

Original Research Article

Dye Decolorization of Industrial Soil by using Dye Degrading Bacteria

ABSTRACT: Today's world needs to control the industrial pollution through smarter ways. As a significant class of synthetic organic compounds, textile dyes are frequently used in industrial processes and cause pollution. They are mass-produced and have the potential to pollute the environment both during manufacture and during the dyeing process of the fiber. Therefore, it is necessary to create treatment techniques that are more successful in removing dyes from the source, which is the soil used for textile waste. Out of 11 isolates, *Staphylococcus saprophyticus* was shown to be the most active dye degrader. It was isolated from the soil of a textile plant. Investigations were conducted on the significant factors that affect crystal violet decolorization, such as temperature, pH, carbon, and nitrogen supply. With sucrose and beef extract serving as the energy sources; dye decolorization (92.35%) was effectively accomplished under ideal conditions in 120 hours at 30°C and pH 8.

Key Words: *Staphylococcus saprophyticus*, crystal violet, textile waste, industrial soil, temperature, pH, carbon and nitrogen source.

INTRODUCTION: Since the advent of the industrial revolution in the 19th century, the environmental pollution has grown with time and it badly affected the air, water, soil and related ecosystems. Pollution results from different agricultural or urban/industrial sources in the form of fertilizers, pesticides, dyes, etc. The textile and paint industries release large quantities of polluted water containing artificial dyes in the surrounding ecosystem (Bibi *et al.*, 2018). Dyes are aromatic xenobiotic compounds and are used extensively in the textile industry, to dye nylon, wool, silk, and paper, cotton, and leather industries. Dyes are colorant that becomes molecularly dispersed at some points during application to fiber and exhibit some degree of permanence. There are many application classes of dyes, including acid dyes, natural dyes and synthetic dyes, some of the used as a biological stains and in veterinary medicine. The total world textile dye production is estimated to be in the range of 700000 tons per year. During the textile dyeing process, up to 40% of dyes may remain unfixed to the fiber and could contaminate the industrial waste water, which in many cases are flushed directly into water ways. This represents a world dye release ranging from 30000 to 150000 tons per year. These organic colored substances are very stable and difficult to degrade. The textile factory daily discharges millions of liter so fun treated effluents in the form of waste water into public rains that eventually empty into rivers. This alters the pH, increases the biochemical oxygen demand (BOD) and chemical oxygen demand (COD), and gives the rivers intense colorizations Ajayi and Osibanjo (1980). The use of these water resources is limited and the ecosystem is affected. About 10-15% of all dyes are directly lost to waste-water in the dyeing process. Thus, the waste-water must be treated before releasing into the natural environment. Several dye degrading microorganisms have been reported and characterized such as *Bacillus* sp., *Staphylococcus* sp., *Streptomyces* sp., *Arthobactersp.*, *Micrococcus* sp., *Vibreosp.*, *Pseudomonas* sp., *Mycoplasma* sp., *Sarcinasp.* and *E. coli*. Banat *et al.* (1996) & Azmi *et al.* (1998). Ozonation can degrade such molecules. But the initial investment and subsequent operation costs are high. Therefore, developing a bioremediation process seems essential. Bio-treatment offers a cheaper and eco-friendly alternative for colour removal in textile effluent. The ubiquitous nature of bacteria makes them invaluable tools in effluents bio-treatment. The aim of present study was to isolate and identify potential dye decolorizing bacterial strains from industrial soil samples and to optimize various culture parameters to enhance dye decolorization.

Materials and Methods

Isolation of bacteria: Bacteria were isolated from industrial soil using serial dilution method described by (Parshettiet *al.*, 2006).

Comment [MF1]: could potentially be modified to be more specific and focused. ("Isolation and characterization of *Staphylococcus saprophyticus* from textile industry soil for decolorization of crystal violet dye")

Comment [MF2]: A modified abstract addressing the above could be: "The contamination of the environment by textile dyes is a matter of environmental concern." The objective of this research was to extract microorganisms capable of breaking down dyes from dirt found in industrial areas. Out of the 11 isolates that were examined, *Staphylococcus saprophyticus* exhibited the greatest crystal violet decolorization rate of 92.35% at the ideal circumstances of 30°C, pH 8, and with the presence of sucrose and beef extract. The study examined the impact of temperature, pH, carbon, and nitrogen sources on the process of decolorization ... [1]

Comment [MF3]: To enhance the abstract, it would be beneficial to condense it and concentrate on the primary goals and discoveries of the investigation. Several possible vulnerabilities and alterations: The introductory statement on the management of industrial pollution is very broad and without clear relevance to the study's focus. Suggest excluding this from the abstract. The background information on textile dyes is relevant, however, it may be condensed ... [2]

Comment [MF4]: 1. The timeframe of "since the 19th century" lacks specificity. Suggest providing a more precise delineation of the specific era within the industrial revolution.
2. Describing dyes as "mass produced" is a valid statement, but it would be more authoritative to support it by referencing global data on textile dye manufacturing.
3.3. The organisation of the paragraph might be enhanced to improve the overall ... [3]

Comment [MF5]: The heading "Materials and Methods" would be more clear as separate sections "Materials" and "Methods".

"Bacteria were isolated from industrial soil using serial dilution method" - Recommend specifying the serial dilution technique employed (e.g. pour plate method).

"Screening of isolated bacteria for dye decolorization" - "Isolated" is redundant ... [4]

Screening of isolated bacteria for dye decolorization: Soils containing industrial effluents were collected from different industries like saw mill, textile mill, bangle mill and cotton mill. After collecting a soil sample serial dilution of each sample up to 10^{-6} to 10^{-8} level were made. These dilutions were used in pour plate method. After plating, the isolates were inoculated in nutrient broth at 37°C for 24h. To check the dye decolorizing activity 1ml of inoculated nutrient broth was added to 98ml sterilized nutrient broth and with 1ml of dye (crystal violet) the volume was made up to 100ml and it was left on shaker for 24-168h at room temperature. Then the dye decolorization activity was detected by spectrophotometer at 590nm. This method was used for all the isolates (Parshettiet al., 2006).

Determination of decolorization activity: Colour was measured at the dye's optimum wavelength (590nm). For this purpose, samples were centrifuged at 3000rpm for 15min and absorbance of supernatants was determined. The decolorization efficiency was expressed as a following equation described by Chong *et al.* (2006).

$$\text{Decolorization (\%)} = (I-F)/I * 100$$

Where I= initial absorbance and F= absorbance of decolorized medium

Selection of dye decolorizing bacteria: The strain, which was showing highest decolorizing percentage on Nutrient Broth, was selected for further study.

Effect of temperature: Arrange of temperature ($20-60^{\circ}\text{C}$) was used to study the effect of the temperature on dye decolorization. In this medium 10ml inoculums (10% v/v) was added with 1ml dye (0.50mg/1000 ml) along with 89 ml sterilized nutrient broth at pH7 to make a volume of 100ml then it was incubated for different time intervals (24-120h), respectively. After every time interval i.e. 24, 48, 72, 96 and 120h, the dye decolorization activity was detected by centrifuging the supernatant at 3000rpm for 15min in spectrophotometer at 590nm. This method was used for all the parameters.

Effect of pH: Effects of pH for decolorization of industrial soil containing dyes (0.50mg/1000ml) were studied over a pH range 5 to 10 by adjusting pH with HCL and NaOH. In this process 10ml inoculums (10% v/v) was used with 1ml dye (0.50mg/1000ml) along with 89ml sterilized nutrient broth at 30°C to make a volume of 100ml then it was incubated over a period of 24-120h.

Effect of different carbon sources on decolorization: Effect of various carbon sources on decolorization of industrial soil was assessed by growing the isolate in the sterilized 79ml nutrient broth with 10ml inoculums and 1ml dye at 30°C and pH8 along with different carbon source such as glucose (1%), mannitol (1%), sucrose (1%), maltose (1%) and lactose (1%), respectively then incubated for different time intervals i.e. 24-120h.

Effect of different nitrogen sources on decolorization: Effect of various nitrogen sources on decolorization was assessed by growing the isolate in the 69ml sterilized nutrient broth with 10ml inoculums, 1ml dye and 10ml carbon source i.e. sucrose (1g/100ml) at 30°C , pH 8 and different organic nitrogen source such as peptone (1%), beef extract (1%), malt extract (1%), yeast extract (1%) to make a volume of 100ml. Same procedure was used for different inorganic nitrogen sources such as NaNO_3 (1%), NH_4NO_3 (1%), KNO_3 (1%), NH_4Cl (1%) and $(\text{NH}_4)_2\text{SO}_4$ (1%), respectively.

Statistical analysis: The data recorded during the course of investigation was statistically analyzed using analysis of variance ANOVA (two way classification), correlation and t-test at 5% significance level.

Results and Discussion

Incidence of dye decolorizing bacteria in industrial soil samples: In the present study total 12 bacteria were obtained from the soil sample of saw mill among them three (25%) isolates showed positive dye decolorization activity.

Table 1 Sample collection sites

Sample No.	Sample site	Total No. of isolates	Total No. of positive isolates
1	Sawmill(Naini)	12	3(25%)
2	Textilemill(Naini)	15	3(20%)
3	Bangle mill(Ferozabad)	10	3(30%)
4	Cottonmill(Prayagaraj)	09	2(22.22%)

Significant $t_{cal} (6.52) > t_{tab} (5\%) (2.44); dof=6$

Almost same observation was obtained from textile mill, where total 15 isolates were obtained in which 3 (20%) showed positive result. From bangle mill, number of isolated bacteria was 10 in which 3 (30%) isolates have dye decolorizing capacity. From cotton mill 9 bacteria were isolated among them 2 (22.22%) isolated showed positive test i.e. showing dye decolorization potential. The result was found to be statistically significant ($p < 0.05$) there was a significant difference in the incidence of dye decolorizing bacteria from different industrial soil samples (Table-1).

These observations were similar to the findings of Meehan et al. (2001) who found an azo dye reducing, endospore forming bacterium isolated from textile industry. *Staphylococcus saprophyticus* was isolated from textile soil and selected as the most active azo dye degrader of 19 isolates by Seesuriyachanet al., (2007). Most of the results were found in textile industries, the reason was that textile industry contains azo compounds which were very toxic in nature and very hard to degrade but there was an enzyme called laccase was present not in every bacteria but most of them. This enzyme had ability to degrade dyes, Joseph et al., (2007).

Screening of potential isolate for dye decolorization: The isolate showed random increased decolorization % between 24-120h, after that the increasing percentage was nearly steady. Total 12 isolates from saw mill soil samples were obtained out of which 3 isolates i.e. SM1, SM2 and SM3 showed dye decolorizing ability.

When the isolates were studied at different time intervals, it was observed that SM1, SM2 and SM3 showed maximum dye decolorizing activity after 120h i.e. 48.48, 47.45 and 73.39%, respectively. Similar percentage activity was showed by three isolates of textile mill namely TM1, TM2 and TM3. Maximum was at 120h with 29.16% (TM1), 40.19% (TM2) and 84.17% (TM3) activity. Almost similar observations were seen in the soil samples collected from bangle mill. Three isolates were obtained that possess dye decolorization ability and were designated as BM1, BM2 and BM3. On comparing BM1, BM2 and BM3 isolates, maximum activity was observed with BM1 after 120h. of incubation. In the case of cotton mill isolates namely CM1 and CM2, the maximum decolorization was observed at 120h i.e. 43.66% (CM1) and 42.99% (CM2).

From all the data obtained it was clearly observed that TM3 was showing most decolorizing percentage at 120h after that time it seems to be constant. It was observed that the rate of removal of acidic dyes increases with increase in contact time to some extent. Further increase in contact time does not increase the uptake due to deposition of dyes on the available adsorption site on adsorbent material, Sumanjit et al., (2008). So all the parameters were optimized at 120h and this strain was selected for further studies. The results were found to be significant ($p < 0.05$) means the decolorization was supported by the time duration (Table-2). These observations were similar to the findings of Chong et al., (2006) who found 53.60% decolorization of direct blue 15 at 120h.

Comment [MF6]: The lack of regular structure/organization in the results hinders the ability to draw accurate comparisons. Suggest categorising the content into distinct parts that align with each parameter being evaluated.

Table and figure The captions or labels should be more explicit and informative in order to facilitate a quick comprehension of the material.

Certain tables may not include statistical analysis to establish the importance of data. Suggest including statistical tests such as t-test or ANOVA where appropriate.

Sentences that convey numerical outcomes might be challenging to comprehend. Recommend representing all quantities in a quantitative manner using tables or figures.

There are minor grammatical and spelling issues in the text, such as using " t_{cal}/t_{tab} " instead of " t_{cal}/t_{tab} " and "dye degradation" instead of "dyedecolorization".

The discussion section might enhance the credibility of its analysis by including additional sources and drawing parallels to a broader range of literature.

The rationale for choosing certain test circumstances over other options might be bolstered by the obtained findings.

Proposed revisions:

Organise the content into distinct and well-defined parts

Include comprehensive and descriptive descriptions for tables and figures.

Present all outcomes in numerical form.

Incorporate quantitative analysis

Proofread for grammatical and spelling problems.

Enhance the discourse by providing further citations.

Provide a rationale for selecting optimised settings.

As an example, the conversation on the outcome of temperature may be:

The decolorization reached its highest level of 80.36% at a temperature of 30°C, as shown in Table 3. This is consistent with the findings of the research mentioned in [cite study]..."

Table-2:Percentage dye decolorization by isolated bacteria.

Sl.	Sample no.	Isolate no.	Decolorization%						
			24h.	48h.	72h.	96h.	120h.	144h.	168h.
1	Saw mill	SM1	21.44	25.12	34.01	42.24	48.48	48.64	48.00
		SM2	17.63	22.72	24.36	39.27	47.45	47.63	47.81
		SM3	42.59	62.06	66.95	69.12	73.39	73.46	73.54
2	Textile mill	TM1	18.16	24.18	27.65	28.72	29.16	30.44	32.17
		TM2	18.70	28.32	37.23	39.56	40.19	40.64	40.73
		TM3	30.97	40.17	55.57	76.93	84.17	84.42	84.59
3	Bangle mill	BM1	32.54	41.38	57.58	59.35	60.53	60.67	60.82
		BM2	19.17	28.02	37.46	44.24	51.90	52.21	52.50
		BM3	14.35	23.58	30.51	35.89	42.82	43.33	44.10
4	Cotton mill	CM1	17.09	21.60	28.70	36.64	43.66	44.27	44.73
		CM2	20.42	26.84	36.34	40.61	42.99	43.46	44.18

Significant for hour: $F_{cal}(55.45) > F_{tab}(5\%)(2.17)$ S.E. = 2.72 C.D. = 5.9024

Significant for isolates: $F_{cal}(46.6) > F_{tab}(5\%)(1.91)$ S.E. = 2.17 C.D. = 4.1447

Table-3: Effect of temperature on decolorization of crystal violet.

Temperature	Decolorization%	Variation%
20°C	54.83	-29.34
30°C	80.36	-3.81
40°C	52.80	-31.37
50°C	39.44	-44.73
60°C	27.76	-56.41

Non-significant $t_{cal}(3.15) < t_{tab}(5\%)(3.18)$; $r = -0.7628$; dof=3

Table-4: Effect of pH on decolorization of crystal violet at 30°C.

pH	Decolourization%	Variation%	Temperature
5	40.58	-43.59	30°C
6	42.33	-41.84	
7	66.77	-17.4	
8	82.28	-1.89	
9	33.22	-50.95	
10	28.01	-56.16	

Non-significant $t_{cal}(0.3875) < t_{tab}(5\%)(2.776)$; $r = -0.1902$; dof = 4

Table-5: Effect of carbon source on decolorization of crystal violet at 30°C and pH8.

Carbonsource (1%)	Decolorization %	Variation %	Temperature	pH
Mannitol	58.77	-25.4	30°C	8
Maltose	52.81	-31.36		
Glucose	47.19	-36.98		
Sucrose	89.66	+5.49		
Lactose	45.39	-38.78		

Significant $t_{cal}(7.28) > t_{tab}(5\%) (2.13)$; dof = 4

Microbial decolorization of acid black 24 (dye conc. 0.1g/l) a water soluble, benzidine based azo dye was studied by Ozdemir *et al.*, (2005). They found decolorization was 74% under shaking conditions within 336h, although dye reduction was stable between 144h and 336h. In our study the dye decolorization was stable between 120-168h. In shaking conditions the dye decolorization was due to adsorption of dye by viable or died cells.

Identification of bacterial strain: Based on cultural, morphological and biochemical characteristics tests the TM3 was identified as *Staphylococcus saprophyticus* (Holt *et al.*, 1986).

Effect of temperature: The decolorization of crystal violet was most efficient at 30°C, with 80.36% of colour removal, followed by 20, 40, 50 and 60°C. The decline of microbial activity on decolorization could be due to the loss of cell viability and denaturation of enzyme Pearce (2003). The results were found to be non-significant ($p > 0.05$). Our findings were similar to the findings of Ilhan *et al.*, (2004) who discovered a bacterial strain *Staphylococcus saprophyticus* which has ability to degrade or remove chromium, lead and copper ions from industrial waste water at 30°C with 66, 91 and 48% degradation at 120h, respectively.

Effect of pH: The optimum pH for decolorization in this study was pH8, in which decolorization efficiency was 82.28%. Amongst pH, pH8 was used for subsequent experiments as it was slightly basic and suitable for industrial application. The results were found to be non-significant ($p > 0.05$) (Table-4). Similar findings are reported by Sumanjit *et al.* (2007) who tested the dye decolorizing activity was maximum at 30°C and pH8 which is slightly basic against *Staphylococcus saprophyticus* with 78% decolorization of acid red 119. These results indicated that dye decolorization was due to the degradation or conversion of complex substances into smaller substances by particular strain.

Effect of carbon source: In an attempt to enhance decolorization performance with extra supplements of carbon source in a medium 89.66% decolorization with sucrose (1%) was found in 120h with pH8 and temperature 30°C. Results were found to be statistically significant ($p < 0.05$) (Table-5).

The decolorization process requires carbon substrates as an energy source. Sucrose (1%) was the best energy source tested with Methyl Orange. This particular dye was degraded to 39% of the normal level in the presence of sucrose by *Lactobacillus casei* described by Seesuriyachan *et al.* (2007).

Effect of organic nitrogen source: In an attempt to enhance decolorization performance with extra supplements of organic source in a medium we found 92.35% decolorization with beef extract (1%), in 120h with carbon source sucrose, pH8 and temperature 30°C. The results were statistically significant ($p < 0.05$) (Table-6).

Table-6: Effect of organic nitrogen source on decolorization of crystal violet at 30°C and pH8 with carbon source sucrose.

Organic nitrogen Source (1%)	Decolorization %	Variation %	Temperature	pH	Carbon source
Peptone	78.28	-5.35	30°C	8	Sucrose
Beef extract	92.35	+8.18			
Malt extract	55.09	-29.08			
Yeast extract	83.46	-0.71			

Significant $t_{cal} (9.72) > t_{tab} (5\%) (2.35)$; dof=3

Table-7: Effect of inorganic nitrogen source on decolorization of crystal violet at 30°C and pH 8 with carbon sourcesucrose

Inorganic nitrogen Source (1%)	Decolorization %	Variation %	Temperature	pH	Carbon source
NaNO ₃	70.00	-14.17	30°C	8	Sucrose
NH ₄ NO ₃	80.97	-3.2			
KNO ₃	88.95	+4.78			
NH ₄ Cl	14.28	-69.89			
(NH ₄) ₂ SO ₄	20.11	-64.06			

Significant $t_{cal} (3.39) > t_{tab} (5\%) (2.13)$; dof=4

Effect of inorganic nitrogen source: In an attempt to enhance decolorization performance with extra supplements of inorganic nitrogen source in a medium we found 88.95% decolorization with potassium nitrate (1%), in 120h with carbon source sucrose, pH8 and temperature 30°C. The results were found to be statistically significant ($p < 0.05$) (Table-7).

Wong and Yuen (1998) studied the decolorization of n,n-dimethyl-p-phenylene diamine by *Klebsiella pneumoniae* and *Acetobacterliquefaciens* with adding nitrogen source as ammonium sulphate (1%) they found 80 and 45% decolorization by both the strains.

The study revealed that maximum decolorization was obtained against crystal violet (0.50mg/l) at 30°C, pH8; sucrose (1%) and beef extract (1%). Using all these modified parameters the decolorizing activity was increased up to 92.35% otherwise it is 84.17%.

References

Ajayi, S.O. and Osibanjo, O.(1980) The state of environment in Nigeria, In:Pollution studies of Textile Industries in Nigeria, Edition3:Nigeria University Press : 76-86

Azmi,W., Sani, R.K. and Banerjee, U.C.(1998). Biodegradation of Triphenylmethane Dyes, *Enzyme Microbial Technology*; 22: 185-191.

Comment [MF7]: The reference style incorporates a combination of many styles, such as using numbers and authors' full names, which requires standardisation. Either Harvard or Vancouver would be appropriate.

Several sources lack crucial information such as the year of publication and the volume/issue numbers. These elements must be included in order to achieve comprehensiveness.

There are inconsistencies between the citations inside the text and the references listed, and vice versa. Verification of consistency is necessary.

The lack of alphabetical order in the references hinders efficient scanning. Arrange in alphabetical order.

Verify the accessibility of all sources - some reference information seems to be insufficient for locating sources.

The majority of sources are from the period between 1980 and 2010. Require additional contemporary literature (within the last 5-10 years) to substantiate the results.

Non-English sources, such as the final reference, should be omitted for the intended readership.

In order to ensure clarity, it is necessary for journals and publishers to use complete names rather than abbreviations.

Recommendations:

Implement a uniform referencing style
Verify that all references include comprehensive and specific information.
Verify and compare citations and references for accuracy and consistency.
Arrange the references in alphabetical order.
Please include more up-to-date and easily accessible references.
Translate or remove any sources that are not in the English language.
Please include the entire names of the journals and publishers.

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To enhance the abstract, it would be beneficial to condense it and concentrate on the primary goals and discoveries of the investigation. Several possible vulnerabilities and alterations: The introductory statement on the management of industrial pollution is very broad and without clear relevance to the study's focus. Suggest excluding this from the abstract.

The background information on textile dyes is relevant, however, it may be condensed to enhance conciseness.

The stated purpose of "creating treatment techniques" lacks specificity. I suggest clarifying the target as identifying and characterising bacteria that are capable of degrading dyes.

Merely listing one isolate (*Staphylococcus saprophyticus*) as the most active is inadequate. I suggest specifying the percentage of decolorization and the circumstances under which the tests were conducted to accurately quantify the results.

Factors like as temperature, pH, and carbon/nitrogen supply are important to include, however they might be stated more succinctly.

1. The timeframe of "since the 19th century" lacks specificity. Suggest providing a more precise delineation of the specific era within the industrial revolution.
2. Describing dyes as "mass produced" is a valid statement, but it would be more authoritative to support it by referencing global data on textile dye manufacturing.
3. 3. The organisation of the paragraph might be enhanced to improve the overall coherence and smoothness of the text. Propose consolidating the two paragraphs on dye characteristics and use, and adding a separate paragraph discussing the consequences of textile effluents.
4. The quantification of textile wastewater discharge volume in terms of "millions of litres" is insufficient. Please provide authoritative references for average effluent quantities per textile factory.
5. The impacts mentioned, such as pH alteration, increased BOD/COD, and coloration, are plausible but would benefit from the inclusion of statistical data to provide more precise information on the extent of these changes, rather than relying on general remarks.

6. The amount of dye that is released into wastewater varies significantly across different sources. Suggest choosing a solitary, reliable statistic.
7. The importance and discoveries of various dye-degrading bacteria are not mentioned. Recommend eliminating this list to enhance brevity.

Page 1: [4] Comment [MF5]

Maier

4/23/2024 1:12:00 AM

The heading "Materials and Methods" would be more clear as separate sections "Materials" and "Methods".

"Bacteria were isolated from industrial soil using serial dilution method" - Recommend specifying the serial dilution technique employed (e.g. pour plate method).

"Screening of isolated bacteria for dye decolorization" - "Isolated" is redundant after stating the source as industrial soil. Recommend removing.

"After plating, the isolates were inoculated in nutrient broth at 370C for 24h" - 370C should be 37°C.

"To check the dye decolorizing activity 1ml of inoculated..." - Inoculated is redundant, suggest removing.

"Then the dye decolorization activity was detected..." - Suggest specifying the detection method used (spectrophotometer).

"Selection of dye decolorizing bacteria" - Recommend a clearer heading like "Selection of the most active dye-degrading isolate".

Some method descriptions could be made more concise for clarity.