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BIOREMEDIATION OF HEXAVALENT CHROMIUM BY USING CYANOBACTERIA AND ITS APPLICATION OF THE BEST ISOTHERMS

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ABSTRACT

The present study aimed to evaluate the efficiency of hexavalent chromium Cr(VI) removal from synthetic waters using locally available Cyanobacteria is also called blue-green algae are commonly found in lakes, rivers, and ponds. Various sorption factors like optimum pH, period of exposure, biomass dose, and primary chromium concentrations were investigated to originate their impacts on the sorption of Cr(VI). FTIR (Fourier-transform infrared spectroscopy) and SEM (Scanning electron microscopy) were used to examine the biosorption mechanisms of Cr(VI) ions onto blue-green algal biomass. The Langmuir and Freundlich isotherm models accurately illustrate the equilibrium experimental results. The Results indicated that the biosorption of blue-green algal biomass was shown to be biomass and pH-dependent. The hexavalent chromium removal efficiency was found to be 97.6% for an initial chromium concentration of 500 mg/L within 60 minutes at pH 2, 250 rpm, and a 10g/L blue-green algal biomass dose. According to the Langmuir isotherm, the highest biosorption ability was about 396 mg/g of dry biomass, and the Freundlich constants Kf and n were 0.514 [mg/g (1/mg) n] and 32.73, respectively. At the outset, the study of "blue-green algae" can be well-advised as a propitious and precious universal adsorbent to treat the waters contaminated with toxic Cr(VI) ions.

Keywords: Biosorption, Blue-green algae, Hexavalent chromium, Heavy metal pollution, Isotherm models, Water pollution.

Introduction

Water contamination is the world's most vulnerable issue. Major research and the state of art technologies are coming to treat the wastewater and to remove the pollutants from the wastewater. Pollution of the water mainly due to toxic heavy metals containing effluents from textile, paint, leather tanning, etc. is discharging the wastewater into the water bodies. Currently, this is one of all the major environmental concerns within the world.

In heavy metals Chromium, being one of the most hazardous and carcinogenic metals has drawn a lot of interest from researchers. Only two of the chemical forms of chromium (Cr (III) and Cr(VI)), are stable and found in nature. Electroplating, chromate production, alloy manufacturing companies, metal purification and handling, leather processing, and

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wood maintenance are just a few of the industrial sources that employ this metal and its derivatives. Because of its significant adverse health properties, Cr (VI) should be effectively removed before disposal. Ramsenthil (2018).

Many researchers reported that the different treatment technologies for removal of chromium like membrane separation, ion exchange, chemical reduction/precipitation, and adsorption. However, these methods are not economically facing able, which, need a very huge amount of chemical reagents and a lot of energy, to overcome these problems researchers proposed biosorption to adsorb pollutants through biological sources as a potential alternative.

Innovative ways of using various biological sources, rockweed, amphibious plants, and plant-based sorbents as economical and effective absorbents are being developed. Because of its environmentally benign character, even wastewaters with metal pollution may be remedied with this high-performance, low-cost domestic approach, biosorption has become an essential and state-of-the-art technology in recent years. M. Costa (2003), G. Donmez (2002), Chi-ChuanKan (2017), WC Leung, (2001), R Majumder (2017), S.K Das (2007), D. Park (2005), Parul Sharma (2007), S Basha (2008), P Suksabye (2007), H Gao et al (2008).

Studies have shown that, the short-term accumulation of chromium (VI) by contacts with Cyanobacteria using their capability to seize chromium. D Shukla (2002). Aksu & Balibek (2007) studied the impact of salt addition on the adsorption of Cr (VI) by dried *Rhizopusarrhizus*. Arica et al. (2005) investigated the kinetics of Cr (VI) adsorption from synthetic waters expending free and restrained biomass produced from *Lentinussajorcaju*. Arica (2015). As a result, fungal species may remove chromium ions as well. The biosorption of Cr (VI) ions on the cell surface of trichoderma fungus under aerobic conditions at pH 5.5 was found to be 97.39 percent Vankar et al (2008). *Chlamydomonas reinhardtii*, natural, heat-treated, and acid-treated microalgae, was used for chromium (VI) ion biosorption.

The purpose of this research is to study the effect of several factors on the removal efficiency of chromium ions, such as adsorbent dosage, initial pH, time duration, and optimum Cr (VI) levels, on the adsorption of hexavalent chromium from synthetic chromium solutions using blue-green algae as an absorbent. To describe the experimental data, adsorption isotherms were used.

Materials and methods:

Biomass preparations:

A blue-green alga sample was taken from a small water body near Rajendra Nagar in Hyderabad, India. To eliminate contaminants and other undesirable components like sand and soil particles, the biomass was thoroughly washed in running tap water, then three to four times in Millipore water. The collected biomass was allowed to air dry before

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being dried in a 60°C oven. Dry biomass was mashed in a marble crusher blender and mesh sieve to achieve the desired particle size (0.5mm).

Preparation and analysis of metal solution

The Chromium primary solution was made by dissolving 2.827g potassium dichromate ($K_2Cr_2O_7$) in Milli-Q water. It was then diluted with ultra-pure ultra-distilled water to make solutions with concentrations of 500 to 1500 mg/L. The complete study was conducted in batches at 28±2°C. The hexavalent chromium concentration was determined by a UV-Spectrophotometer method based on red-violet colored complex production of chromate ions by the interaction of DPC (1,5-diphenylcarbazide) in an acidic solution. Gilcreas et al (1965). The Systronic-2205UV-Vis spectrophotometer was used to detect absorbance across a wavelength of 540 nm after 15 minutes. The pH was adjusted using Systronic pH system-361, well-calibrated with NIST traceable pH buffers. Remi manufactured a mechanical shaker used for adsorption and kinetic studies.

Hexavalent chromium adsorption studies:

250 ml conical flasks were swirled at 250 rpm on a stirrer at ambient temperature (28±2°C) for batch biosorption studies. The impact of pH solutions ranging from 1.0 to 10.0, exposure time (060 minutes), and optimal Cr(VI) ions concentration (500 to 1500 ppm with 10g biomass dosage) on the biosorption rate and efficiency were investigated To explore the adsorption efficiency of Cr(VI) and blue-green algal biomass, 10g/L biomass was soaked in Cr (VI) synthetic water of various concentrations ranging from 500 - 1500 ppm to evaluate biosorption isotherms. The samples were obtained at various periods (0 to 60 mins). The supernatant was tested for residual chromium metal ion concentration after centrifugation at 4500 rpm for 15 minutes. The following equation was used to calculate the quantity of Cr (VI) ions adsorption efficiency per unit biomass of the adsorbent under equilibrium conditions Qe (mg/g).

$$\mathrm{Qe} = (\mathrm{C_o} - \mathrm{C_e})\mathrm{V} \div \mathrm{m} \qquad \text{Equation-1}$$

Where, C0 and Ce (mg/L) are initial & equilibrium concentrations of chromium solution respectively, V is the volume of solution (L), and m is Blue-green algal biomass (g).

The efficiency of biosorption (%) was determined using the following equation:

$$\mathrm{R\%} = \frac{\mathrm{C_o} - \mathrm{C_e}}{\mathrm{C_o}} \,\mathrm{X}\, 100 \qquad \text{Equation-2}$$

Characterization of adsorbent

The studies were conducted using a Perkin Elmer Model Spectrum BXI FTIR spectrophotometer (FTIR) on KBr discs with a finely powdered 1% sample. In the

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wavenumber varies from 650-4000cm^{-1}, spectral data with a resolution of 4 cm^{-1} was analyzed using spectrum software. The biomass was evaluated after and before the chromium ion interaction. The surface structure and metal adsorption on biosorbent were studied using a scanning electron microscope (SEM).

Equilibrium Isotherms analysis:

The biosorption data were applied to several sorption isotherms, notably the Freundlich and Langmuir, to quantitatively explain chromium metal sorption by the blue-green algal biomass. The nonlinear regression method was used to determine qe and b in this investigation. The findings of the correlation coefficient (R2) were used to determine which of the two models described above was the most well-fitting.

The Freundlich isotherm is an empirical equation that defines adsorption on a heterogeneous surface with non-uniform energy distribution. The biosorption studies were conducted out with a predetermined initial adsorbent dosage (10g) and various initial adsorbate levels (500, 750, 1000, 1250, and 1500 mg/L) solutions, with the data's relevance to the Langmuir adsorption isotherm being evaluated. The tests were performed for sufficient time to achieve equilibrium at the original pH of 2. The Langmuir model was used to deal with uncertainties.

Results and Discussion:

Cr (VI) adsorption by blue-green algae is optimum when the pH is 2 and the biomass dose is 10g. According to the findings of this study, the highest adsorption capacity of blue-green algal biomass is 396 mg/g, and the optimum agitation rate of 250 rpm is continued during the 60-minute preset time. The current results of blue-green algae's maximal adsorption capacity are compared to similar research on Cr (VI) adsorption utilizing various sorbents. The highest adsorption rate using activated charcoal (made from wood apple shell) employed to absorb chromium from water with a concentration of 1250 mg/g was reported to be 151.51 mg/g at a pH of 1.8. Their substance is shown to be more effective at low pH, and their qmax was lower than this research Doke & Khan(2017).

At pH 2 and 0.2g of dosage, a magnetic natural zeolite Chitosan composite was used as an absorber to absorb Cr (VI) from a 200 mg/L aqueous solution, with a removal efficiency of 98% Gaffer et al (2017). The chemically-treated banana peels were used as an adsorbent in 400 mg/L chromium synthetic water and revealed that the maximum removal efficiency was 6.178 mg/g within 120 minutes of contact time with 4 g/L dosages at pH 3 Ali et al (2016).

pH Impact on adsorption:

The objective of this study was to determine the ideal pH for removing chromium ions from aqueous solutions. Experiments were performed in batches with various concentrations of chromium solution by ranging the pH levels from 1 to 10 and results

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were evaluated (Figure 1). In aqueous solutions, chromium is known to have pH-dependent equilibria. When the pH varies, the equilibrium shifts. The $HCrO^{4-}$ and $Cr_2O_7^{2-}$ ions were in equilibrium in the pH range of 1 to 10. On the other hand, at pH 2.0, Cr_3O^{10-} and $Cr_4O_{13}^{2-}$ species are released. The optimal initial pH for Cr (VI) bioremediation using this biosorbent was found to be pH 2.0, suggesting that lower pH causes more polymerized chromium oxide molecules to be produced. The decreased chromium removal effectiveness at higher pH is thought to be owing to ions being repelled by anions on the surface of the adsorbent. The removal efficiency rose as the pH was reduced, reaching 97.6% at 500 mg/L Cr (VI) concentrations, according to the findings. Some of the organic carbons in the biomass were transformed to inorganic carbon during Cr (VI) reduction (HCO3- and CO2). Protons were consumed during absorption when pH decreased.

Effect of Contact Time

The amount of Cr (VI) absorbed varies depending on the starting concentration, which ranges from 500 to 1500 mg/L at pH 2. (Table 1). Since the pH affects the system's sorbent equilibrium, the combination of chromium levels and adsorbent is an important factor to consider for successful biosorption. The time it took for the system to reach equilibrium was less than 60 minutes. Metal uptake was affected by variables disrupting mass flow from the bulk solution to binding sites Mohanty et al (2018).

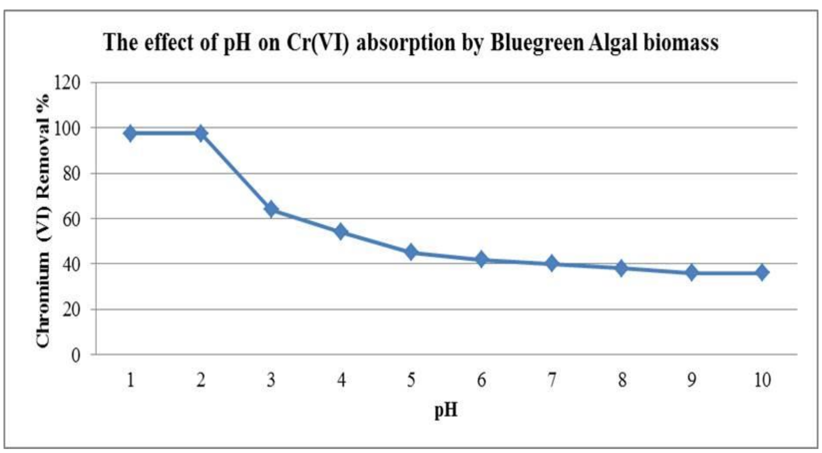

Figure 1. The effect of pH on the removal efficiency of hexavalent chromium.

However, even though sorption equilibrium was achieved at the same time, chromium ion biosorption declined with time. It is explained as a result of a rise in the number of ions vying for accessible binding sites in biomass, as well as a scarcity of binding sites. Because binding sites are saturated at greater concentrations, more Chromium ions are left in the solution.

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Table 1: Chromium (VI) removal percentage at a different contacting time using blue-green algae

Removal Percentage of chromium VI by using blue-green algal biomass						
Concentration (ppm)	**10 min**	**20 min**	**30 min**	**40 min**	**50 min**	**60 min**
500	40	56	68	74	89	98
750	36	48	52	68	72	96
1000	32	54	58	76	84	92
1250	28	59	66	80	88	88
1500	16	28	43	56	66	72

FTIR Spectra Analysis:

An unreacted, chromium-treated blue-green algae sample was prepared and scanned using FTIR, with percentage transmission for various wavenumbers shown. The attribution of corresponding functional groups to absorption bands identified using acquired spectra is explained.

The existence of OH groups on the biosorbent surface was indicated by wavenumbers of 3,000 and 3,399 cm^{-1} for blue-green algae. The existence of C-H groups is indicated by the dip seen at 2,927 cm^{-1} and 893 cm^{-1}. The presence of an amide band is shown by the 1,649 cm^{-1} band, which is the consequence of CO stretching mode coupled to NH deformation mode. The dip at 1,154cm^{-1} is caused by CO or CN groups, which proves the existence of numerous efficient ions on the surface of blue-green algae that bind Cr(VI) ions. (Figure 2).

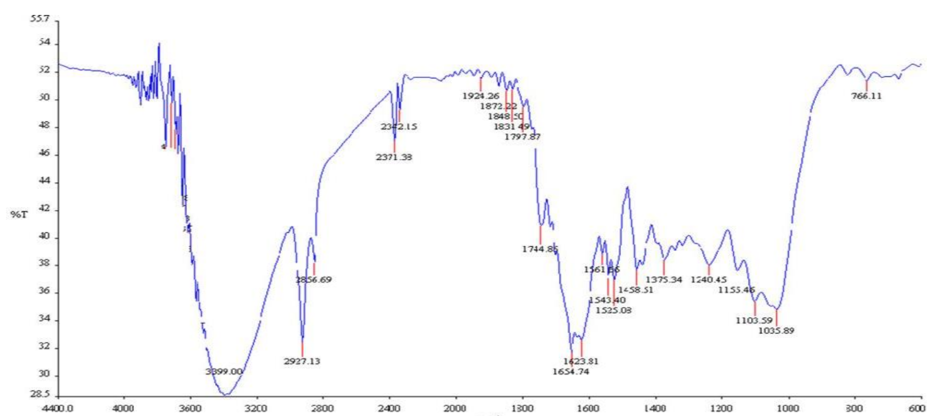

Figure 2. FTIR Spectrum for blur green algae biomass.

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Scanning Electron Microscope (SEM) combined with Energy Dispersive X-ray (EDX) spectroscopy was used to explore the Cr (VI) adsorption and surface structure of the blue-green algal biomass sample. EDX spectroscopic experiment found the percent quantity of Cr (VI) in the biomass after biosorption, which was used to determine the percentage of elements.

The blue-green algal biomass sample was tested against 500 mg/L hexavalent chromium, and the biomass removed 97.6% of the Cr (VI) ion using 10 g of biomass at pH 2. This indicates that the biomass's surface area is acting as a biosorption agent. The morphology of biomass was explained by SEM micrographs, as illustrated in Figs. 3 and 4, respectively.

Biosorption equilibrium studies:

Experiments were conducted through adsorbent doses of 10 g/L and various adsorbate contents (500-1500 mg/L) solutions, the results were examined by Langmuir adsorption isotherm. The tests were performed for sufficient time to achieve equilibrium at the original pH of 2. The findings were familiar to the Langmuir model that can be articulated by using the equation.

$$q_e = \frac{bq_{max\,C_e}}{1+bC_e} \qquad \text{Equation – 3}$$

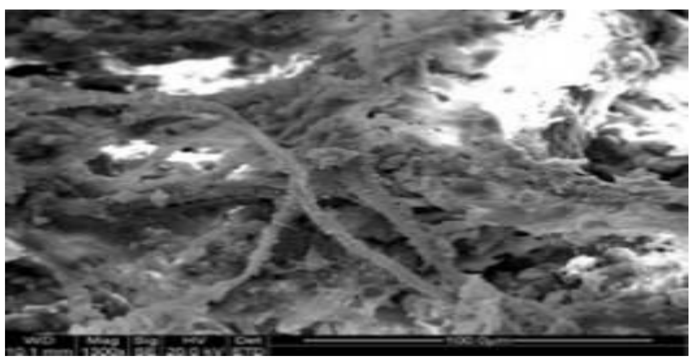

Fig. 3. SEM of blue-green algae biomass before biosorption.

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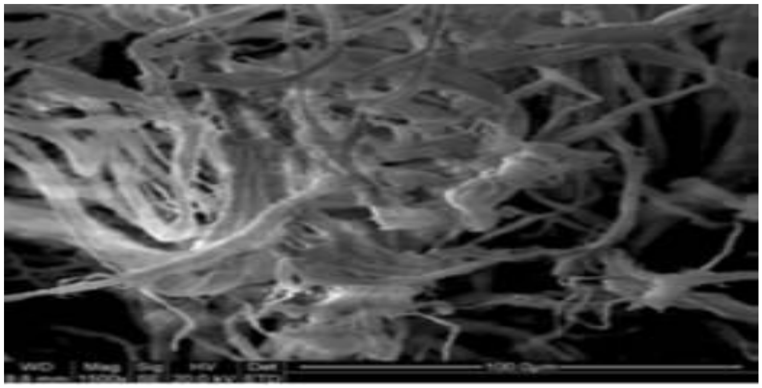

Fig. 4. SEM of Bluegreen algae biomass after biosorption

Where q_e is the metal uptake (mg/g) at equilibrium; q_{max} is the maximum Langmuir uptake (mg/g); C_e is the final metal concentration at equilibrium (mg/L); b is the Langmuir affinity constant (L/mg of the metal). The Langmuir affinity constant was found to be highly linked with the similarity between biomass and Cr (VI), with a higher value indicating a high affinity. Using a linear representation of the Langmuir model (Ce/qe vs Ce), these adsorption variables may be derived from the isotherm:

$$\frac{C_e}{q_e} = \frac{C_2}{q_{max}} + \frac{1}{bq_{max}} \qquad \text{Equation –4}$$

These assumptions underpin the Langmuir isotherm. Langmuir (1916). Metal ions are adsorbed chemically at a finite number of well-defined sites, each of which can only hold one ion at a time. The ions do not interact, and all sites are energetically equivalent.

The linear plot of C_{eq}/q vs C_{eq} shows the adsorption follows the Langmuir adsorption model (Figure 5). 0.99 was the correlation coefficient. The slope and intercept of the figure were used to determine b and qmax, which were 0.06 L/mg and 396 mg/g, respectively.

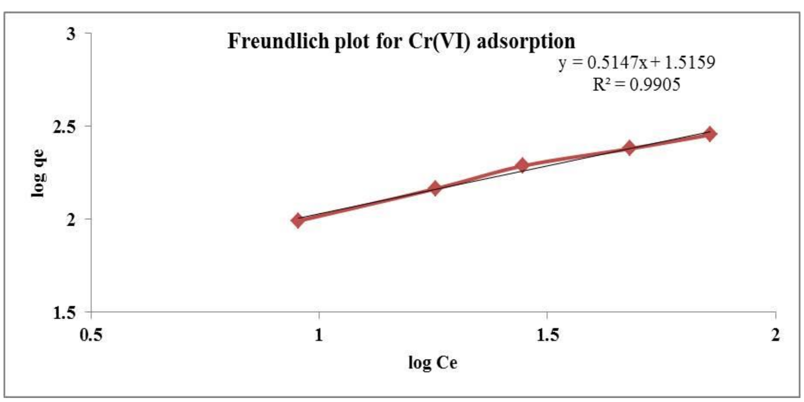

Figure 5. Freundlich plot for hexavalent chromium adsorption efficiency.

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Separation factor - R_L

The main characteristics of the Langmuir isotherms may be represented as dimensionless constant separation factors or equilibrium parameters. R_L, which is well-defined as:

$$R_L = \frac{1}{1+bC_o} \qquad \text{Equation -5}$$

Where C_o=initial concentration in mg/L; b=Langmuir constant

R_L values define the isotherm categories; if the R_L value is greater than one, the isotherm is unfavorable and linear; if the R_L value is less than one, the isotherm is favorable; For Cr (VI) adsorption, the R_L values obtained are smaller than one (Table 2). R_L values between 0 and 1 recommend good adsorption Mcka et al (1982).

Table 2.The values of Separation factor

C_o	R_L
500	0.032209
750	0.021705
1000	0.016368
1250	0.013137
1500	0.010972

The adsorption of chromium (VI) on a blue-green algal biomass was also investigated using the Freundlich isotherm, which was assessed using the equation below Freundlich (1906).

$$\log q_e = \log K_F + \frac{1}{n}\log C_e \qquad \text{Equation-6}$$

Where Kf is a constant proportional to the Freundlich biosorption capability (L/mg), and the log is an experimental measure indicating sorption efficiency, which differs with substance variability. Freundlich isotherms derived by applying equilibrium data to equation 6 are shown in Figure 6.

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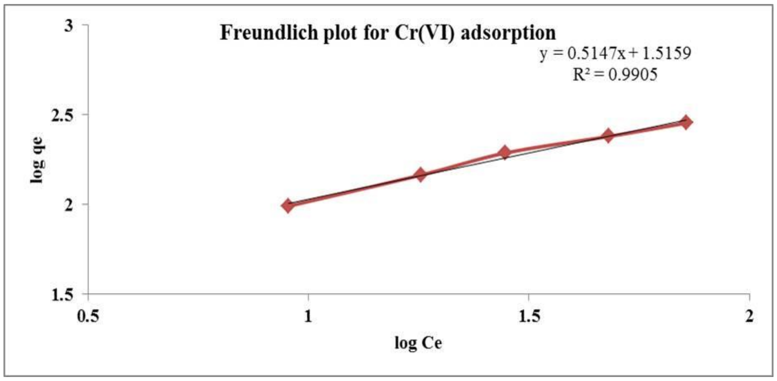

Figure 6. Freundlich plot for hexavalent chromium adsorption efficiency.

Kf and 1/n were found to have values of 32.74 and 0.541, respectively. The1/n results falling well under the specified values (0- 1), which denotes chromium ion adsorption was satisfactory under these conditions. Magnitudes of Kf and n reveal a strong adsorption capability and removal efficiency of hexavalent chromium from contaminated waters. Ozel Ucun et al (2002).

Conclusion

According to the results of this study, blue-green algae is a viable substitute for absorbing Cr (VI) from the waters. In biosorption, the results of FTIR bands related to its functional groups made a crucial impact. The optimum hexavalent chromium removal percentage was optimum at pH.2, and raising the pH from acidic to alkaline resulted in a decrease in chromium removal percentage. The maximal chromium VI ion removal was determined to be 97.6% in 60 minutes at pH 2 with 250 rpm agitation and 10 g/L blue-green algae biomass. Studies of equilibrium isotherms indicated that they were significant and fit well within the allowable limits. Cr(VI) ion biosorption on blue-green algae eventually reached a maximum capacity of 396 mg/g biomass. Blue-green algae is an inexpensive and easily available biosorbent, making it a viable choice for removing chromium ions from contaminated wastewaters.

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Declaration of Competing Interest

All the authors confidently declare that there is no conflict of interest, and all authors for publication approve the paper.

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Tricolporate pollen of caesalpiniaceae medicinal plants at Kotla Vijaya Bhaskara Reddy botanical garden in Cyberabad, Telangana

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Abstract---This paper presents the study of a tricolporate pollen morphology of 08 Caesalpiniaceae medicinal plant taxa viz. *Bauhinia purpurea* L., *Caesalpinia pulcherrima* (L.) SW.,*Cassia fistula* L., *Delonix regia* (Hook.) Raf., *Peltophorum pterocarpum* (DC.) K.Heyne., *Senna auriculata L., S. sophera* (L.), Roxb. and *Tamarindus indica* L. The flower buds of these plants were collected from blocked category of Cyberabad area i.e. Kotla Vijaya Bhaskara Reddy Botanical Garden. By using Erdtman's (1960) acetolysis technique, the collected flower buds were processed. The result of the study showed that Caesalpiniaceae tricolporate pollen grains have diversity in their pollen morphological characters like Polarity, Symmetry, Shape, Aperture and Sporoderm. The observations of this study will be useful for authentic identification of the taxa of Caesalpiniaceae.

Keywords---Tricolporate, Kotla Vijayabhaskarareddy, botanical garden, caesalpiniaceae.

Introduction

Cyberabad is a technological hub with a radius of 52.48 km spreading approximately around 15,000 acres area, located in Hyderabad District, Telangana, India. Cyberabad is all about IT hub, IT companies and MNCs. Kotla

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Vijaya Bhaskara Reddy Botanical Garden is located in the Cyberabad. It is situated in between latitude 17º 27' 58.9392"and longitude: 78º 20' 17. 9232". Caesalpiniaceae family contains a number of medicinal plants. The aperture is the dominant character for identification of the pollen taxa. An aperture,a germpore, is the dominant charavter for identification of pollen taxa. Caesalpiniaceae pollen grains are having diversified apertural characters viz., Inaperturate, colpate, porate and colporate. Most of the Caesalpiniaceae pollen grains are tricolporate which may be useful as a taxonomic tool for identification of palynotaxa.

Methodology

In this study, 08 medicinal plants flower buds of the Caesalpiniaceae were collected from blocked category i.e. Kotla Vijaya Bhaskara Reddy Botanical Garden of Cyberabad during 2021 to 2022. The collected flower buds were processed by means of Erdtman's (1960) acetolysis technique to recover the pollen. The morphological characters of pollen were studied under Olympus trinocular research microscope. The pollen slides were preserved in Palaeobotany-Palynology research lab, University college of Science, Saifabad, Osmania University, Hyderabad

Observation

The author studied 8 medicinal plants of Ceasalpiniaceae which are having various medicinal properties viz., *Bauhinia purpurea* L., *Caesalpinia pulcherrima* (L.) SW., *Cassia fistula* L., *Delonix regia* (Hook.) Raf. *Peltophorum pterocarpum* (DC.) K.Heyne., *Senna auriculata L., Senna sophera* (L.) Roxb. and *Tamarindus indica* L. are collected from Kotla Vijaya Bhaskara Reddy Botanical Garden. These pollen were studied and recorded the diversity of pollen morphological characters.

***Bauhinia purpurea* L.**

Bark : Anti- diabetic, Fibrolytic, Anti-Obesity
Root : Antimalarial, Anti-fungal, Anti bacterium, Anticancer
Leaves : Antimicrobial, Amelioration of Hyperthyroidism, Antiseptic, Anti-inflammatory Antipyretic activity and Anti-Ulcer

Pollen Morphology

Aperture : Tricolporate, colpi broad,blunt ends, ora lalongate.
Polarity : Isopolar
Polar view (Amb) : Triangular 45-50µm
Shape : Prolate- spheroidal
Size : Polar Axis 59-65 µm. Equatorial Axis 64-69 µm.
Symmetry : Bilateral
Exine stratification : 2- 2.8 µm thick, sexine 1-1.5µm thick, nexine 1-1.3µm thick.
Ornamentation : Striate-reticulate.

***Caesaipinia pulcherrima* (L.) SW**
Medicinal uses

Root: Used in the treatment of diarrhoea and miscarriage
Leaves: Miscarriage, stimulates menstrual flow, reduces fever and used to treat in stomach-aches

Pollen Morphology

Aperture	: Tricolporate, elongated colpi with acute tips, lalongate ora.
Polarity	: Isopolar
Polar view (Amb)	: Round 52.3µm.
Shape	: Spheroidal
Size	: Polar Axis - 68-70 µm, Equatorial Axis- 68.8-70.5µm.
Symmetry	: Radial
Sporoderm stratification	: 3.2 µm thick, sexine and nexine almost equal
Ornamentation	: Reticulate

***Cassia fisula* L.**
Medicinal uses

Stem, Leaves, Flower	: Antioxidant
Stem bark	: Anti-inflammtory, Anti diabetic
Leaves	: Wound Healing, Anti- Ulcer
Legume	: Hypolipidemic activity
Seeds	: Anticancer activity, Anti fertility

Pollen Morphology

Aperture	: Tricolporate.
Polarity	: Isopolar
Polar view (Amb)	: triangular, 29. µm
Shape	: Prolate- spheroidal
Size	: Polar Axis - 27-30µm, Equatorial Axis - 24-27 µm
Symmetry	: Radial
Exine stratification	: 1.5-2.5 µm thick, both the sexine and nexine are similar in thickness.
Ornamentation	: Reticulate.

Delonix regia (Hook.) Raf.

Bark	: reduce fever, laxative, flatulence, emetic, CNS depressant, preventing periodic returns of disease and used in the treatment of anemia and fever
Flowers	: Gynecological disorders destroy parasitic worms, reduce fever, inflammation, diarrhoea
Leaves	: Anti-diabetic, body pain gastric problems, respiratory infection and rheumatic joints pain
Root	**:** Gastric problems

Pollen Morphology

Aperture : Tricolporate, elongated colpi with blunt ends, ora faint more or less
Polarity : Isopolar
Polar view (Amb) : Round 50-54 µm.
Shape : Oblate- spheroidal
Size : polar Axis 53-54 µm, Equatorial Axis 57-60 µm
Symmetry : Bilateral
Exine stratification : 5.2µm thick, sexine 3 µm thick, nexine 2 µm thick, sexine thicker than nexine.
Ornamentation : Reticulate

Peltophorum Pterocarpum (DC.) K.Heyne

Medicinal uses

Bark : Used as in reduce joint pains, and swelling and as a lotion for eye troubles, contusion, muscular pains and reduce pains after birth. It is also used for gargles and tooth powders
Leaflets and buds: Used as Fungicides
Flowers : Used as Bacteriocides and anti-inflammatory effect

Pollen Morphology

Aperture : Tricolporate, elongated colpi with acute tips, lalongate.
Polarity : Isopolar
Polar view (Amb) : Round 45-47.5µm.
Shape : Sub-prolate
Size : Polar Axis 48-50 um,Equatorial Axis 39-41µm.
Symmetry : Bilateral
Sporoderm stratification : 4µm thick, sexine thicker than nexine.
Ornamentation : Reticulate, muri 4.5µm, polygonal

***Senna auriculata* L.**
Medicinal uses

Flowers : These are used to cure urinary discharges, ejaculations during sleep, anti-diabetic and throat irritation.
Bark : These are used to address the dermatology issues.
Leaf extract : Its nature is to protect the liver related problems that occur due to the consumption of alcohol, protects from alcohol induced oxidative stress and also softens the skin tone.
Seeds : They are used to control the inflammation of an eye or conjunctiva.
Roots : They are used to treat the skin diseases and pulmonary problems.
Fruits : They are used to treat for anthelmintic parasites

Pollen Morphology

Aperture : Trizonocolporate.
Polarity : Isopolar
Polar view (Amb) : Triangular 26-28μm.
Shape : Prolate
Size : Polar Axis 37.2μm, Equatorial Axis 25.3μm.
Symmetry : Bilateral
Exine stratification : 1.4μm thick, both the sexine and nexine are similar in their thickness.
Ornamentation : Reticulate.

Senna sophera **(L.) Roxb**

Medicinal uses

Bark : Used in pulmonary diseases
Leaves, root : Asthma, bronchitis, bloating, Gonorrhea

Morphology

Aperture : Tricolporate
Polarity : Isopolar
Polar view (Amb) : Triangular 45-46μm.
Shape : Prolate
Size : Polar Axis 24-25 μm, Equatorial Axis 41-42μm.
Symmetry : Bilateral
Exine stratification : Exine 1.8μm thick, both the sexine and nexine are similar in their thickness.
Ornamentation : Granular

Tamarindus indica L.

Flower : Microbial infections
Fruit pulp : Cold, Fever Laxtive scury
Leaf : Hypotension, Respiratory disorders
Bark : Jaundice, pain
Seeds : Antidiabetic, pepticulcers.

Pollen Morphology

Aperture : Tricolporate.
Polarity : Isopolar
Polar view (Amb) : 42μm
Shape : Oblate -spheroidal
Size : Polar Axis 33.8μm, Equatorial Axis 43.8μm.
Symmetry : Radial
Sporoderm stratification : Exine 1.5μm thick, both the sexine and nexine are similar in their thickness.
Ornamentation : Striate.

Table 1
Diversified pollen characters

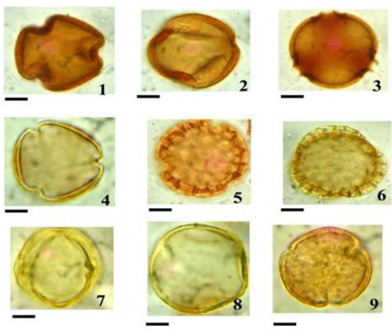
S.no	Palynotaxa	Symmetry	Size	Shape	Sporoderm	Medicinal use
1	*Bauhinia purpurea* L.	Bilateral	PA:59-65 µm.EA: 64-69µm.	Prolate-spheroidal	Striate-reticulate	Anti-diabetic, anti-obesity,antimicrobial
2	*Caesaipinia pulcherrima* (L.) SW.	Radial	PA: 68-70 µm. EA-68.8-70.5µm.	Spheroidal	Reticulate	Miscarriage,stimulates Menstrual flow., reduce fever
3	*Cassia fisula* L	Radial	PA:29.8µm. EA: 26.9µm	Prolate-spheroidal	Reticulate	Antiondant activity Anti-inflammtory , Anti-diabetic, Wound Healing, Anti- Ulcer Hypo-lipidemic activity Anti-cancer, Anti-fertility
4	*Delonix regia* (Hook.) Raf.	Bilateral	PA:53-554µm. EA:57-60µm	Oblate-Spheroidal	Reticulate	Reduce fever, laxative, flatulence, emetic, CNS depressant, preventing periodic returns of disease and used in the treatment of anemia and fever
5	*Peltophorum Pterocarpum* (DC.) K.Heyne	Bilateral	PA:48-50µm. EA:39-41µm	Sub-Prolate	Reticulate	Reduce joint pains, swelling and as a lotion for eye troubles, contusion, muscular pains and reduce pains after birth. It is also used for gargles and tooth powders, Anti-microbial activity
6	*Senna auriculata* L.	Bilateral	PA:37.2µm. EA: 25.3µm	Prolate	Reticulate	To cure the liver related problems; protects from alcohol induced oxidative stress and also softens the skin tone.
7	*S.sophera*(L.) Roxb	Bilateral	PA:24µm EA:4µm	Prolate	Granular	Used in Pulmonary diseases, bloating,

						gonorrhoea
8	*Tamarindus indica* L.,	Radial	PA:33.8μm. EA: 43.8μm	Oblate-Spheroidal	Striate	Microbial infections Laxative, scurvy Hypo-tension, Respiratory, Anti-diabetic,peptic ulcers.

Discussion

The diversified pollen characters viz., symmetry, shape, aperture and sporoderm are useful for authentic identification of taxa. The 08 taxa belong to Caesalpiniaceae have common tricolporate pollen characters but variation in the other characters (Table-1 & Plate-1). These tricolporate pollen exhibit variation in the position of aperture i.e trizonocolporate, tricolporate. *Cassia auriculata* L. is a trizonocolporate, remaining 7 plants are colporate. These recorded taxa show diversity in symmetry, shape and ornamentation. Radial symmetric polynotaxa are *Caesalpinia pulcherrima* (L.) SW., *Cassia fistula* L., *Tamarindus indica* L., and Bilaterally symmetric are *Bauhinia purpurea* L., *Delonix regia* (Hook.) Raf., *Peltophorum pterocarpum* (DC.) K.Heyne., *Senna auriculata* L., and *S. sophera* (L.) Roxb.,Prolate-spheroidal shape taxa are *Bauhinia purpurea* L,, *Cassia fistula* L., and *Caesalpinia pulcherrima* (L.) whereas Oblate-spheroidal is in *Delonix regia* (Hook.), *Tamarindus indica* L., Prolate shape is in *Senna auriculata, S. sophera* (L.) Roxb., Sub-prolate in, *Peltophorum pterocarpum* (DC.) K.Heyne. Spheroidal is in *Caesalpinia pulcherrima* (L.). Reticulate ornamentation is recorded in *Delonix regia* (Hook.) Raf., *Peltophorum pterocarpum* (DC.) K.Heyne., *Senna auriculata* L., *Caesalpinia pulcherrima* (L.) SW, *Cassia fistula* L. Straitae reticulate was recorded in *Bauhinia purpurea* L, Striate ornamentation was recorded in *Tamarindus indica* L., and granular was present in *Senna sophera* (L.).

PLATE-1



Explanation of the Plate-1 Scale bar: — 10µm

1. ***Bauhinia purpurea*** **P.V, 2.** ***B. purpurea*** **E.V.**

3. ***Caesalpinia pulcherrima*****, 4.** ***Cassia fistula***
5. ***Delonix regia*****, 6.** ***Peltophorum pterocarpum***
7. ***Senna auriculata*****, 8.** ***Senna. sophera*****,**
9. ***Tamarindus indica***

Plate 1. Tricolporate pollen of Caesalpiniaceae

All the 8 taxa are useful for medicinal purpose to cure various diseases. These taxa were earlier recorded in various honey samples of Adilabad, Medak, Nizamabad and Mahabubnagar districts of Telangana State,Visakhapatnam district of Andhra Pradesh and Howrah district of West Bengal (Swathi and Ramakrishna 2012, 2013; Chaya and Varma 2008; Ramakrishna and Bushan 2004; Devender et.al., 2016, 2017; Devender and Ramakrishna 2013; Chakraborty and Saha 2019) and spider webs of Hyderabad and Warangal districts of Telangana (Vijayabhaskar Reddy et.al., 2004 and Seetharam et.al., 2015)

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(57) Abstract :
[27] The present invention discloses a processing herbal medicine and 5 composition from medicinal plant for external skin applications and preparation method thereof. The method for preparing the composition includes, but is not limited to, a combination of a water extract of an aerial part of Rhodomyrtus tomentosa; a water extract of an aerial part of Cipadessa baccifera; a methanol extract of a fruit of Woodfordia fruticose;.(10 Leaves of Cyphostemma auriculatum and Capparis divarcata) a water extract of a tender shoot of Camellia sinensis as an antioxidant; and cosmeceutically acceptable carriers. Further, the composition further comprising beeswax, stearic acid, glycerol monostearate, olive oil, Aloe vera gel, rose water, glycerine, triethanolamine, propylene glycol, geranium oil, 15 sandalwood oil, vetiver oil, methyl paraben and propyl paraben in amounts of 4.4-5%; 3.5-4%; 6.5-7%; 20-25%; 11-12%; 20-25% 14-18% 1.5-2%; 6-8%; 0.5-1%; 0.5-1%; 0.5-1%; 0.15-0.2% and 0.15-0.2% respectively, wherein the said constituents are expressed in terms of weight %.

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