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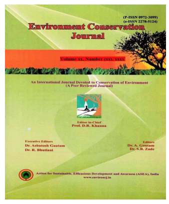

Efficiency of spent mushroom (*Agaricus Bisporus*) waste biomass for the biosorption of basic fuchsin dye from aqueous solution

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ABSTRACT

The dumping of wastewater containing the dyes is harmful to the health of aquatic living beings. The colour in water bodies reduces the penetration of light and thereby reduces the concentration of dissolved oxygen (DO) of water bodies. The decreased value of DO is also harmful to aquatic organism. Therefore treatment of wastewater containing dyes becomes essential. Mushrooms have proven to be highly efficient and economical for removing pollutants through bioabsorption. Therefore, in the present study an attempt has been made to study the efficiency of Spent Mushroom Waste (SMW) *viz. Agaricus bisporus* as biosorbent for the biosorption of Basic Fuchsin Dye (BFD) from aqueous solution. The effects of certain factors such as the dose of adsorbent, temperature, exposure time, and pH were studied on the dye degradation by a given biomass of SMW. The results of the present study revealed that the optimum value of temperature, contact time, adsorbent dose, pH, was 7, 20 minutes, 20 mg, and 30°C respectively. The biosorption efficiency of the used SMW ranged from good to excellent. The results of the present study revealed that the SMW of *Agaricus bisporus* is an economically and environmentally sound adsorbent and can be used for the degradation of dyes from water based solutions. Further investigation is required to enhance the adsorption rate of SMW of *Agaricus bisporus*.

Introduction

Water is the most important natural source and therefore its treatment is essential for the survival of humanity on this planet (Bhutiani and Ahamad, 2018; Bhutiani *et al.,* 2021). The color in the effluents enhances the toxic effects of effluents. Usually effluents containing color due to the presence of dyes long with other pollutants is treated using various physicochemical processes. But all these physicochemical processes are less efficient in dyes removal, expensive, and not flexible as per the nature of dye. Various types of effluents especially industrial effluent is complex in nature and possesses diverse sorts of organic dyes and pollutants (Mahmooda, 2014; Feng *et al.,* 2022; Islam *et al.,* 2023). Most of the synthetic dyes are classified into cationic (basic), anionic (direct, acid, and reactive) and nonionic (disperse) based on the presence of functional groups. Due to their high soluble nature it is very difficult to remove the dyes from effluents and therefore their dumping in the aquatic bodies can cause mutations and can produce secondary products which are toxic in nature to

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aquatic life either in one way or in other (Farhan Hanafi and Sapawe, 2020).Biosorption is defined as "the elimination of undesired substances from solution by biotic material (living or dead) and or their derivatives, which form complexes using ligands or serviceable clusters of ions present on the cell surface" (Volesky, 2001). It is a property of both alive and lifeless organisms (and their components); and is believed to be a favorable biological method for the elimination (and retrieval) of metals, dyes, radionuclides and organic pollutants for countless years due to their several properties such as (i) its simplicity; (ii) operation analogous to conventional ion-exchange technique; (iii) apparent efficiency; and (iv) easy availability of different biosorbents (Gadd, 2009; Chukki and Shanthakumar, 2016). Qin *et al.* (2023) studied the adsorption efficiency of mushroom along with the impacts of present minerals of its efficiency and concluded that the present minerals such as sodium, potassium, calcium, and magnesium enhance its cadmium adsorption potential from aqueous solutions. AbuQamar *et al.* (2023) studied the potential of algae's for the remediation of emerging pollutants from aqueous solutions and concluded that mycoremediation is a suitable technology but there is a need of process optimization and pilot scale studies. Chaurasia *et al.* (2023) wrote review on the mycoremediation techniques applied for heavy metal, dyes, pesticides, insecticides, herbicides, and pharmaceutical wastes remediation from wastewater mushrooms were used even before man understood the nature of other organisms. Mushroom cultivation started in the ancient times for their nutritional value and flavor (Quimio and Royse, 1990; Baysal *et al.,* 2014; Chakraborty *et al.,* 2016). Mushrooms have rich nutritional value with high content of proteins, vitamins, minerals, fibers, trace elements and low calories and cholesterol (Wani *et al.,* 2010; Waktola and Temesgen, 2018). Besides nutritive value, mushrooms also possess some medicinal properties (Thakur and Singh 2013; Meng *et al.,* 2016). The mushrooms (fungi) have been proven to be highly efficient and economical for the removal of pollutants even from dilute aqueous solutions through biosorption because of their filamentous morphology and high proportion of cell wall. The groups of fungi that have mainly been used in biosorption of heavy metals, dyes etc. comprise filamentous fungi (Ayimbila and Keawsompong, 2023).Spent mushroom waste (SMW) is the waste product of mushroom industry generated during different processes of mushroom production. Approximately 5 times of SMW is generated during the manufacturing of unit quantity of mushrooms (Del Campo *et al.,* 2018). The disposal of this huge quantity of waste causes environmental pollution. SMW is highly rich in protein, chitin, chitosan, cellulose, and hemicelluloses having certain important serviceable clusters such as amide, carbonyl, and hydroxyl. All these functional groups provide dynamic binding locations for contaminants in the effluent treatment process. Literature suggests that unprocessed SMW can be used for the degradation of dyes but it has a partial ability to remove acidic/basic dyes in environments (Savoie *et al.,* 1996; Vos *et al.,* 2017). The process of wastewater treatment requires environmental friendly, low cost, and efficient adsorbents. The efficiency of the dye uptake by a given microbial biomass is subject to a variety of factors including temperature, pH, biosorbent concentration and initial concentration of the dye in the reaction system (Ahmed and Ebrahin 2020; Aragaw and Bogale, 2021). The advantages of biosorbent in comparison other adsorbents are given in figure 1 and the factors affecting the adsorption process are given in figure 2.The Basic Fuchsin ($C_{20}H_{20}N_3Cl$) is also a triphenylmethane dye. It is a mixture of three dyes pararosaniline, rosaniline, and magenta II and is also known as magenta II. Literature suggests that for the degradation of basic fuchsin dye very few biosorbents have been employed (Yamil *et al.,* 2020). Therefore the present study was designed to study the efficiency of spent mushroom waste (SMW) biomass of *Agaricus bisporus* for the degradation of basic fuchsin dye.

Material and Methods

Spent mushroom waste (SMW)

The spent mushroom waste (SMW) of *Agaricus bisporus* was present in laboratory at Department of Botany, KVSCOS, Swami Vivekanand Subharti University, Meerut, Uttar Pradesh, India. The procedure described by Yan and Wang (2013) is used to prepare the absorbent from SMW (Figure 3).

Effects of different factors such as SMW dosages, contact time, temperature, and pH on the biosorption process was also studied.

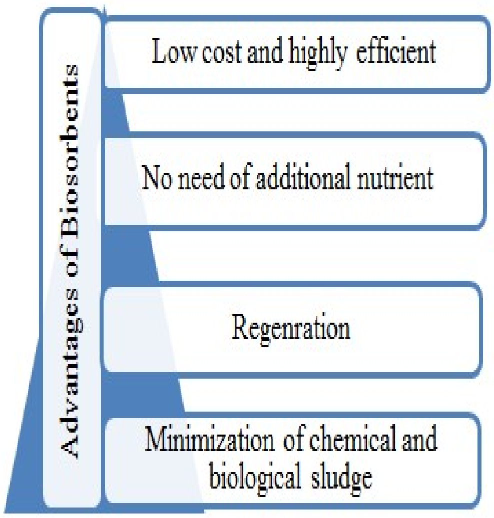

Figure 1: Showing the advantages of Biosorbent (Source: Okoro *et al.*, 2022)

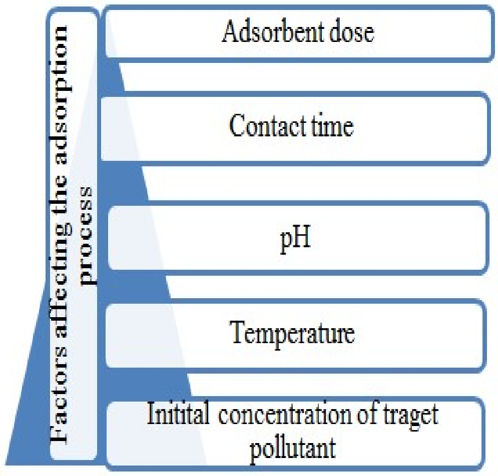

Figure 2: Showing the factors affecting the adsorption process (Source: Okoro *et al.*, 2022)

Preparation of Basic Fuchsin Solutions of different concentrations

One gram of analytical grade Basic Fuchsin dye ($C_{20}H_{20}N_3 \cdot HCl$) (Sinopharm Chemical Reagent Co., Ltd., Shanghai, China) was dissolved in distilled water and then diluted to one liter with the help of distilled water. The final concentration of the stock dye solutions was 1 g/L.

The basic fuchsin dye was used to assess the ability of the SMW biomass to adsorb dyes. The stock solutions of the dyes were prepared and then a solution containing 500 mg/l of dyes in representative solutions was prepared.

Experimental setup

A total of 12 sets of flask of were prepared for each selected adsorbent dose. Among which 3 were used as control while the rest of the flask were designated as experimental. Each flask contains 100ml sample of 500 mg/l solution of Basic Fuchsin dye.

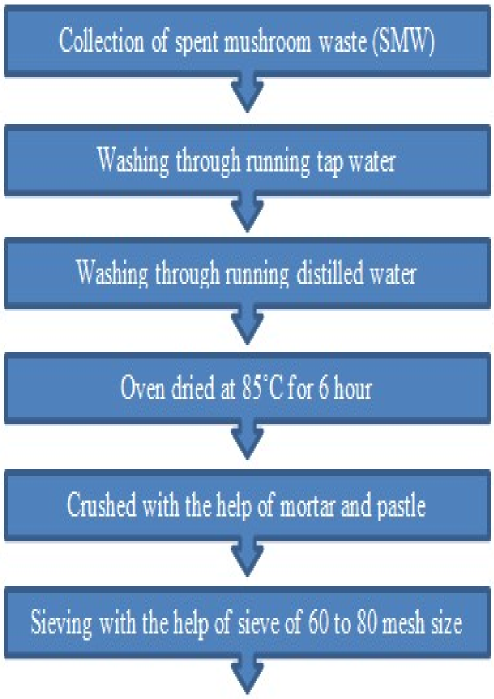

Figure 3: Showing the process of absorbent preparation from SMW (process adopted from Yan and Wang, 2013)

Effect of different adsorbent dose, pH, and temperature at the efficiency of SMW for basic Fuchsin dye reduction: 100 ml of 500 mg/l solution of basic Fuchsin dye solution were taken in each of a set of 12 flasks of 250 ml capacity. To these flasks, different pH (5.5, 7.0 and 8.5) of the dye solutions were adjusted with HCl (0.1N) and NaOH (0.1N) solution using an ESICO pH meter (ESICO). To these flasks, dead SMW biomasses were added as under. For each selected dose (10, 20, 30 mg/l), 3 flask were prepared for the first selected pH (5.5) for three different selected temperature (20, 25, 30˚C) and required time period (10, 20, 30 minutes). In the similar way flask were prepared for second selected pH (7.0) and third selected pH (8.5). In this way 9 experimental flasks were prepared for each dose.

Running of Experimental

All these flasks were then placed on a rotary shaker at 110rpm for the required time period. The rpm and time was selected based on the available literature (Yan and Wang, 2013; Dardouri and Sghaier, 2017). The fungal biomass was separated by filtering the mixture through a nylon sieve and the unadsorbed dye (that remaining in the solution) was estimated in supernatant using a *uv-vis*spectrophotometer (EI India, Model SL-3375) at 618 nm and 550 nm wave lengths. The adsorbed quantity (Q) and adsorption efficiency (E) was calculated as follows:

$$Q\ (mg/g) = \{(C_i - C_f) \times V\} / m$$

$$E\ (\%) = \{(C_i - C_f)/ C_i\} \times 100$$

where,
E=reduction in percentage
Q = dye uptake (mg dye/g biosorbent)
V = the liquid sample volume (ml)
Ci = the initial concentration of the dye in solution (mg/l)
Cf = the final concentration of the dye in solution (mg/l)
m = the amount of added biosorbent on the dry wt. basis (g)

The biosorption efficiency of particular biomass was interpreted as under:

1. 0–10 Very poor
2. 10–20 Poor
3. 20–40 Moderate
4. 40–60 Good
5. 60–80 Very good
6. 80–100 Excellent

Results and Discussion

Effects of various variables such as dose of adsorbent, pH, temperature, and contact time were studied in the present study. Initial concentration of the Basic Fuchsin dye was taken as 500mg/l. All the results are given in table 1. Maximum adsorption percentage efficiency of Basic Fuchsin Dye by Spent Mushroom (*Agaricus Bisporus*) at different chosen factors such as (a) Dose (b) Time (c) pH value and (d) Temperature is given in fig. 4.

Effect of different biomass dose

Three different doses 10, 20, and 30mg of SMW were taken for the study. On increasing the adsorbent dose from 10 mg to 30 mg, the adsorbent efficiency first increased and then decreased. Different efficiencies were observed at different doses of SMW at different pH, temperature, and contact time. Highest efficiency was observed at 20mg/l adsorbent dose and 30˚C at a contact time of 20 minutes at a pH of 7.0. Lowest efficiency was observed at 10mg/l adsorbent dose and 35˚C at a contact time of 30 minutes at a pH of 5.5. The adsorption percentage increased with the increasing dose but after certain dose it starts reducing. This may be due to availability of more active sites and sorption surface area (Mall *et al.,* 2005; Hameed, 2009; Tian *et al.,* 2011; El Haddad, 2016; Ali *et al.,* 2020). At the increased adsorbent dose, the decrease in removal efficiency may be due agglomeration of adsorbent molecule at active sites (Malekbala *et al.,* 2012; Ahmed and Ebrahin, 2020). The dose below which the adsorption percentage increased and at that dose the percentage reduction is highest and starts reducing is termed at optimum dose. In the present study, the optimum dose is 20mg. Hameed (2009) used the spent tea leaf for the reduction of basic dye concentration from aqueous solution and observed the reduction from 44 to 96%. Mall *et al.* (2005) studied the adsorption potential of bagasse fly ash for the removal of malachite green dye from aqueous and observed the similar reduction efficiency. Ali *et al.* (2020) found the highest efficiency of activated charcoal for the removal of Malachite Green Dye at 27mg/l and 45minutes. The spent mushroom waste was observed to have uptake capacity of 950.0 mg/g to 3920.0 mg/g for Basic Fuchsin dye.

Effect of variation in contact time

Contact time is an important factor for the treatment of wastewater using adsorption process (Doğan *et al.,* 2005). Three different contact times (10, 20, 30 minutes) were chosen based on

Table1: Efficiency of dead biomass of spent mushroom waste (*Agaricus bisporus*) for the reduction of basic fuchsin dye

Initial concentration of dye = 500 (mg/l)																											
Adsorbent dose = 10 (mg/l)																											
pH	5.5									7									8.5								
Temperature	25			30			35			25			30			35			25			30			35		
Contact time	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30
Final concentration of dye (mg/l)	210	189	203	189	149	183	212	195	220	146	134	140	119	96	113	148	139	146	198	177	187	145	108	154	202	184	197
Extent of dye biosorption (mg/l)	290	311	297	311	351	317	288	305	280	354	366	360	381	404	387	352	361	354	302	323	313	355	392	346	298	316	303
% Adsorption	58	62.2	59.4	62.2	70.2	63.4	57.6	61	56	70.8	73.2	72	76.2	80.8	77.4	70.4	72.2	70.8	60.4	64.6	62.6	71	78.4	69.2	59.6	63.2	60.6
Q Value	2900	3110	2970	3110	3510	3170	2880	3050	2800	3540	3660	3600	3810	4040	3870	3520	3610	3540	3020	3230	3130	3550	3920	3460	2980	3160	3030
Adsorbent dose = 20 (mg/l)																											
pH	5.5									7									8.5								
Temperature	25			30			35			25			30			35			25			30			35		
Contact time	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30
Final concentration of dye (mg/l)	200	184	197	175	107	168	203	189	211	136	122	130	108	87	105	142	127	135	187	169	175	132	109	129	192	175	187
Extent of dye biosorption (mg/l)	300	316	303	325	393	332	297	311	289	364	378	370	392	413	395	358	373	365	313	331	325	368	391	371	308	325	313
% Adsorption	60	63.2	60.6	65	78.6	66.4	59.4	62.2	57.8	72.8	75.6	74	78.4	82.6	79	71.6	74.6	73	62.6	66.2	65	73.6	78.2	74.2	61.6	65	62.6
Q Value	1500	1580	1515	1625	1965	1660	1485	1555	1445	1820	1890	1850	1960	2065	1975	1790	1865	1825	1565	1655	1625	1840	1955	1855	1540	1625	1565
Adsorbent dose = 30 (mg/l)																											
pH	5.5									7									8.5								
Temperature	25			30			35			25			30			35			25			30			35		
Contact time	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30
Final concentration of dye (mg/l)	204	192	202	168	112	174	209	201	215	145	128	132	121	106	117	152	133	144	195	183	196	156	110	151	199	188	210
Extent of dye biosorption (mg/l)	296	308	298	332	388	326	291	299	285	355	372	368	379	394	383	348	367	356	305	317	304	344	390	349	301	312	290
% Adsorption	59.2	61.6	59.6	66.4	77.6	65.2	58.2	59.8	57	71	74.4	73.6	75.8	78.8	76.6	69.6	73.4	71.2	61	63.4	60.8	68.8	78	69.8	60.2	62.4	58
Q Value	987	1027	993	1107	1293	1087	970	997	950	1183	1240	1227	1263	1313	1277	1160	1223	1187	1017	1057	1013	1147	1300	1163	1003	1040	967

literature study. Batch experiments were carried out to study the effect of contact time. The lowest adsorption 56.0% was observed at 30minutes contact time and 35˚C at 10mg/l adsorbent concentration at a pH value of 5.5. The highest adsorption 82.6% was observed at 20minutes contact time and 30˚C at 20mg/l adsorbent concentration at a pH value of 7.0. Gradual increase in adsorption revealed the fact that adsorption increases with the increment in time despite of the dye concentration. Even high dose of dye can adsorb in prolonged time/ long exposure of time (Tong *et al.,* 2018; Ihsanullah *et al.,* 2020). Finally, the contact time of 20 min and dose on 20 mg is determined as the optimum contact time for further investigations. Keeping all the variables fixed, the adsorption efficiency was observed high in the starting of experiment due to availability of large number of active sites and the reduction efficiency decreased at a particular contact time due to repulsion forces between the adsorbed and free molecules (Malekbala *et al.,* 2012; Yan and Wang, 2013) and agglomeration process (Mall *et al.,* 2005). After 20 minutes of contact period, reduction efficiency decreased on increasing contact time and was found negligible after 90minutes. According to Batana *et al.* (2022) the maximum biosorption of *Fusarium oxysporum* was determined to be about 79%. Doğan *et al.* (2007) observed the adsorption equilibrium at 4 hour contact time during the reduction of two different dyes (methyl violet and methylene blue) using sepiolite bagasse fly ash as an adsorbent. Similar results were observed by Mall *et al.* (2006) in case of removal of Orange-G and Methyl Violet dyes using bagasse fly ash bagasse fly ash as an adsorbent. El Haddad (2016) observed the highest adsorption rate at 40 minute contact time after that the rate starts decreasing and complete equilibrium was attained at 60 minute. Yildirim *et al.* (2020) also observed the similar results while studying the reduction in the concentration of heavy metals with the help of fungal extract.

Effect of variation in temperature

Variation in adsorption rate was studied at different temperatures ranging from 25 to 35˚C. The results were depicted in table 1. As far as temperature is considered high adsorption 70.2 to 82.6% was observed at 30˚C, which is far ahead of 60% absorption at 20˚C. Adsorption percentage decreased on increasing temperature may be due to exothermic nature of adsorption process (Yan and Wang, 2013). Yan and Wang (2013) observed the maximum adsorption efficiency at 30 ˚C and concluded the requirement of lower temperature for adsorption process. Ali *et al.* (2020) studied the sorption rate at different temperatures ranging from 0 to 60˚C and observed the highest sorption rate at 45 ˚C.

Effect of different pH

The pH value of the solution greatly influences the adsorption percentage especially the initial pH (El Haddad *et al.,* 2012; Kooli *et al.,* 2015; El Haddad, 2016). The adsorption rate depends on the presence of functional groups at the surface of adsorbent whose dissociation depends on the pH of solution (Ho and McKay, 2000). The adsorbent surface may attract both H^+ and OH^- based on the charge of own surface (Kocaoba *et al.,* 2007; Malik *et al.,* 2007; Nethaji *et al.,* 2010; Alhujaily *et al.,* 2018). Effect of different pH (5.5, 7.0. 8.5) value was also studied on the adsorption of basic fuchsin dye from aqueous solution using SMW. The required pH was obtained by adding the 0.1M HCl and 0.1M NaOH solution. Highest adsorption 82.6% took place at pH 7.0 on 20minute contact time, 30˚C temperature and 20mg/l adsorbent dose while the lowest adsorption 57.0% took place at pH 5.5 on 30minute contact time, 35˚C temperature and 30mg/l adsorbent dose. Therefore we can interpret that neutral to slightly basic pH favour the biosorption through dye adsorption phenomenon if pH is considered as sole parameter. The initial pH of the dye solution strongly affected the chemistry of both the dye molecules and fungal biomass in an aqueous solution. El Haddad (2016) observed the highest adsorption rate at a pH of 9.2 using calcined mussel shell material (CMS). The author concluded that the negative charge on the surface of CMS is responsible for the highest adsorption rate at a pH of 9.2 and decreasing rate at acidic value of pH. At a low pH (in acidic media), occurred greatly between cationic dyes (MB, MG) ions and positively charged groups on the surface of the mushrooms. On the contrary, with increasing pH, electrostatic attractions between cationic dye ions and negatively charged sites on mushrooms' surface were enhanced both cationic dyes adsorption (Tong *et al.,* 2018; Liu and Lee, 2021). These results indicate that the adsorption of BF is more influenced by acidic nature of pH on the surface of spent waste mushrooms. Tian *et al.* (2011) observed the highest adsorption rate at strong acid pH in case of Congo red dye reduction from aqueous solution. Ali *et al.* (2011) observed the highest adsorption rate in acidic medium. The author observed the decrease in adsorption rate at a pH greater than 5.

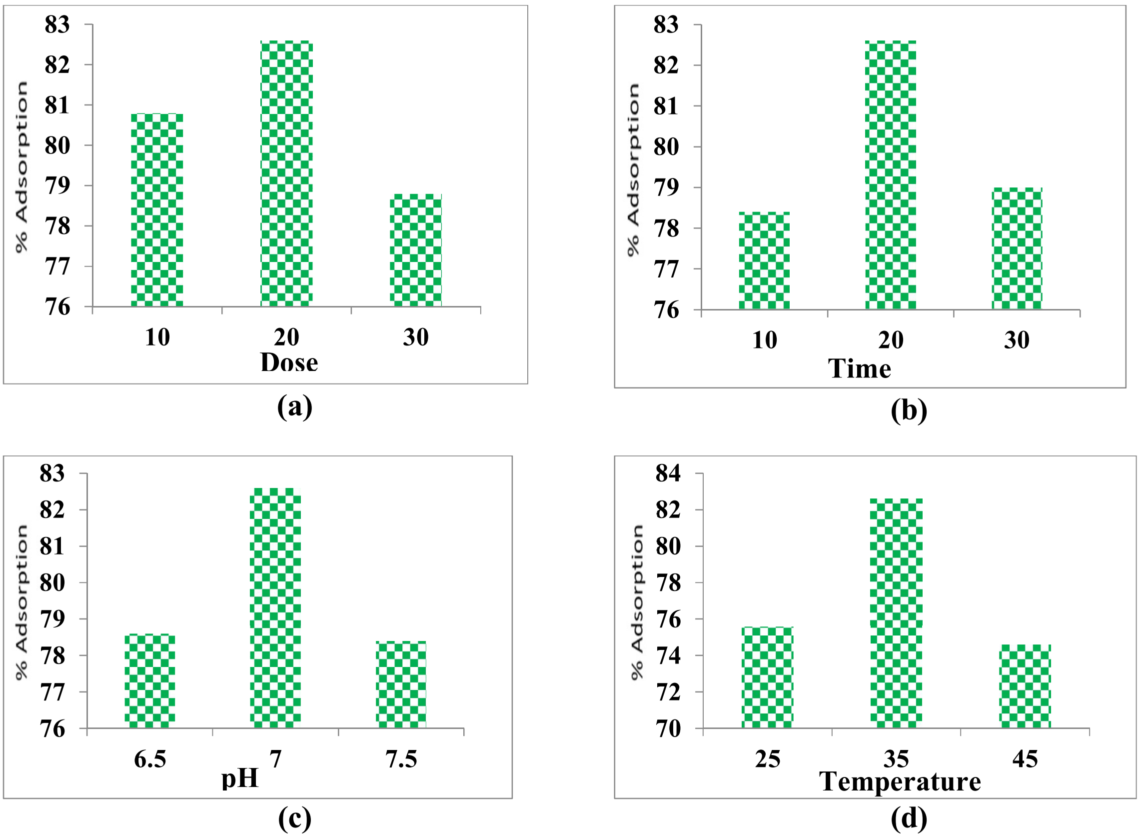

Figure 4: Maximum adsorption percentage efficiency of Basic Fuchsin Dye by Spent Mushroom (*Agaricus Bisporus*) at different chosen factors such as (a) Dose (b) Time (c) pH value and (d) Temperature.

Conclusion

Although various good adsorbents were reported in the literature for the removal of dyes from the aqueous solutions but due to their high cost, harmful impacts on environment, and regeneration ability, now the whole world is focusing on biosorbent. Therefore, in the present, an attempt has been made to study the efficiency of Spent Mushroom Waste (SMW) *viz. Agaricus bisporus* as biosorbent for the biosorption of Basic Fuchsin Dye (BFD) from aqueous solutions. The effects of the dosages of SMW, temperature, contact time, and pH were studied on the adsorption efficiency of SMW of *Agaricus bisporus*.

Batch experiments results obtained revealed that the mushrooms can also be used for the reduction of dyes from aqueous solutions in place of high cost adsorbents. The biosorption efficiency of the used SMW ranged from good to excellent. The efficiency of the mushrooms can also be improved using the further optimization process.

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Conflict of interest

The authors declare that they have no conflict of interest.

References

AbuQamar, S. F., Abd El-Fattah, H. I., Nader, M. M., Zaghloul, R. A., Abd El-Mageed, T. A., Selim, S., & El-Saadony, M. T. (2023). Exploiting fungi in bioremediation for cleaning-up emerging pollutants in aquatic ecosystems. *Marine Environmental Research*, 106068.

Ahmed, H. A. B., & Ebrahim, S. E. (2020). Removal of methylene blue and congo red dyes by pretreated fungus biomass-equilibrium and kinetic studies. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, *66*(2), 84–100.

Alhujaily, A., Yu, H., Zhang, X., & Ma, F. (2018). Highly efficient and sustainable spent mushroom waste adsorbent based on surfactant modification for the removal of toxic dyes. *International journal of environmental research and public health*, *15*(7), 1421.

Ali, F., Bibi, S., Ali, N., Ali, Z., Said, A., Wahab, Z. U., ... & Iqbal, H. M. (2020). Sorptive removal of malachite green dye by activated charcoal: Process optimization, kinetic, and thermodynamic evaluation. *Case Studies in Chemical and Environmental Engineering*, *2*, 100025.

Aragaw, T. A., & Bogale, F. M. (2021). Biomass-based adsorbents for removal of dyes from wastewater: a review. *Frontiers in Environmental Science*, *9*, 558.

Ayimbila, F., & Keawsompong, S. (2023). Nutritional Quality and Biological Application of Mushroom Protein as a Novel Protein Alternative. *Current Nutrition Reports*, 1-18.

Batana, F. Z., Bouras, H. D., & Aouissi, H. (2022). Biosorption Of Congo Red And Basic Fuchsin Using Micro Fungi Fusarium Oxysporum F. Sp. Pisi As A Biosorbent: Modeling Optimization And Kinetics Study. *Egyptian Journal of Chemistry*, *65*(13), 225–235.

Baysal, E., Yigitbasi, O. N., Colak, M., Toker, H., Simsek, H., & Yilmaz, F. (2007). Cultivation of *Agaricus bisporus* on some compost formulas and locally available casing materials. Part I: Wheat straw based compost formulas and locally available casing materials. *Afr. J. Biotechnol.* 6(19): 2225-2230.

Bhutiani, R., & Ahamad, F. (2018). Efficiency assessment of Sand Intermittent Filtration Technology for waste water Treatment. *International Journal of advance research in science and engineering (IJARSE)*, *7*(03), 503-512.

Bhutiani, R., Ahamad, F., & Ruhela, M. (2021). Effect of composition and depth of filter-bed on the efficiency of Sand-intermittent-filter treating the Industrial wastewater at Haridwar, India. *Journal of Applied and Natural Science*, *13*(1), 88-94.

Chakraborty, B., Chakraborty, U., Barman, S., & Roy, S. (2016). Effect of different substrates and casing materials on growth and yield of Calocybe indica (P&C) in North Bengal, India. *Journal of Applied and Natural Science*, *8*(2), 683–690.

Chaurasia, P. K., Nagraj, Sharma, N., Kumari, S., Yadav, M., Singh, S., & Bharati, S. L. (2023). Fungal assisted bio-treatment of environmental pollutants with comprehensive emphasis on noxious heavy metals: Recent updates. *Biotechnology and Bioengineering*, *120*(1), 57-81.

Chukki, J., & Shanthakumar, S. (2016). Optimization of malachite green dye removal by Chrysanthemum indicum using response surface methodology. *Environmental Progress and Sustainable Energy*, *35*(5), 1415–1419.

Dardouri, S., & Sghaier, J. (2017). Adsorptive removal of methylene blue from aqueous solution using different agricultural wastes as adsorbents. *Korean Journal of Chemical Engineering*, *34*(4), 1037-1043.

Del Campo, I., Alegria, I., Otazu, E., Gaffney, D., Iglesias, M., Ihalainen, P., &Perez, M. (2018). Biorescue: Getting high added value products from mushroom compost. In *European Biomass Conference and Exhibition Proceedings,* pp. 1084–1088. ETA-Florence Renewable Energies.

Doğan, M., Özdemir, Y., & Alkan, M. (2007). Adsorption kinetics and mechanism of cationic methyl violet and methylene blue dyes onto sepiolite. *Dyes and Pigments*, *75*(3), 701-713.

El Haddad, M. (2016). Removal of Basic Fuchsin dye from water using mussel shell biomass waste as an adsorbent: Equilibrium, kinetics, and thermodynamics. *Journal of Taibah University for Science*, *10*(5), 664-674.

El Haddad, M., Mamouni, R., Saffaj, N., & Lazar, S. (2012). Removal of a cationic dye–Basic Red 12–from aqueous solution by adsorption onto animal bone meal. *Journal of the Association of Arab Universities for Basic and Applied Sciences*, *12*(1), 48-54.

Farhan Hanafi, M., & Sapawe, N. (2020). A review on the water problem associate with organic pollutants derived from phenol, methyl orange, and remazol brilliant blue dyes. In *Materials Today: Proceedings* (Vol. 31, pp. A141–A150). Elsevier Ltd.

Feng, K., Li, H., Cui, J., Dong, Y., Li, S., & Hou, J. (2022). Study on the preparation of MCGA and its adsorption performance and mechanism of organic dyes. *Zhongnan Daxue Xuebao (Ziran Kexue Ban)/Journal of Central South University (Science and Technology)*, *53*(10), 3838–3848.

Gadd, G. M. (2009). Biosorption: critical review of scientific rationale, environmental importance and significance for pollution treatment. *Journal of Chemical Technology & Biotechnology: International Research in Process, Environmental & Clean Technology*, *84*(1), 13-28.

García-Delgado, C., Alonso-Izquierdo, M., González-Izquierdo, M., Yunta, F., & Eymar, E. (2017). Purification of polluted water with spent mushroom (Agaricus bisporus) substrate: from agricultural waste to biosorbent of phenanthrene, Cd and Pb. *Environmental Technology (United Kingdom)*, 38:1792–1799.

Hameed, B. H. (2009). Spent tea leaves: A new non-conventional and low-cost adsorbent for removal of basic dye from aqueous solutions. *Journal of hazardous materials*, *161*(2-3), 753-759.

Ho, Y. S., & McKay, G. (2000). The kinetics of sorption of divalent metal ions onto sphagnum moss peat. *Water research*, *34*(3), 735-742.

Ihsanullah, I., Jamal, A., Ilyas, M., Zubair, M., Khan, G., & Atieh, M. A. (2020). Bioremediation of dyes: Current status and prospects. *Journal of Water Process Engineering*. Elsevier Ltd.

Islam, M. M., Mohana, A. A., Rahman, M. A., Rahman, M., Naidu, R., & Rahman, M. M. (2023). A Comprehensive Review of the Current Progress of Chromium Removal Methods from Aqueous Solution. *Toxics*, *11*(3), 252.

Kocaoba, S., Orhan, Y., & Akyüz, T. (2007). Kinetics and equilibrium studies of heavy metal ions removalby use of natural zeolite. *Desalination*, *214*(1-3), 1-10.

Kooli, F., Yan, L., Al-Faze, R., & Al-Sehimi, A. (2015). Removal enhancement of basic blue 41 by brick waste from an aqueous solution. *Arabian Journal of Chemistry*, *8*(3), 333-342.

Liu, X., & Lee, D. J. (2021). Corrigendum to “Thermodynamic parameters for adsorption equilibrium of heavy metals and dyes from wastewaters” *Bioresour. Technol.* 16: 24–31

Mahmooda, T. (2014). Bioremediation Of Xenobiotics: Use Of Dead Fungal Biomass As Biosorbent. *International Journal of Research in Engineering and Technology*, *03*(01), 565–570.

Malekbala, M. R., Hosseini, S., Yazdi, S. K., Soltani, S. M., & Malekbala, M. R. (2012). The study of the potential capability of sugar beet pulp on the removal efficiency of two cationic dyes. *Chemical Engineering Research and Design*, *90*(5), 704-712.

Malik, R., Ramteke, D. S., & Wate, S. R. (2007). Adsorption of malachite green on groundnut shell waste based powdered activated carbon. *Waste management*, *27*(9), 1129-1138.

Mall, I. D., Srivastava, V. C., & Agarwal, N. K. (2006). Removal of Orange-G and Methyl Violet dyes by adsorption onto bagasse fly ash—kinetic study and equilibrium isotherm analyses. *Dyes and pigments*, *69*(3), 210-223.

Mall, I. D., Srivastava, V. C., Agarwal, N. K., & Mishra, I. M. (2005). Adsorptive removal of malachite green dye from aqueous solution by bagasse fly ash and activated carbon-kinetic study and equilibrium isotherm analyses. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *264*(1-3), 17-28.

Meng, X., Liang, H., & Luo, L. (2016). Antitumor polysaccharides from mushrooms: a review on the structural characteristics, antitumor mechanisms and immunomodulating activities. *Carbohydrate research*, *424*, 30-41.

Nethaji, S., Sivasamy, A., Thennarasu, G., & Saravanan, S. (2010). Adsorption of Malachite Green dye onto activated carbon derived from Borassus aethiopum flower biomass. *Journal of hazardous materials*, *181*(1-3), 271-280.

Okoro, H. K., Pandey, S., Ogunkunle, C. O., Ngila, C. J., Zvinowanda, C., Jimoh, I., ... & Adeniyi, A. G. (2022). Nanomaterial-based biosorbents: Adsorbent for efficient removal of selected organic pollutants from industrial wastewater. *Emerging Contaminants*, *8*, 46-58.

Qin, K., Li, J., Yang, W., Wang, Z., & Zhang, H. (2023). Role of minerals in mushroom residue on its adsorption capability to Cd (II) from aqueous solution. *Chemosphere*, *324*, 138290.

Quimio, T. H., Chang, S. T., & Royse, D. J. (1990). Technical guidelines for mushroom growing in the tropics. *F.A.O. Plant Production and Protection*, *106*, 62–70.

Savoie, J. M., Bruneau, D., & Mamoun, M. (1996). Resource allocation ability of wild isolates of *Agaricus bisporus* on conventional mushroom compost. *FEMS Microbiology Ecology*, *21*(4), 285–292.

Thakur, M. P., & Singh, H. K. (2013). Mushrooms, their bioactive compounds and medicinal uses: A review. *Medicinal Plants*.

Tian, X., Li, C., Yang, H., Ye, Z., & Xu, H. (2011). Spent mushroom: a new low-cost adsorbent for removal of congo red from aqueous solutions. *Desalination and Water Treatment*, *27*(1-3), 319-326.

Tong, D. S., Wu, C. W., Adebajo, M. O., Jin, G. C., Yu, W. H., Ji, S. F., & Zhou, C. H. (2018). Adsorption of methylene blue from aqueous solution onto porous cellulose-derived carbon/montmorillonite nanocomposites. *Applied Clay Science*, *161*, 256–264.

Volesky, B. (2001). Detoxification of metal-bearing effluents: Biosorption for the next century. *Hydrometallurgy*, 59: 203–216.

Vos, A. M., Heijboer, A., Boschker, H. T., Bonnet, B., Lugones, L. G., & Wösten, H. A. (2017). Microbial biomass in compost during colonization of Agaricus bisporus. *AMB Express*, *7*, 1-7.

Waktola, G., & Temesgen, T. (2018). Application of mushroom as food and medicine. *Adv. Biotechnol. Microbiol*, *11*(3), 10-19080.

Wani, B. A., Bodha, R. H., & Wani, A. H. (2010). Nutritional and medicinal importance of mushrooms. *Journal of Medicinal plants research*, *4*(24), 2598-2604.

Yamil, Y. L., Georgin, J., dos Reis, G. S., Lima, E. C., Oliveira, M. L. S., Franco, D. S. P., & Dotto, G. L. (2020). Utilization of Pacara Earpod tree (*Enterolobium contortisilquum*) and Ironwood (*Caesalpinia leiostachya*) seeds as low-cost biosorbents for removal of basic fuchsin. *Environmental Science and Pollution Research*, *27*(26), 33307–33320.

Yan, T., & Wang, L. (2013). Adsorptive removal of methylene blue from aqueous solution by Spent Mushroom Substrate: Equilibrium, Kinetics, and Thermodynamics. *BioResource, 8*(3), 4722-4734.

Yildirim, A., Baran, M. F., & Acay, H. (2020). Kinetic and isotherm investigation into the removal of heavy metals using a fungal- extract- based bio-nano sorbent. *Environmental Technology & Innovation*, *20*, 101076.

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