, respectively. While in (A) samples, the removal percent in order of *A. flavus*> control> *A. niger* > *A. flavipes* with percent of 66%, 47%, 43%, and 39% after the 10th, 15th, 10th, and 15th day, respectively. Figure 4 shows that the maximum removal of COD was reached to 99 %, 97%, and 94 % for *A. niger*, *A. flavipes,* and *A. flavus,* respectively, after the 15th day for the (I) sample. While in the (A) sample, the maximum removal of COD reached 99.8 % with *A. niger* followed by *A. flavipes* and *A. flavus at* 98% on the 10th day. For the control sample of (I and A) samples, COD removal reached 96% and 97%, respectively, after the 10th day. Whereas, Fig. 5 shows that the removal of total phosphorus of the (I) sample was 89% in control while with *A. flavipes*, *A. niger,* and *A. flavus* were 78%, 73%, and 70%, respectively, after 25th day and 10th day. As shown in Fig. 6, the removal percentage order of TN in the (I) sample was *A. flavus*> *A. flavipes*> control> *A. niger* by 69%, 46%, 42%, and 36% after 10th, 25th, 5th, and 25th day, respectively. While in (A) sample was *A. niger*> *A. flavipes*> control by 99%, 62%, and 23% after the 25th, 25th, and 10th day, respectively. In Fig. 7, the maximum

Table 2 Water quality parameters of initial (I) and (A) wastewater samples used in the study (Mean±SD)

Water quality parameters of initial wastewater samples used in the study									
Parameters Samples	**pH**	**Turbidity (NTU)**	**TDS (g/L)**	**EC Ms/cm**	**Salinity (%)**	**COD (mg/L)**	**BOD (mg/L)**	**TP (mg/L)**	**TN (mg/L)**
Industrial	8.3±0.19	44.2±0.0	13.08±0.0	25.1±0.0	13.5±0.0	12880±0.0	119±1.0	1.38±0.04	0.936±0.0
Agricultural	8.6±0.01	5.4±0.16	1.25±0.0	2.77±0.0	1.3±0.0	41920±1.5	109±0.6	0.069±0.0	0.468±0.01
Standard value Resolution No. 44 of 2000	6–9.5	–	–	–	–	1100	600	25	100

TDS: Total dissolved solids, EC: Electrical conductivity, COD: Chemical oxygen demand, BOD: Biochemical oxygen demand, TP: Total phosphorus, TN: Total nitrogen and SD: Standard deviation, I: Industrial wastewater, A: Agriculture waste

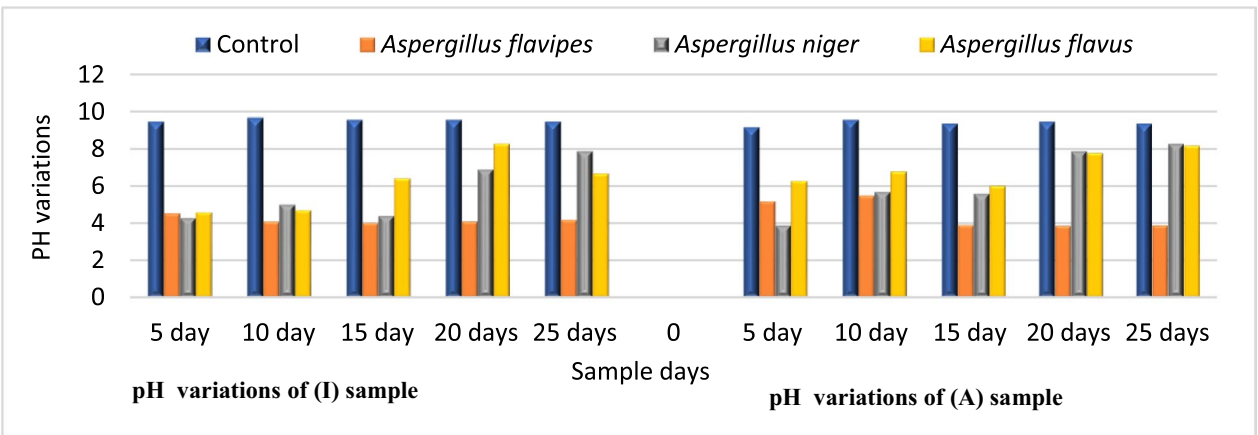


Fig. 2 Effect of fungal species on pH of (A) and (I) wastewater samples

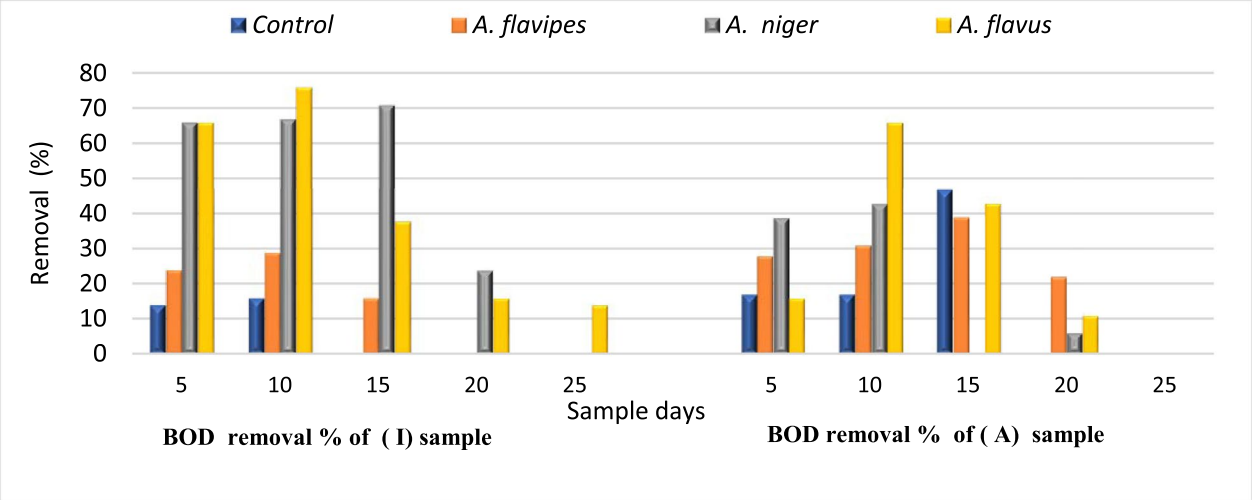


Fig. 3 Removal % of BOD in (I) and (A) wastewater samples

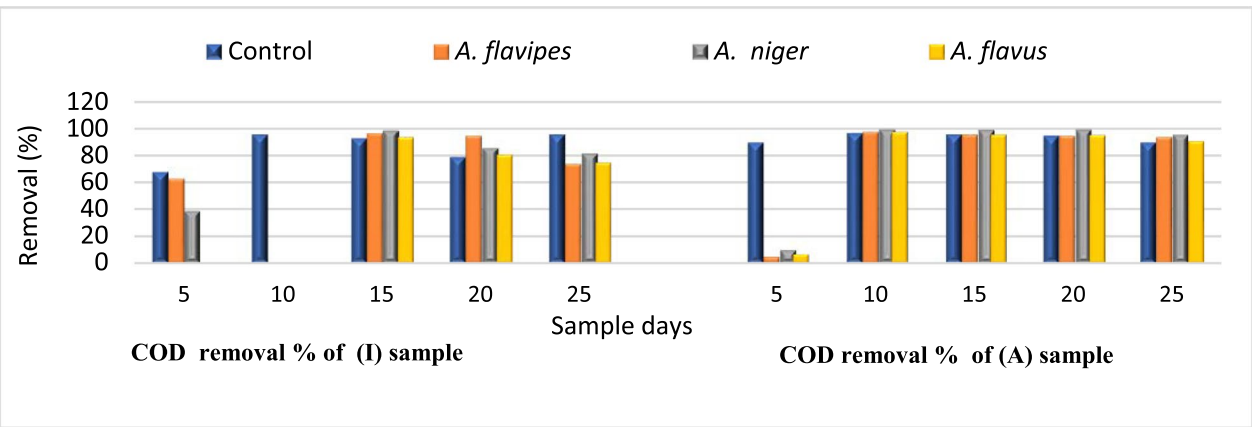


Fig. 4 Removal % of COD in (I) and (A) wastewater samples

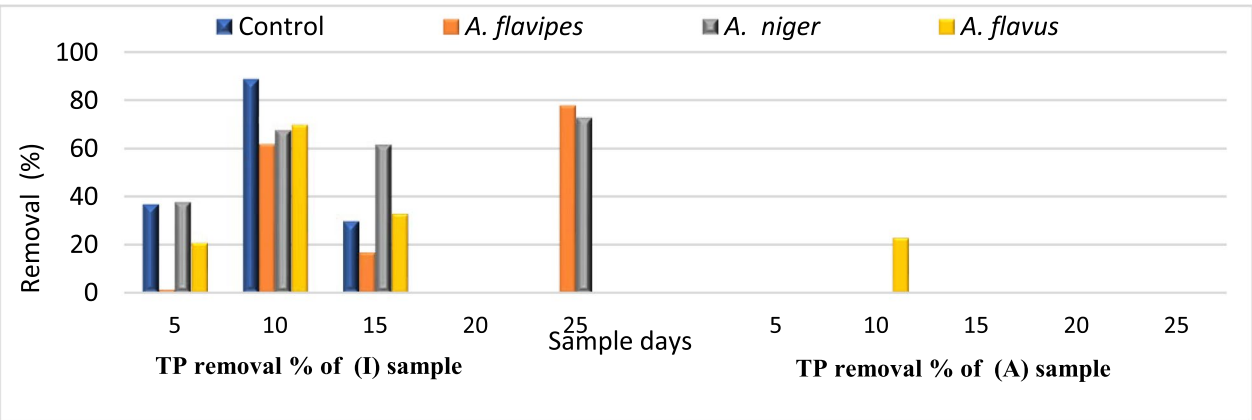


Fig. 5 Removal % of TP in (I) and (A) wastewater samples

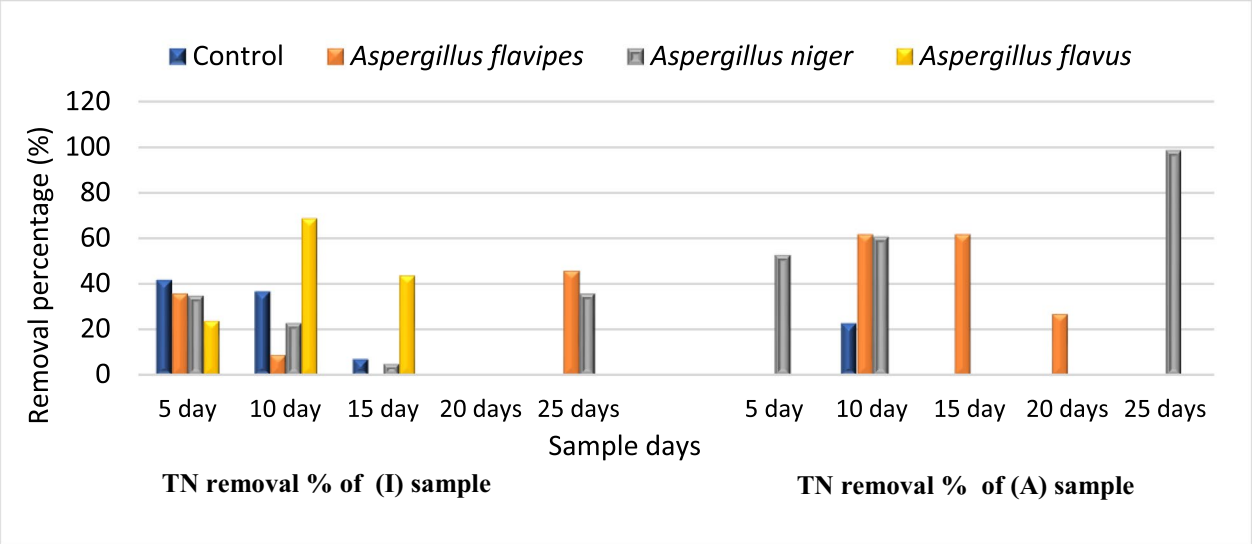


Fig. 6 Removal % of TN (I) and (A) wastewater samples

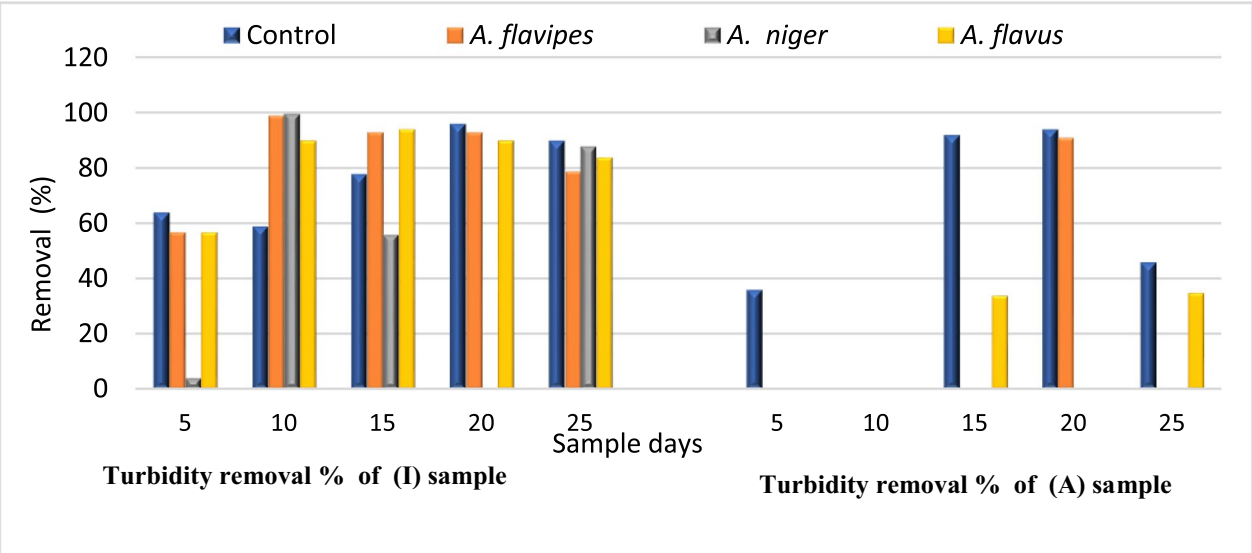


Fig. 7 Removal% of turbidity in (I) and (A) wastewater samples

removal percent of turbidity in the(I) sample was 99.7%, 99.0%, 96%, and 94% of *A. niger, A. flavipes,* control, and *A. flavus* after 10^{th}, 10^{th}, 20^{th}, 15^{th} day, respectively. In (A) sample, the removal percent reached 94%, 91%, and 34% by control, *A. flavipes,* and *A. flavus* after the 20^{th}, $20^{th,}$ and 15^{th} day, respectively.

In Fig. 8, only *A. flavus* and the control sample had the ability to reduce the TDS values of the (I) sample by a percent of 1.3% after the 5^{th} day. In the (A) sample, the maximum removal percent of TDS was 4% from the control sample after the 5^{th} day. Results in Fig. 9 indicated that the removal of EC of (I) sample was 11.5% in control after the 10^{th} day, while with *A. flavus*, *A. flavipes,* and *A. niger* were 10.7, 7.5%, and 1.2%, respectively, after 10^{th}, 10^{th}, and 15^{th} day. In the (A) sample, there is no removal of EC by any fungal species, only control recorded removal of EC by 6.8% after 20^{th} day. In both (I and A) samples, only the control samples recorded salinity removal by a percentage of 0.7% and 7.7%, respectively, after the 5^{th} day, Fig. 10.

Table 3 explains the two ways ANOVA analysis of physicochemical parameters of (I and A) samples treated

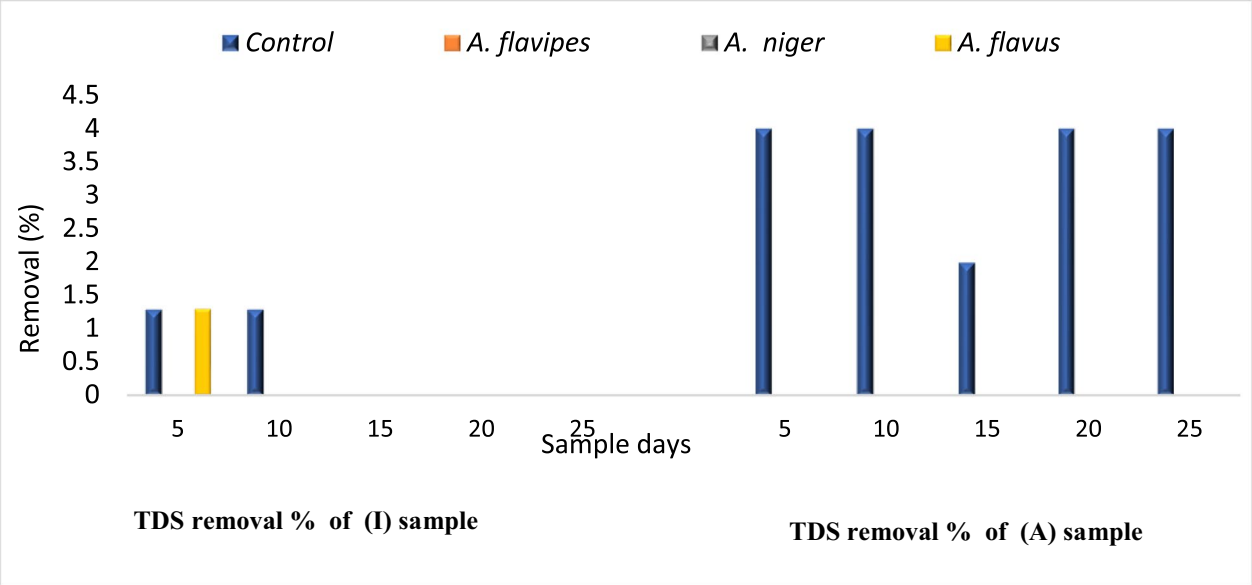


Fig. 8 Both *A. flavus* and the control are the more efficient in reducing TDS in (I) sample while the control is the only one that reduce TDS in (A) sample

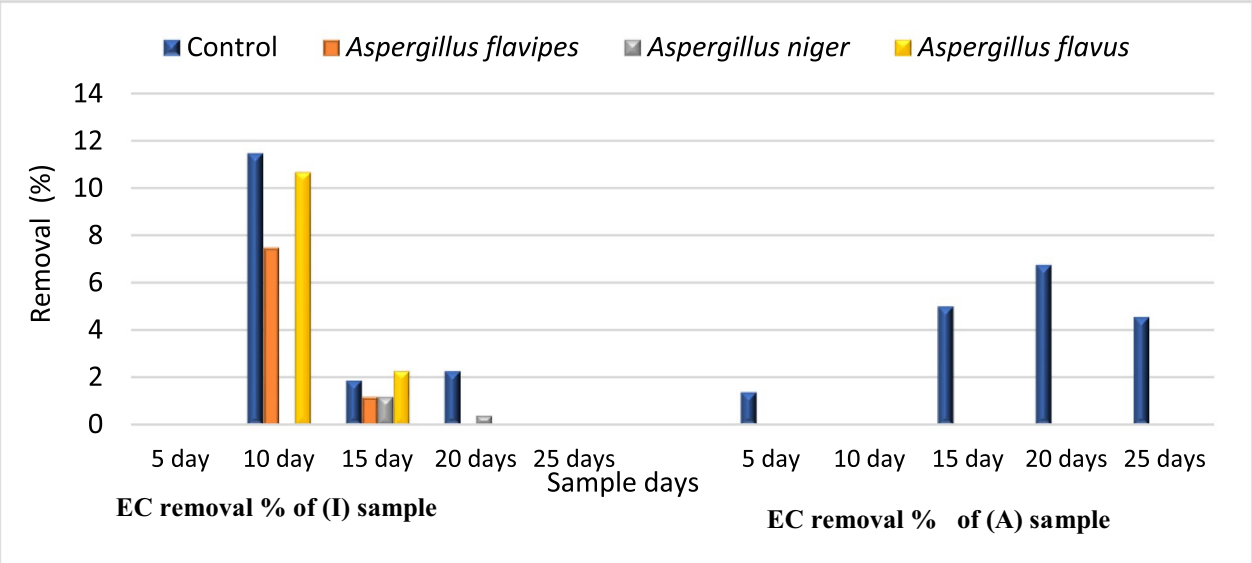


Fig 9 *A. flavus*, *A. flavipes*, *A. niger*, and control have ability to reduce EC in (I) sample while control is the only one that reduce EC in (A) sample

with *A. flavipes*, *A. niger,* and *A. flavus* in addition to the control sample through 25 days. The parameters of pH, turbidity, TDS, EC, BOD, TP, and TN have a significance value of ($P > 0.05$), except COD had a value of ($P \leq 0.001$) for industrial wastewater samples, while the physicochemical parameters of pH, turbidity, TDS, EC, COD, BOD, TP, and TN have a significance value of ($P < 0.001$) for agricultural wastewater samples. The linear regression analysis showed the correlation according to pH, turbidity, TDS, EC, salinity, COD, BOD, TP, and TN with values of R^2= 0.87, 0.04, 0.26, 0.05,0.46, 0.28, 0.21, and 0.007, respectively.

4 Discussion

Biodegradation is the process by which a material was changed into new compounds through enzymatic reactions while being carried out by living organisms.

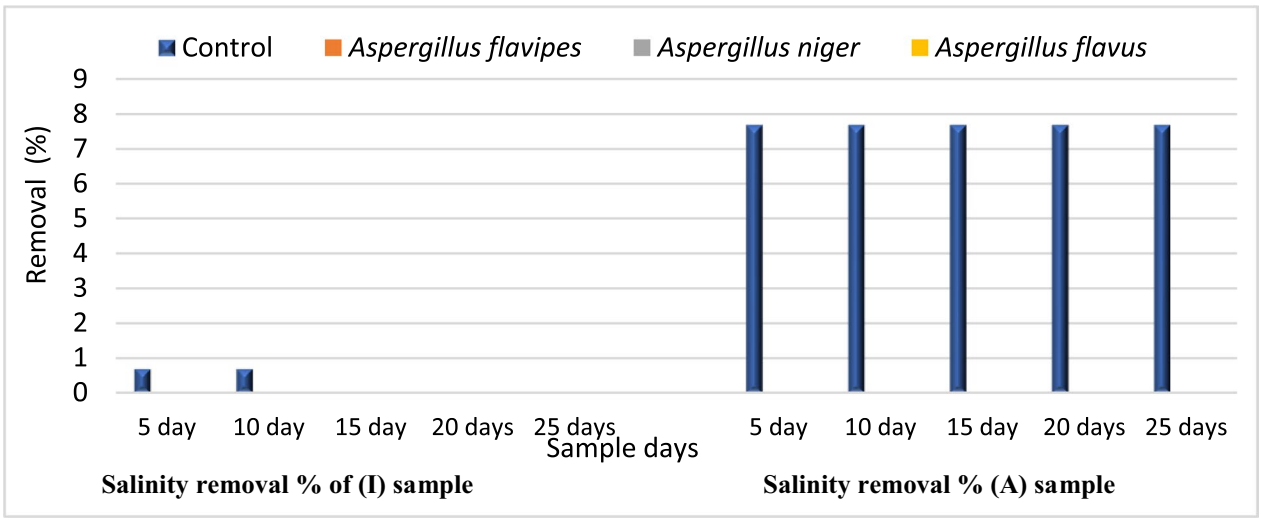


Fig. 10 Only control has ability to reduce salinity in both (I and A) samples through the study

Table 3 Two-way analysis of variance (ANOVA) of physicochemical parameters of (I and A) samples with study treatments (*A. flavipes, A. niger and A. flavus*)

Parameters	Days		Treatments		Days*Treatments	
	F value	*P value*	*F value*	*p value*	*F value*	*P value*
pH (I)	276839	4.4^{oo}	475360	^{oo} 4.6	238311	4.3^{oo}
pH (A)	10	0.00***	157	0.00***	11	0.00***
Turbidity (I)	61.8	1.3^{oo}	42.1	1.9^{oo}	9.2	3.6^{oo}
Turbidity (A)	693336	0.00***	2545591	0.0***	608288	0.00***
TDS (I)	46180	1.07^{oo}	7791	2.3^{oo}	4809	3.4^{oo}
TDS (A)	171	0.00***	438	0.00***	141	0.00***
EC (A)	14080	0.00***	40860	0.00***	12294	0.00***
COD (I)	8552	0.00***	7122	0.00***	670	0.0***
COD (A)	228376056	0.00***	179353739	0.00***	218676983	0.00***
BOD (I)	34.63	1.6^{oo}	503.11	8.7^{oo}	18.19	1.5^{oo}
BOD (A)	1439	0.00***	269	0.00***	204	0.00***
TP (I)	63699	1.7^{oo}	3528	1.7^{oo}	7496	4.8^{oo}
TP (A)	81495	0.00***	40556	0.00***	17783	0.00***
TN (I)	1160	9.04^{oo}	1116	1.4^{oo}	587	5.6^{oo}
TN (A)	8985	0.00***	58214	0.00***	6622	0.00***

^{oo} =Nonsignificant (P > 0.05), * = low significant (P ≤ 0.05), ** = intermediate significant (P ≤ 0.01), and *** = highly significant (P ≤ 0.001).

Because fungi are microorganisms that may chemically change dangerous pollutants into less damaging chemicals, they can be employ for remediation [30]. Through the results in Table 2, both wastewater samples (I and A) before treatment were within the allowable level according to standard value resolution No. 44 of 2000 [31], except values of COD of both were above that, and that agree with Liu et al. [32] who stated that many companies generate wastewater that is more than what is allowed by different national standards. The study results of pH were in agreement with Kshirsaga [5], who found that the pH value of wastewater treated with *A. terreus*, *A. niger*, *Rhizopus nigricans,* and *Cunninghamella* sp. were increased. Also similar to Tostain et al. [9] who revealed that increasing in pH from 3.5 units to 8.5 by using *A. terreus var. africanus* and *A. niger* in the biodegradation of wastewater. The pH profoundly affects the chemical interaction between metal-ligand and cell wall, with hydrolysis, complexation, oxidization, and biosorption reactions [10]. Filamentous fungi were used

in bioconversion to absorb and immobilize solid particles in wastewater, resulting in larger bulked flocs that improve separation and degradability [33]. During nitrogen absorption from sources such as protein for microorganism growth, and ammonium release may increase the medium's pH [9]. The fungus's production of salts of organic acids and its degradation by enzymes produced by the fungus called a manganese peroxidase enzyme may explain the decrease in pH [34]. The removal percentage of BOD for (I) sample was in the order of *A. flavus*> *A. niger*> *A. flavipes*> control. Results of BOD agree with Chau et al. [12], who achieved BOD removal (21%) by *A. niger*. When compared to other examined fungi, we find that the *A. niger* had the best performance for COD removal from (I and A) samples. This result agrees with Kshirsaga [5] and Tostain et al. [9], who found that COD removal reached to 77.57% by using *A. niger*. The study by Hamdi and Ellouz [35] revealed that 52.5% of COD were removed by *A. niger*, while the study by Isnadina et al. [36] explained that the removal percent ranged from 35 to 64%. In addition to the results obtained by Chau et al. [12], the percent removal of COD was 30%. In addition, our results achieved higher COD removal by *A. flavus* than Chi et al. [11], who mentioned that the COD removal percent was (57.37%). The decreasing COD values may be due to the negatively charged functional groups in fungal cell membranes having the ability to adsorb elements and positively charged minerals, leading to their deposition and disposal. Additionally, breaking complex materials into simpler materials would make them easier for other organisms, like fungi, to exploit [37]. High removal of COD by *A. niger* may be influenced by many causes as substrate availability and increasing organic load causing more COD removal. In addition, the presence of laccases and peroxidase enzymes causes a breakdown of organic matter and effect on COD levels. *A. niger* with its robust enzymatic profile and adaptive metabolism makes it a good approach for bioremediation [38]. Results stated a high performance of *A. flavipes*, *A. niger,* and *A. flavus* in TP removal, and that agree with Kshirsaga [5], who found that the best phosphate and COD removal from wastewater was recorded by *A. niger*. However, *A. flavus* recorded the only removal of TP by 23% of (A) sample. Our results disagree with Isnadina [39], who found that adding mushrooms to treat domestic wastewater did not reduce the concentrations of ammonia and phosphate. The results indicated the ability of tested species of *Aspergillus* in the removal of TN, which may be because these fungi have extracellular enzymes that can break down complicated substances by oxidative reactions. As a result, they can act as organic compound decomposers in low-pH effluent. This reaction is unsuitable for bacterial growth. This confirms the potential efficiency of removing nitrogen from wastewater samples. As a result, the fungi can grow faster and more effectively utilize the resources that infections need to survive. Moreover, fungi have a more rapid rate of denitrification than bacteria. By eliminating nitrite and nitrate compounds, this denitrification process helps to further clean wastewater from these substances [39]. The fungus can absorb inorganic nitrogen and mineralize organic nitrogen to increase their biomass. Through denitrification, certain fungi can convert nitrate (NO^{3}–) or nitrite ((NO^{2}–) to gaseous nitrogen oxides such as nitric oxide (NO), nitrous oxide (N_2O), and dinitrogen (N_2), as well as ammonium (NH^{4+}) through ammonia fermentation. Some denitrifying fungi possess dissimilatory nitrate reductase for NO^{3-} reduction to NO^{2-} [40].

The results revealed a high removal percent of turbidity in (I and A) samples, similar to Jebun et al. [41] who found that six fungal supernatants showed good turbidity removal in Kaolin suspension, reaching 95% in addition to Chi et al. [11] who reached to high removal percent of turbidity by *A. flavus* (26.71%). Most bioflocculants, such as *A. flavus*, have drawn attention from the scientific and business communities as viable flocculant substitutes because of their high flocculation performance, ecofriendly, and biodegradability [42]. The results agree with Vázquez et al. [30], who argued that fungi could be utilize as a therapeutic agent since these microbes can chemically change dangerous pollutants into less dangerous ones. Bioflocculants are capable of bridging and neutralizing charges that lead to the aggregation of particles and cells. The majority of the solids suspended in the water has a negative charge and repelled by each other [41]. The reduction in TDS values by *A. flavus* and the control sample was in agreement with Chi et al. [11], who stated that *A. flavus* has the ability to remove TDS by a percentage of (21.18%). *A. flavus*, *A. flavipes,* and *A. niger* had the ability of EC reduction for the (I) sample, while only the control had the ability of removal for the (A) sample. In both (I and A) samples, only the control sample recorded salinity removal. Because several functional groups in the cell wall of fungi, such as phosphate, carboxyl, carbonyl, amine, and amide, can interact chemically with both inorganic and organic pollutants, fungus biomass is an effective biosorbent. The most important mechanism for removing pollutants in adsorption is the interaction with cell membranes. This mechanism includes the fungus biomass of both alive and dead species. Dead cells can adsorb certain metallic ions in much more significant quantities than live cells [4]. The ability of control to remove some pollutants may be due to the role of bacteria. To synthesize certain enzymes that can degrade the relevant contaminants, bacteria must be modify. Different strains of the white rot fungus can destroy different

organic compounds, including persistent contaminants, to varying degrees [43]. According to two-way ANOVA analysis, it was shown that there is a nonsignificance variation of all physicochemical parameters for (I) wastewater samples among days, treatment, and days with treatment ($P > 0.05$) except COD showed highly significant variation ($P \leq 0.001$), while there is a highly considerable variation of parameters in (A) wastewater sample with fungal species used in treatment over 25 days of study. For linear regression, there was a weak correlation between (I and A) parameters according to turbidity, TDS, EC, COD, BOD, salinity, TP, and TN, indicating significant variation between the (I and A) samples. On the other hand, there was a strong correlation between (I and A) samples according to the pH, which showed a large similarity between the samples in their pH values.

5 Conclusions

Through this work, using fungal endophytes such as *A. flavipes*, *A. niger*, and *A. flavus* in the remediation of agricultural and industrial wastewater improves its efficiency in wastewater treatment. As *A. flavus* has higher removal of BOD for both (I and A) samples by percent of 76 and 66 %, respectively, in addition to TDS 1.3% in the (I) sample. *A. niger* has maximum removal of COD by 99%, 99.8% in (I, A) sample, respectively, and TN by 99% in (A) sample and removal of turbidity by 99% in (I) sample. *A. flavipes* has high removal of TP 78% in (I) sample and removal of turbidity 94% in (A) sample. *A. flavus*, *A. flavipes*, and *A. niger* had removal of EC in (I) sample by 10.7%, 7.5%, and 1.2%, respectively. The control sample has high removal of some pollutants such as TDS, turbidity, salinity, and EC by percent 4%, 94% in (A) sample, (7%, 7.7%) in (I, A) sample, and (11.5%, 6.8%) in (I, A), respectively. The authors recommended using *A. niger* and *A. flavus* in industrial and agricultural wastewater treatment.

Abbreviations

BOD	Biological oxygen demand
COD	Chemical oxygen demand
EC	Electrical conductivity
TN	Total nitrogen
TP	Total phosphorus:
TDS	Total dissolved salts
NTU	Nephelometric turbidity unit

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Author contributions

Mamdouh S.Serag (M.S.S) the point of research. M.S.S. collected and identified the plant and collected the bark samples. Marwa T. Mohesien (M.T.M) identified fungal strains and prepared the inocula of fungal strains. Amany F. Hasballah (A.F.H.) carried out all the lab work regarding water analysis and wrote the draft of the manuscript. All authors read and approved the manuscript

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Consent for Publication

Not applicable.

Competing of 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. The authors declare that they have no conflict of interest.

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