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Prospects of Effective Microorganisms (EM) in Bioremediation of Textile Industrial Wastewater

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Abstract

Existing wastewater treatment systems face several significant challenges. So, the main purpose of this study was to apply an effective technology for these systems especially textile industrial wastewater (TIW). Currently, beneficial microorganisms are gaining widespread adoption. One of them is referred to as Effective Microorganisms (EM). Which is a product in liquid form which consists of many varieties of non-pathogenic microorganisms which coexistence between aerobic& anaerobic microorganisms? This liquid EM is used to bio remediate TIW. This study evaluates the efficacy of various EM dosages (5, 10, 15, 20 and 25ml / 525ml sample) during different retention times (15 and 35 days) along the experiment and quantifies multiple physico–chemical parameters and their respective removal percentages. These parameters are: Electrical Conductivity (EC), pH, Temperature (Temp.), Biological Oxygen Demand (BOD_5),Chemical Oxygen Demand (COD), Nitrite (NO_2), Ammonia-nitrogen (NH_3-N), Phosphate – phosphorus (PO_4-P),Nitrate (NO_3) and some heavy metals (HMs) of (Cr, Ni, Cu, Fe, Pb and Cd). EM demonstrates significant potential for application in TIW, as it achieves high removal percentages for parameters such as ammonia with 96% removal efficiency, phosphorus by 100% and $BOD_5$by 72.38%) at minimal EM dosages of 5 ml EM dose. However, it was ineffective in reducing COD and some of HMsaverage values.
It was concluded that utilization of EM for bioremediation of TIW offers numerous advantages from economic viability, ease of design and environmentally friendly & sustainability.

Keywords: Textile industrial wastewater, Effective Microorganisms (EM), duration times, physico–chemical parameters, dyes

1. Introduction

Water pollution caused by wastewater improperly disposed of by the textile industry is one of the major problems facing the entire globe today. The textile industries have a significant effect on the state of the global economy and the environment in several nations, including South Africa's estuaries and China [1].

The textile sector generates a lot of brightly colored wastewater that contains a range of persistent pollutants, making dyed wastewater a significant environmental contaminant, which has adverse effects on aquatic life) that also has an effect on human health [2]. Dye is frequently divided into several categories according to its usage, composition, and source [3].

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Many synthetic dyes are used in the textile industry, including azo, direct, reactive, mordant, acid, basic, dispersion, and the most widely used colors, sulfide dyes. The textile industry makes use of both natural and synthetic fibers, including wool, cotton, acrylic and silk [4].

Water pollution caused by wastewater improperly disposed of by the textile industry is one of the major problems facing the entire globe today. The textile industries also utilize a great deal of extremely dangerous chemicals at various stages of the process, such as brightening, de-sizing, softening, finishing, and sizing agents [5].

From the dyes which are commonly utilized in the textile sectorfor their vibrant colors and long-lasting ability to resist fading is anthraquinone and the majority of these dyes are harmful, cancer-causing, and gene-altering, making them challenging to break down [6]

Heavy metals, specifically lead (Pb), chromium (Cr), cadmium (Cd), and copper (Cu), are widely used in the production of color pigments for textile dyes. These heavy metals can be found naturally in textile structures or can enter textile fibers through manufacture, dyeing, or protective chemicals used during storage. Aquatic life, natural water bodies, and maybe even soil can bio accumulate these extremely hazardous heavy metals that have escaped into the environment [7]

Textile dyes degrade water bodies by interfering with photosynthesis, stunting plant growth, entering the food chain, causing recalcitrance and bioaccumulation, and potentially increasing toxicity, mutagenicity, and carcinogenicity. They also raise the biochemical and chemical oxygen demand [8].

The massive volumes of water used in the fabric manufacturing process result in large volumes of wastewater with high concentrations of dissolved solids, organics, metals, salts, and refractory colors[9]. The high solubility and durability of synthetic dyes in water renders conventional treatment methods largely ineffectual [10]. Thus, the use of sophisticated techniques is required due to secondary pollution and the ineffective removal of organic load upon discoloration [11, 12].

EM technology presents itself as a potentially effective means of enhancing the water quality of lakes and rivers. Because this technology is more environmentally friendly and uses fewer resources in the form of capital, expenses, and inputs than other conventional methods, it has gained significant traction.

EM is considered advantageous microbes that work together to either directly or indirectly develop a wide range of compounds that can be used to stop disease progression, enhance health, and stop environmental deterioration [13]**.**About 80 different species of microorganisms, including actinomycetes, yeasts, fermenting fungi, photosynthesizing bacteria and lactic acid bacteria may be found in EM and are capable of purifying and reviving the natural world. The primary species typically involved are the *Actinomycetes* or *Streptomyces griseus* and *Albus*, the bacteria that produce lactic acid The photosynthetic bacteria *Rhodopseudomonas palustrus* and *Rhodobacter spaeroides*, the yeasts *Saccharomyces cerevisiae* and *Candida utilis*, the fermenting fungi *Aspergillus oryzae*, *Penicillium* sp. and *Mucor hiemalis* are among the *Lactobacillus plantarum*, *Lactobacillus casei* and *Streptoccus lactis*.

EM is composed of microorganisms that are neither pathogenic, genetically modified, toxic, or chemically manufactured. They are referred to as beneficial microorganisms because they have the ability to possessively alter the decomposition of organic materials, turning it back into a process that encourages life [14].

Upon introducing EM into the natural environment, the impacts of individual microorganisms are enhanced in a synergistic manner. Growing, applying, controlling and reestablishing large populations of advantageous microbes in a system or an environment are all part of EM technology. It is an organic natural technology that has been shown to benefit humanity in many ways. Sustainable agriculture, industrial, health (human, pet and animal), waste management and recycling, environmental remediation and eco-friendly cleaning are a few of the claims made for EM uses [15].

Generally, the increase in research is correlated with the United Nations' Sustainable Development Goals (SDGs) for 2030 being implemented in 2016, especially SDG 6 on clean water and sanitation for all. Additionally, as previously noted, the textile industry significantly contributes to the rise in water contamination. Therefore, this research may help efficiently to achieve SDG 6

This research aims to treat TIW as a bio remediation treatment in a safe manner, while also minimizing the cost of designing treatment plants and minimizing detention times to achieve the best results actually with eco-friendly natural resources acting in effective microorganisms (EM) which are composed of environmental components from more than 80 microorganisms live in communalism with each other.

Materials and Methods:

Sampling and preservation

A composite sample was obtained from a general collective textile industrial waste water drain for some textile factories located in the 2nd industrial zone in Borg El Arab City, Alexandria, Egypt. Samples were collected in a container of 50-liter capacity. Sampling and preservation were performed according to the standard methods published by the American Public Health Association press (APHA, 2017) [16].

Determination of physico-chemical characteristics

An anaerobicsystemis performed and composed of tied blue capped bottles with 500 ml volume and adding for different doses of EM as will be described below.

By a set of HQ Series Multi, HQ 4100 model, Loveland, USA; all the physico-chemical parameters: Temperature (Temp.), pH, ElectricalConductivity (EC), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD_5), Ammonia-nitrogen (NH_3-N), Nitrite (NO_2), Nitrate (NO_3), Phosphate – phosphorus (PO_4-P)measures were tested according to APHA, 2017 [16].

Different doses of EM of (5, 10, 15, 20 and 25 ml) to select the most effective one was applied to net volume of 525 ml of sample for each anaerobic system for duration time reaches to 15 days and complete to reach to 35 days. As shown in Figure 1.

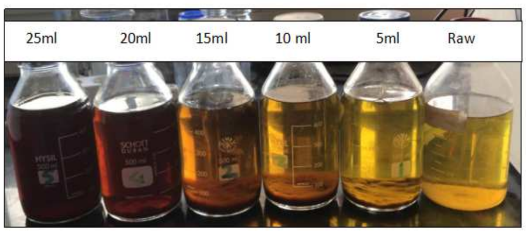

Figure 1: Anaerobic system at zero time (dose/ 525ml)

Determination of Heavy Metals (HMs)

By Atomic Absorption Spectrometer for Flame and Hydride, ContrAA model, Analytik Jena GmbH Co., Germany; HMs of Cr, Ni, Cu, Fe, Pb and Cd were determined after both duration times 15 and 35 days for all units of the experiment.

Equation (1) calculates EM removal percentage of any parameter:

= (Concentration of a parameter of the dose - Concentration of a raw sample for the same parameter) %

100

Results and Discussion

The physico–chemical characteristics after duration time (15 days & 35 days)

Tables 1&2 represent average values of physico – chemical parameters` results after duration times (15& 35 days) of the experiment.

Table 1: Average values of physico–chemical parameters` results of Anaerobicsystem after duration time 15 days (dose/ 525ml)

Parameters	EM dose					
	Raw	5ml	10 ml	15ml	20ml	25ml
Temp. (°C)	20.2	20.2	20.1	20.2	20.2	20.3
EC(ml Se/cm)	1.56	1.35	2.78	3.63	4.00	5.82
pH	6.7	2.14	2.42	2.45	3.33	3.43
NH_3 (mg/l)	36.3	1.32	2.5	2.8	2.9	3.2
Removal percentage (%)	……	96.36	93.11	92.28	92.01	91.18
NO_2 (mg/l)	ND	ND	ND	ND	ND	ND
NO_3 (mg/l)	0.384	10.18	12.88	27.7	28.024	29.18
PO_4(mg/l)	22	ND	ND	ND	ND	ND
BOD (mg/l)	210	58	74	79	77	80
Removal percentage (%)	……	72.38	64.76	62.38	63.33	61.90
COD (mg/l)	666.5	984	2190	3060	4390	4190

Table 2: Average values ofphysico–chemical parameters` results of Anaerobicsystem after duration time 35 days (dose/ 525ml)

Parameters	EM dose					
	Raw	5ml	10 ml	15ml	20ml	25ml
Temp. (°C)	20.0	20.3	20.3	20.31	20.31	20.3
EC (ml Se/cm)	1.56	2.42	4.45	5.58	7.04	8.53
pH	6.7	2.88	2.44	2.33	2.31	2.2
NH_3 (mg/l)	36.3	1.15	2.1	3.3	3.5	4.8
Removal percentage (%)	……	96.83	94.21	90.90	90.35	86.77
NO_2 (mg/l)	ND	ND	ND	ND	ND	ND
NO_3 (mg/l)	0.384	8.64	13.854	49.5	96.4	150.4
PO_4(mg/l)	22	ND	ND	ND	ND	ND
BOD (mg/l)	210	35	42	48	53	62
Removal percentage (%)	……	83.33	80	77.14	74.76	70.47
COD (mg/l)	666.5	1130	2520	4180	5700	6946

From the last tables1&2, Raw means zero EM dose and (ND) means Not Detectable and it was found that temperature was recorded around 20.2 and 20.3 °C all over the duration times of the experiment (15 & 35 days), respectively.pH was decreased gradually from 6.7 till 3.34 in case of duration time of 15 days and to 2.2 after 35 days. As EC measures how many dissolved substances, chemicals and minerals are dissolving in the sample units of the experiment, average values ranged from 1.56 ml S/cm at the raw sample to reach 5.82ml S/cm and 8.53 ml S/cm after the duration times of the experiments (15 & 35 days), respectively at 25 ml EM dose. In both duration times, the effective dose of EM was at 5 ml/525 ml for ammonia removal, in which NH_3 concentration was 36.3 mg/l for raw sample and was decreased to 1.32 mg/l with removal percentage of 96.36 % and was decreased to 1.15 mg/l with removal percentage of 96.83 % after (15 & 35 days), respectively. In addition, both nitrite ($NO_{2)}$ and Phosphate – Phosphorus (PO_4) were not detected in all treated samples in both duration periods of time, while nitrate ($NO_{3)}$ was increased from 0.384mg/l to 29.18 mg/l after 15 days experiment and increased to 150.4 mg/l after 35 days. Regarding BOD_5 average values, the best result was achieved at a 5ml EM dose that, ranged from 210 mg/l to reach 58mg/l with removal percentage of 72.38% and to reach 85 mg/l with removal percentage of 83.33% after (15 & 35 days), respectively. The dramatic increase happened in COD average values to reach 4190 mg/l after 15 experimentaldays and to reach 6946 mg/l after 35 days experimental days with 25 EM dose. Figure 2. Shows virtually gradually variations in the experiment of the anaerobic system at zero, 15 and 35 days (dose/ 525ml).

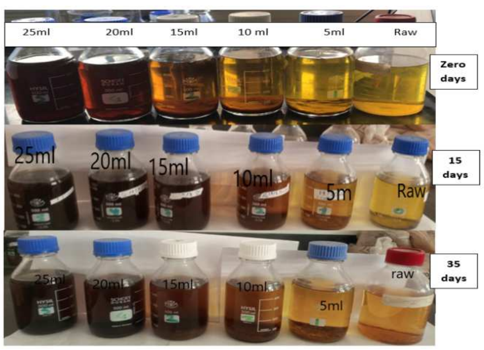

Figure 2: Anaerobicsystemafter duration times of (zero, 15 and 35) days (dose/ 525ml)

Both Figures 3 & 4. Show the variations in chemical parameters average values as a result of exposure textile waste water samples to different doses of EM (5, 10, 15, 20 and 25ml/525ml) after 15 &35 days experimental time.

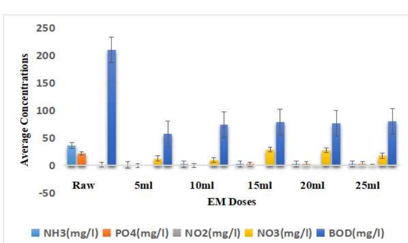

Figure 3: Effect of EM bioremediation to textile waste water chemically after duration time 15 days (dose/ 525ml)

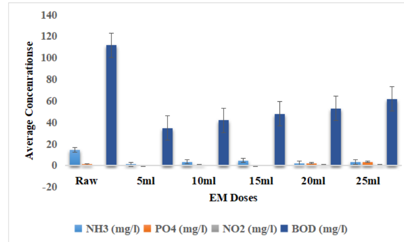

Figure 4: Effect of EM bioremediation to textile waste water chemically after duration time 35 days (dose/ 525ml)

Results are compatible with each other, that a decreasein pH indicates increasing H^+ ions in the solution, first because the nature of EM solution, it is acidic [15]. Second, all ammonia was converted into nitrates that the hydrogen ions produced translated into acidic pH values [17]. Also,when EC increases, this means increasing the solubility of components of this solution and this may lead to increase values of COD [17,18]. Phosphate-phosphorus is eliminated through the precipitations of divided dye fragments in the anaerobic phase, which act as a sludge capable of absorbing phosphate. As a result, the dissolved phosphorus concentration usually decreases to a value that is lower than it was at the beginning of the cycle [17].

The nitrification process, which occurs naturally and involves bacterial species converting ammonia to nitrate, is what caused the increase in nitrate concentrations. The reaction involved in the nitrification process is as follows [17]:

$$2NH^{4+} + 3O_2 \rightarrow 2NO^{2-} + 4H^+ + 2H_2O \quad (2)$$

$$2NO^{2-} + O_2 \rightarrow 2NO^{3-} \quad (3)$$

To prove the results of this study, recent researches havee proved that microorganisms from each bacteria, fungi, yeast and algae can all break down the azo bonds found in dye molecules through their enzymatic activity [19, 20], this will explain why the COD average result values are raising in a severe pathway by increasing doses of EM and on the other hands, decreasing of BOD_5 average result values. The decolorization by bacteria is significant due to their abundant degenerative enzymes, which give them the capacity to degrade a broad range of dyes[21].A class of enzyme, azoreductase [22].The reduction reaction that breaks down the azo bonds (-N=N-) in dyes and transforms them into aromatic amines and colorless compounds is carried out by azoreductase enzymes. The enzyme laccase is also useful in the treatment of numerous hazardous textile dyes [23].

Additionally, a number of researchers have documented the decolorization of dyes using actinomycetes [24],noting that actinomycetes caused

64–94.7% of the dyes to become decolorized.Since dyes are organic pollutants derived from aromatic hydrocarbons, bacteria can use them as a source of energy by catabolizing them[25]. Phytoremediation studies indicate that algae use azo dyes as a source of energy and carbon. The dyes undergo initial degradation to form aromatic amines, which are subsequently converted into basic inorganic and organic compounds [26]. Shi *et al.*, 2020[27], discovered that employing the bacteria *Providencia rettgeri* eliminated Brilliant Crocein dye 100% whereas Fareed *et al*., 2022[28] discovered 80–100%. However, some research found that decolorizing different subgroups of a single species of bacteria is insufficiently effective in remediating them [29]. The high performance of dye removal is explained by the fact that EM is a consortium of various species of bacteria, yeasts and algae [24].

Determination of Heavy Metals (HMs)

Tables 3& 4 represent average values of determination of Cr, Ni, Cu, Fe, Pb and Cd HM results after duration times (15& 35 days) of the experiment.

From last tables 3& 4, Raw means zero EM dose and (ND) means Not Detectable and it was found that removal percentages of Cr were ranged from 64.03 % (5 ml EM dose) to 0.89% (25 ml EM dose) after 15 experiment days experiment but after 35 experiment days, the removal percentage ranged from ~ 100% to reach to 97.50%. Results showed that the highest removal percentage for Ni was~ 100 % in case of 5 ml dose EM in both after 15 and 35 days but after 15 days this percentage decreased to reach 48% and 97.5% after 35 days experiment. A severe increase of average values of Cu was found to be increased gradually from 5.332 mg/lto reaching 129.66 mg/l at 5 ml and 25 ml doses of EM after 15 days and 7.401 mg/l till reaching 400.1 mg/l at 5 ml and 25 ml doses of EM after 35 days. It was noticed that a steady behavior of average values of Fe translated into stable values during the experiment with its two duration time. Pb and Cd values were not detected in the raw sample or in any unit form the experiment, this may due to the composition of the dyes[13]. Actually last results of behavior of heavy metals along this study, researches proved that in case of increasing average values of these HMs with increasing of retention times was justified by the reduced ability of EM to biodegrade TIW due to DNA cell damage of EM [16]. Moreover, the viability of EM cells was positively correlated with the ability of EM for COD removal rate, which explained the high presence of COD results of treated TIW. On the other hand, the high average values of HMs of treated TIW are affected also by the highly acidic pH in the EM solution itself. This may lead to an increase in the solubility of HMs in treated TIW, also may lead to reduce the viability of EM cells and at the same times increase the COD values in the treated TIW. Perhaps the uniqueness of the heavy metals is their abilityy to integrate with the EM cell enzymes or proteins. So, if the average values of HMsin TIW reach the HMs tolerance values for EM, its effectiveness for TIW treatment would decrease [15].

Table 3: Average values of HM results of Anaerobic system after duration time 15 days (dose/ 525ml)

HMs	EM dose					
	Raw	5ml	10 ml	15ml	20ml	25ml
Cr	0.4251	0.1529	0.2036	0.2368	0.3544	0.4213
Removal percentage (%)	……	64.03	52.10	45.81	16.63	0.89
Ni	0.0602	ND	0.0224	0.0236	0.0277	0.0313
Removal percentage (%)	………	~100	62.79	60.70	53.98	48.00
Cu	0.0578	5.332	29.56	40.50	100.3	129.66
Fe	1.157	1.258	1.263	1.263	1.263	1.263
Pb	ND	ND	ND	ND	ND	ND
Cd	ND	ND	ND	ND	ND	ND

Table 4: Average values of HMs results of Anaerobic system after duration time 35 days (dose/ 525ml)

HMs	EM dose					
	Raw	5ml	10 ml	15ml	20ml	25ml
Cr	0.4251	0.1529	0.2036	0.2368	0.3544	0.4213
Removal percentage (%)	……	64.03	52.10	45.81	16.63	0.89
Ni	0.0602	ND	0.0224	0.0236	0.0277	0.0313
Removal percentage (%)	……….	~100	62.79	60.70	53.98	48.00
Cu	0.0578	5.332	29.56	40.50	100.3	129.66
Fe	1.157	1.258	1.263	1.263	1.263	1.263
Pb	ND	ND	ND	ND	ND	ND
Cd	ND	ND	ND	ND	ND	ND

Conclusions

This study came to the conclusion that if HMs were found in the TIW, they ought to be eliminated through a pre- treatment procedure. This action would increase EM's effectiveness in treating TIW.

However, by inducing it through certain chemical and physical processes, EM may be resistant to HMs.
EM exhibits considerable potential for TIW treatment, requiring minimal dosages and retention times, which confer substantial cost benefits. Further research is necessary to address HMs removal or to develop per-treatment processes prior to EM application.

Conflicts of interest
"There are no conflicts to declare".

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